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GEOTECHNICAL PROPERTIES OF WASTE ENGINE OIL CONTAMINATED LATERITES

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Abstract
Surface disposal of waste engine oil is common in many parts of Nigeria and this result in the attendant contamination of soils. It is therefore important to investigate the effect of this on laterites which are commonly used as bases for road construction. In this work, laboratory tests were performed on four lateritic soils classified as GC and SC in accordance with the Unified Soil Classification system. The contaminated soils were prepared by mixing the dry soil samples with 3%, 6%, 9% and 12% of waste engine oil in terms of weight. The results show a general decrease in optimum moisture content, liquid limits and Permeability. There were also observed increase in shear strength, maximum dry density and CBR for three of the samples. These results are therefore useful in the prediction of the behaviour of these contaminated soils.

Keywords: Geotechnical properties, waste engine oil, contamination, laterites

1. Introduction

The uncontrolled discarding of waste engine oil (WEO) is common in many cities in Nigeria. The use of this discarded oil by timber harvesters, farmers and other industries result in soil contamination. This is proven by [1] where they showed that 200 million liters of waste engine oil are generated annually in Nigeria, with a great part of it being discarded than recycled or used in the production of other products.

Laterites on the other hand comprises a wide variety of red, brown, yellow, fine-grained residual soils of light texture as well as nodular gravels and cemented soils which are characterized by their Silica-sesquioxide (S-S) ratio and are also commonly used as bases for road construction purposes especially in the tropics. In fact Nigeria consisted of uplifted continental land mass which resulted in the formation of lateritic soils [2].

Several works have been carried out on contaminated soils including soils contaminated with crude oil and WEO. Such works include but are not limited to [3], [4], [5], [6] and [7]. While considering the effect of crude oil on soils in the Niger Delta area of Nigeria, [7] observed that there were decreases in the values of undrained cohesion, undrained angle of internal friction, optimum moisture content, coefficient of consolidation and coefficient of permeability for a range of silty sands and clays.

The work of [8], focused on the contamination effect of waste engine oil on poorly graded sands and clays and for which he showed that the effective angle of internal friction for the poorly graded sands decreased from 36.5° to 24.5°& at 9% level of contamination thereby reducing its bearing capacity at failure while Hydraulic conductivity decreased with a maximum decrease at 3% contamination level. Another important observation of [8] is the increase in the California Bearing Ratio (CBR) of the poorly graded sand in an unsoaked condition which increased from 0 to 6% contamination and decreased afterwards. The clays in this case showed an increase from 35% to 58.8% in compression index at 9% contamination with the coefficient of consolidation decreasing as contamination increased.

This paper is therefore aimed at investigating the geotechnical properties of WEO contaminated Laterites so as to know the possible recommendations with respect to civil engineering works since they are of very common use especially in the tropics.

2. Sample collection and preparation

All the samples were collected at Nsukka, Nigeria. The first three samples titled OPPCG, HT and IK were collected from existing borrow sites while the fourth titled MV was obtained at a foundation depth of a proposed single storey building. They are classified as GC (clayey gravel), SC (clayey sand), GC and SC respectively according to the Unified Soil Classification System with the classification, location of soil deposit and meaning of soil designation shown in table 1 below.

The soil samples were contaminated with WEO at 3, 6, 9 and 12% contamination by weight of dry samples respectively and allowed to age and equilibrate for three days [9].

3. Experimental tests

All experimental tests were done in accordance with BS 1377 [10] standard and the tests include Sieve analysis, Atterberg's limit, Compaction test, Specific gravity test, Unconsolidated Undrained Triaxial (UU) Test, California Bearing Ratio (CBR) test and Permeability test.

Specimens for the UU and CBR (un soaked) tests were prepared at the optimum moisture content (OMC) and maximum dry density (MDD) using the CBR compaction mould while that of the Permeability test was prepared using the proctor mould.

The minerals present in the soil samples were identified using the X-ray diffraction (XRD) test while the percentage chemical composition of the soils were identified using the X-ray fluorescence (XRF) test.

