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Geotechnical Evaluation of Some Soils from Part of Southwestern Nigeria, Usable as Liners in Waste Disposal Landfills

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ABSTRACT

Urbanization and population rise are major factors that contribute to increase quantity of waste generation and its disposal constraint especially in developing countries. This study investigates the geotechnical properties of five soils from southwestern Nigeria for their use as liners in sanitary landfill for disposal of solid waste. The required parameters for soils to be considered as liners were determined in accordance with the British Standard Institute. Results obtained showed that the percentage of fines range from 42% to 82% and index of plasticity values range from 25.0% to 32.6%. Clay activity varies between 0.47 and 0.88. Thus, the soils are classified as non-expansive clay of low to medium plasticity. The maximum dry density values at standard Proctor energy of compaction range from 1.46g/cm^3 to 1.96g/cm^3 while those obtained at modified Proctor energy range from 1.57g/cm^3 to 2.09g/cm^3 .The highest coefficient of permeability value obtained for all soils investigated is 2.99 x 10^{-9}m/s. All values compare favourably with those suggested by regulatory agencies. Consequently, they are suitable for use as liners in sanitary landfills.

Keywords: Liners, Nigeria, Landfill, Geotechnical, Sanitary, Waste Disposal, Soil, Clay Activity

1. INTRODUCTION

One of the major problems facing urban communities today is the efficient and long term disposal of Municipal Solid Waste (MSW). Consequences of interaction of waste with the ecosystem include health hazards such as viral, bacterial, and protozoan infections, infectious diarrhea, salmonellosis and shigellosis (Olayemi, 2004). Because waste contains mixture of plastics and other synthetic fabrics, toxic fume (dioxine) usually accompany the option of burning (Agunwamba, 2000). Fat and oil components of waste may produce polycyclic aromatic hydrocarbons (Stevenson and Butler, 1969); these may be washed into the soil by rain thereby contaminating the surface and groundwater source.

Orlov and Yerochicheva (1969) reported that interactions of humic acids with soils' sesquioxides (Iron and Aluminium oxides) may weaken their strength and suitability as engineering construction materials. Waste management methods such as burning, recycling, reduce, reuse, reduction, incineration, composting etc, have been practiced to curtail menace of waste generation. Despite advancements in these modern technologies to increase employment of energy and materials recovery, landfills will still be necessary for disposal of a final and/or unusable waste.

Disposal of solid waste in sanitary landfills is now increasingly gaining acceptance in many nations of the world (Montgomery, 2000). This is because of environmental pollution effects commonly associated with other methods of waste disposal (Asiwaju-Bello and Akande, 2004; Montgomery, 2000 and Kurian *et al*., 2005). In developing countries where incineration is mostly practiced, importation of incinerators as well as expertise for the installation and initial maintenance are issues of concern. However, most of the materials required for the construction of sanitary landfills are naturally occurring and in abundance in the study area. Also, equipment (scrapers, bulldozers, graders etc.) required for the construction of sanitary landfill are readily available in Nigeria and are currently being used for other engineering earth works.

Liners are natural clayey soils or artificial (geomembrane) impermeable materials in sanitary landfills to prevent migration of waste leachate into groundwater body. This is because interaction of chemical pollutants with surface and underground water bodies will pose adverse effects on their quality (Al- Dakheel *et al*., 2009).

Several naturally occurring materials have been tested and used as liners in sanitary landfills. Chalermyanont *et al*. (2008) studied the potential use of lateritic and marine clay soils as landfill liners to retain heavy metals. The potential of a lateritic soil and marine clay, typical of those found in hot and humid climatic regions, was assessed for use as landfill liner material. Experimental results showed that the marine clay had better adsorption capacity than that of the lateritic soil and that its hydraulic conductivity was an order of magnitude lower.

