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Effect of municipal solid waste contamination on some geotechnical properties of soil.

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Abstract

This study examined some geotechnical engineering properties of municipal solid waste contaminated soils in selected locations in Nigeria. Samples of soil were collected at 0.5m depth from the selected dumpsite, and a free land (uncontaminated soil) which served as control. The properties of the soils investigated include: particle size distribution, natural moisture content, consistency limits, maximum dry density, optimum moisture content and specific gravity. Test results revealed that the contaminated soils possess lower plastic limit, maximum dry density and specific gravity than the uncontaminated soil. However, the contaminated soil yielded higher natural moisture content, liquid limit, plasticity index, optimum moisture content and fine particles content than the uncontaminated soil. Therefore, within the limit of this study, it can be inferred that the geotechnical properties of the contaminated soil were reduced due to the influence of the municipal solid waste, and this makes the soils unsuitable for engineering applications.

1. Introduction

Waste has been identified as a common problem of the world today; as most of the developed and developing countries are facing a serious challenge in mitigating the problems emanating from waste disposal and management. Municipal solid wastes refer to non-liquid wastes emanating from residential, recreational, treatment plant sites and commercial activities. They consist of different materials with various compositions. Solid wastes are materials which are inevitably discarded owing to human activities; involving either indirect or direct usage of natural matter [1]. Large quantities of municipal solid wastes are being generated on a daily basis. They are often disposed sporadically; and this tends to constitute environmental degradation. Apparently, the leachate emanating from the wastes tend to affect both soil and water through infiltration. The solid waste characteristics generated vary from one country to the other [2]. In developing countries like Nigeria, municipal solid waste management is observed as an issue of great concern. Schwarz-Herion et al. [3] pointed out that unlike in developed countries of the world, such as Germany, where effective municipal solid wastes management systems are in practice, municipal solid waste management is a major issue in developing countries like Nigeria even in major cities. The threats caused by municipal solid waste dumps are even observed more in the developing countries where large quantities of solid wastes are dumped indiscriminately and thereby, putting pressure on scarce water resources and land and also affecting soil properties [4]. The municipal solid waste generation has been observed to increase geometrically in urban areas owing to high rate of population.

Previous researchers have worked on the management and characterization of municipal solid waste in Nigeria together with their impacts on groundwater quality [5 - 8]. Owing to rapid development and unprecedented search for land, some urban dwellers have resorted to erecting houses on abandoned municipal solid waste disposal sites. Research is therefore needed to evaluate the geotechnical properties of municipal solid waste contaminated soil. Engineering properties of soil are parameters which ascertain the various purposes for which the soil can be used.

2. Material and Methods

2.1. Study area

This study was performed on soil samples from dumpsites located in Ahiaeke Ndume, Umuahia North local government of Abia state, Nigeria. It is a commercial city with a terrain elevation of about 155m above sea level and is on Longitude: 7°31'44.76" and Latitude: 5°30'37.33". The climate of the area is classified as tropical. There tends to be significant rainfall during most months of the year. It has an average annual rainfall of 26°C and average precipitation of 2153 mm. The area is surrounded by rivers as tributaries. The dumpsite consists of paper, plastics, metals, Glass, wood, ashes etc because of the location of the dumpsite.

2.2. Sampling and analysis.

Soil samples were collected from municipal solid waste dumpsite located at Ahiaeke. Disturbed soil samples were collected at the site. One sample was collected from uncontaminated soil (sample 1) at 0.3m vertical profile, which served as control while two soil samples were collected from the dumpsite (Sample 2 and sample 3) at 0.5m depth and 0.2m depth respectively. For the contaminated soil, samples were collected from natural soil below the municipal solid waste in trial pits at the centre (0.5m depth) and at the extreme end (0.2m depth) of the dumpsite. Whereas, for the un-contaminated soil, the control trial pit was located with utmost precaution so as to be far from leachate emanating from the decomposition of the municipal solid waste and from the horizontal direction of flow from the leachate.

2.3 Geotechnical properties tested

The geotechnical properties tested include the following; particle size distribution, natural moisture content, consistency limits, maximum dry density, optimum moisture content and specific gravity. All tests were carried out in accordance with the guidelines in (9).

