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ANALYSIS OF ENGINEERING PROPERTIES OF BLACK COTTON SOIL IN NUMAN LGA, ADAMAWA STATE

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ABSTRACT

Black cotton soils for the study were derived from Numan LGA of Adamawa State, Nigeria, The study used both disturbed and undisturbed soil sampling technique to select soil from a depth of 1m, 1.2 m and 1.5 meters. Physical and geotechnical properties of the soil samples were studied in the laboratory. The tests conducted were grain size analysis, specific gravity, atterberg's limits, and standard Proctor compaction. Results as obtained were compared with the standard code. The test results showed that there is increase in the clay content attributed to black cotton soil in the study area. The study concluded that black cotton soils formed a major soil in Numan LG, Adamawa State. The study recommends that engineering properties of Black cotton soil should be checked before construction takes place, and effort should be made to completely remove Black cotton soil in sites in Numan, where construction sites are not too large.

KEYWORDS: *Engineering Properties, Black Cotton, Construction, Site Condition*

INTRODUCTION

Soil is the crucial element of the earth. The important of soil to human race is unlimited and almost all human attached to it in one way or another (Haresh and Chandresh, 2015). All human activities, livelihood and development happened on the soil. Origin of word "soil" can be traced to Latin word "solium" which implies the upper layer of the earth that may be dug or plowed. In most cases, the soil is usually regarded as the loose surface material of earth in which plant grows (Rathan-Raj et al., 2016). However, in soil engineering, soil is expressed as an unconsolidated material, composed of solid particles produced by disintegration of rocks (Srikanth-Reddy et al., 2018). The voids space between particles may contain air, water or both. Also, the solid particles in the soil are likely to contain organic matter, separated by such mechanical means as agitation and water.

So, the black cotton soil is cohesive soil. The black cotton soil is characterized by high shrinkage and swelling properties (Sudharani et al., 2017). The particular case of black cotton soil with a wide range of challenges associated with the construction at sites with black cotton soil. In case of coarse grained soil, the mineralogical composition of the grain hardly affects the engineering properties of the soils perhaps the grain to grain friction is influenced.

Problems Statement

It is a common fact that water is one the worst enemy for various structures, especially responsible for soil expansive in many areas. It takes water three different sides which include the top surface, and bottom layers to penetrate foundation in the form of capillary action. Therefore, for effective construction that will not fail from foundation there must be consideration for water factor in the construction specifications in expansive soil areas. It is always an ideal practice to ensure that the surfacing be impervious, sides paved and soil beneath is well treated, to curtail the capillary rise of water.

It has been found during handling of various investigation project assignments for assessing causes of structural failures that water has got easy access into the foundations. It saturates the soil and thus lowers its bearing capacity, ultimately resulting in heavy depressions and settlement. Water lubricates the soil particles and makes the mechanical interlock unstable. In the top surface, raveling, stripping and cracking develop due to water stagnation and its seepage into the bottom layers. Generally, construction agencies do not pay sufficient attention to the aspects of construction and maintenance of sides. In expansive soil areas, unpaved offsets pose the maximum problem as they become slushy during rains, as they are most neglected lot.

LITERATURE REVIEW

Physical Properties of Black Cotton Soil

Table 1: According To (Fulzele Et. Al. 2016)

S. No	Properties	Values
1	Liquid Limit (%)	40–120 %
2	Plastic Limit (%)	20–60 %
3	Optimum Water Content (%)	20–35 %
4	Free Swell Index (%)	40–180 %
5	Specific Gravity	2.60–2.75
6	Swelling pressure	50 – 800 KN / m^2
7	C.B.R. (soaked)	1.2–4.0
8	Fines (<75µ)	70–100 %
9	2µ Fraction	20–60 %
10	Soil classification (1498–1970)	CH or MH Clay/Silt of High plasticity
11	Procter Density	1350–1600 Kg / m^3