A laboratory study was undertaken to investigate the feasibility of sepiolite as a liner material sepiolite and the other one rich in kaolinite mineral, as well as their mixtures were subjected to geomechanical, hydraulic, and environmental tests (Guney *et al*., 2008). The results of the study indicated that relatively high hydraulic conductivity and shrinkage capacity of sepiolite necessitates addition of kaolinite before being used as landfill material. The results indicated that the clay mixtures used in the study provide good geo-mechanical, hydraulic and metal adsorption properties which may justify their potential use as a liner material in solid waste landfills.

Osinubi *et al*. (2006) studied the design of compacted lateritic soil liners and covers. Laboratory tests were conducted on three lateritic soil samples to illustrate some considerations in the design of compacted lateritic soil liners and covers. The three design parameters investigated are hydraulic conductivity, dessication-induced volumetric shrinkage, and unconfined compressive strength. Test specimens were compacted at various molding water contents using four compactive efforts. The line of optimum was identified as a suitable lower bound for overall acceptable zones were affected by the fines contents of the soils. Results of experimental evaluation of rubber and bentonite added fly ash showed good promise as potential candidate in construction of a liner (Cocka, *et al*., 2004).

Albert *et al* (2001) studied the effect of desiccation on compacted natural clays. Results of the study indicate that volumetric shrinkage strains are influenced by soil properties and compaction conditions. Volumetric shrinkage strain increased with increasing plasticity index and clay content, and as the compaction water content increased or decreased relative to optimum water content. Volumetric shrinkage strain decreased with increasing compactive effort. Specimens with the largest volumetric shrinkage strains typically contained the largest number of cracks. Hydraulic conductivity testing indicated that cracking of the specimens resulted in an increase in hydraulic conductivity, sometimes as large as three orders of magnitude.

The seals are placed within the top sealing system to prevent percolation of run-off into the waste column, and at the bottom sealing system, to prevent migration of generated leachate into the groundwater bodies (Fig. 1). Different types of seals such as clayey soils, synthetic membranes (artificially manufactured mixtures: bentonite, asphalt and cement) have been studied (Acar and Oliveri, 1990; Bagchi, 1994).

Thus, this study aimed at assessing geotechnical properties of some lateritic soil samples for their usability as liners in landfill construction. This is a relatively new research field in this region of the world and therefore will open up another face of the usefulness of natural material (laterite) to promote healthy environment.

2.0 MATERIALS AND METHODS

2.1 Soil Samples

About 3kg of highly weathered lateritic samples, derived from migmatite (OK 1, OK 2), granite gneiss (NG) and quartzite (OM1, OM2) were collected along Oko-Omu and Ilorin – Eyenkorin roads (Fig. 2) respectively, for the purpose of preparing. The samples were collected from road-cut and pitting between 20th and 26th February, 2006 and stored in an air-tight plastic container before being air dried at room temperature for 72h. The samples vary in texture, sampling depth and colour (Table 1). They were air-dried for two weeks while analyses of parameters were performed between 12th March and 28th June, 2007.

The classification tests were carried out at the Civil Engineering laboratory of the University of Ilorin, while density and coefficient of permeability tests were carried out at the Civil Engineering Laboratory, Yaba, Nigeria. All analyses were done in accordance with British Standards Institute (1990). Compaction and falling head permeability tests were carried out at maximum dry densities and respective optimum Moisture contents.

2.2 Sample Preparation

The samples were air-dried and lightly crushed into small pieces. The crushed samples were then sieved through 4.75mm opening. The sieved portion was wetted with tap water (PH= 7.4) and sealed in a plastic bag and stored for 3 days to allow moisture equilibration and hydration (BS 1377, 1990). The soil was later used for other geotechnical tests. The tests were conducted in duplicate for each particular soil condition to ensure the reliability of the test result.

The soil was compacted with two different Proctor energies (modified and standard) which represent the commonly used energy of compaction on the field as recommended by Daniel and Benson (1990) and Daniel and Wu (1993). The hydraulic conductivity was measured using the rigid-wall permeameter under falling head condition as recommended by Head (1994). Compaction was carried out on the soils at two different energies under different water contents within the permeameter. The permeant liquid was tap water and hydraulic gradient was 15. Permeation was conducted on the sample until steady condition was achieved.

