Assessment of Cassava Wastewater on the Geotechnical Properties of Lateritic Soil.

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ABSTRACT

Soil contamination is one of the largest environmental challenges facing developing countries like Nigeria. It is a problem because sustainability of the environment depends largely on the sustainable ecosystem in which soil is a contributing agent. Pollution poses a serious hazard to all the users of an ecosystem. In conjunction with this, engineering use of soil in building and road construction is a function of its properties which could also be affected by the contamination.

This research is aimed at assessing the impact of cassava wastewater as effluent on the geotechnical properties of lateritic soil found in Ogbomoso community, Southwestern Nigeria, as Civil Engineering Material. In order to achieve our research goal, the following laboratory soil tests were carried out on the contaminated and uncontaminated samples as control: particle size distribution analysis, Atterberg limit test, compaction test [British standard (BS), West Africa standard (WAS), American Association of State Highways and Transportation Officials (AASHTO)], and California Bearing Ratio in accordance with British Standard 1377 (1990) and Head (1992), after the soil was contaminated with cassava wastewater and left for 28 days for saturation. Chemical composition analysis of the cassava wastewater was done as well.

Chemical analysis of the effluent gives 4.5mg/l of cyanide and trace quantity of heavy metals especially zinc, lead, manganese, and copper which has highest concentration of 0.2mg/100g of the metals. Grain size analysis shows that the percentages passing No. 200 BS sieve are 12.83%, 20.04%, 14.83%, and 24.37% for samples 1, 2, 3, and 4, respectively. The liquid limit ranges between 23.18% and 28.39%, plastic limit ranges between 13.57% and 17.63%, plasticity index is between 9.61% and 12.63%, and shrinkage limit ranges between 4.3% and 7.1%. The maximum dry density ranges between 2.01g/cm^3 and 2.18 g/cm^3 for BS, 2.11 g/cm^3 and 2.32 g/cm^3 for WAS, and 2.09 g/cm^3 and 2.26 g/cm^3 for AASHTO respectively. Also, their optimum water contents ranging between 8.50 and 11.20% for BS, 6.20 and 10.22% for WAS, 7.12 and 12.33% for AASHTO, respectively while California bearing ratio (soaked) is between 51.92% and 69.77%.

The result indicates that cassava wastewater affects geotechnical properties of the soil especially Atterberg limits with the value of plasticity index lesser than 10% specified by Federal Ministry of Works, Nigeria (1997) thereby renders the contaminated soil unfit as subgrade, sub-base and base materials.

(Keywords: cassava wastewater, contamination, lateritic soil, soil gradation, Atterberg limit, compaction and California Bearing Ratio)

INTRODUCTION

Soil contamination is composed of either solid or liquid hazardous substances mixed with the naturally occurring soil. Usually, contaminants in the soil are physically or chemically attached to soil particles, or if they are not attached, are trapped in the small spaces between soil particles. The concern over soil contamination stems primarily from health risks, from direct contact with the contaminated soil, vapors from the contaminants, and from secondary contamination of water supplies within and underlying the soil. Soil contamination is caused by the presence of anthropogenic (human-made) chemicals or other alteration in the natural soil environment.

This type of contamination typically arises from the rupture of underground storage tanks, application of pesticides, percolation of contaminated surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills, or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead, and other heavy metals. This occurrence of this phenomenon is correlated with the degree of industrialization and intensities of chemical usage.

Soil-waste interaction affects almost all the soil properties. The effects of pollutants on soil are complex, they can be better understood if various factors are isolated and consider independently. Ions exchange or mature pore fluid influence the properties of soil.

The predominant chemical present in cassava wastewater is cyanide. Cyanide is released during peeling, slicing and crushing of cassava tuber. The major process affecting the transport and distribution of cyanide in soil are volatilization and biodegradation. Ions of cyanide can form complex with heavy metals particularly ion and precipitate out of solution (Lagas et al., 1982; Chatnin, 1989). The rate of hydrogen cyanide and the metal cyanide absorption in the soil is not tangible when compared with rates of volatilization and biodegradation (ATSDR, 1991; Callaham et al., 1979).

