Foundation Soil's Properties At Old Dumpsite Under Short - Term Restoration From Effect Of Municipal Solid Waste Disposal.

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Abstract

Foundation soil properties at old dumpsite, as the soil rehabilitates, in short term (about 8 years), from the previous effect of MSW leach ate contamination was investigated by auguring and coring dumpsite soil samples at intervals of 0.5m to 2 cm depth for laboratory analyses. Soil texture, Atterberg limits, plasticity index (PI), optimum moisture content (DMC) and maximum dry density (MDD) were determined for both dumpsite and non-dumpsite soils. The data were statically analyzed and evaluated for shear strength and future settlement for engineering use of restored soil. Texture properties for sand, fine sand and clay showed no significant difference at P<0.05 but correlated perfectly (P<0.01) between dumpsite and non-dumpsite samples. Soil MDD of 2.06 and 2.02 corresponding with OMC of 10.25 and 10.00 respectively for dumpsite and control soil were obtained while their respective values were 39.50 and 41.00 for liquid limit and 36.95 and 20.55 for plastic limit, giving PI of 2.75 and 20 respectively. Difference was not significant for LL but significant for PL and PI at P<0.05, with r = 0.35 between the samples. Dumpsite soil had significant restoration from the degrading impact of MSW disposal and leach ate in a short term (8 years) and showed good prospect for use as foundation soil with increased shear strength and decreased settlement if compacted at OMC before construction.

Keywords: abandoned dumpsite, soil restoration, foundation properties, Atterberg limits, plasticity index, shear strength

1. Introduction

All types of structures (e.g. buildings, bridges and highways, etc) rest directly on, in, or against soil as the foundation; hence proper analysis of the soil may help the design of the structure to fit the soil type, if it must be used, and this, in turn, will ensure that such a structure remains safe and free from undue settling and eventual collapse [1].

The type of soil is defined or characterized by its properties but its basis-for use as foundation is identified and classified by its engineering properties, particularly its water indices. Useful significant foundation properties are found to include texture, structure, consistence and coarse fragment amongst others [2]. In making judgment with regards to their application, the four states of consistency – the three Atterberg limits and the plasticity index – are useful values for identifying and classifying such soils. The liquid limit, of physical significance, is the limiting state of soil moisture content at which the shear strength of the soil becomes so negligible that the soil flows, which no foundation soil in undrained state should be so characterized, while the plastic limit is the water content at which the undrained soil will crumble or collapse. It is the lower bound of the plastic behavior of a given soil [1] . The plastic limit is affected by the particle size of the soil as it tends to increase in numerical value as the grain size decreases. Therefore, knowing these Atterberg limits, plasticity index and grain size distribution will be useful in assessing the foundation prospects of a given soil. However, problem arises where the soil is contaminated as is the case at the municipal solid waste (MSW) dumpsite. Dumpsites contain a variety of contaminants which can pollute the soil of the area [3], [4]. The soil under MSW disposal at open dumpsite is contaminated by the leachate egress from the biodegrading solid waste, which usually comprises garbage and rubbish, or organic and inorganic wastes [5], [6], [7], [8], [9] . Consequently, the properties of the in-situ soil below the waste dump and in the peripheral soils surrounding the dumpsite could vary in depth.

Also leachate characteristics are extremely waste and site-specific and vary widely depending on the type of waste, and any pre-treatment it received prior to deposition, the rate of evaporation, net precipitation (which is climate dependent) retained in the waste, and the amount of generated leachate that migrates into the underneath and surrounding soil [7]. Soil properties affected by leachate have been found to retain heavy metals in soil and sediment materials [5]. Foundations are vulnerable to attack by destructive compounds of heavy metals [10], [11] soil properties affect dam designs [12]. This implies that the degree of contamination of the soil by leachate under particular solid waste cannot be generalized and have to be established by proper assessment of the soil's engineering properties.