4. Results

4.1 Soil and WEO Properties

The dynamic viscosity of the WEO used in this work is 2.78Poises while its other properties are assumed to be the same with other Nigerian waste engine oil as extensively researched by [11].

Table 1: Classification, designation and location of Laterite deposits

S/N	Designation	Laterite Location	USC Classification
1	OPPCG	Opposite University gate	Clayey Gravel (GC)
2	HT	Hill Top section of the University	Clayey Sand (SC)
3	IK	Ikeagwu Hill	Clayey Gravel (GC)
4	MV	Mechanic village	Clayey Sand (SC)

Table 2.0: Result of Chemical analysis of Nigerian waste engine Oil (Virgin Oil without lead)

S/N	TEST PARAMETERS	USED OIL (A)	USED OIL (B)
1	Specific Gravity @15.6^o	0.901	0.8952
2	API Gravity @ 15.6 ^{o}	25.55	26.57
3	Copper (mg/litre)	1.09	1.18
4	Chromium (mg/Litre)	0.06	0.07
5	Nitrate (mg/Litre)	10	4
6	Calcium (mg/Litre)	80.6	80.6
7	Iron (mg/Litre)	81.8	72.7
8	Barium (mg/Litre)	4	4
9	Magnesium (mg/Litre)	0	0
10	Phosphorus (mg/Litre)	0.36	0.58

Table 3: Chemical Classification of Soil Samples (X-Ray Fluorescence)

Chemical composition	Concentration (%)			
	HT	OPPCG	MV	IK
Al_2O_3	24.00	27.5	27.00	30.00
SiO_2	45.90	46.8	43.30	37.6
K_2O	0.24	0.11	0.079	0.16

Chemical composition	Concentration (%)			
	HT	OPPCG	MV	IK
CaO	0.27	0.21	0.12	0.27
TiO_2	4.81	4.95	4.04	4.61
V_2O_5	0.18	0.19	0.16	0.19
CrO_3	0.033	0.023	0.033	0.030
MnO	0.041	0.022	0.031	0.010
Fe_2O_3	20.73	20.20	23.90	26.34
Sc_2O_3	0.003	-	-	-
Bi_2O_3	4.10	-	-	-
P_2O_5			-	0.73
MoO_3			-	0.33
Ag_2O			1.63	

Table 4: Mineralogical Composition of the soil Samples (XRD)

SOIL SAMPLES	MINERALS
HT	Sillimanite, Kilchoanite, Wollastonite, Tridymite
MV	Dombassite, Moganite
OPPCG	Rosenhahnite
IK	Rankinite, Tridymite