Chatwin (1989) stated that the small quantity of cyanide in soil may be oxidized to cyanate. Recent case histories of structural damage to industries and residential buildings resulting from chemical contamination of soils serve to emphasize the importance to be given to the problem of modification in engineering properties of soil due to chemical contamination (Sridharan et al., 1981; Abdullah Assaad, 1998; Sinha et al., 2003). Oil leakages from damaged pipelines, oil storage tanks, and processing plants may also cause oil contamination in the surrounding soils (Evgin et al., 1992).

A previous study by Acar et al. (1989) showed that pore fluid affects the fabric, hydraulic conductivity and physiological properties of soil. Crude oil affects the physiological nature and microstructure of laboratory prepared clay soil; it also reduces the specific surface area, cation exchange capacity and double layer thickness of clay minerals. The Atterberg plastic limits of oil contaminated soil increase by 3-5% when compared with that of uncontaminated soil (Habir et al., 2007). Mallikarjuna Rao and Chinnappa Reddy (1996) also reported that textile dye waste induces cementation or bonding flocculation to soil resulting in improving engineering properties of the soil. In further research by Mallikatjuna et al. (2008) shows that spent orange dye effluent was found to reduce compression index, increase coefficient of consolidation, reduce swelling pressure and impart apparent pre- consolidation pressure to the soil.

In Nigeria, different researchers have worked on the geotechnical and engineering properties of lateritic soils in all geo-political zones of Nigeria (Ola, 1983; Gidigasu and Kuma, 1987; Alao, 1980; Arumala and Akpokodje, 1987; Ogunsanwo, 1989; Agbede, 1992; Adeyemi, 2002; Oladeji and Raheem 2002; Adewoye et al., 2004; Agbede and Osuolale, 2005; Bello, 2007; and Bello et al., 2007). Also, investigations on contamination and its effects on engineering properties of soils have been worked upon in Nigeria and also in different part of the world (Lagas et al., 1982; Chatnin, 1989; Poulos, 1989, Mitchell, 1993; EPA, 1994; MicKinley, 1995; Gratchev et al., 2003; and Ghosh, 2003).

It is discovered that few works have been done on the likely effects of the cassava waste/effluents on the engineering properties of soil in Nigeria. This scenario has therefore prompted the need for this research work because there is cassava processing going on everywhere in Nigeria and many Africa countries. Hence, the main aim of this investigation is to examine the likely effects of the effluents on the engineering properties of soil and making necessary recommendations for engineers and contractors.

LOCATION OF COLLECTED SAMPLES

The soil samples used in this study were obtained as disturbed samples from the Reynolds Construction borrow pits in Aroje Ogbomosho, Oyo State, which lies within the geographical coordinates of 8°2'N and 4°11'E. Geologically, the study area falls within the basement complex of south-western Nigeria which consists predominantly of magmatized and undifferentiated gneisses and quartzite (Akintola, 1982 and Areola, 1982; Bello and Adegoke, 2010).

Fresh cassava wastewater was collected at a cassava processing site in Isale-afon of Ogbomoso Township.

MATERIALS AND METHODS

Preparation of Samples

Lateritic soil material was placed in five (5) layers of approximately 150mm inside a clean polyvinyl drum of about 0.90m high and 0.50m diameter and compacted with the use of 45 blows of wooden stick of approximately 500g weight in such a way the soil materials were not broken so as to at least simulate its undisturbed state. The cassava wastewater was used to contaminate the soil by pouring it on soil sample. This was repeated at 7 day interval for a period of 1 month. The contaminated specimen was left for over 30 days after which it was extruded in three layers at 250mm interval. The Samples were prepared in accordance with BS 1377 (1990) and Head (1992). Prior to preparing the test specimens, the materials were air-dried and broken into smaller fragments, care being taken not to reduce the sizes of the individual particles.

