THE USE OF GUM ARABIC AS STABILIZING AGENT FOR SUB-BASE IN ROAD CONSTRUCTION

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ABSTRACT: *There is in need to upgrade the capability of soil, by stabilization instead of throwing it away. In order to find how a black clay soil can be improved, an investigation was carried out to see how an improved black clay soil can be used as sub-base material for road construction. The analysis conducted on the soil; stabilized with 15% Gum Arabic has produced the Liquid Limit of 25, Plastic Index of 8.77, M.D.D of 1.75, O.M.C of 15.92 and CBR of 30%. The results are in line with ASHTO recommendation for soil to be used as sub-base in road construction.*

Keywords: Yamaltu Deba, Black clay soil, Gum Arabic, soil stabilization,
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INTRODUCTION

In Geotechnics, soil improvement could either be by modification or stabilization, or both. In stabilization, the soils are treated to enable their strength and durability to be improved such that they become totally or at least nearly suitable for construction beyond their original classification. A lot of laterites gravels and pisoliths, which are good for gravel roads, occur in tropical countries of the world, including Nigeria (Abubakar, 2004). There are instances where a laterites may contain a substantial amount of clay minerals that its strength and stability cannot be guaranteed under load especially in the presence of moisture. These types of laterites are also common in many tropical regions including Nigeria where in most cases sourcing for alternative soil may prove economically unwise but rather to improve the available soil to meet the desired objective (Akanbi, 2005). Over the times, Gum Arabic has been used for stabilizing soils. The over dependent on the utilization of industrially manufactured soil improving additives (Gum Arabic etc.), have kept the cost of construction of stabilized road financially high. This hitherto have continued to deter the underdeveloped and poor nations of the world from providing accessible roads to their rural dwellers who constitute the higher percentage of their population and are mostly, agriculturally dependent. Thus the use of agricultural waste (such as Rice Husk Ash - RHA) will considerably reduce the cost of construction and as well reducing the environmental hazards they causes. It has also been shown by Arora (2005) that Gum Arabic, by the nature of its chemistry, produces large quantities of CO_2 for every ton of its final product. Therefore, replacing proportions of the Gum Arabic in soil stabilization will reduce the overall environmental impact of the stabilization process. Soil in Civil Engineering can be said to be a material that is of great importance, especially if one is talking of construction, since foundation is the bed rock of any structure and sub-base is a very important part of a road. Soil and rocks materials are used mostly in the construction of Civil Engineering structures. The soil used in construction of road or building must be checked to see whether it is suitable or not otherwise, an unsuitable soil can lead to failure of structure because of its geotechnical formation and type. In most cases, if a soil is not suitable or it is unfit for its intended purpose to avoid any problem, the Engineer may choose to use a more suitable soil by hauling it to the site and replacing it with the suitable ones, but if it is not possible to do that, the next thing that comes to the mind of the Engineer is to stabilize it so as to make it fit for it intended purpose. This is exactly what this research work intends to do. In this era of technological advancement, it is better to improve on a material (like soil), than throwing it away. Thus, Engineers should focus on modifying or stabilizing of soil, in a road construction project, rather than having the wrong impression that the soil is useless and cannot be used. Therefore, the communities living in North Eastern part of Nigeria, where this black cotton soil in common, should think of how the soil can be modified for any engineering use, rather than seeing it as useless. This research work will specifically focus on the possibility of adding Gum Arabic to improve upon the geotechnical properties of black cotton soil. The soil (black cotton soil) was obtained from Yamaltu-Deba town, headquarters of Yemaltu Deba Local Government area of Gombe State.

STATEMENT OF PROBLEMS

The major problems that black cotton soil have are swelling, high plasticity, instability, low shear strength. Also, slow draining which lead to water logging, impermeability and excessive volume change due to moisture absorption. With these kinds of properties, there is need to stabilize this type soil, so as to make it fit for use in construction of Civil Engineering structures such as roads, especially where suitable soils are scarce.

AIM AND OBJECTIVES

The research work is aimed at improving the geotechnical properties of black cotton soil and checking the effect of Gum Arabic in stabilizing it.

OBJECTIVES

1. To assess the effect of the admixtures on the index and engineering properties of stabilized black cotton soil.
2. To find out the effect of the additives on the properties of black cotton soil.
3. To see to it the strength value obtained at the optimum percentage of additives.

