Permeability characteristics of lateritic soils from a dumpsite in Ado-Ekiti, Southwestern Nigeria

Abstract

The permeability characteristics of the lateritic soil from Ilokun dumpsite were studied with a view of investigating its suitability or otherwise as liners in sanitary landfills. Disturbed and undisturbed soil samples were collected from trial pits established at different depths within the lateritic zone. The disturbed samples were subjected to specific gravity test, grain size distribution analysis, consistency limits, and compaction tests while permeability test was carried out on undisturbed sample.

The ten soil samples taken from different depths within the lateritic zone in the pits are generally well graded. The study also revealed that the soils are of medium to low plasticity and hence low compressibility. The maximum dry density (MDD) values obtained for all the studied soil samples range from1.72t/m^3 to 2.02t/m^3 for Standard Proctol and the maximum dry density (MDD) values of the studied soil range from1.78t/m^3 to 2.08t/m^3 for Modified Proctol while the optimum moisture content (OMC) values of the studied soil range from 9.0% to 14.0% for Standard Proctol and the optimum moisture content (OMC) values of the studied soil range from 7.0% to 13.0% for Modified Proctol. It was revealed that the higher dry density values were obtained when the soil samples were compacted with higher energy of compaction and the increase in energy of compaction drastically reduces optimum moisture content of the studied soils.The coefficient of permeability obtained for the samples range from 1.5 x 10^{-3}mm/s to 2.5 x 10^{-2}mm/s. The coefficient of permeability obtained for samples taken from varying depths is significantly higher than the maximum value of 10^{-6} mm/s recommended for the soil that should form the base of landfills.

It is therefore recommended that in-situ compaction and lining be done if the soils at the location will be used as barrier and liners in landfill. This will significantly prevent lateral and vertical movement of liquid phase of the wastes.

KEYWORDS: Compaction, Grain size, Landfill, Lateritic soil, Permeability

INTRODUCTION

The world population is increasing on daily basis, so is the corresponding quantity of solid wastes being generated. Rapid technological changes, increased population growth and high concentration of people in urban centres are compounding the problems of maintaining the environment at a healthy level due to enormous wastes generated. No other issue has perhaps dominated the environmental scene in the developing countries as that of management of solid waste. Sittig (1979) attributed this to the increased awareness of the consequences of environmental change to future generations by indiscriminate dumping of refuse.

Waste management has been identified as one of the most challenging environmental problems facing cities in most developing countries. Disposal of waste is a challenge for many communities in both developed and developing countries because of the risks to human health and the general environment. There is need for these wastes to be properly and safely disposed to minimize environment damage. In Nigeria, the situation has worsened mainly because of the spate of industrial developments, coupled with rapid human population growth in the most urban areas. Hence there is need for effective waste management strategies relevant for this part of the world. However sanitary landfill has been recommended as the best facility for handling waste in developing countries (Ziess and Atwater,1987).

The city of Ado-Ekiti which is the capital of Ekiti State falls into southwestern region political of Nigeria. Ado-Ekiti according to the National Population Commission (2006) census figures has a population of 409,060 people with an enormous amount of waste at an estimate of 0.5kg/person generated on daily basis as a result of domestic, agricultural and industrial activities. The bulk of the wastes generated include leaves, paper, nylon, food waste, tins, glass, plastics, rags, metals etc. In an attempt to curtail environmental pollution arising from indiscriminate dumping of wastes in open spaces, river banks, road side etc. a major final waste disposal site has been strategically located at Ilokun, the outskirt of the city. However, the selection, design, construction and operational activities of this site did not consider the geology and impacts on the environment. Ilokun open dumpsite along Ado-Iworoko road has been thoroughly investigated in this study.

This study is therefore aimed at evaluating the permeability characteristics of the lateritic soil from Ilokun dumpsite with a view of investigating its suitability or otherwise as liners in sanitary landfills.

Compacted soils are widely used as barrier in sanitary landfill to isolate hazardous and other waste materials from environment and groundwater. The effectiveness of compacted soils is controlled or enhanced by its hydraulic conductivity and permeability. Waste material in waste containment facilities are made isolated from the surrounding environment by providing barriers.

STUDY AREA

Ilokun dumpsite is an active dumpsite which runs throughout the year. The dumpsite is situated in Ado-Ekiti along Ado-Iworoko road. The dumpsite is located within Longitude 5.27 and 5.30 and Latitude 7.65 and 7.66 in decimal degrees respectively (Figure 1).