Test Procedures

The following tests viz; chemical composition test, particle size analysis test, Atterberg limit test, British Standard (BS) ompaction test, West Africa standard (WAS) compaction test, American Association of state highways and transportation officials (AASHTO) compaction test, and California bearing were carried out on each of the disturbed samples.

The procedures of these tests are as follows:

Chemical Composition: The quantitative analysis of cyanide and heavy metals such as copper (Cu^{2+}), lead (Pb^{2+}), zinc (Zn^{2+}), and manganese (Mn^{2+}) were carried out on the cassava waste effluent at Kappa Biotechnologies Laboratories, a research center at Ibadan, Nigeria. The cyanide test was carried out in milligram per liter and the heavy metals were in milligram per 100grm. Each of these tests was done three times to justify the exact quantity of the elements.

Sieve Analysis: Representative sample of approximately 500g was used for the test after washing and oven-dried. The sieving was done by mechanical method using an automatic shakers and a set of sieves.

Liquid Limit Determination: Soil sample passing through 425µm sieve, weighing 200g was mixed with water to form a think homogeneous paste. The paste was collected and placed into the Casangrade's apparatus cup with a grove created and the number of blows to close it was recorded. Also, moisture contents were determined.

Plastic limit determination: Soil sample weighing 200g was taken from the material passing the 425µm test sieve and then mixed with water till it became homogenous and plastic to be shaped to ball. The ball of soil was rolled on a glass plate until the thread cracks at approximately 3mm diameter. Therefore, the moisture contents were determined.

Linear Shrinkage Limit Determination: Sample of the paste was placed inside the linear shrinkage mould and well compacted using spatula. The sample was oven dried for 24hours and the shrinkage measured using a Vernier caliper after cooling of the sample. Then, the percentage shrinkage values of the two specimens were determined and the average value found.

Compaction: Compaction tests were carried out on the air dried soil samples which were mixed with 2% water addition according to British standard (BS), West Africa standard (WAS) and American Association of state highways and transportation officials (AASHTO). Maximum Dry Density and Optimum Moisture Contents were calculated for each of the standards.

California Bearing Ratio (CBR): Air-dried soil was mixed with about 2% of its weight of water. This was put in C.B.R mould in 5 layers with each layer compacted with 62 blows using 4.5kg hammer. The compacted soil and the mould was weighed and placed under C.B.R machine and a seating load of approximately 4.5kg was applied. Load was recorded at penetration of 0.5, 1.0, 2.0, 2.5, 3.5, 5.0 and 6.5mm. The moisture content of the compacted soil was determined.

RESULTS AND DISCUSSION

Chemical Composition

Three tests carried out for each element show the same result. cyanide (CN) gives 4.5mg/l, zinc (Zn^{2+}) with 0.05mg/100g, lead (Pb^{2+}) gives 0.02mg per 100g of the cassava effluent, copper (Cu^{2+}) gives 0.2mg per 100g of cassava wastewater and manganese (Mn^{2+}) gives 0.05mg per the effluent. The results are as shown in table 1 below. This reveals that the effluent contains large quantity of cyanide.

Table 1: Analysis of Cassava Wastewater

Parameters	Values
Total Cyanide (mg/L)	4.5
Zn^{2+} (mg/100g)	0.05
Pb^{2+} (mg/100g)	0.02
Cu^{2+} (mg/100g)	0.2
Mn^{2+} (mg/100g)	0.05

Geotechnical Analysis Results

The summary of the geotechnical tests carried out on the samples are as shown in the Table 2.

Table 2: Summary of Geotechnical Tests Results of Soil Samples.