MATERIALS AND METHOD

Clays are expansive soils which swell and shrink excessively due to change in moisture content (Akanbi, 2010). When roads are built on expansive soils they experience either settlement or heave depending on the swelling pressure of the soil (Cassagrandix, *et al*, 1990). The design and construction of roads on expansive soils poses a serious challenge as the frequency of road pavement failures have been of great concern to road engineers in Nigeria (O'Flaherta, 2002). Roads sitting on expansive soils (like black cotton soil) suffers from both structurally and non-structurally damages due to the alternate expansion and contraction of the soil as a result of moisture changes (Alera, 1994). Sub-base soil is an integral part of pavement structures by supporting the pavement hence the soil to be used in its construction must be one that can give adequate support and stability under adverse loading conditions (Akanbi, 2010). In Nigeria black cotton soils (expansive clays) are typically found in low lying areas of North Eastern States of Gombe, Borno, Yobe, Adamawa, Taraba, and Bauchi States. The soils according to Akanbi (2010) occurs in discontinuous stretches as superficial deposits; usually not more than 2m thick. In view of the problematic nature of the black cotton soil, attempts have been made by researchers all over the world to stabilize the expansive soil using various materials and methods evidenced by the volume of literature on the subject matter. In most instances, Geotechnical Engineers can avoid the potential soil problems by either, removing the problem soil and replacing it with another soil of superior quality (which is not the best option) or by modifying/stabilizing the soil's properties with other available materials. Each of these methods could be use to enhance the properties of soil for engineering purposes (Akanbi, 2010).

Factors such as economy and availability of replaceable materials, the choice of stabilizing the soil is becoming more feasible and common. The mixing of two or more materials and compacting them improves the strength of the treated soil, this improvement is known as stabilization (Abubakar, 004).

Soil identification

Soil is the relatively loose mass of mineral and organic materials and sediments produced by the physical or chemical disintegration of rock. It consists of layers of mineral constituents of variable thickness, which differ from the parent material in physical, morphological, chemical and mineral characteristics. According to the detailed description of the method of describing soils contained in BS 5930, the basic soils are boulders, cobbles, gravels, sand, silt, and clay. As for black cotton clay of North-Eastern Nigeria, it is grayish black in colour and of heavy texture when wet; this clayey soil is very soft but become hard when dry. In the areas where these black clay occur, syntax crack of up to about 150mm are being common particularly around November (Ola, 1978).

Soil stabilization

This is the process of improving the engineering properties of a soil mass either mechanically or by the addition of chemicals reagent such as lime, Gum Arabic, cement, bitumen, rice husk ash etc and sometimes thermal or electrical means to improve its serviceability as a construction material. When the soil is loose or highly compressible or have unsuitable consistency indices to high permeability or any other undesirable property making them unsuitable for use in a construction project, they may have to be stabilized. The stabilization may consist of any of the following:

Increasing the soil density

- Adding materials to effect a chemical or physical change in the soil materials.
- Lowering the water table (soil drainage).
- Removal and/or replacement of poor soil (which is sometimes uneconomical.)

Any alteration of the physical or engineering properties of a soil mass require investigation of economics alternatives such as relocation on the site or using an alternative site. These days, thinking of alternative site is what may look difficult in most cases. Therefore, it is more easier and in some cases, economical to modify or stabilize the site soil to obtain the needed properties. In cases such as earth dams' construction of an embankments sub-base and bases, levels or other fills where selection of materials in sufficient quantities may not be available, selective use of the available materials, and understanding of both the function of the earth structure and the mechanics of the earth mass can process a satisfactory solution.

GUM ARABIC

According to Abubakar (2004), Gum Arabic is the dried exudates obtained from the stems or branches of Acacia Senegal or closely related species. It is a natural gum harvested from the exterior of Acacia trees in the form of dry, hard nodules up to 50mm in diameter and ranging from almost colorless to brown. The plant tolerates water deficit and therefore able to endure conditions of prolonged drought associated with the arid region of Nigeria. The Gum Arabic growing states, in Nigeria, include Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe and Zamfara states. Globally, the majority of Gum Arabic found in International markets originates from the Gum belt of sub-Saharan African with Sudan accounting for about 80% of the world production and 60% of the market. Nigeria is the second largest after Sudan. Therefore, to stabilize a soil using Gum Arabic in Nigeria, in order to improve its performance, should not be difficult or very expensive, since the stabilizer needed is available here.