The size of the dumpsite is about 7,700 square meters. There is a good accessibility to the dumpsite. There is an Ebira community within the study area occupying close to fifteen houses which is about 400 metres to the dumpsite. The composition of Ilokun dumpsite are organic materials, polythene and plastic materials, meta scraps, animal wastes etc. (Lateef *et al.).* There are farmlands around the study area where the people staying in the area practice farm work. The dumpsite was commissioned by Mrs. Hadiza Ibrahim Maiafia who was the then minister of environment. The dumpsite was commissioned on the 17th June, 2012. We have the site to be part of National Environment Standard and Regulation Agency

GEOLOGY

The study area, Ado-Ekiti, forms part of the area underlain by the Precambrian Basement Complex rocks of southwestern Nigeria Rahaman (1988) and it comprises of igneous and metamorphic rock units such as gneisses, masses, including older graniteridges and pegmatites.

The area is underlain dominantly by migmatite-gneiss and it has migmatite (Figure 1). This rock unit manifests as surface outcrops around the study area. The area falls within the tropical rainforest vegetation and also characterised by short dry and long wet seasons. The relief of Ado-Ekiti is moderately low with disengaged slopes (isolated hills) and inselbergs that are dome shaped (Lateef *et al*). At the base of these rocks are boulders littering everywhere. The major waterway depleting the zone is Ireje River which streams (flows) south–East, it is related with simple form type of minor tributaries Ireje River is characterised with decrease in volume or aggregate become scarce in the event of extreme drought. Ado–Ekiti has a planimetric region of about 84km.

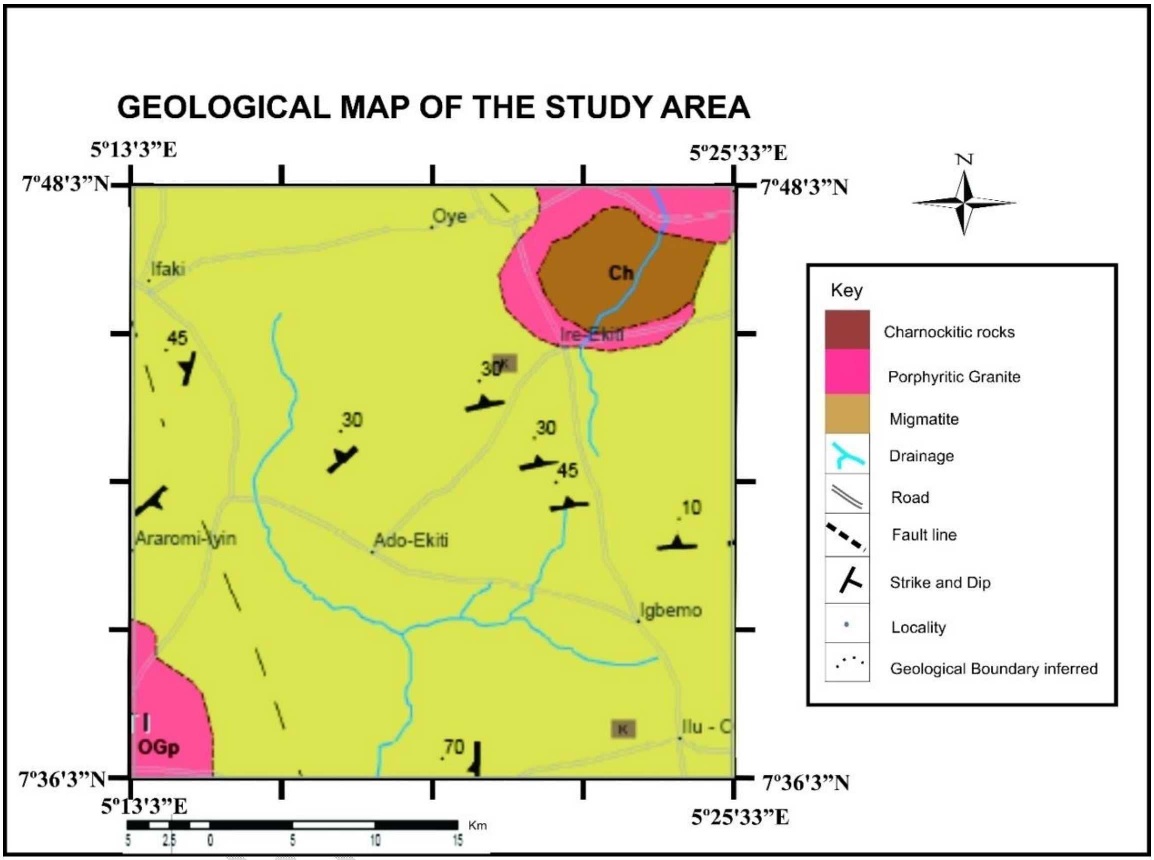

Figure 1: Geological Map of the study Area (Modified after NGSA, 2017)

METHODOLOGY

The research work involved geotechnical method of investigation .This involves collection of soil samples (disturbed and undisturbed) at different depths in a trial pit which is the cheapest method of exploration to shallow depth which enables a clear picture to be obtained of the stratification of soils and the presence of any lenses or pockets of weaker materials.

