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Banana Extract Lateritic Soil Stabilization in Sudan

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Abstract: Soil stabilization otherwise known as soil modification or improvement, is the process of modifying soil properties to render them durable building and road construction materials by using various admixtures, the well-known being cement and lime. The aim of this study, however, to examine the stabilizing effect of banana extract on selected Sudanese lateritic soils. The objective of this study is to develop a new process for stabilizing lateritic soils. The three soil samples were blended with banana raw extract at 17% by weight of the dry soil at optimum extract content (soil + banana solution). High degree of improvement was obtained in both dry (12.60 – 30.54 N/mm²) and wet (1.03 – 5.03 N/mm²) compressive strength. It was concluded that, banana extract has a profound modifying effect over lateritic soils.

Keywords: *Banana Extract, Lateritic, Soil Stabilization*

1. INTRODUCTION

Soil construction methods are used in 80% of urban buildings in Sudan while this figure exceeds 90% in rural areas [2.2]. The main advantage of soil construction is its low cost, ease of use, desirable thermal characteristics, and environmental appropriateness. Due to limited means within developing countries, including the Sudan, it is necessary to seek ways to reduce construction costs, especially for low-income housing and infrastructure, as well as adopting easy and effective solutions for their repair and maintenance. Such objectives can be achieved partially through the production and use of cheap yet durable locally available materials. Ideally, the production of such building materials will contribute to improving development objectives, by generating local employment, rural development, and reduction in construction cost, alleviate the burden of imports. One such material is the compressed stabilised soil building blocks, improved by using conventional stabilizers such as cement or lime, or traditional organic like organic plant juices or extracts. Stabilization is known and practiced centuries ago with an objective being to render soil good and durable building structures. Stabilization was also defined as a means by which soil properties are modified and made more durable for construction purposes, which can be mechanical, chemical and sometimes biological. It was also affirmed that local materials identified for use in stabilization can be classified as either agricultural or industrial wastes. The ability to blend the naturally occurring soil with some chemical extracts to give it better engineering properties in both strength and water proofing is very essential. It was deduced that, the reasons for finding alternative to cement high cost of production, high energy input and emission of CO2 (reason for global warming).

The study was carried out on soil samples collected from three borrow pits within vicinity of greater Khartoum as follows: (a) Al Munshia, Khartoum suburb, lies within longitudes N15^0 09$^/$ 15.7$^{//}$ and latitudes E 32^0 51$^/$ 06.5$^{//}$ (b) Al Drowshab, Khartoum North suburb lies within longitudes N16^0 25$^/$ 25.4$^{//}$ and latitudes E33^0 38$^/$ 13.6$^{//}$ and (c) Jebel Toria, Omdurman suburb within longitudes N15^0 16$^/$ 56.5$^{//}$and latitudes E33^0 27$^/$ 21.2$^{//}$.This study aims at examining the geotechnical properties of soil samples from greater Khartoum Stabilized with local plant extracts.

2. Literature Review

2.1 Markus T. A. (1979) headed a project team from the University of Strathclyde, Glasgow, UK, to critically review stabilized soil as an under-utilized resource for low cost building in developing countries. The work contained through review of the material soil; its formation, variation, properties, clays, classification, and tropical soils. The Study also included an elaborate Chapter on soil stabilization; stabilization mechanisms and various stabilizers including natural organic stabilizers.

2.2 Adam E. A. (1983) has experimented with three Sudanese soils representing the basic soil groups stabilized with lime and lime-gypsum as part of a programme designed to develop improved soil building blocks, at the Building Research Establishment (BRE), UK. The produced stabilized blocks were subjected to both strength and durability testing, giving high quality building blocks.

2.3 Adam E. A. and Agib A. A. (2001), published a book on the production and use of stabilized soil building blocks in the Sudan *''Manufacture of Compressed Stabilized Earth Blocks in the Sudan'', UNESCO funded and UNESCO publication.* In this manual the stabilization mechanism is thoroughly described together with various stabilizers and their compatibility to soil types and properties.

2.4 Otto Ruskulis (2008) updated a technical brief for the British NGO Practical Action on additives to clays. Such organic additives are derived from natural sources such as: (a) vegetable additive (fibres, oils and fats, tannins, gum Arabic, palmo copal, sap and latexes, and molasses); (b) Animal additives (fibre, urine, dung, animal glues, casein, excrements, oils and fats).

