

The Effects of Wood ash on the Geotechnical Properties of Lateritic Soil

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Abstract

The importance of soil stabilization in road construction cannot be overemphasized as it improves the geotechnical properties of the lateritic soil. It is not in all cases that soil has the desired geotechnical properties in its natural state; hence there is need for modification. The study was carried out in two phases. The first phase was to determine the geotechnical properties of the soil without adding any additives (control experiment) and the second phase was to add varying percentage of additives (test experiment). Woodash was added to the soil sample in varying amount of (0, 2, 4, 6, 8 and 10% of weight of sample) to stabilize the soil while the following tests; Atterberg's limit, Compaction and California Bearing Ratio) were carried out on the stabilized soil. The results showed that the addition of woodash can significantly increase the strength of the soil. It was found that there was an increase in Optimum Moisture Content from 7.7% at 0% woodash to 17.23% at 10% woodash and with a corresponding decrease in Maximum Dry Density from 1970 kg/m³ at 0% woodash to 1840 kg/m³ at 10% wood ash. The CBR value increases from 31.44% at 0% woodash to 46.13% at 10% woodash; hence percentage increase of 46.72%.

Key words

Wood ash, lateritic soil, stabilization, Optimum moisture content, California Bearing ratio, dry density

1. Introduction

Soils are naturally occurring materials that are used for the construction of all underlying courses except the surface layers of pavement (asphalt and concrete); that are subject to classification tests (ASTM D2487) to provide a general concept of their engineering characteristics. Soil properties vary with time, location, and environmental conditions. Climatic factors such as rainfall and temperature changes affect the properties of the soil. Rainfall affects moisture levels of the soil which otherwise affects the strength while temperature changes affect the pavement (Dallas, 2000).

Laterite is a highly weathered material, rich in secondary oxides of iron, aluminum, or both (Amadi *et al*, 2015). The word Laterite describes no material with reasonable constant properties. To those in the temperate countries, it could be described as a red friable clay surface. To those in the hilly tropical countries, it could be described as a very hard homogenous vesicular massive clinker – like material with a framework of red hydrated ferric oxides of vesicular infill of soft aluminium oxides of yellowish colour and in less hilly country, it could exist as a very hard, or soft coarse angular red (Amu *et al.*, 2015). The laterite typically has a porous or vesicular appearance which tends to crush easily under impact, disintegrating into a soil material that may be plastic (Amu *et al.*, 2012). Lateritic soils may be self-hardening when exposed to drying; or if they are not self-hardening, they may contain appreciable amounts of hardened laterite rock or laterite gravel. The engineering properties of lateritic soil are determined from some of the following; particle-size distribution, plasticity and its compaction and compressive strengths. The needs for adequate provisions of transportation facilities are enormously increasing with increase in population and also the maintenance of the existing one. Highway engineers are faced with the problems of providing very suitable materials for the Highway construction (Amu *et al.*, 2015).

The materials used in the construction of roads are of great interest to the highway engineer, in contrast to many other branches of civil engineering where the engineer may not be deeply concerned with the properties of the materials being used. All highways are found on the underlying courses of lateritic soil; hence there is need to determine the geotechnical properties of lateritic soil prior construction and also, the percentage efficiency of locally available materials in improving the geotechnical properties. One of the

objectives of road construction is selection of locally available lateritic soil with adequate engineering properties at a reasonable distance of haulage; otherwise require little or full treatment to improve their strength. It becomes necessary to investigate the possibilities of improving their engineering properties by finding a way of stabilizing the lateritic soils to suit the engineering purposes for which it is meant for. In bid to improve the engineering properties of soil to make it suitable for road construction, this led to the concept called “soil stabilization”, Soil stabilization is the alteration of one or more properties by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties and thus made more stable (Guyer, 2011). This may be either a temporary process to permit the construction of a facility or may be a permanent measure to improve the performance of the completed facility.

The result of an application of a technique may be; increased strength, reduced compressibility, reduced permeability, or improved ground water condition (Mohie and Nehad, 2017). The transformation and improvement of soil properties accordingly involves the application of chemicals such as Portland cement, lime, fly ash, sawdust ash, Rice husk ash etc or combination of them (Amadi, 2010). Over the years, cement and lime have been the two main materials used for improving soil properties; these materials have rapidly increased in price due to share increase in the cost of energy (Neville, 2000). In order to beat the high price of these soil additives there is need to source for alternative materials that are relatively cheap and readily available. Wood is a naturally occurring material obtained from trees. Some of the trees are used for structural works, furniture works, cooking etc. Its end product when burnt in the course of cooking gives a substance called “wood ash”. Wood ash in general has a pozzolanic property which alters most properties of soil that makes it become suitable for construction (Okagbue, 2012). The introduction of wood ash to soil is to serve as stabilizer or conditioner for the soil. Also, wood ash works on coagulation of loose soil (Amu *et al*, 2005).

2. Research Methodology

2.1 Materials and Sourcing

The lateritic soil was obtained at three (3) different spots at interval of 5m located at Hajj camp area, Adewole, Ilorin, Kwara state on coordinates ($8^{\circ}30'N$ and $5^{\circ}E$). The wood ash; a product of burnt wood was obtained at a bakery in Malete, Kwara State. The ash obtained was sieved to remove

foreign materials such as stones, wood and others so as to obtain its fines, portable drinking water was used in the course of the research work.