For the purpose of this work geotechnical sampling involved the establishment of four trial pits. Both disturbed and undisturbed samples were obtained at different depth within the lateritic zone. The variation in the depth of soil sample was necessary to know the geotechnical properties of the laterite zone which may be useful as mineral seals in the construction of sanitary landfill. The disturbed samples collected in polythene bags were obtained using digger and shovel.

The undisturbed samples were obtained using cutters (100mm x150mm) with marshal rammer ramming it into place. The core cutter was sealed on both edges immediately with candle wax melted on the field to prevent loss of moisture. The disturbed samples were subjected to specific gravity test, grain size distribution analysis, consistency limits, and compaction tests while permeability test was carried out on undisturbed sample at soil laboratory according to BS 1377 [16] standard. The results obtained were later compared the recommendation of several previous authors, researchers and regulatory agencies.

RESULTS AND DISCUSSION

The general laboratory assessments required for lateritic soils to be used as mineral seals are specific gravity, the grain size distribution, the Atterberg consistency limits, the moisture content-density relationships and the coefficient of permeability (ÖNORM S2074, 1990; Oeltzschner, 1992; Jessberger, 1994; Seymour and Peacock, 1994; Taha and Kabir, 2006; USEPA, 2005; Ash and Jeggar, 2008).

Specific gravity of grains

The specific gravity of soil particles is an important engineering index property often employed in estimating the degree of laterization of lateritic soil (Lohnes and Demirel, 1973; Truncer and Lohnes, 1977). It is an important property in identifying and evaluating aggregates for construction purpose (Gidigasu, 1976).

Alexander and Cady (1962), gave values of 2.50 to 3.60 for specific gravity of lateritic soils while De-Graft Johnson (1969) recommended a range of value between 2.60 and 3.40 for specific gravity of lateritic soils. Thus, the specific gravity value of the derived soil samples fall within the stipulated range.

Truncer and Lohnes (1977) noted that the specific gravity of soil particles is a very good primary index property to characterize lateritic soils as it reflects their iron and sesquioxide content and the extent of laterization. High specific gravity values indicate a high degree of laterization.

Akroyd (1963) had suggested the use of specific gravity in assessing the maturity of lateritic soils. The higher the specific gravity of lateritic soils and the degree of laterization, the stronger the soils would be.

Table 1 shows that there is a very close range in the values of the specific gravity of the grains of the studied soils since the soils are of the same genetic origin and in the similar weathering environment. The specific gravity ranges from 2.62 between 2.76.

Table 1: Result of Specific Gravity of the migmatite-gneiss-derived soil samples at depth 2m

Sample	**ADE-1**	**ADE-2**	**ADE-3**	**ADE-4**	**ADE-5**	**ADE-6**	**ADE-7**	**ADE-8**	**ADE-9**	**ADE-10**
Specific Gravity	2.71	2.73	2.76	2.74	2.66	2.62	2.73	2.75	2.75	2.75

Comparing the results obtained with that of Bowels (1979) specification as shown in the table 2 below, sample ADE-1 is classified as Clay (Inorganic), ADE-5 and ADE-6 are classified as clay (Organic), ADE-2, ADE-3, ADE-4, ADE-7, ADE-8, ADE-9 and ADE-10 are classified as Silt.

Grain size distribution characteristics

This test is important in the estimation of relative proportion of various size grades in the samples. The physical and engineering properties of lateritic soils have been found to depend on their textural characteristics.

A combination of grain size distribution characteristics of a soil with plasticity enhances an easy classification of the soil. Although grading characteristic has little relevance in the characterization of fined-grained soils, most of the engineering properties of coarse-grained soils are closely associated with the predominant particle size.

The amount of fines in a soil which is the percentage finer than 63 micrometer (clay and silt-size) is an important parameter often employed in the classification and characterisation of soils. The higher the amount of fine particles in the soil, the poorer the soil for construction purpose.

The amount of clay-sized particles has been found to have some relationships with plasticity and hence workability of lateritic soil (Gidigasu, 1976).This relationship is influenced by the degree of leaching and laterization to which the lateritic soils have been subjected. While the colloidal content of clay deposits provides the necessary plasticity and workability (Lee, 1961), the sand-size particles contribute to the mechanical strength (Lee, 1961; Akinmusuru and Adebayo, 1981).