Chemical Properties of Black Cotton Soil

- PH Value> 7 (Alkaline)
- Organic Content 0.4 to 2.4 %
- CaCo3 1–15 %
- SiO2 50–55%
- SiO2 / Al2O3 3–5 %
- Montmorillonite Minerals 30–50

METHODOLOGY

Method of Sampling

Two methods were used in collecting the soil sample; disturbed and undisturbed methods of sampling were used. Disturbed method of sampling digger was used to dig loose the soil and a shovel was used to collect it from the pit. The sample was kept in a polythene bag and air tight to avoid loss moisture from the soil.

Undisturbed method of sampling secondly, undisturbed samples were taken 150 mm diameter cylindrical core, cutter, collar, s hammer and chisel. The core cutter was driven into the ground until it completely sinks down. Having done that, the chisel and hammer were used to dig round the core cutter until it was completely exposed. Then the cutter was carefully removed and trimmed with knife or any sharp edge blade. The core cutter containing the undisturbed soil was kept in an air tight polythene bag and taken to laboratory for analysis.

Site Condition

The site selected for the test is mainly of Black cotton soil. The soil on the surface was indicating shrinkage cracks of around 40mm width. The light weight structures with load bearing type of walls having foundations laid at shallow depth on the in-situ soil have developed cracks, indicating the typical features of expansive clays such as Black cotton soils. So, a shallow foundation is usually provided when the soil at a shallow depth has adequate capacity to support the load of the structure. However, in situation where the soil at shallow depth is poor, in order to transmit the load safely, the depth of foundation has to be increased till a suitable soil stratum is met. In view of increased depth, such foundations are called deep foundations. Piles, piers and wells are examples of deep foundations (Tavakoli et al., 2014).

Particle Size Distribution (Sieve Analysis)

Any types of soil consist of all assemblage of discrete particles of various sizes. The objective of particle size distribution is to group these particles into separate range of size and to determine the relative properties by dry mass of each.

Method of wet-sieving analysis soil was wet-sieved to removes to the clay and silt sized particles (N0.06mm) oven dried at 105–110c and then dry sieve to determine the percentage proportion of coarse particles (>0.006).

Procedure

- 500g of soil was weighed
- Volume of distilled water was added
- The sample was stirred carefully and poured into series of sieves arrange
- Soil retained on each sieve was weighed
- Specific gravity of soil particles

The specific gravity of soil, usually given, the notation Gs is widely used in laboratories and analysis work. A value of Gs is of course required the use of Stoke's law in particle size analysis. Two methods are usually employed; the density bottle for fine grain soil, the pycnometer method for coarse grained and fine soils.

Procedure

- The density bottle + stopper was completely dried and weighed W1
- The soil sample passing sieve 2mm BS was riffed from large sample
- Sample dried at 105-110c, cooled in a density bottle
- The soil sample + bottle + stopper were weighed W2

- The bottle was filled with distilled water, vigorously shaken to remove all air bubbles
- The bottle + stopper + soil + distilled water was weighed W3
- The bottle emptied, Cleaned and filled with distilled water
- The bottle + stopper + distilled water was weighed W4

RESULTS

Particle Size Distribution

Table 1: Trail Pit 1 Sample Collected At 1.M

Sieve Sizes	Weight Retained	Percentage Retained	Cumulative Per. Retained	Percentage Passing
¾	-	-	-	100
3/8	5.3	1.1	1.1	98.4
4	33.6	6.7	7.8	92.2
7	38.1	7.6	15.4	84.6
14	71.6	14.3	29.7	70.3
25	13.6	2.7	32.4	67.6
36	36.8	7.4	39.8	60.2
52	53.1	10.6	50.4	49.6
100	39.0	7.8	58.2	41.8
200	26.6	5.3	63.5	36.5
<200	182.6	36.5	100	
Total	**500**	**100**		