3.0 RESULTS AND DISCUSSION

Several limits have been proposed by various researchers with respect to the geotechnical properties of soil usable as liners. Such limits are presented here along with the results obtained from this study.

3.1 Grain Size Distribution

In the soils studied, the largest grain has diameter less than 10mm (Table 2). This compared favorably to the ≤63mm suggested by ONORM S, 1990) and the values of between 30 and 50mm suggested by Daniel, (1993). The percentages of fines contained in the soils are: OK1 = 42%, OK2 = 67%, OM1 = 78%, OM2 = 82% and NG = 54%. The values agreed with ≥ 15% proposed by ONORM S, 1990). These results also fall above ≥30 suggested by Daniel, (1993), Bagchi, 1994), Benson *et al*., (1994), Rowe *et al*., (1995) and Mohammed and

Antia, (1998). The percentage of gravel recommended by Daniel, (1993); Bagchi, (1994) and Rowe *et al*., (1995) is ≤ 30%. All samples except OK1, with gravel percentage of 48% have gravel percentage less than recommendation.

3.2 Atterberg Consistency Limits

The least value of index of plasticity (Ip) is 25.0% obtained from OK1 sample while the highest value of 32.6% was obtain from OM1 (Table 3). Thus, the samples conform ≥10% suggested by Rowe *et al*. (1995). All soils fall in the zone of inorganic clay of low plasticity (CL) on the Casagrande's plasticity chart (Fig. 3). Thus, the soils are classified as non-expansive-kaoline-dominant clay type. Clay activities (A_C) for the soils are also presented in Table 3. The results obtained show that the soils range from 0.47 to 0.88. These values are better than ≥ 0.3 recommended by Benson *et al* (1995).

3.3 Specific Gravity

In the soils studied, the specific gravity values obtained are: OK1 = 2.70, OK2 = 2.65, OM1 = 2.63, OM2 = 2.62 and NG = 2.60 as shown in Table 2. These values are much higher than ≥ 2.2 recommended by ONORM S, 1990) for soils to be suitable for use as liner in sanitary landfills.

3.4 Maximum Dry Densities (MDD)

The maximum dry density (MDD) and optimum moisture content (OMC) at different energies of compaction (standard and modified Proctor) are presented in Table 4. From the Table, only OK1 has MDD value above 1.7 g/cm^3 stipulated in ONORM S, 1990) under standard Proctor energy. All the samples have MDD values above ONORM S, 1990) suggestion under modified Proctor. Irrespective of energy of compaction, the samples values are better than 1.45g/cm^3 (standard Proctor) and 1.64g/cm^3 (modified Proctor) recommended by Kabir and Taha, (2003) for soils produced from Basement Complex rocks usable as liner.

3.5 Coefficient of Permeability (k)

The coefficient of permeability is the key parameter affecting soil suitability as liners (Daniel and Benson, 1990). Several investigators have recommended ≤ 1 x 10^{-9}m/s as the minimum allowable value for soils usable for this purpose (Oeltzschner, 1992; Seymour and Peacock, 1994; Lee and Lee, 2005). From Table 4, values lower than recommended were obtained from all the soils studied when compacted with both standard and modified Proctor energy.

4. 0 CONCLUSION

Geotechnical properties of five different soil types have been clearly evaluated in order to recommend them as liners in sanitary landfills. The physical characteristics suggest that the soils are generally reddishbrown in colour, expect sample OM1 which is purple. The soils varied in texture from clayey to gravelly but are generally classified as sandy clay.

Atterberg limits values showed that the soils are non-expansive inorganic clay dominated by kaoline mineral. The maximum dry density values indicated that the soils are compactable and require low moisture content even at standard compaction energy. Most of the soil samples have high coefficient of permeability at standard energy of compaction but get better with reduced coefficient of permeability at modified compaction energy.