2.5 Lalaina R. A. and Gabriely R. V. (2021) conducted a study on soil stabilization mechanism using natural stabilizers (sweet potato, banana, zebu manure). The general objective of the study is to develop a new process for stabilizing lateritic soil. Each organic additive is given as soil stabilizer in increments of 5%, 10%, 15%, and 20% per mass. High quality results were achieved in both dry (3.9 MP – 17 MP) and wet (1.7 MP – 5.2 MP) compressive strength.

2.6 Navami Chandran B, and Veena Vijayan L (2021), have investigated the strength characteristics of cohesive soil stabilized with rice husk ash, banana fibre, and bamboo fibre. The main objective of the study is to investigate the strength behaviour of soil stabilized with organic additives. The study concluded that, the properties of the clayey soil have been greatly improved by the addition of rice husk ash, banana fibre, and bamboo fibre.

2.7 Terra Fusion International, Inc. claimed the development of an organic additive that proven through years of field testing, proprietary innovative multi-enzyme based formulation of ECOBRIX provide increase in strength, density and durability. ECOBRIX is a complex concentrate, multi-enzymatic formulation that modifies the properties of soil material, providing one of the most effective methods to increase bonding and strength of a soil composition. The product contains additional organic compounds designed to accelerate bonding of ionic, charged soil particles. Soil composition adequate for ECOBRIX stabilization should contain at least 15% of cohesive materials (clay, silt); one lire of ECOBRIX is required to treat 25 m^3 of raw soil.

2.8 Olutaiwo A. O. and Lawal A. O. (2017), have investigated the effect of Banana Leaf Ash (BLA) on cement stabilized lateritic soil. The objective of the study is to improve soil engineering properties for highway construction in Nigeria. The soil was blended with BLA in varying increments of 0%, 2%, 4%, 6%, 8%, 10%, and 12% by weight of the soil; the effect of BLA on the soil sample was then determined for Liquid Limit, Plastic Limit, Compaction (MDD, OMC), CBR and Unconfined Compression. It was concluded that, BLA has a weak pozzolanic activity.

2.9 Emeka Sergun Nnochiri and Olufikayo O. Aderinlewo (2016), investigated the geotechnical properties of lateritic soil stabilized with banana leaf ash in Nigeria. Preliminary soil tests such as natural moisture content, specific gravity, and atterberg limit at its natural state, together with engineering tests such as compaction, California bearing ratio and unconfined compressive strength tests. Banana leafs ash was then added to the soil at varying proportions of 2%, 4%, 6%, 8%, and 10% by weight of the soil. The computed result showed that, the banana leafs ash improved the strength of the lateritic soil. It was therefore concluded that, the banana leafs ash satisfactorily acts as a cheap stabilizing agent for subgrade purposes.

2.10 Shobana *et al* (2021), investigated the stabilization process using banana fibre and disposable face masks focusing on the improvement of engineering properties of soil for pavement and earth slope construction. The aim of the study is to determine the effectiveness of banana fibre-mask combination in the process of soil stabilization. Tests carried out in this study include specific gravity, standard proctor compaction test, direct shear test and unconfined compression test. The study claimed improved soil properties

3. Research Methodology

The aim of the study is to investigate the effect of Banana juice for the modification of local soil properties to render them durable building and road construction materials. The methodology followed in this study is as follows: (a) soil samples collected, analyzed, identified, and classified. (b) Samples of banana waste (leaves and stem) were collected its juice was extracted and analyzed. (c) Banana juice was added in fixed increments to each soil type and samples were formed, cured and subjected to durability tests. (d) Results computed were then analyzed, interpreted, discussed and conclusions were drawn.

4. Experimental Investigation (materials and methods)

4.1 Soil

The soil samples were collected from Khartoum, Almunsheia area at depth of 1.0 meter. Omdurman, Jebel Toria sample was taken at a depth of 4.0 meter. Khartoum North, Aldrowshab area at depth of 0.5 meter. It was later brought to the geotechnical Laboratory of Building and Road Research Institute (BRRI) of the University of Khartoum, and marked, indicating the soil description, sampling depth and date of sampling. The soil was air dried for two weeks to allow for partial elimination of natural water which may affect the analysis, then sieved with sieve No 4 (4.75 mm opening) to obtain the final soil samples for the tests. After the drying period, lumps in the samples were pulverized under minimal pressure. The initial tests such as the particle size distribution test, Atterberg limit tests and specific gravity tests, compaction tests, and unconfined compressive strength tests were performed on the un-stabilized soil samples.