The grain size distribution curves of the Ten studied soil samples are presented in Figure 2. The summary of the grain size distribution characteristics of the studied soils are shown in the Table 2 below. The graphical representation of the results of the grain size analysis of soil sample ADE-1 gave an indication that it is clayey-silt, ADE-2 is clayey-sand, ADE-3 is sandy-silt, ADE-4 is clayey-gravel, ADE-5 is sandy-gravel, ADE-6 is clayey-sand, ADE-7 is gravelly-sand, ADE-8 is sandy-gravel, ADE-9 is sandy-gravel, ADE-10 is sandy-gravel.

The ten samples of Ilokun dumpsite have gravel percentage ranging from 2% to 55%, percentage of sand ranging from 25% to 69%, silt percentage ranging from 6% to 40%, clay percentage ranging from 2% to 31%. This shows that the total amount of fine range from 18% to 66%.

All the samples would be classified as well graded but the results of the grain-size analyses clearly reflect the mineralogical and textural characteristics of the parent rock. It can be seen that the soils have a much lower percentage of fines (clay and silt-sized particles) indicating better geotechnical characteristics. The lower the amount of fines in a soil sample, the better the engineering properties of the soil. The lower the clay size fraction, the higher the degree of the laterization and consequently the higher the crushing strength (Adeyemi *et al.* 1990). Topographic condition and the position of soil in the profile also affect the grain size distribution.

Daniel (1993b) recommended amount of fines of at least 20% for landfill seals i.e. for soil that can be good for base of landfill. Therefore the studied soils meet this standard specification and can be used for base of landfill except sample ADE-10 that has less than 20% of fines.

The higher the percentage of sand-sized particles in the soil the better the load bearing capacity of the soil (Olusanya, 2001). From the data obtained, the high percentage of sand particles in the studied soils could be attributed to the mineralogical composition of the parent rocks. The rock sample taken from the parent rock is composed of high percentage of quartz. The sand size fraction is also contributing to the mechanical strength of any soil.
The least uniformity coefficient of the soil samples is 17.27. This value is greater than one, which is indicative of a well graded soil and hence a good highway sub-base and sub-grade materials.

Table 2: Grain size distribution characteristics of the studied soils

SAMPLES	**% GRAVEL**	**% SAND**	**% SILT**	**% CLAY**	**AMOUNT OF FINES (%)**	**UNIFORMITY COEFFICIENT (D_{60}/D_{10})**	**D_{50}(mm)**	**COEFFICIEENT OF PERMEABILITY $K=CD^2_{50}$, C=0.00357**
ADE-1	13	25	36	26	62	150	0.008	6.4×10^{-5}
ADE-2	15	43	11	31	42	380	0.12	1.4×10^{-2}
ADE-3	2	32	40	26	66	17.27	0.0065	4.2×10^{-5}
ADE-4	45	20	12	23	35	3846.15	0.05	2.5×10^{-3}
ADE-5	42	25	14	19	33	5000	3.5	1.2 x 10
ADE-6	5	69	6	20	26	3846.15	3.0	0.9 x 10
ADE-7	30	38	16	16	32	150	0.35	1.2×10^{-1}
ADE-8	42	36	20	2	22	369.23	1.2	1.44
ADE-9	45	34	18	3	21	270	1.5	2.25
ADE-10	55	27	15	3	18	657.14	3.0	0.9 x 10