Table 2: Trail Pit 1 Sample Collected At 2.0m

Sieve Sizes	Weight Retained	Percentage Retained	Cumulative Per. Retained	Percentage Passing
¾	-	-	-	100
3/8	4.5	0.9	0.9	99.1
4	46.7	9.3	10.2	89.8
7	40.5	8.1	18.3	81.7
14	60.6	12.1	30.4	69.6
25	11.8	2.4	32.8	67.2
36	32.8	6.6	39.4	60.6
52	45.6	9.1	48.5	51.5
100	33.4	6.7	55.2	44.8
200	26.8	5.4	60.6	39.4
<200	197.3	39.4	100	
Total	**500**	**100**		

Table 3: Trail Pit 2 Sample Collected At 1.0m

Sieve Sizes	Weight Retained	Percentage Retained	Cumulative Per. Retained	Percentage Passing
¾	-	-	-	100
3/8	17.0	3.4	3.4	96.6
4	49.8	10.0	13.4	86.6
7	35.9	7.2	20.2	79.4
14	57.8	11.6	32.2	67.8
25	10.7	2.1	34.3	65.7
36	30.0	6.0	40.3	59.7
52	38.5	7.7	48.0	52.0
100	29.6	5.9	53.9	46.1
200	22.1	4.4	58.3	41.7
<200	208.6	41.7	100	
Total	**500**	**100**		

Table 4: Trail Pit 2 Sample Collected At 2.0m

Sieve Sizes	Weight Retained	Percentage Retained	Cumulative Per. Retained	Percentage Passing
¾	-	-	-	100
3/8	3.9	0.8	0.8	99.2
4	32.5	6.5	7.3	92.7
7	30.0	6.0	13.3	86.7
14	39.1	7.8	21.1	78.9
25	39.1	1.9	23.0	77.0
36	27	5.4	28.4	71.6
52	39.6	7.9	36.3	63.7
100	33.8	6.8	43.1	56.9
200	29.2	5.8	48.9	51.1
<200	255.3	51.1	100	
Total	**500**	**100**		

Table 5: Trail Pit 3 Sample Collected At 1.0m

Sieve Sizes	Weight Retained	Percentage Retained	Cumulative Per. Retained	Percentage Passing
¾	-	-	-	100
3/8	5.4	1.1	1.1	98.9
4	44.3	9.0	10.1	89.9
7	27.7	5.5	15.6	84.4
14	41.8	8.4	24.0	76.0
25	8.1	1.6	25.6	74.4
36	22.2	4.4	30.0	70.0
52	34.5	6.9	36.9	63.1
100	30.7	6.1	43.0	57.0
200	27.7	5.5	48.5	51.5
<200	257.6	51.5	100	
Total	**500**	**100**		

Table 6: Trail Pit3 Sample Collected At 2.0m

Sieve Sizes	Weight Retained	Percentage Retained	Cumulative Per. Retained	Percentage Passing
¾	-	-	-	100
3/8	2.3	0.5	0.5	99.5
4	12.5	2.5	3.0	97.0
7	17.7	3.5	6.5	93.5
14	43.5	8.7	15.7	84.3
25	9.3	1.9	17.1	82.9
36	26.0	5.2	22.3	77.7
52	40.3	8.0	30.3	69.7
100	33.0	6.6	36.9	63.1
200	28.0	5.6	42.5	57.5
<200	287.4	57.5	100	
Total	**500**	**100**		

Atterberg Limit Tests

Table 7: Casa Grande Method Tp1 At 1.0m

Container No	GB2	BB	AA	GB6	GA13	4
Number of blows	11	18	22	31	-	-
Wet of sample + container (g)	40.09	39.87	41.04	39.76	35.79	17.0
Dry sample + container (g)	37.88	37.76	38.59	37.65	35.38	16.60
Container	32.51	32.85	32.80	32.30	32.80	13.95
Water	2.21	2.11	2.45	2.11	0.41	0.40
Dry sample	4.99	4.91	5.79	5.35	2.58	2.65
Moisture content = ww / wd x 100	44.3	43.0	42.3	39.4	15.9	15.1
Average					**15.5**	