4.2 Banana waste leave and stem

Banana fruits exist in abundance along the banks of the river Nile and its tributaries in the Sudan, producing huge hazardous waste for Khartoum state. Such waste amounts for more than 920,000 and 950,000 tones, respectively. One of the study problems is the recycling of banana leaves and stem wastes by utilizing it as a construction material for both buildings and roads. Banana plant sample was collected from Dmazen area, Blue Nile State. The sample consisted of both stem and leaf. The specimen was then air dried, reduced to small particles manually via a hammer, then milled and screened with sieves passing No.20mm Sieve and retained on 60 µm. A standard method was used to determine the chemical properties of the sample such as ash, cellulose, moisture, and lignin contents for banana leaf and stem. The major oxides present in the ash are calcium, magnesium, potassium, sulphate, phosphate, carbonate, and silicate. Also engineering tests such as compaction (maximum dry density and optimum moisture content), and unconfined compressive strength tests were carried out on the stabilized samples using banana juice additive – organic plant extract at 17% of the dry soil at optimum extract content.

5. Result

Table 1. Values of preliminary tests of soil samples

Test element	Locations of soil samples		
	Al Munshia	Al Drowshab	Jebel Toria
Natural moisture content (%)	27.9	17.9	18.9
Specific Gravity (%)	2.69	2.46	2.46
Liquid Limit (%)	43	37	36
Plastic Limit (%)	26	18	19
Plasticity Index (%)	17	19	17
Linear shrinkage (%)	9.29	6.24	9.29
Maximum Dry Density (MDD) gm/cm³	1.55	1.78	1.79
Optimum Moisture Content (OMC) %	17.5	15.5	16.2
Gravel (%)	00	08	02
Sand (%)	03	34	13
Silt (%)	80	38	68
Clay (%)	17	20	17

Table 2. Chemical analysis of soil samples used in the investigation

Oxide content (%)	Locations of soil samples		
	Al Munshia	**Al Drowshab**	**Jebel Toria**
Na_2O	00.657	02.157	00.301
MgO	03.009	03.836	04.084
Al_2O_3	19.684	15.191	17.144
SiO_2	51.985	56.417	51.775
CaO	05.746	07.631	09.529
Fe_2O_3	14.086	10.339	12.515
K_2O	00.965	00.917	00.828
TiO_2	02.728	02.071	02.480

Table 3. Mineralogical analysis of soil samples used in the investigation

Mineral type/content (%)	Locations of soil samples		
	Al Munshia	**Al Drowshab**	**Jebel Toria**
Kaolinite	48.77	20.51	42.35
Smectite	51.23	75.09	54.15
Illite	00.00	03.00	01.20
Chlorite	00.00	01.40	02.30

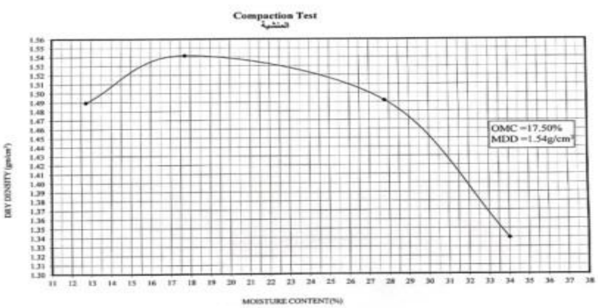

Fig .1. Optimum moisture content maximum dry density relationship, Al Munshia Soil

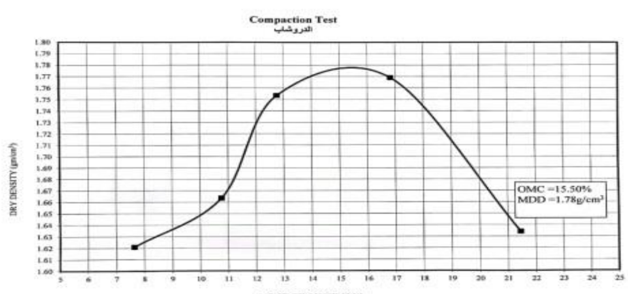

Fig .2. Optimum moisture content maximum dry density relationship, Al Drowshab Soil