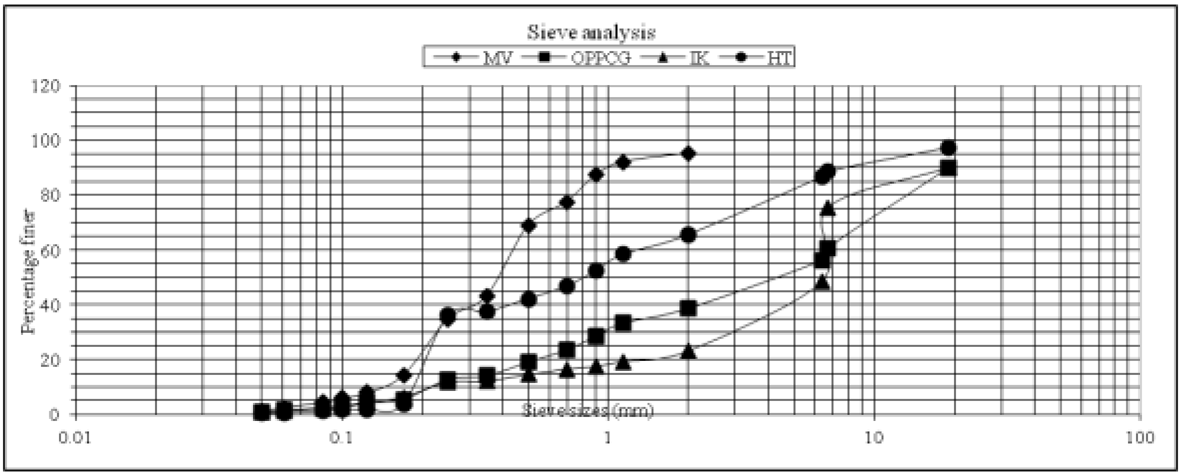

Fig 1: Sieve analysis of the soil samples

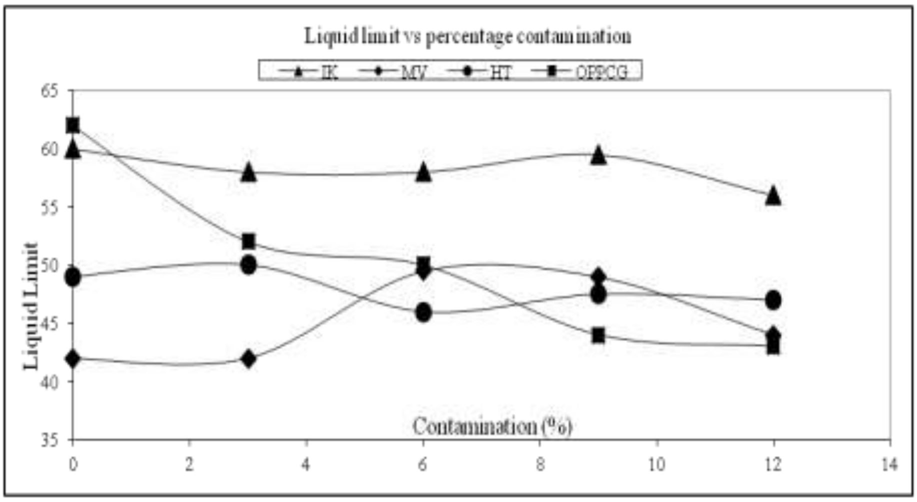

Fig 2: Graph of Liquid limit vs. percentage contamination

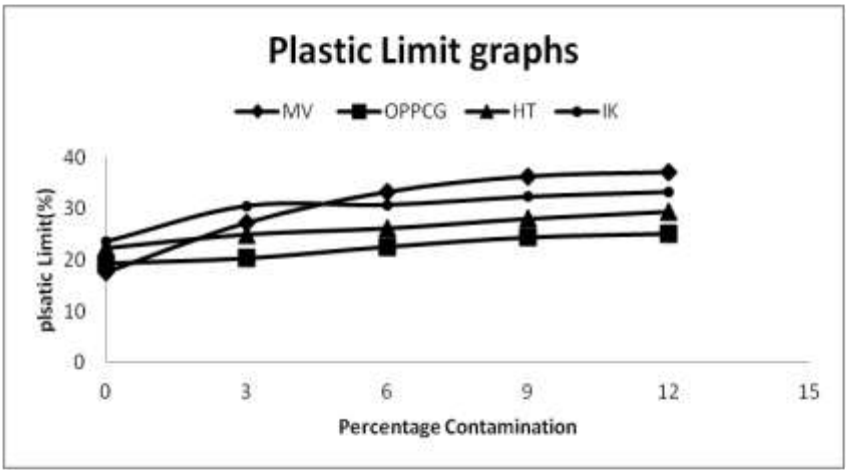

Fig 3: Graph of plastic limit vs percentage contamination

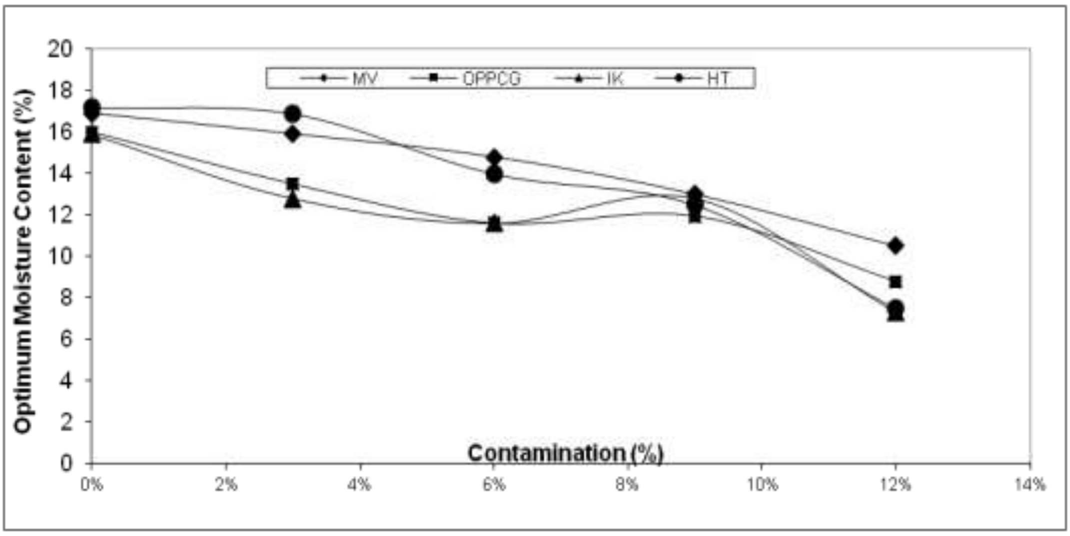

Fig 4: Graph of Optimum moisture content vs. Percentage contamination

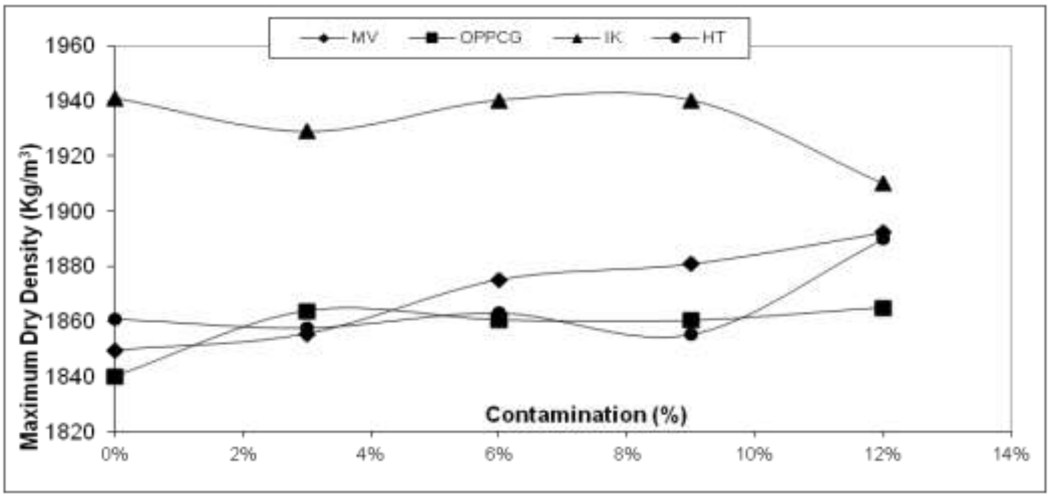

Fig 5: Graph of maximum dry density vs. percentage contamination

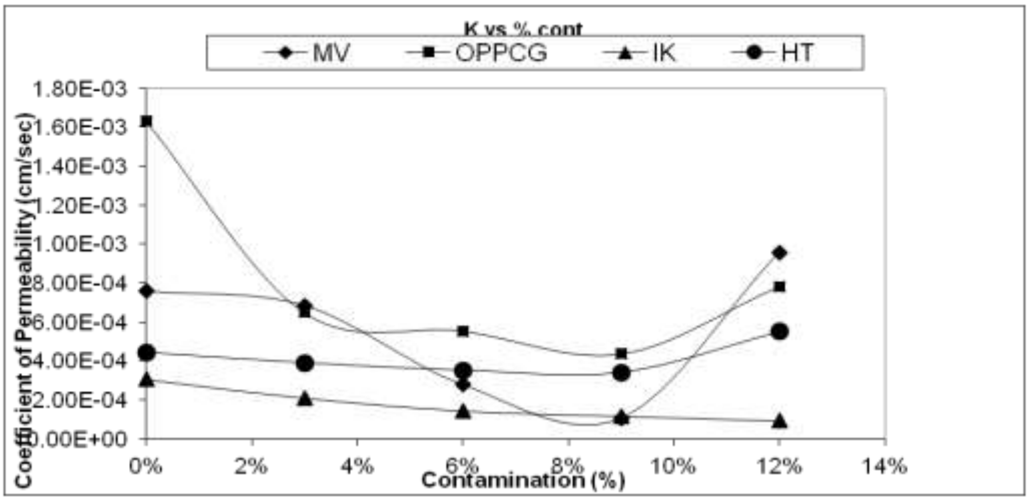

Fig 6: Graph of Coefficient of Permeability vs. Percentage contamination

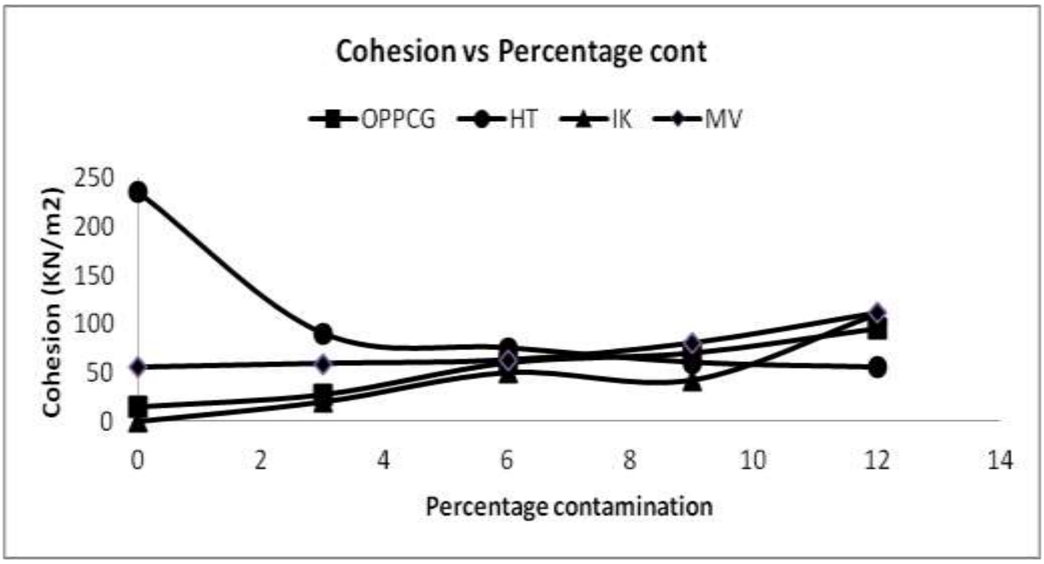