Table 8: Casa Grande Method Tp1 At 2.0m

Container No	GA2	GA11	CA11	GA3	GB7	GA7
Number of blows	11	19	28	33	-	-
Wet of sample + container (g)	39.69	38.12	40.66	41.50	34.77	35.50
Dry sample + container (g)	37.26	36.36	38.16	38.87	34.26	34.81
Container	32.44	32.63	32.57	32.80	32.59	32.56
Water	2.43	1.76	2.50	2.63	0.51	0.69
Dry sample	4.82	3.73	5.59	6.07	1.67	2.25
Moisture content = ww / wd x 100	50.4	47.2	44.7	43.3	30.1	30.7
Average					**30.4**	

Table 9: Casa Grande Method Tp2 At 1.0m

Container No	BGA	GA14	GB3	GB1	GA9	GB14
Number of blows	13	17	27	32	-	-
Wet of sample + container (g)	39.80	41.13	40.21	40.71	35.68	35.23
Dry sample + container (g)	37.40	38.47	37.83	38.27	35.19	34.81
Container	32.35	32.69	32.50	32.70	32.61	32.56
Water	2.40	2.66	2.38	2.44	0.49	0.69
Dry sample	4.95	5.78	5.33	5.57	2.58	2.25
Moisture content = ww / wd x 100	47.5	46.0	44.7	43.8	19.0	17.7
Average					**18.4**	

Table 10: Casa Grande Method Tp2 At 2.0m

Container No	5	M	A1	A3	6	7
Number of blows	12	16	27	33	-	-
Wet of sample + container (g)	32.50	32.70	22.52	22.94	17.24	17.26
Dry sample + container (g)	19.25	20.11	20.00	20.37	16.66	16.68
Container	14.06	14.12	14.17	14.25	14.04	14.08
Water	2.43	2.70	2.52	2.57	0.58	0.58
Dry sample	5.19	5.99	5.83	6.12	2.62	2.60
Moisture content = ww / wd x 100	46.8	45.1	43.2	42.0	22.1	22.3
Average					**22.2**	

Table 11: Casa Grande Method Tp3 At 1.0m

Container No	GA12	GB5	GB11	GA4	GA10	GB9
Number of blows	12	16	27	33	-	-
Wet of sample + container (g)	43.64	41.59	40.09	42.99	36.33	36.52
Dry sample + container (g)	40.00	38.99	38.00	39.88	35.69	35.82
Container	32.66	32.48	32.60	32.74	32.58	32.43
Water	3.64	2.60	2.09	2.78	0.64	0.70
Dry sample	7.34	6.51	5.40	7.14	3.11	3.39
Moisture content = ww / wd x 100	49.6	39.9	38.70	38.90	20.60	20.70
Average					**20.70**	

Table 12: Casa Grande Method Tp3 At 2.0m

Container No	1	7	3	2	5	M
Number of blows	11	19	24	32	-	-
Wet of sample + container (g)	21.74	21.16	21.12	22.89	16.49	16.40
Dry sample + container (g)	19.36	18.95	18.99	20.20	16.48	16.40
Container	14.24	14.08	14.25	14.03	14.07	14.12
Water	2.38	2.21	2.13	2.69	0.37	0.36
Dry sample	5.12	4.87	4.74	6.17	2.04	1.92
Moisture content = ww / wd x 100	46.5	45.4	44.9	43.6	18.1	18.8
Average					**18.5**	