Samples		Uncontaminated (1)	1st Layer Contaminated (2)	2nd Layer Contaminated (3)	3rd Layer Contaminated (4)
% Passing 0.075µm		12.83	20.04	14.83	24.37
Liquid Limit (%)		28.37	23.18	28.43	28.39
Plastic Limit (%)		17.63	13.57	15.80	17.20
Plastic Index (%)		10.74	9.61	12.63	11.19
Shrinkage Limit (%)		4.30	4.70	5.50	7.10
BS	Maximum dry density (g/m^3)	2.18	2.04	2.05	2.01
BS	Optimum moisture content (%)	8.50	11.20	10.10	11.01
WAS	Maximum dry density (g/m^3)	2.32	2.17	2.15	2.11
WAS	Optimum moisture content (%)	10.22	6.20	8.00	6.42
AASHTO	Maximum dry density (g/m^3)	2.26	2.11	2.11	2.09
AASHTO	Optimum moisture content (%)	12.33	7.12	10.83	11.58
CBR (Soaked %)		67.87	68.14	69.77	51.92

Particle Size Distribution: The grain size analysis as shown in Figure 1 shows that the percentages passing No. 200 BS sieve are 12.83%, 20.04%, 14.83%, and 24.37% for uncontaminated sample, 1st layer, 2nd layer, and 3rd layers contaminated samples respectively. All these results satisfy the specification limits of 35% or less for road according to Road and Bridges Specification Revised Edition of Federal Ministry of Works, Nigeria (1997). This shows that contamination has little or no effect on the percentage passing of the grain particles and thereby makes the specimen suitable as sub-grade, sub base and fill material.

Atterberg Limits: the Liquid limit ranges between 23.18% and 28.39%, plastic limit ranges between 13.57% and 17.63%, plasticity index is between 9.61% and 12.63%, and shrinkage limit ranges between 4.3% and 7.1%. Federal Ministry of Works and Housing (1972) for road works recommend liquid limits of 50% (35%) maximum for sub-base and base materials.

All the studied soil samples fall within this specification except plasticity index for contaminated soils which have values above 10% maximum recommended by Federal Ministry of Works and Housing. This shows that contamination increases the plasticity of soil. The results also show that contamination has early effect on the Atterberg limit properties but soil later regains its strength back, that is, after biodegradation and volatilization.

Compaction: As shown in Figures 2 – 4, the maximum dry density ranges between 2.01g/cm^3 and 2.18 g/cm^3, 2.11 g/cm^3 and 2.32 g/cm^3, and 2.09 g/cm^3 and 2.26 g/cm^3 for BS, WAS, and AASHTO, respectively. Also, their optimum water contents ranging between 8.50 and 11.20%, 6.20 and 10.22%, and 7.12 and 12.33% for BS, WAS, and AASHTO, respectively. This result shows that cassava waste contamination reduces the maximum dry density and increases the optimum moisture content of soil as it is clearly shown in all the three methods of compaction used.

California Bearing Ratio: CBR (soaked) values are 67.87%, 68.14%, 69.77% and 51.92% for uncontaminated, 1st layer, 2nd layer and 3rd layer of contaminated sample respectively as shown in Figure 5. This result shows that contamination has little or no effect on the strength of the soil. This might result from the fermentation of the wastewater which leads to the conversion of the wastewater from toxic to less toxic form. Federal Ministry of Works (1997) recommended that subgrade, sub-base, and base soils be less than or equal to15%, 35%, and 80%, respectively. Thus all the samples satisfy the condition of subgrade and sub-base materials