Fig 7: Graph of Cohesion vs. Percentage contamination

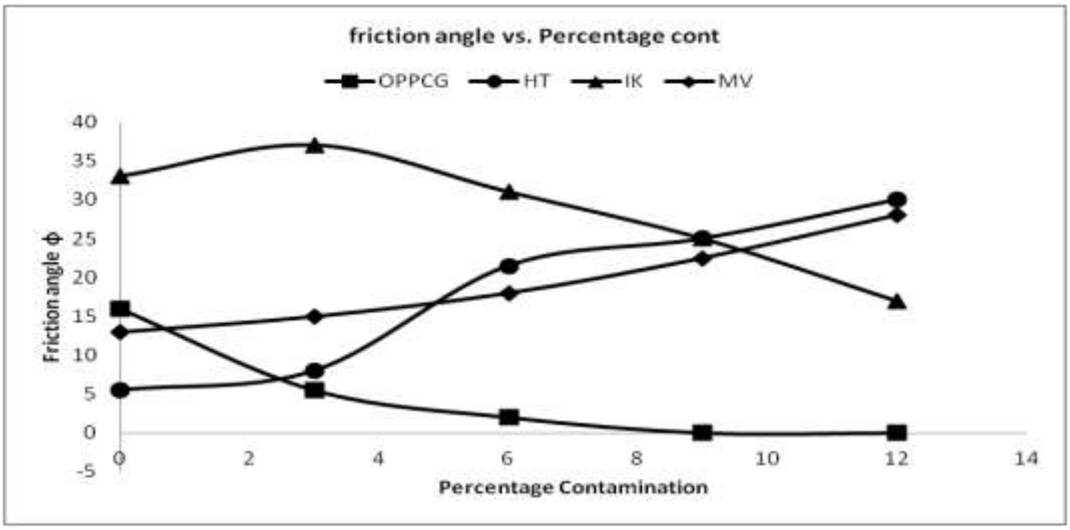

Fig 8: Graph of Friction angle vs. Percentage contamination

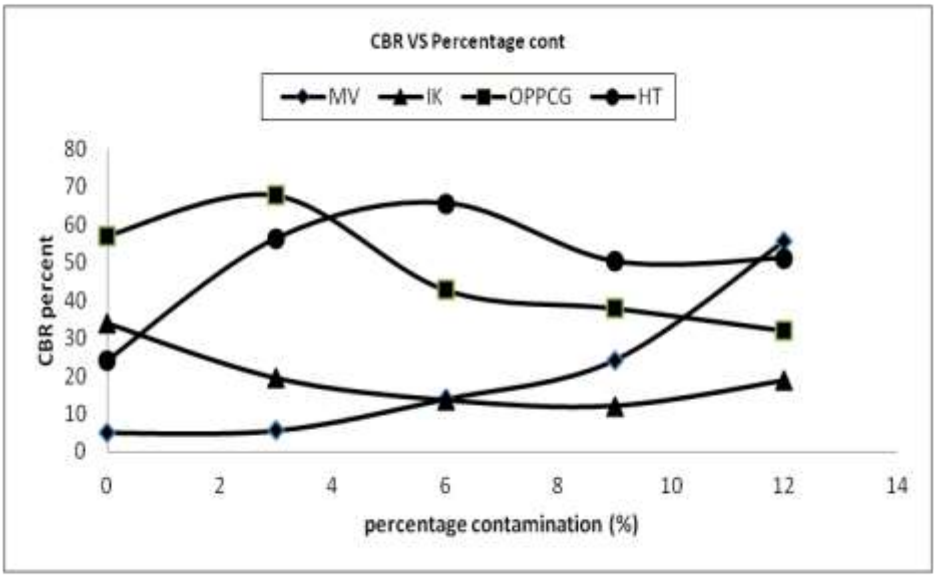

Fig 9: Graph of CBR vs. Percentage Contamination

5. Discussion of results

5.1 Atterberg's Limit

The variation of Liquid limit (LL) with increasing contamination is shown in fig 2. The result indicates a general decrease in liquid limit of the contaminated soil samples with the liquid limit of OPPCG samples having a decrease of 80.65% at 12% contamination. This agrees with [12] who showed that if water is used as pore fluid, the influence of mechanical factors would remain the same. However, if an organic fluid is used instead of water, then the physical properties of the fluid such as viscosity would influence the liquid limit. IK sample showed the least variation with 6% decrease at 12% contamination. HT showed a slight increase in LL at 3% before decreasing and remaining fairly stable between 6-12%. MV also increased at 6% contamination before finally decreasing. It can also be seen that the liquid limit depends on physicochemical factors [13] and to a lesser degree on mechanical factors other than the pore fluid density. The lowering of the liquid limit is therefore as a result of the physicochemical factors of the oil such as low dielectric constant values which causes the clay particles to behave more like a granular material with attendant reduction in adsorbed water.

Fig 3 shows a general increase in plastic limit (PL) with increasing percentage contamination for all the samples with MV showing the highest increase of 109.6% at 12% WEO contamination. This implies that the water content at which the soil mixture changes from the plastic state to the semisolid state is increased. This can be attributed to the oil coatings on the soil surface which increases the cohesion of the soil particles to cracking when the sample is being worked.