Determination of Specific Gravity Using Density Bottle

Table 13: TP1 Sample Taken At 1.0m

Bottle No	2
Mass of bottle MI (g)	17.89
Mass of bottle + material M2 (g)	39.27
Mass of bottle + material + water M3 (g)	82.62
Mass of bottle + water full	69.53
Mass of material used M3-M2 (g)	43.35
Mass of material used m2 – m1 (g)	21.38
Volume of water used (m4-m1)- (m3-m2) (g)	8.29
Gs+ m2-m1/ volume of water	2.60

Table 14: TP1 Sample Taken At 2.0m

Bottle No	2
Mass of bottle MI (g)	15.84
Mass of bottle + material M2 (g)	37.05
Mass of bottle + material + water M3 (g)	79.73
Mass of bottle + water full	67.01
Mass of material used M3-M2 (g)	42.68
Mass of material used m2 – m1 (g)	21.21
Volume of water used (m4-m1)- (m3-m2) (g)	8.49
Gs+ m2-m1/ volume of water	2.50

Table 15: TP2 Sample Taken At 1.0m

Bottle No	2
Mass of bottle MI (g)	17.89
Mass of bottle + material M2 (g)	39.43
Mass of bottle + material + water M3 (g)	82.60
Mass of bottle + water full	69.53
Mass of material used M3-M2 (g)	43.17
Mass of material used m2 – m1 (g)	21.54
Volume of water used (m4-m1)- (m3-m2) (g)	8.47

Gs+ m2-m1/ volume of water	2.54

Table 16: TP2 Sample Taken At 2.0m

Bottle No	1
Mass of bottle MI (g)	15.84
Mass of bottle + material M2 (g)	35.46
Mass of bottle + material + water M3 (g)	78.74
Mass of bottle + water full	67.01
Mass of material used M3-M2 (g)	43.28
Mass of material used M2 – M1 (g)	19.62
Volume of water used (M4-M1)- (M3-M2) (g)	7.89
Gs+ M2-M1/ volume of water	2.50

Table 17: TP3 Sample Taken At 1.0m

Bottle No	1
Mass of bottle MI (g)	15.84
Mass of bottle + material M2 (g)	33.74
Mass of bottle + material + water M3 (g)	77.76
Mass of bottle + water full	67.01
Mass of material used M3-M2 (g)	44.02
Mass of material used M2 – M1 (g)	17.90
Volume of water used (M4-M1)- (M3-M2) (g)	7.15
Gs+ M2-M1/ volume of water	2.50

Table 18: TP3 Sample Taken At 2.0m

Bottle No	1
Mass of bottle MI (g)	17.89
Mass of bottle + material M2 (g)	35.64
Mass of bottle + material + water M3 (g)	80.45
Mass of bottle + water full	69.53
Mass of material used M3-M2 (g)	44.81
Mass of material used M2 – M1 (g)	17.75
Volume of water used (M4-M1)- (M3-M2) (g)	6.83
GS+ M2-M1 / volume of water	2.60

Particle Size Distribution

The Sieve Analysis Shows The Following Results.

TP1 at the depth of 1.0m,

6.7 % are within gravel size

56.8 % are within sandy size

36.5 % passes sieve 200mm

TP1 the depth of 2.0m

10.2 % are within grave size

50.4 % are within sandy size

39.4 % passes sieve 200mm

TP2 at the depth of 1.0m

13.4 % are within grave size

44.9 % are within sandy size

41.7 % passes sieve 200mm

TP2 at the depth of 2.0m

7.3 % are within grave size

41.6 % are within sandy size

51.1 % passes sieve 200m

TP3 at the depth of 1.0m

10.1 % are within grave size

38.4 % are within sandy size

51.5 % passes sieve 200mm

TP3 at the depth of 2.0m

3.0 % are within grave size

39.5 % are within sandy size

57.5 % passes sieve 200mm

Therefore, looking at the results shown above, the soil has high quantity of sand and silt. Hence, the soil is classified as silty-sand.