2.2 Experimental Procedure

Quantitative analysis was carried out on the woodash to determine the percentage composition of chemical compounds contained in the ash. The lateritic soils obtained were kept in different polythene bags with proper soil descriptions, then sealed with adhesive tape and kept safe in the laboratory. All samples collected from different spots were mixed together to have a representative material, slightly pulverized with minimal pressure to break up lumps in order to facilitate air drying. The samples were then sieved with sieve No. 4 (4.76mm opening) to obtain samples for the relevant tests. The samples were then mixed together and the following tests; Particle size distribution Analysis, Atterberg's, Compaction test, and California Bearing Ratio etc were carried out on the soil sample when no additives was added and when additives were added in varying percentages (2, 4, 6, 8 and 10%) of wood ash by weight of the sample (stabilization) and the afore mentioned tests were carried out.

Table 1-Experimental Results On Specific Gravity Of Soil

Sample number	1	2	3
Mass of empty bottle (W_1) in grams	125.52	116.2	120.61
Mass of bottle+ dry soil (W_2) in grams	325.52	316.2	320.61
Mass of bottle + dry soil+ water (W_3) in grams	506.2	456.67	482.39
Mass of bottle + water (W_4) in grams	306.2	256.67	282.39
Specific gravity	2.95	2.79	2.83
Average Specific gravity		2.86	

Table 2- Experimental Results On Physical Properties Of Wood Ash

Test	Values
Average particle diameter (mm)	0.28
Bulk density kg/m^3	780
pH	12.4

Table 3: Chemical Properties Of Wood Ash

Compound	Composition (%)
SiO ₂	33
Al ₂ O ₃	25
Fe ₂ O ₃	1.98
CaO	12.8
MgO	8.7
K ₂ O	9.5
Na ₂ O	7.8

Table 4-Determination Of Moisture Content And Dry Density For 0% Wood Ash

CONTAINER NO:	1	2	3	4	5	6	7	8
Weight of soil tin (grams)	89	101	88	123	120	110	95	85
Weight of dried soil tin (grams)	86	99	85	118	113	104	89	80
Weight of tin (grams)	24	24	24	24	24	24	24	24
Weight of dry soil (grams)	62	75	61	94	89	80	65	56
Weight moisture (grams)	3	2	3	5	7	6	6	5
Moisture content (m) (%)	4.8	2.7	4.9	5.3	7.9	7.5	9.2	8.9
Average Moisture (%)	3.75		5.12		7.7		9.07	
Wet density kg/cm ³	1.71		1.907		2.123		2.103	
Dry Density kg/cm ³	1.65		1.81		1.97		1.93	

Table 5: Determination Of Moisture Content And Dry Density For 10% Wood Ash

CONTAINER NO:	7B	2G	15V	7 ^E	1F	14T	1
Weight of soil tin (grams)	128	118	137	121	141	118	149
Weight of dried soil tin (grams)	120	105	125	105	126	103	129
Weight of tin (grams)	24	22	24	24	24	24	24
Weight of dry soil (grams)	96	83	101	81	102	79	105
Weight moisture (grams)	8	12	11	16	15	15	20
Moisture content (m) (%)	8.3	15	11	20	14.7	19	19.1
Average Moisture (%)	7.2	12.8		17.23		19.02	
Wet density kg/cm ³	1.9	2.038		2.166		2.153	
Dry Density kg/cm ³	1.8	1.81		1.84		1.81	

Table 6- Summary of OMC, MDD and CBR Results of Laterite Soil with wood ash

Wood ash (%)	Optimum Moisture Content (%)	Maximum Dry Density (kg/m ³)	California Bearing Ratio (%)
0	7.7	1970	31.44
2	9.4	1950	32.12
4	11.81	1890	33.56
6	13.58	1870	41.2
8	15.15	1860	43.33
10	17.23	1840	46.13