Clay	Silt	Sand	Gravel

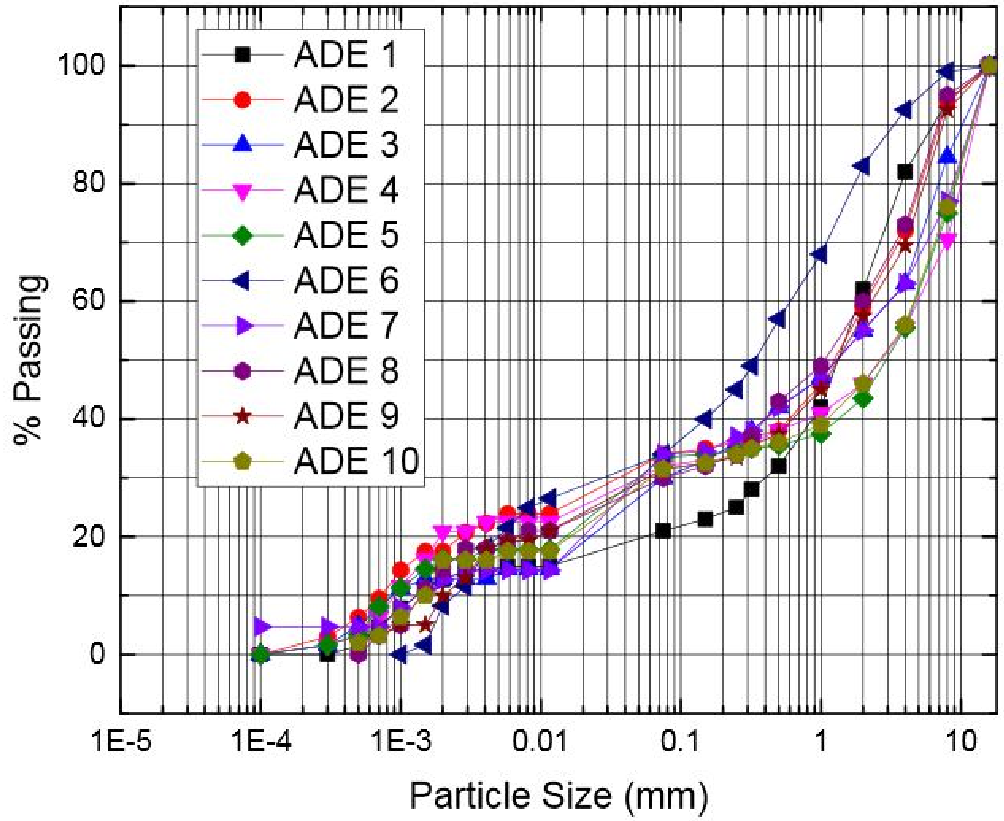

Figure 2: Grading curves of residual lateritic soil samples

ATTERBERG (CONSISTENCY) LIMITS OF SOILS

A consistency limit characteristic is an important factor in the selection of lateritic soils as lining materials.

The plasticity of a soil is a measure of the affinity which a soil has for water. It is often expressed in terms of the plasticity index which is the numerical difference between the liquid limits and plastic limits. The mineralogical composition of the soil and the parent rock affects its plasticity significantly. For instance, alkali feldspar is transformed into kaolinite while biotite changes to the clay mineral vermiculite, both of which are highly hydrophilic. Excessive plasticity often leads to waviness which is a type of road failure that results from plastic flow of wet soil upon the application of axle load.

The Atterberg consistency (degree of firmness) limits tests evaluate the relationship between moisture content and soil consistency. According to Bagchi (1994), a lateritic clayey soil with liquid limit (LL) ≥30% and plasticity index (PI) ≥ 15% is recommended. Clayey soils with liquid limit (≥35%) and plasticity index of >15% are good for consideration as mineral seal (Oeltzschner, 1992). Mitchell (1976) preferred inorganic clay of medium plasticity, whereas Oweis and Khera (1990) suggested inorganic clay of high plasticity.

Table 3 summarizes the consistency limits of the studied soils at Ilokun, Ado-Ekiti. It shows that the liquid limit of the soil samples ranges from 21.6% to 32.0%. The plastic limit of the soil samples range from 17.5% to 21.3%. All the samples plot in the low plasticity regime except ADE-6 and ADE-9. According to Bagchi (1994), a lateritic clayey soil with liquid limit (LL) ≥30% and plasticity index (PI) ≥ 15% is recommended as mineral seal. Ilokun soils meet this standard specification and therefore can be used as mineral seal. Ilokun site has lateritic soil that is geologically suitable with low plasticity and hence low compressibility.

The Casagrande chart classification (Figure 3) places virtually all the soil samples in the low plasticity/compressibility region and hence the soils would be expected to exhibit low swelling potential (Ola, 1982). All the lateritic soil samples from Ilokun fall within the field of inorganic clays of low plasticity (Casagrande, 1948). All the soil samples except one are of low plasticity and this indicates that the soil will not swell much when it is in contact with water.

According to Terzaghi, (1958), lateritic soils which plot below A-line have proved problematic when the soils are used for construction purposes.

Philips (1952) cited in Wahab (1997) indicated that any lateritic soil having a liquid limit in excess of 30% and plasticity index above 12 should be rated poor for use under bituminous surfacing. However, the Federal Ministry of Works and Housing (1974) specified a maximum liquid limit of 40% and a maximum plasticity index of 20 for highway sub-grade material.

According to the Federal Ministry of Works specifications, all the samples meet the 40% maximum standard. The higher the liquid limit of a soil, the poorer the material for road construction. The plasticity indices of the soil samples range from 5.6% to 14.8%. The plasticity values were generally lower than 25, the maximum value recommended for sub-grade tropical Africa soils (Medina 1963, in Simon *et al*. 1973). All the soil samples meet this standard specification.

Seven out of ten soil samples fall within the field of inorganic clays of low plasticity while three samples fall within the field of inorganic clays of medium plasticity (Casagrande, 1948). All the soil samples except two are of low plasticity and this indicates that the soil will not swell much when it is in contact with water.