The evaluated geotechnical properties of the soils compare favourably with the recommendations of several researchers. Therefore, they are useful as liners in sanitary landfills for disposal of solid waste. However, higher energy of compaction is recommended because it gives lower values of coefficient of permeability.

The results from the study present basic geotechnical requirement for suitability of a liner in sanitary landfill. Other tests such as cation exchange capacity and strength tests may be carried out, as demanded by the condition of local terrain.

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6.0 REFERENCES

Acar, Y. & Oliveri, I (1990), Pore fluid effects on the fabric and hydraulic conductivity of laboratory compacted clay. Trans. Res. Record, 1219: 144-159.

Agunwamba, J.C. (2000), Solid waste management in Nigeria: Problems and Issues. Journal of Environmental Management. 22(6): 849-856.

Albrecht, B.A. & Benson, C.H. (2001), Effect of desiccation on compacted natural clays. Journal of Geotechnical and Geoenvironmental Engineering. 127**(1)**: 67-75.

Al-Dakheel, Y.Y., A.H.A. Hussein, A.S. El Mahmoudi & M.A. Massoud, (2009), Soil, water chemistry and sedimentological studies of Al Asfar evaporation lake and its inland Sabkha, Al Hassa Area, Saudi Arabia. Asian

Journal of Earth Sciences, 2: 1-21.

Asiwaju-Bello, Y.A. and O.O. Akande, (2004), Urban groundwater pollution: Case study of a disposal sites in Lagos metropolis. J. Water Resources. 12. 22-26.

Bagchi, A. (1994), Design, Construction, and Monitoring of landfills. 2nd Edn, A Wiley-Interscience Publication, USA, 361p

Benson, C.H. & J.M. Trust, (1995), Hydraulic conductivity of thirteen compacted clays. Clays clay minerals. 43**(6)**, 669-681.

Benson, C.H., H. Zhai & X. Wang, (1994), Estimating hydraulic conductivity of clays Liners. Journal of Geo. Eng. ASCE. 120**(2),** 366-387.

British Standads Institute, 1377 (1990), Method of Testing Soil for Civil Engineering Purposes. 2nd Edn., British Standards, London, ISBN: 9780580183706,

Cawley, M.R. (1999), Compacted Clay Liners – A viable Solution for Landfill Leachate Containment. Winter Semester 1999, Brigham Young University.

Chalermyanont, T. Arrykul, S. & Charoethaisong, N. (2008), Potential use of lateritic and marine clay soils as landfill liners to retain Heavy Metals. Waste management. 29, 117-127.

Cocka, E. & Yilmaz, Z. (2004), Use of rubber and bentonite added fly ash as a liner material. Waste Management. 24**(2),** 153-164.

Daniel, D.E., (1993), Clay Liners. In: Geotechnical Practice for Waste Disposal, Daniel, D.E. (Ed.). Chapman Hall, London, UK, pp: 137-163.

Daniel, D.E. & C.H. Benson, (1990), Water content – density criteria for compacted soil liners J. Geot. Eng., 116**(12)**, 1811-1830.

Daniel, D.E. & Y.K, Wu. (1993), Compacted clay liners and covers for arid sites. Journal of Geotechnical Engineering. ASCE, 119**(2)**, 223-237.

Guney, Y., Koparal, S. and Aydilek, A.H. (2008), Sepiolite as an alternate liner material in municipal solid waste landfills. Journal of Geotechnical and Geoenvironmental Engineering. 138**(8)**, 1166-1180.

Head, K.H. (1994), Manual of Soil Laboratory testing- Volume 2: Permeability, Shear Strength and Compressibility Test, Halsted Press, New York, USA.

