International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

The Properties of Black Cotton Soils as they Affects the Stability of Buildings and Road Constructions in Adamawa State

Dr. Dauda Gana

Department of Technology Education, School of Technology and Science Education, Modbbo Adama University of Technology Yola

Abstract: ***The purpose of this study is to determine the properties of black cotton soil and how they affect the stability of buildings and road construction in Adamawa State. The samples for the study were disturbed samples sourced in seven locations in Adamawa State. Each sample weigh 20kg transported to the laboratory for tests. The tests conducted include: Sieve Analysis, sedimentation Test, Liquid Limit Test, Plastic Limit Test, Activity Ratio, Free Swell Test and Optimum Moisture Content Test. Four research questions guided the study and the findings of the study include; that the samples shows increase percentage smaller or less than 63 microns sizes, which indicate that the samples are more of silt and clay particles. The properties of black cotton soil include liquid limit ranging from 30-45, plasticity index from 20-25 percent, the activity ratio ranges from 1.1-1.6, and free swell test shows above 100 percent. Two strategies proposed for achieving stability of buildings and road construction on black cotton soils of Adamawa State. One of the recommendations made was that, buildings and road constructions in the area of the study should precede a proper soil studies that will determine the soil types and provide bases for basement and pavement design.***

1. Introduction

The black cotton soil by observation looks dark in color and by sample test it is characterized by the phenomenon of swelling when wet and shrinks when dry. These changes describe the nature of black cotton soil obtained in Adamawa State. According to Oliver (2007) the instability inherent in black cotton soil makes it highly destructive to buildings and road constructions in Adamawa State. The origin of black cotton soil according to Joils (2004) is traced to basic igneous rocks e.g. Basalt rich in feldspars and mafic minerals such as montmorllonites. In Adamawa State black cotton soil is found in poorly drained areas such as is obtained in Numan, lafiya Lamorde, Demsa, Fufore, Mayo-belwa, Ngurore, Jimeta and along the Banue basins, where these sediments were believed to have been deposited by receding rivers in expansion during the pick of the rainy seasons. These areas experience alternating wet and dry seasons having annual rainfall below 120cm. According to Marks (2000) the other favorable condition to the formation of these soils includes the cumulative effects of leaching, alkaline environment and retention of calcium and magnesium in the soil.

Black cotton soil shows a discontinuous stretches within the depth of most foundation in road and building construction underlined by sandy sediments. The typical evidence of the activities of the black cotton soil is the rapid changes that is characterized by swelling and shrinkage as the moisture content varies in wet and dry seasons of the area of study Frank (2010).

2. Purpose of the Study

The general purpose of the study is to determine the properties of black cotton soil as they affect the stability of roads and buildings in Adamawa State of Nigeria. The specific purposes include;

1) To determine the particle size distribution of the black cotton soil sample taken for the study.
2) To determine the properties of the black cotton soil sample taken for the study.
3) To determine how the properties of black cotton soil affect the stability of roads and buildings in Adamawa state.
4) To determine the strategies for improving the stability of roads and building construction on black cotton soil in Adamawa State.

3. Research Questions

The following research questions served as a guide to the study

1) What are the particle size distributions of the black cotton soil sample taken for the study?
2) What are the properties of the black cotton soil sample taken for the study?
3) What are the properties of black cotton soil as they affect the stability of roads and buildings in Adamawa state?
4) What are the strategies for improving the stability of roads and building construction on black cotton soil in Adamawa State?

4. Experimental Procedure

4.1 Sample and Sample Collection

The samples collected for the study were in seven locations. Disturbed samples were collected in Ngurore, Demsa, Fufore, Numan, Lafiya Lamorde, Mayobelwa, and Jemeta, all in Adamawa State. 20kg each of the samples were conveyed in jute bags for laboratory analysis which includes: Particle size analysis, sedimentation test, free swell test, Optimum Moisture Content, Liquid Limit test and Plasticity test were conducted. The results of the analysis are shown on table 1&2.