The Atterberg Limit

TP at the depth of 1.0m

Liquid limit 41.0 %

Plastic limit 15.5 %

TP1 at the depth of 2.0m

Liquid limit 46.0 %

Plastic limit 30.4 %

TP 2 at the depth of 1.0m

Liquid limit 45.0 %

Plastic limit 18.4 %

TP2 at the depth of 2.0m

Liquid limit 43.9 %

Plastic limit 22.2 %

TP3 at the depth of 2.0m

Liquid limit 39.0 %

Plastic limit 20.0 %

TP3 at the depth of 2.0m

Liquid limit 44.9 %

Plastic limit 18.5 %

This results shows that all the liquid limits fall below 50%, which means that the soil is plastic in nature. Consequently, based on the findings and unified soil classification system (USCS), the soil is classified as silty- sand and it is poor for engineering works.

CONCLUSIONS

Based on investigations made on Black cotton soil, different conditions are examined and the strength. The black cotton soils which are inorganic clays formed a major soil in Numan LG, Adamawa State. The properties of black cotton soils in the study area are high swelling with shrinkage properties, which is most troublesome for engineering considerations. The soil in Numan is very hard when dry, but loses its strength when in wet condition.

RECOMMENDATIONS

- Engineering properties of Black cotton soil should be check before construction takes place in Numan LGA, of Adamawa state.
- Effort should be made to completely remove Black cotton soil in sites in Numan where construction sites are not too large.
- Other recommended engineering practices should be considered when citing construction project in Numan LGA, Adamawa State

REFERENCES

1. *Ali-Aliabdo, A., Abd-Elmoaty, M. and Hani Hassan, H. (2014). Utilization of crushed clay brick in cellular concrete production," Alexandria Engineering Journal, vol. 53, no. xs1, pp. 119–130, 2014.*
2. *U.G. Fulzele, V.R. Ghane and D.D Parkhe (2016) Study of Structures in Black Cotton Soil International Journal of Advances in Sciences Engineering and technology. Vol. -4 issue-4 pp137.*
3. *Haresh D. G., and Chandresh, D. S. (2015). Studies On Geotechnical Properties Of Black Cotton Soil Stabilized With Furnace Dust And Dolomitic Lime. International Research Journal of Engineering and Technology (IRJET), Vol. 02, issue 8.*
4. *Mohanty, M. K. (2015). Stabilization of Expansive Soil Using Fly Ash, Department of Civil Engineering, National Institute of Technology, Rourkela, Odisha, India.*

5. *Rathan-Raj, R., Banupriya, S. and R. Dharani, R. (2016). Stabilization of soil using rice husk ash, International Journal of Computational Engineering Research, vol. 6, no. 2, pp. 43–50.*

6. *Srikanth-Reddy, S., Prasad, A. C. S. V. and Vamsi-Krishna, N. (2018). Lime-Stabilized Black Cotton Soil and Brick Powder Mixture as Subbase Material. Advances in Civil Engineering, Vol. 3 Issue 12.*

7. *Sudharani, K. Abhishek, S. K. Adarsh, N. and Manjunath, J. (2017). Stabilization of black cotton soil using brick dust and bagasse ash, International Journal for Scientific Research and Development, vol. 5, no. 5, pp. 140–144.*

8. *Mehta, K. S., Sonecha, R. J., Daxini, P. D., Ratanpara, P. B., & Gaikwad, K. S. (2014). Analysis of engineering properties of black cotton soil & stabilization using by lime. Journal of Engineering Research and Application, 4(5), 252.*

9. *Tavakoli, D., Heidari, A. and Pilehrood, S. H. (2014). Properties of concrete made with waste clay brick as sand incorporating SiO2, Indian Journal of Science and Technology, vol. 7, no. 12, pp. 1899–1905.*

10. *Mustapha, S., Voncir, N., & Umar, S. (2011). Content and distribution of nitrogen forms in some black cotton soils in Akko LGA, Gombe State, Nigeria. International Journal of Soil Science, 6(4), 275–281.*