The nuisance and contamination of free-flowing leachate from dumpsite could be controlled by sanitary landfill with protective, fluid-retaining liners; but the use of this technology has been difficult to low economies by various reasons (e.g. financial requirement, lack of political will, and sometimes, the discouraging long delays in waiting to obtain even regional approval for sanitary landfill [7]. Consequently dominant number of low economy states have stuck to the use of open dumpsite (and stream dumping in some cases) to dump their msw in developing urban areas [13].

The use of this open dumpsite for MSW disposal is what obtained in Uyo metropolis, the capital of Akwa Ibom State of Nigeria. Dumpsite is located on the precipice of a gully ravine in order to fill that ravine below it, although there is a flowing spring at the ravine bottom. However, in 2008, a new open-dump ground was opened in the opposite direction to the abandoned dumpsite. The status of leachate contamination of soil at the abandoned dumpsite should have recessed except for residual biodegradation. It is expected that rehabilitation had since commenced, hence a short-term field investigation of the soil properties relevant to foundation was undertaken in view of advanced plan to route a highway with a bridge through the area for urban expansion and settlement on that axis of the municipality.

Therefore the objectives of the study were: (1) To investigate the soil foundation properties at the open dumpsite soil since it was abandoned 8 years ago. (2) To evaluate the effect on the soil foundation properties and make recommendations.

2. Materials and Methods

2.1 Study Area

The dumpsite is in Uyo metropolis located within Latitudes $4^0 54^1$ and $5^0 05^1$N and longitudes $7^0 54^1$ and $8^0 00^1$E; and lies in humid tropical rainforest zone, which may cause the production of much leachate egress in the rains. The dumpsite soil was pre-compacted with clay liner.

2.2 Soil Sampling

The soil characteristics of underlying soil at abandoned municipal solid waste dumpsite were investigated. The dumpsite soil was excavated to the depth of 2m where subsoil layer for foundation was; and soil samples were collected at every 0.5m depth interval from the topsoil down to a depth of 2m. Trashes were removed from the topsoil surface before excavation down to 0.5m depth; then augur and core samples were collected from the soil horizons at the different depth intervals. The same procedure was repeated for soil sampling at the non-dumpsite 200m away from the dumpsite.

2.3 Sample Testing

The soil samples at both the dumpsite and control were analyzed at Soil and Material Laboratory, Ministry of Works and Transport, Uyo for the following engineering properties tests.

Particle size distribution (or texture) by mechanical sieve analysis [1], [14]. Determination of moisture content of soil sample by conventional oven method (ASTM 2216); specific gravity and optimum moisture content test method using pycnometer. (ASTM D854) [1], [14]. Atterberg limits (ASTM D 4318) with the multipoint method A (ASTM D 4318 – 95a). Plastic limit test (ASTM D 4318 – 95a) [1], [14], [15]. Compaction test was used to determine the very important moisture-density relationship of the soil sample.

The samples were air-dried in a wheel barrow for three consecutive days; then lumps were broken and samples were mixed with 6%, 8% and 10% distilled water using hand trowel. The mix was divided into five layers, scooped into mould and rammed with 27 blows [1]. Dry density was plotted against moisture content. From the curve, maximum dry-density (MDD) and optimum moisture content (OMC) were obtained for soil samples at both dumpsite and non-dumpsite.

Permeability test was carried out for both sites using constant head permeameter; and hydraulic conductivity was obtained using the Darcy's law - derived equation [15], [16]:

$$K = [QL]/[aht] \quad (1)$$

where k is hydraulic conductivity (m/s); Q is discharge (m^3/s) collected in time t, (s); a is cross-sectional area of sample (m^2); h(m) is difference in manometer levels; L is distance between manometer tapping points (m); i is hydraulic gradient.

Sieve Analysis test was carried out to determine quantitatively the texture of the soil using mechanical sieve shaker with a set of sieves. The test data were used with textural triangle to determine the particle distribution, hence the soil texture.