Taha, M.R. & M.H Kabir, (2003). Sedimentary residual soil as a hydraulic barrier in waste containment systems. Second International Conference on Advances in Soft Soil Engineering Technology. Putrajaya, Malaysia, 895-904

Kurian, J., R. Nagendran. & P. Palanivelu, (2005), Open Dumps to Sustainable Landfill. Centre for Environmental Studies, Anna University, Channai, India. www.serd.ait.ac.th/sidaSWM/project .

Lee, F.G. & A. Jones-Lee, (2005), Flawed technology of subtitled D landfilling of municipal solid waste. http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf

Mohammed, A.M.O. & H.E. Antia, (1998), Geoenvironmental Engineering.1st Edn. Elsevier Science, Amsterdam, 329p

Montgomery, W.M, (2000), Environmental Geology, 5th Edition, McGraw Hill, USA., 546p.

Oeltzschner, H., (1992), Anforderung an die Geologie, Hydrogeologie und Geotechnik beim Bau von Deponie (Requirement of Geology, Hydrogeology and Geotechnics in the Construction of Landfills). In: THORME-KOZMIENSKY K. J. (ed). Abdichtung von Deponien und Altasten (Sealing of Landfills and Contaminated Site). E. F. Verlag fur Energie und Umwelttechnik GmbH (E.F. Publisher for Energy and Environmental Techniques). 53-82.

Olayemi, A. B. (2007), Crisis of the commons: Global Water Challenge. The 81st Inaugural lecture, Faculty of Science, University of Ilorin. Nigeria. 52p.

Orlov, D. S & N. L. Yeroshicheva. (1967), Interaction of humic acids with the cations of some metals . *Soviet Soil Science.* ***12****, 1799-1806.*

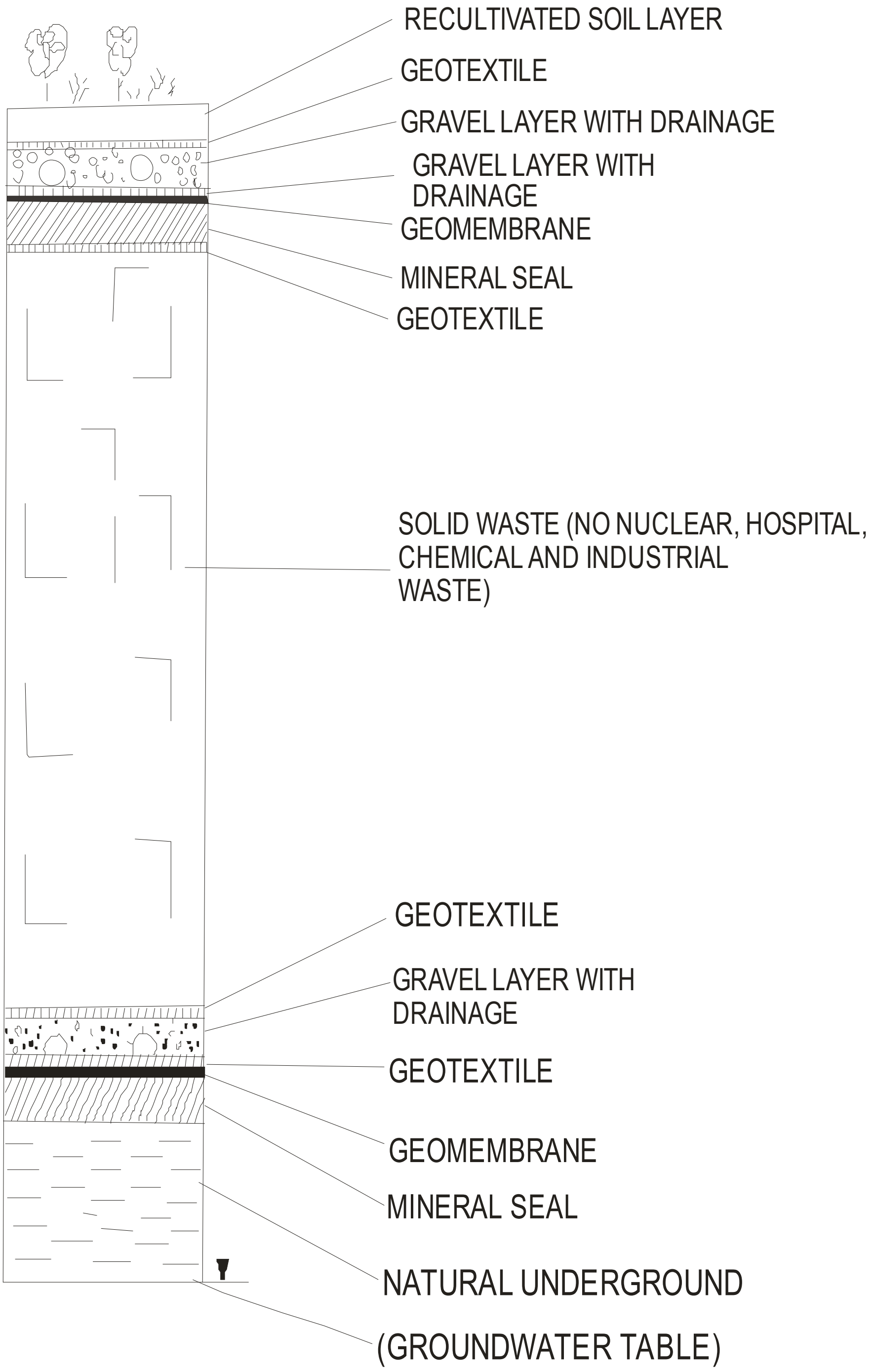
ONORM, S 2074 (1990), Geotechnik in Deponiebau-Erdarbeiten. Osterrichisches Normungsinstitut, Wien (Geotechnics in Landfill Construction-Earthworks, Austrian Standards Institute, Vienna).