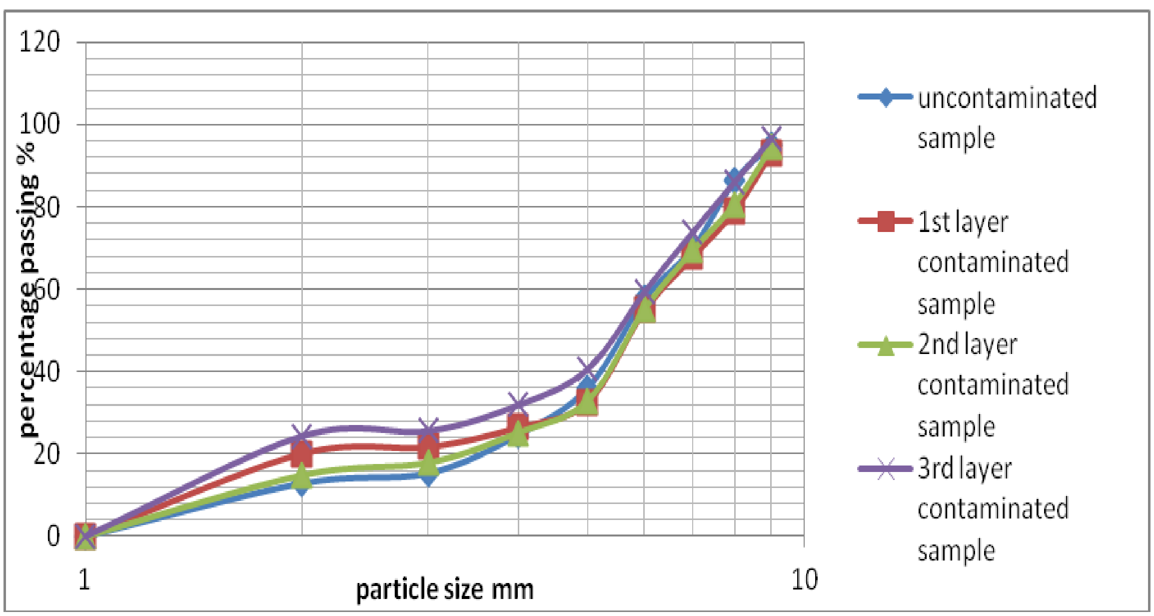

Figure 1: Particle Size Distribution for the four Specimens.

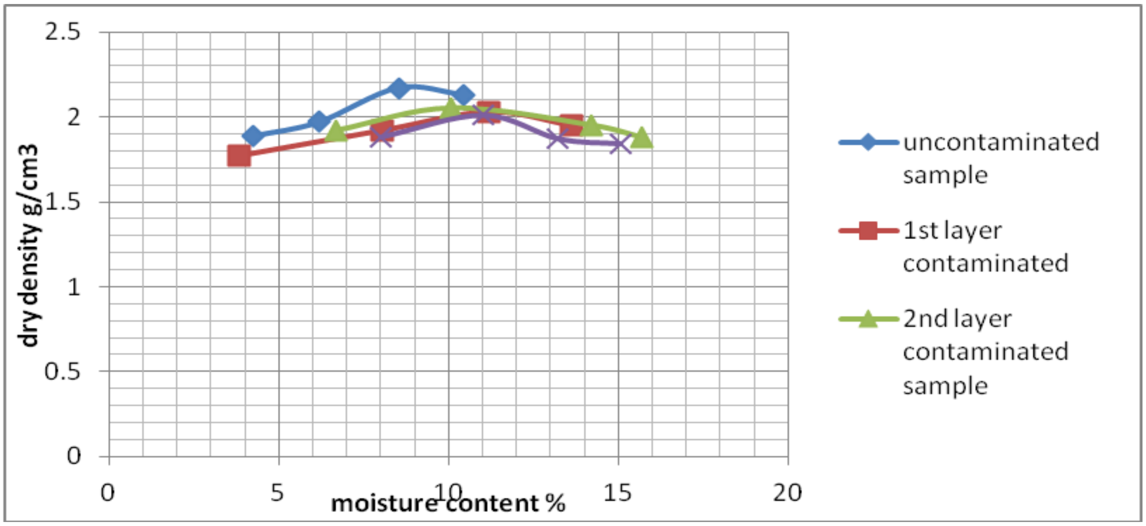

Figure2: Representation of Dry Density (g/cm^3) against Moisture Content (%) (BS Compaction).