Atterberg limit test was used to determine the consistency of the dumpsite and non-dumpsite batch samples using the Casagrande's apparatus for each batch of samples. The moisture content was determined before using the soil sample, and afterwards it was made into properly mixed uniform paste and put into Casagrande's cup. The number of blows as the groove cut on the paste closed was recorded for both Liquid Limit (LL) and Plastic Limit (PL) tests. The multipoint liquid limit method (ASTM D4318 – 95a) and plastic limit test (ASTM D4318 – 95a) [1] were used. The plasticity index (PI) was obtained as [1], [16]:

$$PI = LL – PL \quad (2)$$

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where PI is plastic index. PI indicates the organic content present in the soil; thus the higher the PI, the higher the organic content in the soil. High PI value can be used to compare poor foundation material (i.e poor load-carrying). The number of hammer blows were plotted against the moisture content to obtain the liquid and plastic limits. The LL (liquid limit), is the water content that corresponds to 25 blows while PL (the plastic limit) is the minimum moisture content which the soil can be rolled into a 3mm - Ø thread without breaking.

3. Results

The particle size distribution that defines the texture of the dumpsite soil and the non-dumpsite soil (i.e. control) was analysed and the results are shown in Table 1.

The results of test for moisture density relationship using a fixed number of blows (27 blows) with 4.5kg hammer on the treatment and control samples in a mould obtained for five replications are shown in Figures 1 and 2 and the bar chart (Figure 5).

Moisture density relationship for samples and control soil using fixed number of hammer blows.

The dry density of the soil rallied or fluctuated to an average of 2.08g/c^3 for dumpsite soil and 1.80g/c^3 for non-dumpsite soil. However the moisture increased in both soils under persistent hammering from 8.3% to 22.8% for dumpsite soil and from 8.1 to 17.1g/c^3 for non-dumpsite soil. This gave a significant difference for maximum dry density at $P<0.05$.

Atterberg limits test results. This result is shown in table 2. For increasing number of blows on the same sample (replicated two times), the values in table 2 shows a decreasing variation for the dumpsite soil and somewhat for the control soil except the hump at 19 number hammer blows.

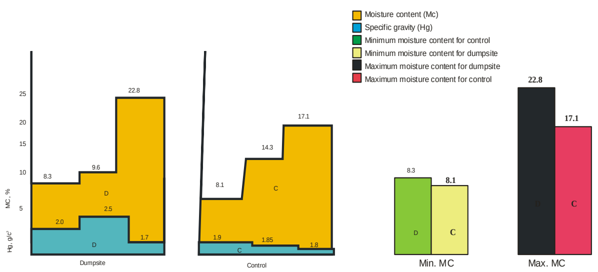

Fig. 5: Bar-chart of moisture – density relationship for dumpsite (D) and Control © soils at Uyo municipal solid waste old dumpsite.

Table 1: Particle size distribution analysis for dumpsite and non-dumpsite soils using mechanical sieve analysis.

Sincre No.	% retained soil	Non-dumpsite soil	Remarks
2.36mm	0	0	
1.18mm	2.97	1.66	Very coarse is low
850 micro	9.71	7.47	Coarse sand is low
435 micro	35.85	34.44	Medium sand is medium
300 micro	20.22	21.16	Medium sand is low
212 micro	15.91	19.6	Fine sand is low
150 micro	8.9	9.96	Find sand is low
75 micro	6.44	5.81	Very fine sand is low