Table 3: Summary of Atterberg (Consistency) limits for soil samples

SAMPLE	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	FLOW INDEX (%)	TOUGHNESS INDEX (%)	SHRINKAGE LIMIT (%)
ADE-1	28.0	18.6	9.4	25.0	0.38	5.3
ADE-2	26.0	20.4	5.6	29.0	0.19	4.9
ADE-3	28.0	19.9	8.1	31.0	0.26	5.7
ADE-4	28.0	18.25	9.75	18.5	0.52	5.3
ADE-5	25.6	15.45	10.15	21.1	0.48	5.2
ADE-6	32.0	21.0	11.0	26.32	0.42	8.2
ADE-7	21.6	18.25	14.8	23.95	0.62	4.1
ADE-8	26.0	17.5	8.5	15.0	0.56	4.7
ADE-9	30.5	21.3	9.2	33.0	0.30	4.6
ADE-10	29.2	20.0	9.2	29.1	0.32	4.7

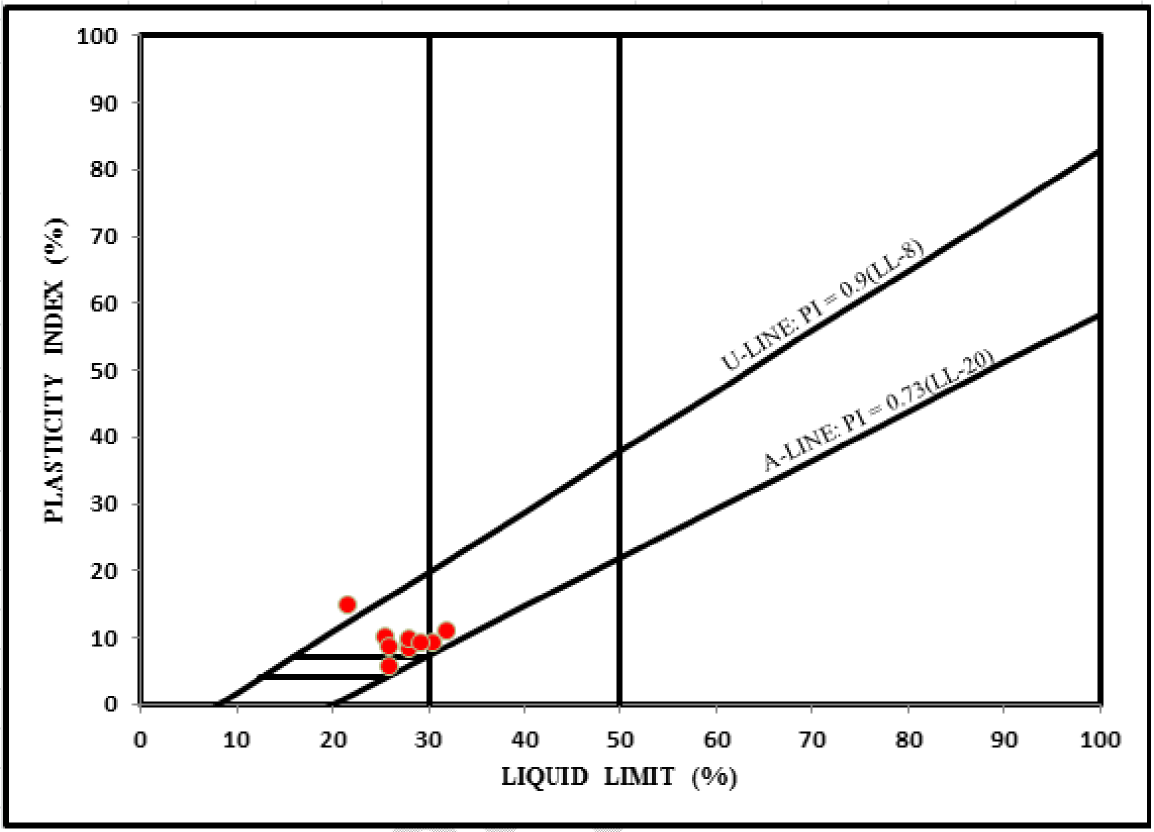

Figure 3: Casagrande Chart Classification of Ilokun Soil Samples

COMPACTION CHARACTERISTICS (MOISTURE CONTENT-DENSITY RELATIONSHIPS)

In any engineering construction work, compaction of soils is done to achieve soils with improved engineering properties. The process of compaction results in a soil mass that is free of large continuous inter-clods voids, increases its density and strength, and reduces its hydraulic conductivity (Benson and Daniels, 1990).

Water content and dry density values can greatly affect a soil's ability to resist the transmission of fluid flow and other physical properties of the soil (permeability, strength and shrinkage potential) that control the performance of a soil as mineral seal (Das, 1998; Taha and Kabir, 2006).