3. Results and discussion

The results of the of the average values of soil parameters investigated are shown in Table 1 while the results of sieve analysis are shown in Figure 1.

Table 1: Average values of Soil parameters determined

Parameters	Optimum Moisture Content	Natural Moisture Content	Specific Gravity	Maximum Dry Density	Liquid Limit	Plastic Limit	Plasticity Index
Sample 1(control)	14.90	10.10	2.50	1.92	35.90	23.80	1.92
Sample 2	17.40	21.20	2.28	1.67	40.00	9.28	30.72
Sample 3	16.10	19.40	2.40	1.72	36.70	4.90	22.10

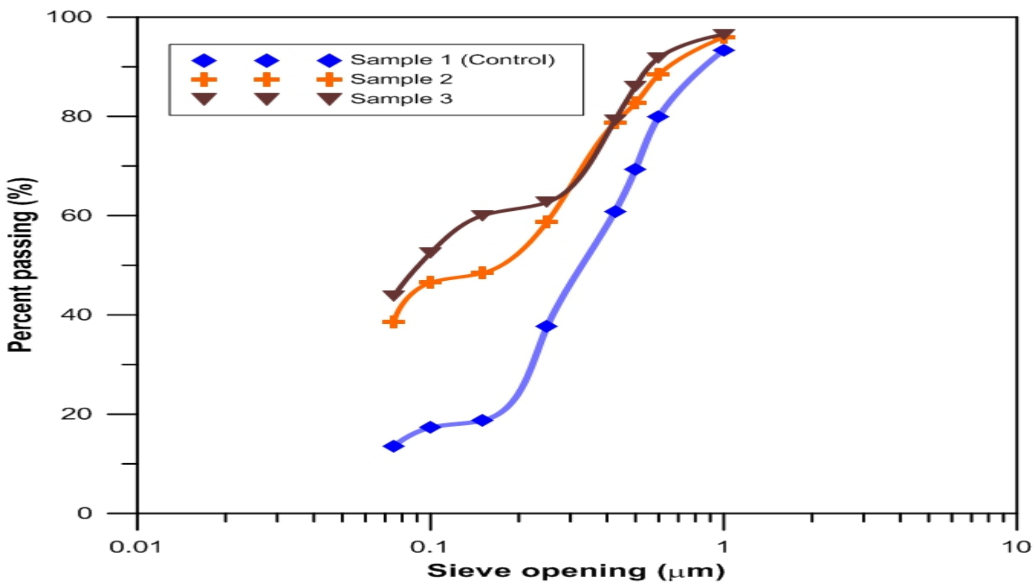

Figure 1: Soil grading curve for the samples

Table 2 shows the result of single factor ANOVA.

Table 2:Sigle Factor ANOVA

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	7	91.04	13.00571	168.1421
Column 2	7	122.55	17.50714	207.4206
Column 3	7	103.32	14.76	163.0992

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	72.07007	2	36.03503	0.200692	0.81997	3.554557
Within Groups	3231.972	18	179.554			
Total	3304.042	20				

Validation test with ANOVA

The following were observed from ANOVA conducted in Table 2.
Sum of squares=72.07
Degree of freedom=2
Mean square=36.04
F value=0.20
Level significance=0.82
% Level of significance is calculated as (100-0.82=99.18%).
From the Analysis in the above the F calculated (0.20) is less than F critical (3.55)
Fcal < F critical
0.20 < 3.55

The 99.18% level of significance difference shows that the soils from sample 2 and 3 are contaminated as a result of municipal solid waste. There was no significant difference ($p > 0.05$) between the contaminated samples and the uncontaminated sample. Thus, soil from samples 2 and 3 are contaminated to a certain extent. Since the F calculated is less than F critical; the null hypothesis is accepted. Therefore, the degree of solid waste contamination is not too high but it should be checked so as to avoid further contamination.