5.2 Compaction Test

The compaction result (fig 4 and 5) indicates a general trend of decreasing Optimum Moisture Content (OMC) with increasing percentage contamination while the Maximum dry density (MDD) for MV, OPPCG and HT showed a gradual increase with increasing percentage contamination. IK sample showed a gradual decrease in MDD with increasing contamination. The increase in MDD implies a gain of strength for MV, OPPCG and HT but a loss of strength for IK with respect to increasing percentage contamination. The increase in MDD is as a result of the oil coatings on the particles which act as an excellent lubricant thereby achieving higher density at lower moisture content [6]. The reduction in MDD for IK sample can be attributed to its grain size distribution as it has the least amount of fines/gravel ratio when compared to other samples.

5.3 Permeability Test

The results from fig 6 show that the coefficient of permeability (K) for IK sample reduced continuously from 0 to 12% while MV, HT and OPPCG showed a decrease in K from 0 to 9% before a sudden increase at 12%. This decrease in the value of K with increasing contamination agrees with [14] and IK sample which has the least amount of fine/gravel ratio will have more oil content at each percentage contamination thereby giving it the least value of K. The sudden increase in K at 12% contamination may be attributed to the fact that at that point, the pore spaces between the different coagulated units of the soils have increased thereby resulting in higher values of K.

5.4 Undrained Triaxial Test

The Analysis of the unconsolidated undrained (UU) tests in fig 7 and 8 using the Mohr-Coulomb equation lead to the conclusion that WEO contamination result in a slight increase of the shear strength of HT, MV and OPPCG samples. IK sample however showed an initial increase at 3% before gradually decreasing. The results of IK sample follows the same trend observed by [4] and [15] while the others differ. The gain in strength is attributed to the spherical agglomeration of particles in the presence of the oil and due to the high confining stress in the UU test. A further observation is that the presence of oil in the soils lowers the internal angle of friction (ϕ) for IK and OPPCG samples which ordinarily ought to have a high value and at the same time increases ϕ for HT and MV samples which ought to have lower values. This is attributed to the physicochemical properties of the oil and to its ability to reduce adsorbed water thereby making soils with higher clay content to behave like granular soils and vice versa for soils with higher sand content.

5.5 CBR Test

Fig 9 shows that the CBR of OPPCG and HT samples unlike that of MV sample which showed a continuous increase, increased at 3% and 6% contamination respectively before decreasing. This initial increase in CBR agrees with [7] and [8]. IK sample showed a continuous decrease. The increase in CBR at certain level of contamination which is an implication of the increase observed in MDD is attributed to the lubrication of the soil grains by oil such that greater densification is achieved. The observed decrease in CBR value beyond 3 and 6% contamination for HT and OPPCG samples could be attributed to the failure under load of the soil-gravel matrix as a result of excessive lubrication and that explains why IK sample which had the least fine/gravel ratio showed continuous decrease in CBR.

6. Conclusion

The following conclusions are therefore reached:

1. The contaminated samples showed general decrease in LL but an increase in PL. This implies that increase in oil contamination resulted in an increase in the soil cohesion to working and also a reduction in adsorbed water.
2. WEO contamination resulted in a gain of shear strength and an increase in the MDD for all the samples except for IK which showed a decreasing trend which is attributed to its particle size distribution. WEO also reduced OMC for all the samples as a result of its lubrication ability.
3. There is a general reduction in permeability for all the samples with an exception at 12% where an increase was noticed in some of the samples.
4. WEO contamination resulted in a progressive increase in CBR for MV sample which did not contain any gravel. This could mean that there is still an increased densification of the soil by oil at 12% contamination.
5. As a result of the increase in CBR, there is therefore a promising application of WEO in road construction.

7. Recommendations

1. MV sample should be further investigated beyond 12% contamination with WEO in order to fully observe its behavior.
2. The contaminated soil samples should be subjected to Scanning Electron Microscope (SEM) tests in order to understand better the interaction between WEO and the soil samples.
3. The applicability of WEO in road construction should be explored.
4. Long term effects of oil contamination should be investigated such that the occurrence of possible chemical reactions between the soil and WEO can be seen.

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