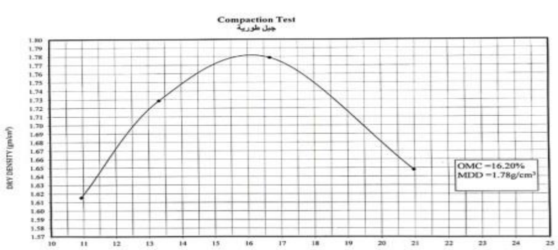

Fig .3. Optimum moisture content maximum dry density relationship, Jebel Toria

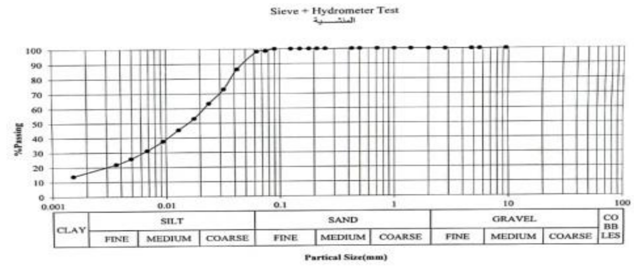

Fig .4. Almunsheia sample - grain size distribution

Grain size distribution

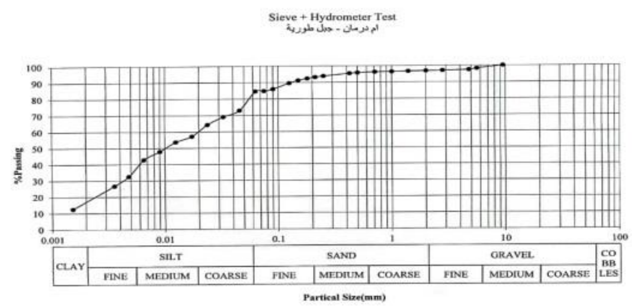

Fig.5. Jebel Toria sample – grain size distribution

Grain size distribution

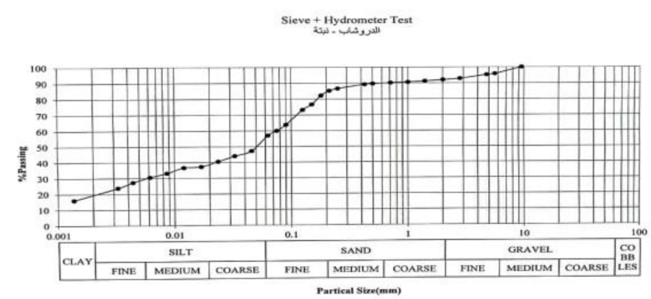

Fig.6. Aldrowshab sample

Table 4. Chemical analysis of banana leaves used in the investigation compared

Plant species	Extract content (%) and type					
	MC%	**MCF%**	**Cellulose%**	**Ash%**	**Lignin%**	**Specific Gravity**
Banana leaves	11.62	0.88	43.74	23.07	36.86	1.38
Acacia Seyal leaves	10.14	0.90	11.97	13.60	12.92	1.55
Calotropis procera	12	0.90	16.29	10.15	10.33	1.45

Table 5. Crushing strength, dry density, OMC values for banana extract treated soils.

location	Crushing Strength (N/cm^2)	Dry Density (g/cm^3)	Optimum Moisture Content (%)
Jebel Toria	Wet 1.029	1.92	14.2
	Dry 12.6	1.81	1.3
Elmunshia	Wet 5.03	1.33	20
	Dry 30.54	1.41	3.6
Eldrowshab	2.85	1.65	15.8
Natural			
Juice Added	3.69	1.64	16.4
Air Dry	13.79	1.31	2.7
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Elmunshia	Wet 5.03	1.33	20
	Dry 30.54	1.41	3.6
Eldrowshab	2.85	1.65	15.8
Natural			
Juice Added	3.69	1.64	16.4
Air Dry	13.79	1.31	2.7

6. Discussion of Results

The results from the initial tests such as natural moisture content, linear shrinkage, maximum dry density and optimum moisture content values, specific gravity, particle size analysis, Atterberg limits and plasticity index before the addition of the extract is given in Table (1). Table (2), however, demonstrates the particle size distribution of the soil sample together with Figures 1, 2 and 3. On the other hand, the chemical examination and the mineralogical analysis values are given in Table (3) and (4) respectively.