Osinubi, K.J. & Nawaiwu, C.M.O. (2006), Design of Compacted Lateritic Soil Liners and Covers. Journal of Geotechnical and Geoenvironmental Engineering. 132**(2)**: 203-213.

Rowe, R.K., R.M. Quigly & J.R. Booker, (1995), Clayey barrier Systems for Waste Disposal facilities.1st Edn., E and FN Spon, New York.

Seymour, K.J. & A.J. Peacock, (1994), Quality control of clay liners. In: Landfilling of Waste: Barriers, Christensen T.H., R. Cossu and R. Stegmann (Eds.). E & EF Spon Publisher, London, 69-79

Stevenson, F.J. & J.H. Butter, (1969), Chemistry of humic acids and related pigments. In: Organic geochemistry: Methods and Results. G. Eglington and M.T.J. Murphy (eds). Springer Verlag, Berlin, Germany. 101-117.



Section Through a waste disposal landfill (Ogunsanwo, 1996) 6)

Table 1: Sampling localities and horizons of sampling

Symbol	Parent Material	Sampling locality	Depth of Profile(m)	Depth of sampling (m)	Texture	Colour
OK1	Migmatite	Along Omu Aran- Oko road	3.5	0.35-0.5(pit)	Gravely	**Reddishbrown**
OK2	Migmatite	Along Omu aran-Oko road	3.5	2.7-3.0(pit)	Clayey	**Brownish grey**
OM1	Quartzite	Off old Omu Aran Isanlu road	5.5	0.9-1.2	Sandy	**Reddishbrown**
OM2	Quartzite	Off Old Omu Aran-Isanlu road	5.5	5.0-5.3	Clayey	**Purple**
NG	**Granite Gneiss**	Orugbangba Town, along new Ilorin-Ibadan express road	**3.0**	**1.9-2.1**	**Sandy**	**Reddishbrown**

*OK1= Oko 1, OK2= Oko 2, OM 1= Omu Aran 1, OM 2 = Omu Aran 2, NG = Granite Gneiss