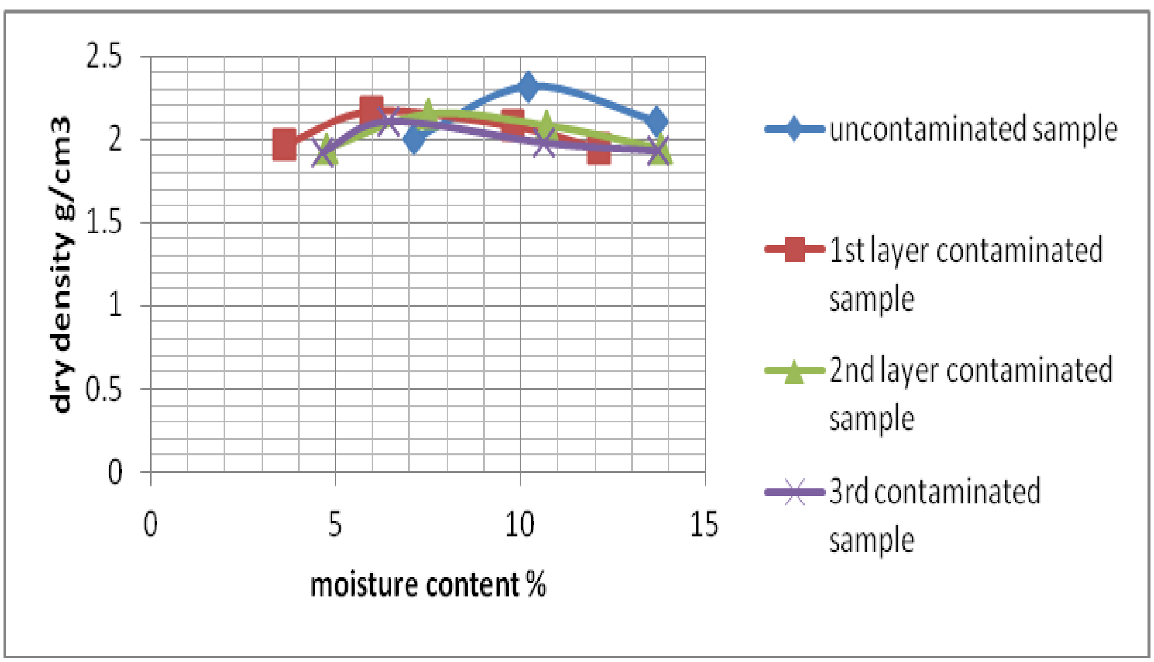

Figure 3: Representation of Dry Density against Moisture Content (%) (WAS Compaction).

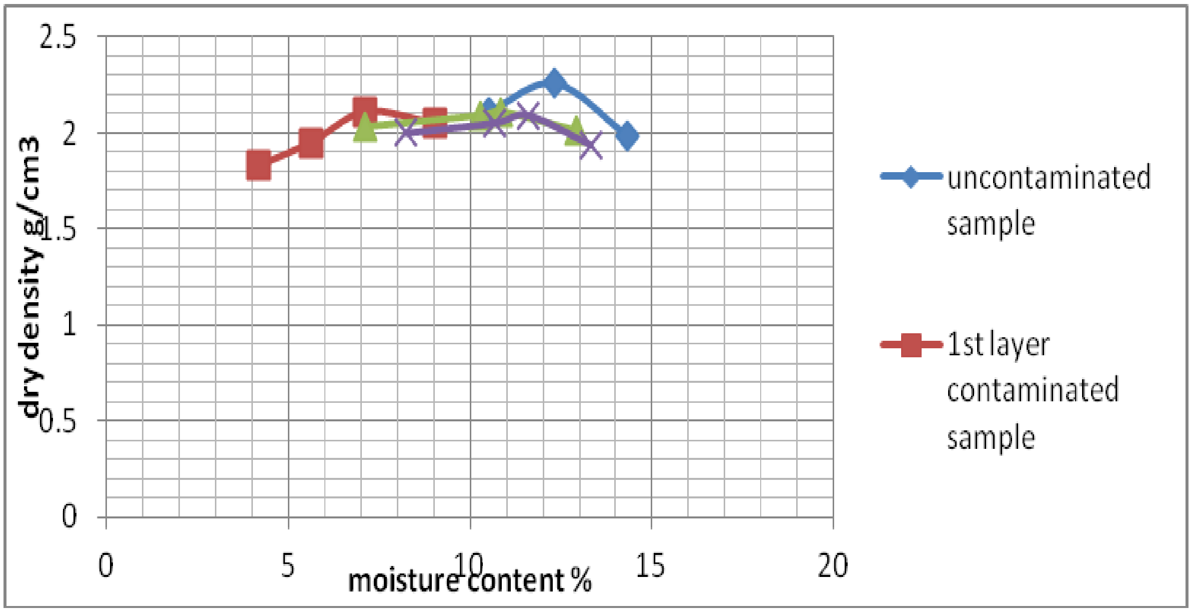

Figure 4: Representation of Dry Density (g/cm^3) against Moisture Content (%) (AASHTO Compaction).