Particle size Distribution

Particle size distribution of a soil is the list of values that define its relative amount by dry mass which is often distributed over certain ranges of particle sizes. The percentages of fine in the soil particles collected from the dumpsite in the present study was between 37.9 to 43.7 % for sample 2 (Figure 1) while that of sample 3 ranged from 21.1 to 31.7%. The soils in the dumpsite were found to have higher percentages of fine when compared to that of the uncontaminated soil used as the control. The observed higher percentage of fine content for the contaminated soil could be as a result of fine particles arising from the decayed municipal solid waste which covers the soil.This conforms to similar work done by Krishna et al.[10]. Similar observation was made by Estabragh et al. [11] while studying the consolidation behaviour of two fine-grained soils contaminated by glycerol and ethanol. Thus, it can be inferred that both physicochemical and mechanical changes in contaminated soils affect their physical properties.
Soil is classified based on five methods such as;US Department of Agriculture (USDA) method, U.S. Bureau of Soil and Public Roads Administration Classification System, Indian Standard Soil Classification System, American Association of State Highway and Transportation official (AASHTO) Classification and Unified Soil Classification System (USCS) [12-15]. It is worthy of note that the unified soil classification system(USCS) is a

type of classification based on test values measured in accordance with the standard set by American Society for testing and materials(ASTM). By and large, the USCS classification of soil is directly linked to the soil properties by which it is defined [16]. According to USCS sytem,soils are categorized into three classes; coarse-grained (sand or gravel), fine-grained (clay or silt) and highly organic soils. According to USCS,the soil samples collected from the study area can be classified thus;sample A is made up of sand-silt mixtures,sample B is made up of sand-clay mixtures while sample C is composed of sand-clay mixtures.

Natural moisture content

Soil natural moisture content refers to the quantity of water contained in a soil sample.It can be given on either gravimetric or volumetric basis. Soil compaction helps to improve the geotechnical properties of the soil. Soil with lower moisture content than the optimum tends to have a lot of void spaces which in turn results in low dry density. Moreover,at moisture content more than the optimum,the dry density is reduced by the additional water which occupies the space which would have been occupied by solid particles[17].

The value of natural moisture content (NMC) for soil sample 2 is considerably higher than that of sample 3 (Table 1). This could be attributed to the nature of the waste found in this area; as that of sample 2 has less of damp material. The NMC of the contaminated soil was generally higher than the uncontaminated soil .This trend could be as a result of the fact that the contaminated soil is expected to be moister, since the natural ground level is covered by the municipal solid waste. Although, NMC is not a major concern to Engineers since it can be managed during construction.

Specific gravity

Specific gravity refers to the ratio of the weight of the soil to the unit weight of water. It is an important parameter in the sense that it helps in the computation of other parameters relating to the soil. The specific gravity of the contaminated soil samples were relatively low when compared to the control sample as it ranged from 2.28 to 2.40 for the contaminated soil samples (Table 1). This implies that waste constituents have impact on the specific gravity of soil.

Atterberg limit characteristics

The Atterberg limits give a quantitative description on the influence of varying water content on the consistency of fine grained soils. They are generally used in soil classification and assessment for engineering purposes. Figures 2,3 and 4 show the liquid limit for 0.3m vertical profile, 0.5m vertical profile and 0.2m vertical profile respectively. The liquid limit for the uncontaminated soil sample (sample 1) in the present study was 35.90% (fig.2) while that of samples 2 and 3(figs 3 and 4) were 40.00% and 36.70% respectively. The plastic limit and the plasticity index varied from 4.90% to 9.28% and 22.10 to 30.72 respectively. The plastic limit for the contaminated samples experienced reduction (Table 1). This could be as result of increased cohesion in the particles of the soil as well as its resistance to cracking.