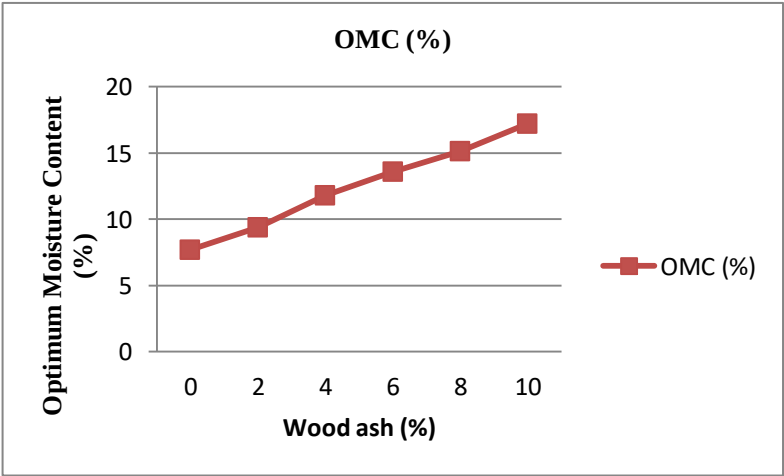


Figure 1 Graph of optimum moisture content against woodash

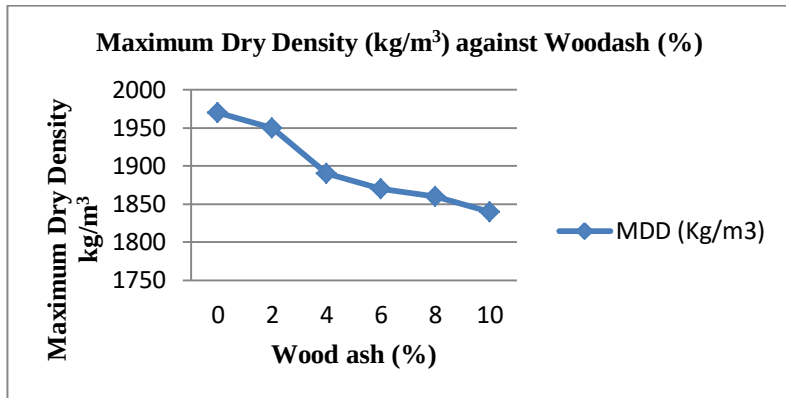


Figure 2 Graph of maximum dry density of lateritic soil against woodash

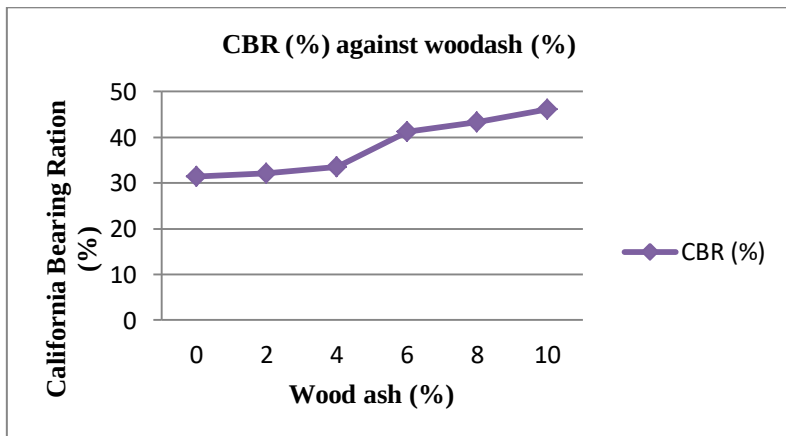


Figure 3 Graph of California Bearing Ratio of lateritic soil against woodash

2. Results and Discussion

The tables and plots above best explain the research work. The properties to be discussed include : Optimum moisture content, California Bearing Ratio, and maximum dry density.

3.1 Optimum Moisture Content

The figure-1 shows that the optimum moisture content increases from 7.7% at 0% woodash to 17.23% at 10% woodash. The percentage increase of optimum moisture content at 2% woodash is 22.1% ; higher than 7.89% at 2% sugarcane strawash as obtained by (Amu *et al*, 2011).

3.2 Maximum Dry Density (MDD)

From figure 2, the maximum dry density decreases from 1970Kg/m³ at 0% woodash to 1840 Kg/m³ at 10% woodash. The MDD of soil at 2% woodash was 1950Kg/m³ greater than 1790Kg/m³ as obtained by (Amu *et al*, 2008). One of the factors that affect density is moisture content, as water content increases, the soil particles get lubricated. The soil mass become more workable and get closely packed together. The dry density of the soil increases with an increase in water content till the optimum content was reached. At that stage, the air voids attain approximately a constant volume. With further increase in water content, the air voids do not decrease, but the total voids (air plus water) increase and the dry density decreases.

3.3 California Bearing Ratio

The Figure 3 shows that the value of CBR increases as the percentage of woodash increases. It increases from 31.44% at 0% woodash to 46.13% at 10% woodash; hence percentage increase of 46.72%. The percentage increase at 8% woodash is 37.82% less than 269.25% as obtained on sample A by (Amu *et al*, 2011) who used sugarcane straw ash.

4 Conclusion

This study presents the results of series of laboratory tests investigating the effect of wood ash on the geotechnical properties of lateritic soil. From the results obtained, the following conclusions were made:

- (i) The addition of wood ash improved the qualities of the soil samples by significantly reducing their plastic indices. According to (Whitlow, 1995), liquid limit less than 35% indicates low plasticity, between 35 and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and between 70 and 90% very high plasticity and greater than 90% extremely high plasticity. This shows that the sample have low plasticity because the liquid limit is less than 35%.

- (ii) The optimum moisture contents and CBR values of the sample were also increased.
- (iii) As the percentage of woodash increases from 0% to 10%, so also the value of optimum moisture content increases and consequently; a decrease in the value of Maximum Dry Density (MDD) in the same order of addition.

In conclusion, besides the research solving the problem of waste (ash) disposal and making cost of construction cheaper by reducing cost of haulage, the study shows that the percentage addition of woodash has tremendously improved the geotechnical properties of lateritic soil and hence, making it suitable for road construction.

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