PROPERTIES OF GUM ARABIC

Solubility

Gum Arabic exhibits highly soluble in water. It can yield solutions of up to 50% concentration. At these high levels, it can actually form a highly viscous gel –like mass similar in character to a strong starch gel. Good grades of gum Arabic gives solutions that are essentially colourless and also impact no taste to the solutions, poor quality dark grade Gum Arabic have an unpleasant astringent flavour and odour probably due to the presence of tannins. It is soluble in oils and in most organic solvents (Cassagradix et al, 1990).

Compatibility

Gum Arabic solution will produce precipitation with many salts, particularly trivalent metallic salts. It is incompactible with some gums, such as gelatin and sodium alginate, but quite compactable with methyl cellulose, carboxyl-methyl cellulose, and larch gum. In most cases, compatibility is subjected to the influence of pH and concentration, and compatibility of Gum Arabic with other components can obtain by proper adjustment of these parameters.

EMULSIFYING PROPERTY

Gum Arabic is a very effective emulsifying agent because of its protective colloid functionality and has found wide spread use in the preparation of varied oil-in-water food emulsion.

Viscosity

While most gums form highly viscous solution at low concentrations of about 1 to 5%, Gum Arabic is unique in the sense that it is extremely soluble and is not very viscous until concentrations of about 40 to 50% are obtained. The ability to form highly concentrated solutions is responsible for the excellent stability and emulsifying properties of Gum Arabic when incorporated with large amounts of insoluble materials.

GUM ARABIC STABILIZATION

The performance of soil-stabilized wearing course under traffic depends on the quality of binder used. Gum Arabic has been successfully used for binding soil particles together, thereby forming a hard stable mass with considerable resistance to abrasion. Gum Arabic can be hard in inorganic soils which can be easily pulverized. The amount of gum required is from 5 percent to 15 percent by volume. The soil to be treated is scarified to a depth of 10 to 15cm; the soil is then pulverized to break up lumps. If lumps are hard, a smooth roller will prove effective if the material is fairly dry. Any additional soil required to improve the grading should be evenly spread over the loosened roadway material before mixing operations begin. The mixing is done with spring-tooth harrows, disc harrows, or rotary tillers. Water is added during the mixing process, preferably with pressure distributors. Sufficient water should be added to hydrate the gum. For strength and durability, it should be at optimum for maximum density. For silt and clay-soil-gum mixtures, the mixture content should be slightly more than the optimum. Gum Arabic is added to the mixture at the rate of 5 to 15 percent by weight of soil. The exact percentage should be determined by laboratory test. The spreading may be done by hand or by mechanical spreader. Harrows, cultivators or gang plows are used to incorporate the gum in the soil to have a uniform mixture. Mixing should be continued until uniform colour and texture are obtained. Tamping rollers should be used for compacting the layer. Upon completion of this consolidation, the surface is slightly dragged with a spike tooth harrows and finish rolling is done with a self-propelled smooth tandem roller so as to form a smooth surface. In a Gum Arabic-stabilized soil each particle of gum may hold several particles of clay in a cluster. Gum Arabic stabilized road should be used for a lighter traffic, say 500 vehicles per day. A surface coating of bituminous material followed by spreading sand or stone chips will improve surface durability and improve water run-off-characteristics (Arora,2008).

METHODOLOGY

Sample Collection

Black cotton soil was collected from Yamaltu Deba, Gombe State. The following tests were carried out, in the Soil Laboratory of Department of Civil Engineering, Kaduna Polytechnic, Kaduna.