According to Daniel (1990), permeability decreases with increasing compactive effort. This is because increasing compactive effort decreases the frequency of large pores (Acar and Oliveri, 1990). ÖNORM S 2074(1990) and Taha and Kabir (2006) recommended a maximum dry density of ≥1.70t/m^3 for soils to offer desire permeability to be useful as mineral seals.

For this study, the soils were compacted at different levels i.e. standard and modified proctors. These were done with a view to determining the best level of compaction for the soil samples derived and also to determine the optimum moisture content (OMC) and maximum dry density (MDD).

Summary of compaction test results for both standard and modified Proctor energies are presented in Figure 4. The maximum dry density (MDD) values range from1.72t/m^3 to 2.02t/m^3 for Standard Proctol while the optimum moisture content (OMC) values range from 9.0% to 14.0% for Standard Proctol compaction condition.

The soils have MDD values range from1.78t/m^3 to 2.08t/m^3 and OMC values range from 7.0% to 13.0% for modified Proctor compaction condition.

As shown in Table 4, the sample ADE 1, ADE 3, ADE 7 and ADE 9 had better compaction parameters than the rest of the soils samples when compacted at Standard Proctol level. The soil sample ADE 3, had the highest MDD and the lowest OMC. The soil samples ADE 7, ADE 3, ADE 1, and ADE 9 had better compaction parameters than other samples compacted at Modified Proctool. The higher the MDD, the better the soil for engineering purpose and also the lower the OMC, the better the soil for engineering purpose. Philip (1952) rated laterite soils having OMC between 8% and 10% as average and above 10% as poor for use as a sub-grade material.

Maximum Dry Density

From the compaction results summarized in Table 4, the maximum dry density (MDD) values of the studied soil range from1.72t/m^3 to 2.02t/m^3 for Standard Proctol and the maximum dry density (MDD) values of the studied soil range from1.78t/m^3 to 2.08t/m^3 for Modified Proctol. From

Table 4, higher dry density values were obtained when the soil samples were compacted with higher energy of compaction. These results conform to the speculation of Taha and Kabir (2006).

The data show that the highest MDD of 2.02t/m^3 and the lowest OMC of 7.0% are exhibited by soil sample ADE 7 compacted at Modified Proctol of the compaction rammer. The basic assumption underlying the compaction test is that the strength of soil increases with increasing dry unit weight.

For any soil to be suitable for general filling and construction of sub-grade and sub-base courses of roads, the maximum dry density (MDD) must exceed 1.70t/m^3 (Nigerian General Standard Acceptable Limits FMW,1997). Taha and Kabir (2006) recommended a maximum dry density of ≥1.70t/m^3 for soils to offer desire permeability to be useful as mineral seals.

Optimum Moisture Content

The optimum moisture content (OMC) values of the studied soil range from 9.0% to 14.0% for Standard Proctol and the optimum moisture content (OMC) values of the studied soil range from 7.0% to 13.0% for Modified Proctol. The increase in energy of compaction drastically reduces optimum moisture content of the studied soils. The lowest OMC produced the highest MDD at Modified Proctol. Modified Protocol has been adjudged to be the best for some southwestern Nigerian lateritic soils (Owolabi, 1991 and Adeyemi, 1992).

The results obtained in this study also show that the compaction at Modified Protocol is the most suitable for all the samples because it produced the best moisture content and dry density parameters.

Table 4: Summary of compaction test results

SAMPLE NO	**STANDARD PROCTOR**		**MODIFIED PROCTOR**	
	Optimum Moisture Content (OMC) %	**Maximum Dry Density (MDD) g/cm^3**	**Optimum Moisture Content (OMC) %**	**Maximum Dry Density (MDD) g/cm3**
ADE-1	9.0	1.98	8.0	2.07
ADE-2	9.0	1.92	7.0	1.99

ADE-3	9.0	2.02	8.0	2.07
ADE-4	9.0	1.95	8.5	1.98
ADE-5	10.0	1.90	9.0	1.97
ADE-6	14.0	1.72	13.0	1.78
ADE-7	9.0	1.97	7.0	2.08
ADE-8	11.0	1.88	10.0	1.94
ADE-9	9.0	1.95	8.5	2.08
ADE-10	10.0	1.93	9.0	1.98

COEFFICIENT OF PERMEABILITY

The coefficient of permeability (k) which is a mechanical property of soil (Terzhagi, 1936) is the main parameter that determines the competence of a clayey soil as mineral seal (Daniel, 1987, 1990; Benson and Daniel, 1990; Benson et al., 1994). The permeability of a soil is dependent on the soil texture and structure. It is a property of soil by virtue of which the soil mass allows fluid to flow through it. The general mechanical properties of clay depend on several interacting factors such as mineral composition, percentage of amorphous material, absorbed cation, distribution and shape of particles, pore fluid chemistry, soil fabric, degree of saturation etc. The effects on the mechanical properties of soil due to a change in any of these factors have been predicted qualitatively using physico-chemical theories (Bagchi, 1994).