The samples were collected using pick axe, shovel, head pan, Jute bags, and weighing scale and were conveyed to the laboratory for analysis.

4.2 Tests Conducted

4.2.1 Optimum Moisture Content

The tests conducted were carried out to determine the moisture content of the samples of black cotton soil obtained for the study. This was done by weighing the dry sample and the wet samples to determine the difference in percentage moisture content. To achieve the desired result the values of the dry weight was reduced from the wet weight and the result was the water absorption rate of the samples given in percentage.

4.2.2 Laboratory Classification Test

The Unified soil classification system was used to classify the various samples of black cotton soil samples taken for the study.

(a) Mechanical Sieve Test

Table 1: Particle Size Analysis.

Sample No	Percentage Passing			% Liquid Limit	% Plastic Limit
	2 microns	.425	63microns		
1	100	90	92	41	25
2	98.8	92	93	49	24
3	99.5	99	91	39	22
4	99	97	90	35	23
5	99	94	38	49	20
6	99.5	92	90	42	25
7	99	93	52	45	22

Table 1, shows the percentage passed BS sieves 63 microns are silt and clay which values ranges from 38-93 with most values from 90-93 percent for all the sieve sizes. The liquid limit values range from 35-49 percent, the plastic limit range between 20- 25. And percentage passing BS sieve 0.425mm ranges from 90-99 percent.

(b) Sedimentation Test

The test was conducted in accordance with British Standard 1377; 1975. This is carried out using hydro-meter analysis for the determination of particle size distribution, applying sodium phosphate as dispersant. This was used to determine the particle size distribution up to micron sizes.

5. Free Swell Test

Free swell test is performed by slowly pouring 10cc of dry soil passing BS .425 microns sieve into 100cc graduated cylinder filled with water and noting the swollen volume of soil after it comes to rest at the bottom. This is computed using the following equation;

Free Swell= $V\text{-}V^{1}/V1$ x100%
V=Soil volume after swelling in cc and
V1=Soil volume before swelling (10cc)
The free swell value for soil with swell potentials above 100%

Table 2: Properties of black cotton soils samples obtained for the study

Sample No	Plasticity Index	%Liquid Limit	%Plastic Limit	%Activity Ratio	%Free Swell	%Optimum Moisture Content
1	16	41	25	1.2	100	12
2	25	49	24	1.0	100	13
3	17	39	22	1.4	130	12
4	12	35	23	1.5	110	12
5	29	49	20	1.2	120	13
6	17	42	25	1.6	100	11
7	23	45	22	1.1	100	12

Table2 shows the properties of the black cotton soil samples obtained for the study. The percentage liquid limit ranges from 25-49 percent, the plastic limit ranges from 20-25 percent, The plastic index ranges from 12- 29 percent. The free swell ranges from 100-130 percent, while moisture content ranges from 11-13 percent and the activity ratio ranges from 1-1.6 percent.

6. Findings of the Study

1) The particles size distribution of the samples taken shows increase percentage smaller than 63 microns size with percentage smaller than 2 microns which indicate that the samples contain silt and more clay particles. Other particle sizes are insignificant.
2) The properties of black cotton soil sample taken include percentage liquid limit ranging from 35-49, plasticity index of between 12-29 percentage, activity ratio is between 1.1- 1.6,uptimum moisture content between 11-13percent and free swell results is above 100 percent.
3) The black cotton soil shows high swell potentials as the plasticity index are above 15% for most samples and free swell above 89% and percentage particles smaller than 1 micron. The activity ratio of all the samples is above 1 %. These result indicate that the black cotton soil is highly unstable due to the mechanism responsible for swelling and shrinkage phenomenon in the black cotton soil. The instability inherent in black cotton soil affects the stability of roads and buildings in Adamawa State.
4) It was found that the following strategies can improve the stability of buildings and road constructions in the study area where black cotton soil is prevalent.
   - It was found that by the depth of the samples collected that the underline soil below the black cotton soil is sand and gravels, the depth of strip and column foundation can be made deeper where the activity of the expansive soil is minimal. The foundation can also in addition be formed on thick layers of sand or crushed stones.
   - The active black cotton soil strata can be replaced by stable materials completely, this may be very costly as the thickness of replacement can vary from 1-2 meter deep.
   - Another strategy that is practically effective and cost effective in the practical improvement of the expansive black cotton soil at the top. The process involves stabilization with line and cement or mechanical stabilization. The top 30cm stabilized layer is expected

to provide a relatively stable work platform and add to structural strength of the pavement.