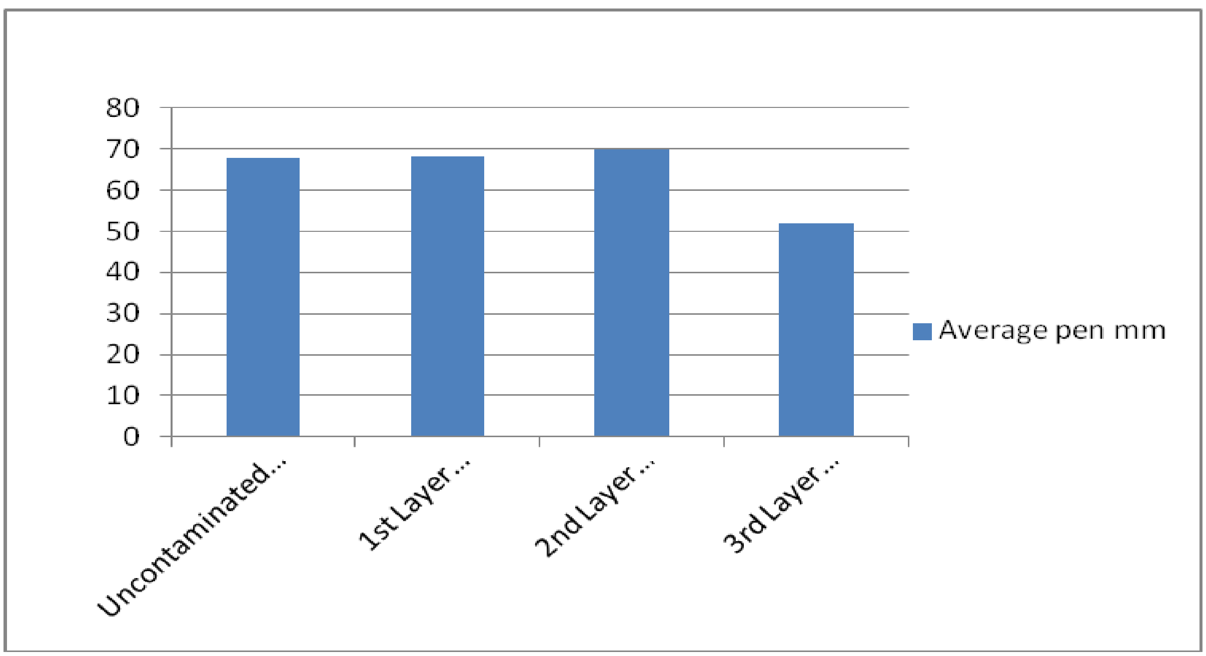

Figure 5: California Bearing Ratio for each of the Samples.

CONCLUSION

The analysis of the geotechnical properties of soil contaminated with cassava waste effluent have been carried out in compliance with BS 1377 (1997) and Head (1990) methods of soil testing for Civil Engineers. The result showed that contamination has early effect on the Atterberg limits but soil regains its strength after biodegradation and volatilization. Contamination increases only the plasticity of the soil while other Atterberg limits meet their standard requirements. Results also show that cassava waste contamination reduces the maximum dry density and increases the optimum moisture content of soil. Based on these results, it is clear that contamination has severe effect on the plasticity and thereby renders the soil unfit as base and sub-base materials while the uncontaminated soil can be used as base, sub-base and subgrade materials.

It is recommended that the soil samples should be collected from the local processing site of cassava in order to show an onsite effect of cassava waste effluents on the geotechnical properties of soil.

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