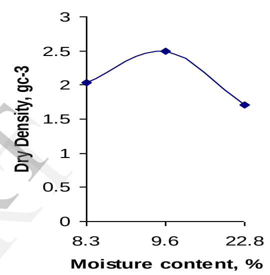

Fig.1: Moisture density relationship for dumpsite soil, Uyo

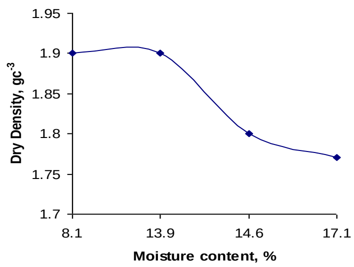

Fig.2: Moisture density relationship for non dumpsite soil, Uyo

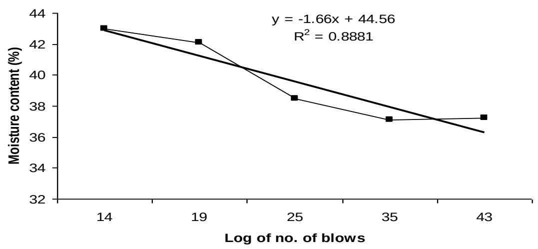

Fig.3: Atterberg Limit and plasticity Index for dumpsite soil, Uyo

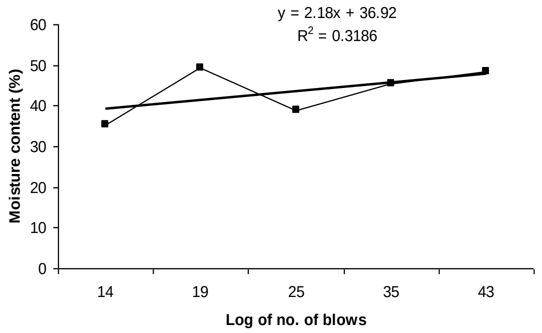

Fig.4: Atterberg Limt and plasticity Index for non dumpsite soil, Uyo

The values in table 2 are summaries showing Atterberg liquid limits, other water indices and their percentage differences between dumpsite soil and control soil.

Table 2: Summary of important water indices, permeability, specific gravity

Index	Dump site	Control	% Difference	t 0.05 LSD
MDD	2.76	2.05	25.72	0.31
OMD	19.25	140.00	2.44	
LL	39.50	41.00	3.66	
PL	36.95	20.55	44.38	
PI	2.55	20.45	87.53	
K x10^{-4}	6.55	4.8	26.15	
SG	2.67	2.73	2.19	

Note: MDD is maximum dry density, g/c^3 OMC is optimum moisture content, %; LL, PL, PI are liquid limit, plastic limit and plastic index respectively; K is hydraulic conductivity m/s; SG is specific gravity.

4. Discussion

4.1 Particle Size Distribution

Soil texture (Table 1) showed marginal differences in sieve analysis into coarse sand (No. 10 sieve), medium sand (No. 40 sieve) and very fine sand (percentage passing No. 200 sieve size). Application of the t-statistics (paired sample test), using SPSS version 17 software, indicated no significant difference (at P<0.05) between the foundation soil samples from dumpsite and non-dumpsite. Both samples had very high and significant correlation (r=0.987 @ P<0.01). The clay component in the non-dumpsite was higher, in the sum, than the value for dumpsite soil.

4.2 Soil Moisture-Density Relationship

The values of the moisture content and the dry density obtained for dumpsite and non-dumpsite soils were separately plotted into graphs. Figure 1 gives the graph of moisture content – density relationship for dumpsite soil. The prolongation of the curve for non-dumpsite soil suggests that the clay content in the control soil, hence its effect, was higher in non-dumpsite soil than in dumpsite soil. The Optimum Moisture Contents (OMC) were 10% and 14.25% for dumpsite and non-dumpsite soils respectively while the corresponding Maximum Dry Densities (MDD) were 2.66 and 2.02 g/c^3 for both soils respectively. Dumpsite soil would require more compaction to devoid it of air pores and stabilize the material for foundation than would the non-dumpsite soil.