Fig. 2: The road map showing samples localities

Table 2: Grain size analysis of the soil samples

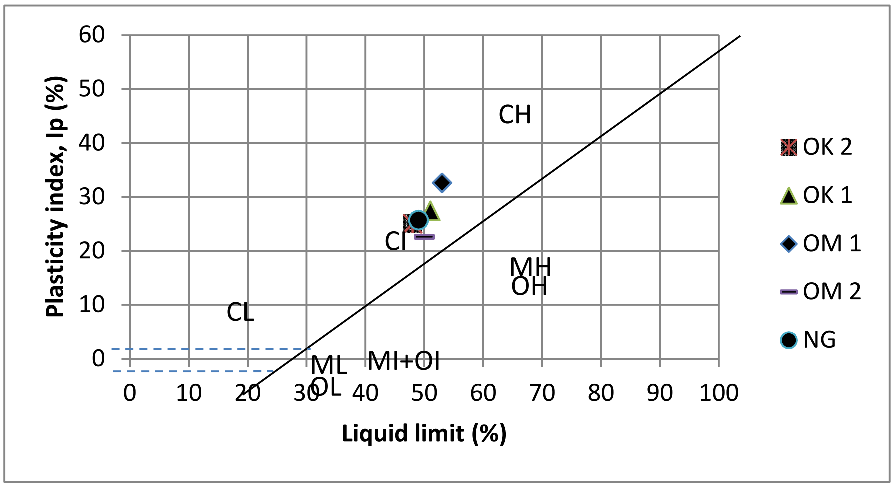
Symbol	Natural density(Mg/m^3)	Specific gravity	Grain size analysis (%)				
			Gravel	Sand	Fine	Clay	Silt
OK1	1.96	2.70	48	10	42	31	11
OK2	1.62	2.65	0	33	67	44	23
OM1	1.54	2.63	7	15	78	57	21
OM2	1.72	2.62	2	16	82	56	26
NG	1.88	2.67	9	37	54	44	10

*OK1= Oko 1, OK2= Oko 2, OM 1= Omu Aran 1, OM 2 = Omu Aran 2, NG = Granite Gneiss

Table 3: Atterberg consistency limits of the soils

Symbol	W_L (%)	W_P (%)	I_P (%)	Plots on the plasticity diagram	Activity of clay(Ac)
OK1	51.0	23.6	27.4	CL: low plasticity clay	0.88
OK2	48.0	23.0	25.0	CL: low plasticity clay	0.57
OM1	53.0	20.4	32.6	CH: high plasticity clay	0.57
OM2	50.0	23.4	22.6	CL: low plasticity clay	0.40
NG	49.0	23.3	25.7	CL: low plasticity clay	0.58

*OK1= Oko 1, OK2= Oko 2, OM 1= Omu Aran 1, OM 2 = Omu Aran 2, NG = Granite Gneiss



Figs. 3: Plasticity chart showing plots of soil samples

Table 4: Maximum dry density (MDD), Optimum moisture content (OMC and the coefficient of permeability (*k*) values.

Symbol	MDD(g/cm^3)		OMC (%)		Coefficient of permeability, *k*, (m/s)	
	Standard Proctor	Modified Proctor	Standard Proctor	Modified Proctor	Standard Proctor	Modified Proctor
OK1	1.96	2.09	12.6	9.10	$1.17X10^{-7}$	$1.04X10^{-9}$
OK2	1.62	1.76	21.4	18.6	$4.84X10^{-8}$	$2.99X10^{-10}$
OM1	1.64	1.76	18.3	15.40	$2.04X10^{-7}$	$2.43X10^{-10}$
OM2	1.46	1.57	28.0	23.70	$4.33X10^{-8}$	$1.11X10^{-9}$
NG	1.68	1.79	17.6	16.30	$3.65X10^{-9}$	$2.13X10^{-10}$

*OK1= Oko 1, OK2= Oko 2, OM 1= Omu Aran 1, OM 2 = Omu Aran 2, NG = Granite Gneiss

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