Determination of Liquid Limit

The aim of liquid limit is to determine the minimum moisture content at which the soil will flow under its own weight; the liquid limit test was conducted in accordance with B.S 1377 (1990) test 1 (A). A sample at least 200g is taken from the soil passing the 425$_{\mu m}$ BS sieve, the soil sample is then placed on the flat spatula until the mass becomes a thick homogenous paste. Then some proportions of the paste is placed in Atterberg limit device and leveled off parallel to the base and divided by drawing the grooving tools along the center of the huge and the blows are applied for the groove to close and the number of blows is taken. The paste is placed in a can and weighed then oven dried. Soil samples are then added to the paste in order to increase the number of blows and initial procedure is repeated 3 times for the liquid limit test. The same samples are taken and moulded into 3mm rolls to test for the plastic limit. The weights of the wet sample are taken and they are dried in an oven for 24 hours, the dry weights are taken and the result tabulated.

Determination of Shrinkage Limit

Some quantity of the soil sample was passed through the N.425mm BS test sieve and mixed with water on glass plate using the spatulas. The sample mixed with water was fed into the shrinkage mould and put inside the oven for 24 hours. The sample was removed after 24 hours and its length measure and found that it has reduced. The shrinkage limit was calculated as follows:

$$\text{Shrinkage} = 1 - \frac{(L_1 - L_2)}{L_1} \times 100$$

L_1 = original length of specimen

L_2= decrease in length

Free Swelling

This test was performed by slowly pouring 10cl of dry soil, passing BS 425 Nm BS test sieve into a 100cl graduated cylinder filled with water and noting the swelling volume of the soil after it carries to rest at the bottom the free swell was computed by the following equation:

$$\text{Free swell} = \frac{V - V_1}{V_1} \times 100$$

V = Soil volume after swelling

V_1 = Soil volume before swelling

California Bearing Ratio (CBR TEST)

In accordance with the code of practice B.S 1377 (1990) part 5, this method covers the determination of the California Bearing Ratio of the soil which is obtained by measuring the relationship between the load and penetration when a cylindrical plunger of cross sectional area of 2500mm is made to penetrate the soil at a given rate. The aim of this test is to evaluate the suitability of the sub-grade and the materials used in sub-base courses. With optimum moisture content obtained from the moisture/density relationship curve, the soil to be tested (6000g was thoroughly mixed) for each percentage of water and was compacted in three layers. Each layer was given 62 blows of the 4.5kg rammer. The plunger was seated on the sample while the loading and was seated on the sample while the loading and penetration gauge were set at Zero. The load was applied for each of the following value 0.25mm, 0.50mm, 0.75mm, 1.00mm, and 1.25mm up to 7.5mm penetration. After the penetration test has been compacted on the samples of the soil, about 350g was taken immediately below the surface of both end of the specimen and the moisture content was determined. The value for C.B.R was calculated at both 2.50mm and 5.00 penetrations. The penetrations were divided by 13.24 and 19.96 at 2.50mm and 5.00mm for both top and bottom respectively.

At 2.50mm penetration

$$\text{TOP} = \frac{\text{Applied force x 100}}{13.24}$$

$$\text{Bottom} = \frac{\text{Applied force x 100}}{19.96}$$

At 5.00mm penetration

$$\text{TOP} = \frac{\text{Applied force x 100}}{13.24}$$

$$\text{Bottom} = \frac{\text{Applied force x 100}}{19.26}$$

Particle Size Distribution Test (SIEVE ANALYSIS)

This test was conducted in accordance with B.S 1377 (1990): it was conducted to determine the particle size distribution of a soil sample. It expresses quantitatively the proportion by weight of the various sizes of particles present in the soil. The wide range of particles size encountered in soil can be conveniently classified into fraction, substantively different properties. The latter will serve as a broad base for the possibility of blending of the various sizes as may be required in any construction works.

A soil sample of known weight was got and sieved using a series of sieves ranging from course to fine. The amount of soil retained on each sieve was weighed and recorded. The retained weight is express in percentage i.e.

$$\% \text{ retain} = \frac{\text{weight on sieve}}{\text{Total wet of soil}}$$

The result of the coarse and fine analysis is then plotted on a graph, the percentage of various fraction are expressed to the nearest 1% and sieve size.