The permeability coefficient values obtained from this study are presented in Table 5. The coefficient of permeability obtained for the samples range from 1.5 x 10^{-3}mm/s to 2.5 x 10^{-2}mm/s. Lambe(1951) in classifying soils based on permeability used a permeability of 10^{-4} mm/s as a borderline between pervious and impervious soils. All the studied soil samples can be classified as pervious soil because they have permeability coefficients higher than the recommended borderline. According to Clayton and Huie (1973), the permeability coefficient for the base of a landfill should not exceed 10^{-6}mm/s. Considering the standard set by Clayton and Huie (1973), all the samples do not meet the standard. This is because the soil samples have permeability coefficients in excess of the recommended figures. It is therefore recommended that in-situ compaction and lining be done if the location is to be used as landfill site. This will prevent lateral and vertical movement of groundwater and liquid phase of the wastes.

The coefficient of permeability obtained for samples taken from varying depths is significantly higher than the maximum value of 10^{-6} mm/s recommended for the soil that should form the base of landfills. It is therefore recommended that in-situ compaction and lining be done if the soils at the location will be used as barrier and liners in landfill. This will significantly prevent lateral and vertical movement of liquid phase of the wastes.

On the suitability of compacted clay soil as mineral seals in sanitary landfill, several recommendations have been proposed (USEPA, 1982; Tavenas et al, 1983; ÖNORM S2074, 1990; Oeltzschner, 1992; Jessberger, 1994, Seymour and Peacock, 1994; USEPA, 2005; Taha and Kabir, 2006). USEPA (1982) recommended that such soils should possess a k-value of <1 x 10^{-9}m/s; ÖNORMS 2071(1990) preferred k-value of 1x 10^{-9}m/s; Oeltzschner (1992) suggested k-value <10^{-10}m/s. Jessberger (1994) recommended k value 1x 10^{-10}m/s; Seymour and Peacock (1994) suggested k-value of 1x10^{-9}m/s. Considering the standard set by USEPA, 1982; Tavenas et al, 1983; ÖNORM S2074, 1990; Oeltzschner, 1992; Jessberger, 1994, Seymour and Peacock, 1994; USEPA, 2005; Taha and Kabir, 2006 all the samples do not meet the standard.

The coefficient of permeability (k) decreases with the increasing compactive effort, because increasing effort decreases the frequency of large pores (Acar and Oliveri, 1990). This reduction in pore size yield lower permeability which also changes with change in compaction water content. Increase water content always results in an increased ability to break down clay aggregates and eliminate inter-aggregate pores (Benson and Daniel, 1990).

Table 5: Summary of permeability test results

Sample	Volume of drained water(Q)cm3	Height of core sample (l) cm	Radius of core sample (r) cm	Area of ore sampler (cm2)A	Hydraulic tread (cm) (h)	Time (t) (sec)	Ksat (cm/s)
ADE-1	51.5	5.5	2.25	15.91	5	300	0.0119
ADE-2	34	4.9	2.2	15.21	5	300	0.0073
ADE-3	30.5	6	2.25	15.91	5	300	0.0077
ADE-4	50	4.9	2.2	15.21	5	300	0.0107
ADE-5	91	5	2.2	15.21	5	300	0.0199
ADE-6	77.5	5.5	2.25	15.91	5	300	0.0179
ADE-7	23	4.9	2.25	15.91	5	300	0.0047
ADE-8	93	6.0	2.2	15.21	5	300	0.0245
ADE-9	46	4.3	2.2	15.21	5	300	0.0087
ADE-10	7	4.9	2.2	15.21	5	300	0.0015

CONCLUSION AND RECOMMENDATION

Based on the study carried out on both disturbed and undisturbed soil samples taken from trial pits at varying depth, the foregoing interpretation and discussion of the basic geotechnical properties of the studied soils, the following conclusions are drawn:

The residual lateritic soil samples are well graded and they exhibit low plasticity. The plasticity indices of the samples are very low hence; they are good engineering soils and can be used for the base of a landfill.

The result of compaction characteristics of the studied soil revealed that they are suitable for general filling, construction of sub-grade and sub-base courses of roads and base of landfill.

The co-efficient of permeability obtained for the studied soil samples are significantly higher than the maximum value recommended for the soil that should form the base of landfills. However, the soil can be used as barrier in landfill if in-situ compaction and lining are done

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