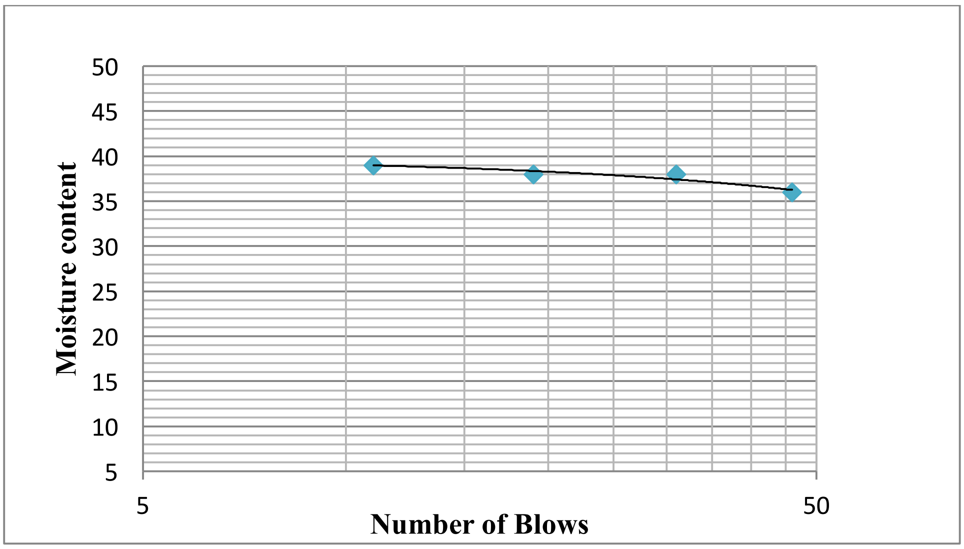

Figure 2: Liquid Limit for sample 1(control at 0.3m vertical profile)

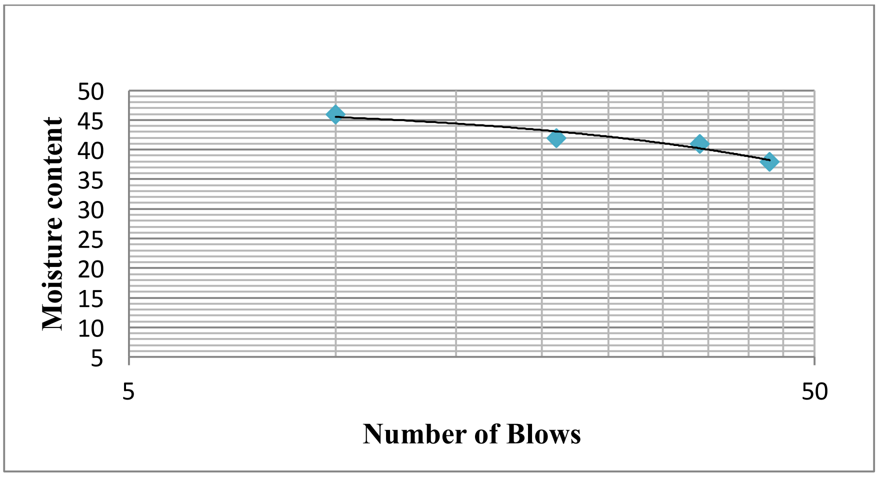

Figure 3: Liquid Limit for sample 2(0.5m vertical profile)

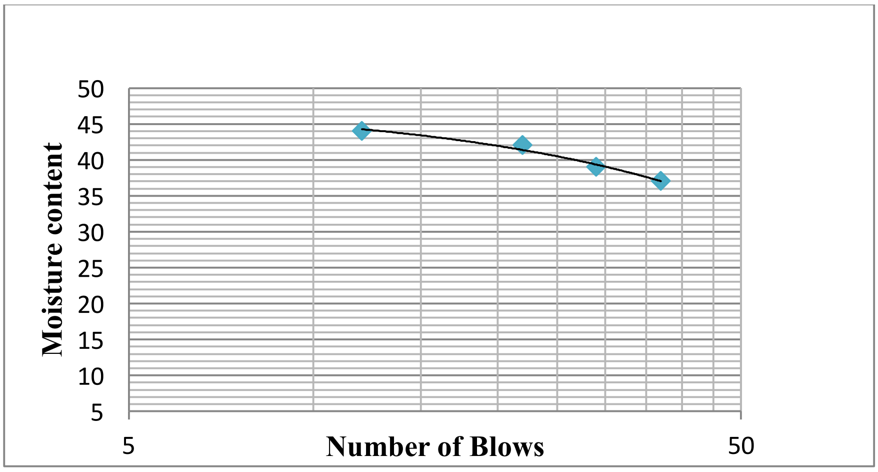

Figure 4: Liquid Limit for sample 3 (0.2m vertical profile)

Compaction characteristics

The compaction test involves the determination of the relationship between dry density and moisture content for a given sample of soil. Figures 5 and 6 show the compaction characteristics for sample 1 and 2. The maximum dry density (MDD) for the soil samples are as follows;1.92g/ml,1.67g/ml and 1.72g/ml for samples 1, 2 and 3 respectively (Table 1); the optimum moisture content (OMC) of sample 1 has a value 14.90 % while sample 2 and sample 3 have values of 17.40 % and 16.10% respectively.