4.3 Atterberg Limits

Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) are valuable limits for identifying and classifying soils. The LL is the higher limit establishing the state of consistency (degree of firmness) for fine-grained soils [1], and it divides the liquid state from the plastic state of the soil. Figures 3 and 4 show the plot of number of blows against groove-closing moisture content of the sample in the water limit device for dumpsite and non-dumpsite soils respectively. The dumpsite soil showed low variability with the best fit line having R^2 = 0.888 while the non-dumpsite soil showed high variability with the best curve having R^2 = 0.319.
The specific gravity of the samples, being between 2.0 and 2.80, indicates that the soil at that depth is not organic soil [1] although they cannot be classified as inorganic clay either, but their properties agree with the properties required for soil as foundation soil. This is very significant since many dumpsite soils have the composting problem that may render them as organic soils, but, the degrading effect is highly diminished even at the foundation depth as such a dumpsite soil is rehabilitated.

Plasticity Index. This is the range of moisture content between two liquid states – the LL and the PL, and was 2.55% and 20.45% for dumpsite and non-dumpsite soils respectively. The wide range of PI for the control soil (Table 2) accounts for the wide difference between the Atterberg limits and may show that the coarser soil is higher in the control soil than in the dumpsite soil, since PI tends to increase in numerical value as grain size decreases [1]. Figures 3 and 4 indicate the relationship curve between compaction or number of blows and soil moisture content from where OMC was obtained at the 25 blows along the log-normal abscissa.
The precision of the estimates of PI was accepted as the difference (2.1%) of the results (21.9 and 19.2%) of the replicate tests for dumpsite soil compared to 2.6% which is the acceptable range of difference for the plastic limit tests on one-point method. For the dumpsite soil, the difference was 0.9 (i.e. 37.3 – 36.6%) and 0.9 < 2.6 (the acceptable range on

single-operator precision [14], hence the precision of the result is acceptable.

4.4 Compaction and future settlement

The Liquid Limit (LL) is the soil water content at which the shear strength of the soil becomes so small that the soil "flows" [1]. The insignificant difference between the LL of the dumpsite and non-dumpsite soil samples confirm that both soil samples have nearly equal high shear strength.
Also maximum dry density (MDD) is used by designers to specify where shear strength is increased maximally by compaction, or to decrease future soil settlement or to achieve the lowest hydraulic conductivity [1]. This is significant for dumpsite soil to indicate shear strength in the event of any undetected residual effect of biodegradation existing. The lowest hydraulic conductivity will be achieved normally when the soil is compacted slightly above the OMC [17]. Thus, if dumpsite soil becomes a foundation soil for a structure in future, compacting the soil slightly above the OMC or 10% will achieved decrease in settlement and increase in shear strength [17]. The values of K (Table 2) indicate that the control soil had a lower value of K compared to the dumpsite value; hence the dumpsite soil was not completely compacted. Therefore, soil compaction level did not recover completely from MSW leachate contamination effect. More time is needed to devoid the pores of air in the foundation soil.
Compression index, C_c for determining the expected consolidated settlements of load on clays [18] is given as:

$$C_c = 0.009\ (LL-10),$$

so that for dumpsite $C_c = 0.266$ and for non-dumpsite, $C_c = 0.279$; both are similar.

5. Conclusion

The soil at old dumpsite, Uyo, abandoned about 8 years ago, was cleared of trash and topsoil to 0.5m, and excavated to 2m depth where it was augured and cored at 0.5m interval for 2m depth and samples were used for testing as foundation soil materials. The following tests were carried out: soil particles distribution by mechanical sieve analysis; moisture content – density relationship (standard proctor compaction test) for MDD and OMC; Atterberg limits and plasticity index. Data for dumpsite soil and non-dumpsite (control) soils were analysed statistically by correlation and ANOVA and significant differences. The OMC was 10% and 10.25% while MDD was 2.66 and 2.02g/c^3 respectively for dumpsite and non - dumpsite soils. Differences were insignificant (at $P<0.01$).
Atterberg limits (LL and PL) and PI were analysed; LL showed similar values but PL and PI showed significant differences between the two samples. Results show that dumpsite soil at 2m depth had recovered significantly from biodegradation effect of MSW disposal and leachate in short-term of 8 years and was a useable foundation soil for structures such as the proposed state highway. It is possible that the lining of the dumpsite soil surface by hard clay facilitated this short - term recovery.

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