- Black cotton soil is vulnerable to volume change with moisture variation so measures should be adopted to reduce the moisture content during construction and the provision of protective layer over the wet strata such as granular layers asphalt or envelopes.

7. Discussion of Findings

The laboratory test data on table 1 shows that the black cotton soil sample taken for the study shows variation in the particle sizes distribution. The percentage content of salt, clay, liquid, and plastic limits and swell potentials shows that black cotton soil should be studied and categorized according to the level of particle sizes; liquid limits, plastic limit and free swell. Edmond (2006) made similar comments on the importance of making design specification he developed for specific categories of black cotton soil. It is therefore very necessary to determine the category of black cotton soils in an area to design specification for the category encountered in a particular area.

The properties of black cotton soil sample indicate a high level of activeness with activity ratio above 1.5 percent, moisture content of 11-13 percent and free swell potential above 100%and liquid and plastic limits rang from 20-45 percent according to US Corps of Engineers and modified by Transportation and Road Research Laboratory (TRRL) (2000) the percent swell must be limited to 2% so that the rate of swelling must be restricted to as law as practicably possible. The design strength in the field must be maintained irrespective of moisture variations, settlement and strict acceptance criteria for insitu density. Moisture content should be adhered to so as to minimize post construction surface deformations and settlements.

The strategies proposed by the current study for improved stability is corroborated by Shelty (2004)who recommended a total replacement of the active black cotton soil strata with stable minerals such as gravel or treated soils in layers to a specific thickness of the excavated black cotton soils. In Adamawa State the black cotton soil strata is generally at a dept of 1-2m across the study area. This shows that total replacement to such depth is uneconomical. The dept of black cotton soil in Adamawa State may require the adoption of another strategy. Demian (2000) suggested a more practicable experience of partial improvement of the expansive soil strata to a thickness of 30cm.This is general stabilization by the use of lime, cement or mechanical stabilization as discovered by the current study. The replacement is carried out in layers of the top soil to the depth of 30cm will provide a stable road construction.

In building construction the dept of strip and pad foundations is taken deeper to firm strata. Jacks (2012) in his study proposed reinforcement of strip foundation at a specific dept away from the black cotton soil on layers of gravels and sand to create stability for the building construction above ground.

8. Conclusion

The samples sourced for the study were disturbed samples conveyed to the laboratory in jute bags weighing20kg each. The soil test conducted include; sieve analysis, liquid limit, plastic limit, sedimentation test, free swell test, and activity ratio and optimum moisture content test. The result of the experiment shows that the black cotton soil sample taken for the study contains silt and clay particles in large amount. This renders the black cotton soil in the area of study prone to changes during moisture variations and the instability of the soil affect the stability of buildings and road constructions in the area of study.

9. Recommendations

1) Construction of buildings and road construction in Adamawa State has to precede soil study to determine the content of the soil type. The category of the black cotton soil will determine the type of foundation and pavement design to ensure stability of construction. The practice of having a blank specification for the design and construction of building and road on black cotton soil sub grade irrespective of type, depth of ground water table, moisture content and climate should not continue.
2) The construction of buildings and road should follow the accurate determination of the properties of the soil to avoid the effects of the soil behavior as indicated by the properties of the soil samples taken for the study.
3) Any of the three strategies proposed can be adopted to help the buildings and road construction remain stable after construction in the area of study: these include total replacement to a specific thickness of the black cotton soil and by partial improvement of the expansive soil through stabilization using lime, cement or mechanical stabilization.

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