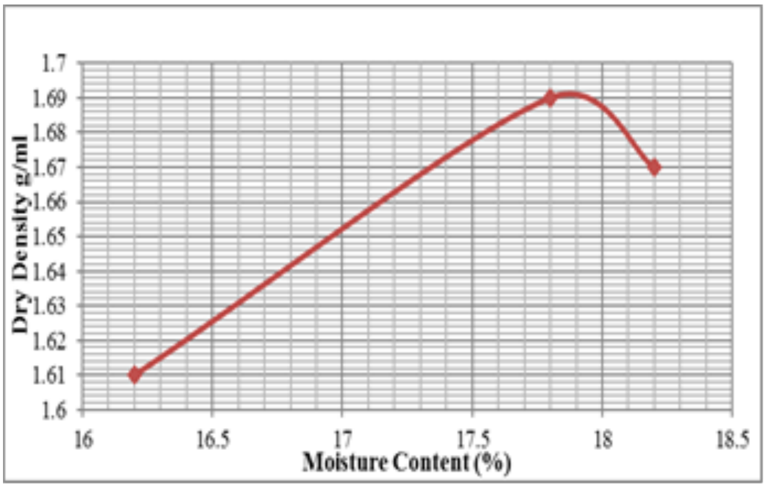

Figure 5: Compaction characteristics for sample 1(control)

The MDD of the contaminated soil is generally lower than that of the uncontaminated soil (Figs. 5 and 6), while the OMC of the contaminated soil is generally higher (Table 1). This result conforms to the results of the particle size distribution, which signify higher percentages of fine fractions in the contaminated soil. Since fine particles of the soil have more affinity for water, and from the classical theory of soil mechanics, the higher the OMC, the lower the MDD. The result is in conformity with earlier results of [18, 19).

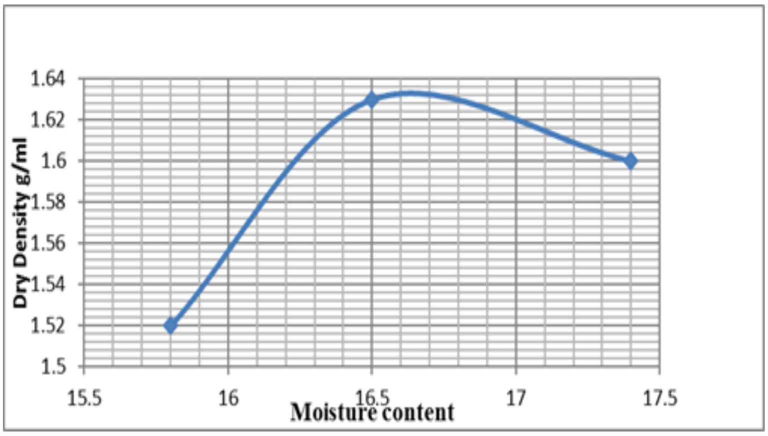

Figure 6:Compaction characteristics for sample 2

Conclusion

The following conclusions were deduced from the observations and findings made.The natural (uncontaminated) soil within and around the dumpsite is relatively homogeneous, though there are some minor discrepancies. The contaminated soil has lower specific gravity and this shows the presence of organic content in the soil. It equally contains more fine particles, lower MDD with higher OMC, when compared with the uncontaminated soil. The contaminated soil has higher natural moisture content than that of the un-contaminated soil and that of sample 2 is higher than sample 3 because of the kind of waste generated there. Thus, it can be suggested that such soils should be stabilized using additives in order to enhance its engineering properties.

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