Table (1) shows that the predominant soil particle in the three soil samples is silt which ranges between 38% and 80%, then sand varies between 3% and 34%, and clay in the range of 17% to 20%. From these figures it is clear that the fines (silt + clay) in the three soil samples can be reported as follows: Al Munshia (97%), Al Drowshab (58%), and Jebel Toria (85%). These figures match the recommendations made by researchers in the field of soil stabilization, in that, soil suitable for stabilization should contain not less than 50% fines (silt plus clay) [2]. These values also expressed clearly in the linear shrinkage figures for the three soil samples as: Al Munshia (9.29%), Al Drowshab (6.24%), and Jebel Toria (9.29%). The Specific Gravity, though, computed for Al Munshia (2.69), Al Drowshab (2.46%), and Jebel Toria (2.46%). These values fall within the figures reported for tropical and lateritic soils [1]. The Atterberg limits were computed for the three samples as follows: Al Munshia LL (43%), PL (26%), PI ((17%); Al Drowshab LL (37%), PL (18%), PI (19%); and Jebel Toria LL (36%), PL (19%), PI (17%). The compaction characteristics are reported as follows: Al Munshia MDD (1.55 gm/cm^3) at 17.5% optimum moisture content; Al Drowshab MDD (1.78 gm/cm^3) at 15.5% optimum moisture content; and Jebel Toria MDD (1.79 gm/cm^3) at 16.2% optimum moisture content.

Table (2) shows the chemical analysis of the soil samples which reveal that the predominant oxides are alumina, silica and iron, where alumina ranges between 15.19% and 19.68%; silica in the range of 52.00% and 56.42%; iron varies between 10.34% and 14.10%, and this shows typical values for lateritic tropical soils. Table (3) illustrates the mineralogical values via XRD analysis for the three samples as follows: Al Munshia (48.77% kaolinite), Al Drowshab (20.51% kaolinite), and Jebel Toria (42.35% kaolinite). The dominance of kaolinite in the three soil samples shows that the clay is less expansive, and this fact is demonstrated in the linear shrinkage values illustrated in Table (1).

Table (4) the chemical analysis of banana leave and stem compared with values of acacia seyal and acacia tomentosa leaves. Banana sample demonstrated the highest value of cellulose content (43.74%), ash content 23.07%), lignin content (36.86%), and lower specific gravity (1.38). On the other hand, acacia seyal and acacia tomentosa leaves show lesser values as compared to that of banana leaves: cellulose content (11.97% - 16.29%), ash content (10.15% - 13.60%), and lignin content (10.33% - 12.92%). Both acacia samples recorded specific gravity 1.55 for acacia seyal and acacia nilotica tomentosa.

Banana juice extract stabilization shows values of dry crushing strength of 30.54 N/mm^2 and wet crushing strength at 5.03 N/mm^2 for Elmunshia, 13.79 $/mm^2$ dry strength and wet crushing strength of 3,69 N/mm^2 for eldrowshab, and 12.60 N/mm^2 dry crushing strength and strength of 1.03 N/mm^2 for Jebel Toria. The lower value density reported were 1.33 g/cm3 compared to Jebel Toria density value were 1.92 g/cm3 and Eldrowshab were 1.65 g/cm3. Elmunshia soil the specific gravity value were 2.69% and extract specific gravity value were 1.38% , this lower specific value of extract will affect both density and strength of the stabilized soil.

7. Conclusion and Recommendation

The study concluded that banana extract has pronounced effect on the durability properties of lateritic soil especially the dry compressive strength which ranged for the three soil samples between 12.60 N/mm^2 to 30.54 N/mm^2 while the wet compressive strength varies between 1.03 N/mm^2 to 5.03 N/mm^2. Banana extract is suitable stabilize for sandy clayey silt soil (Munshia type). It is recommended that further investigation is required to establish the mechanism of strength development in banana juice stabilization for of sandy clayey silt soil.

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