Determination of Moisture Content

The moisture content of a soil is defined as the ratio of weight of water pressure in the soil to dry weight of solid particles expressed as a percentage. The natural moisture content was carried out in accordance with B.S 1377 (1990 PART 2): The information of the moisture content is required to know the condition of the field, for this research work, the moisture content obtained here may not be exactly as what is obtained at the site, where the soil sample was collected in Yamaltu Deba. This is because the sample has stayed for some days before the moisture content was determined. To determine the moisture content of the sample collected from field the air tight container is weighed (w_1). A sample of soil is placed in the container and weighed together with lid (w_2).The container with the soil was placed in an oven at a temperature of 105°c-110°c for 24 hours to dry with lid removed. After the 24 hours, the container with the soil was removed from the oven and covered with the lid to avoid re-absorption of moisture and weighed as (w_3).The difference between w_2 and w_3 is the moisture content, and is calculated from formula:

$$m\% = \frac{W_2 - W_3}{W_3 - W_1}$$

Determination of Plastic Limit

The plastic limit test was performed on a proportion of the sample taken from that used for liquid limit determination. The ball of wet sample was placed between palms rolled and further divided into two sub-samples from which four fairly equal parts were formed. Each of the sub-samples was then rolled into a three millimeter diameter thread and their moisture content was determined. The limit was recorded as the average of the moisture content obtained.

Determination of Plasticity Index (PI)

The plasticity index (PI) was calculated from the Liquid Limit (LL) and Plastic Limit (PL) test result as:

$$Pl = LL - PL$$

ANALYSIS AND DISCUSSION OF RESULT

Geotechnical Properties of stabilized Clay Soil

The properties of stabilized soil sample used in this research are presented as follows:

Table 4.1 Geotechnical Properties of Clay Soil

CHARACTERISTIC OF CLAY	DESCRIPTION
0% passing sieve 200	91.6%
Liquid limit	65.00%
Plastic limit	24.00%
Linear shrinkage	13.50%
Maximum dry density (MDD)	1.52 g/cm3
Optimum moisture content (OMC)	27.37%
AASHTO	A-4 to A-5
Natural moisture content (NMC)	12.04 %

Summary of Results

	Liquid Limit	Plastic Limit	Plasticity Index	OMC	MDD	CBR	ASSHTO
0% Gum Arabic	64.00%	24.00%	40.00%	27.37%	1.53g/cm^3	5.57%	A-7-6
2% Gum Arabic	65.00%	24.00%	41.00%	23.30%	1.61g/cm^3	3.85%	A-7-6
4% Gum Arabic	44.00%	19.65%	24.39%	24.26%	1.54g/cm^3	4.3%	A-7-6
6% Gum Arabic	41.50%	19.05%	22.45%	26.50%	1.47g/cm^3	8.65%	A-7-6
8% Gum Arabic	34.00%	12.02%	21.98%	21.0%	1.40g/cm^3	14.5%	A-6
10% Gum Arabic	34.00%	15.49%	18.51%	15.38%	1.72g/cm^3	35%	A-6
15% Gum Arabic	25.00%	16.25%	8.77%	15.92%	1.75g/cm^3	30%	A-4
20 Gum Arabic	48.50%	17.43%	10.00%	27.89%	1.37g/cm^3	9.9%	A-5
25% Gum Arabic	41.00%	32.00%	9.00%	25.00%	1.47g/cm^3	9.4%	A-5

DISCUSSION OF RESULT

The obtained results of stabilized black cotton clay soil with 15% Gum Arabic are: Liquid Limit of 25, Plastic Index of 8.77, M.D.D of 1.75 and O.M.C of 15.92. The results are in conformity with AASHTO values of Liquid Limit 40 max, Plastic Index10 max, M.D.D of 1.76-2.16 and O.M.C of 9-18%, for sub-base material. Also the California Bearing Ratio (CBR) of 30% at 15% Gum Arabic has met with the requirement, that sub-base should have a CBR of not less than 30% (FGN, 1997).

CONCLUSION AND RECOMMENDATION

CONCLUSION

From the research carried out, it was discovered that at 15% Gum Arabic additive there was an improvement in the soil and the results are in line with AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIAL (AASHTO) classification and a good material for sub-base.

RECOMMENDATION

In view of the research conducted on the black cotton clay soil sample, it is recommended that Gum Arabic can be used as stabilizing agent for materials that will be used as sub-base in road construction, especially using 15% Gum Arabic. It is therefore recommended that further study should be conducted on Gum Arabic as 1% 2% 3% 4% 5% and 6% to check for more effect and further places where it can be used in construction.

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