Effects Of Waste Engine Oil Contamination On The Plasticity, Strength And Permeability Of Lateritic Clay

Isaac I. Akinwumi, Uriel R. Maiyaki, Samuel A. Adubi, Samuel O. Daramola, Bobby B. Ekanem

Abstract— This experimental investigation was carried out to determine the effects of contaminating a lateritic clay soil with waste engine oil on its geotechnical engineering properties. Varying percentages (0%, 2%, 4%, 6%, 8% and 10%) of waste engine oil were mixed with the soil, as a simulation of its contamination. Specific gravity, Atterberg limits, compaction, California bearing ratio (CBR) and permeability tests were conducted on the uncontaminated and contaminated soil samples. The specific gravity, plastic limit, optimum moisture content, maximum dry unit weight, and permeability of the soil decreased as its waste engine oil content increased. The liquid limit, plasticity index and CBR of the soil increased as its waste engine oil content increased. The plasticity and permeability properties of the soil make it unsuitable for use as a construction material, without modification or stabilization of the contaminated soil.

Index Terms— lateritic soil, soil contamination, subgrade, oil-contaminated soil, used engine oil, waste engine oil

1 INTRODUCTION

AN estimated 200,000 m^3 of waste engine oil is annually generated in Nigeria. It is sometimes reused for suppressing dust, wood preservation, automobile spare-parts' rust prevention, lubricating formwork and mould; as fuel for industrial boilers, fuel for bakery furnace, weed killer, hydraulic oil and as gear oil – when mixed with grease [1]. Despite these areas of application, more waste engine oil is still indiscriminately disposed on land. This is of major environmental concern because such disposal has the potential to pollute groundwater, surface water, reduce soil nutrients available to plants and alter the structural behaviour of the soil on which they are disposed. Indiscriminate disposal of waste engine oil can be observed at automobile repair workshops, some industrial sites, in road drainage facilities, etc. Some researchers [2-8] have considered the effects of waste engine oil contamination on different types of soil. Nazir [4] found out that the Atterberg limits and unconfined compressive strength of an over consolidated clay decreased while its coefficient of permeability increased with increasing motor oil content. Rahman et al. [5] found out that the liquid and plastic limits, optimum moisture content (OMC), maximum dry density and permeability of basaltic residual soil decreased with increasing amount of waste engine oil in the soil. Ojuri and Ogundipe [6] found out that the OMC, maximum dry density, unconfined compressive strength and California bearing ratio (CBR) of a lateritic soil decreased with the used engine oil content of the soil. The use and improvement of lateritic soils, which is abundant in tropical and subtropical regions of the world (coupled with rising cost of construction materials), have been the focus of recent research works [9-13]. This paper entails experimental investigation of the effects of waste engine oil contamination of a lateritic clay soil on its plasticity, compaction characteristics, strength and permeability.

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2 MATERIALS AND METHODS

2.1 Materials and Preparation

The soil used was collected from about 10 m depth below the top of a borrow pit at Agbara, Ogun State, Southwestern Nigeria. Soil sample for natural moisture content determination was stored in a water-tight container while that for other laboratory tests were stored in sacks before they were transported to the laboratory. In the laboratory, the soil sample was air-dried, passed through a 4.75 mm sieve and thoroughly mixed with designated amount of waste engine oil.

2.2 Methods

The soil sample was divided into six parts and each part was mixed with 0%, 2%, 4%, 6%, 8% and 10% of waste engine oil, by the respective dry weight of the soil sample. The mixtures were stored in waterproof containers for 24 hours to allow for homogeneity. Particle size distribution was determined for the uncontaminated soil sample by carrying out sieve and hydrometer analyses. Specific gravity, Atterberg limits, compaction, unsoaked and soaked CBR, and permeability tests were conducted on the uncontaminated and on each of the contaminated soil samples, respectively. The procedures for these laboratory tests were in accordance with those outlined in BSI [14], [15].

3 RESULTS AND DISCUSSION

3.1 Properties of Waste Engine Oil and Soil Sample

The specific gravity and American Petroleum Institute (API) gravity of the waste engine oil at 15.55°C were determined to be 0.904 and 25 degree API, respectively. The predominant oxides in the soil sample are silica (SiO_2) and alumina (Al_2O_3). Its silica-sesquioxides ratio is 1.66, which indicates that the soil is lateritic. A ternary of the silica and sesquioxides (Al_2O_3 and Fe_2O_3) of the soil, incorporating Schellmann [16] scheme of classification of weathering product is shown in Fig. 1. The silica and sesquioxides plot falls within the kaolinization part of the Schellmann classification chart, which indicates that the soil sample was taken from a kaolinized profile.

3.2 Uncontaminated Soil

Table 1 presents a summary of the physical and mechanical properties of the uncontaminated soil. The soil sample is classified as A-7-6(7) and sandy lean clay (CL), according to the American Association of State Highway and Transportation Officials (AASHTO) and Unified soil classification (USC) systems, respectively. The plasticity, unsoaked and soaked CBR values and permeability of the uncontaminated soil sample were found to be low. The particle size distribution of the soil is shown in Fig. 2 and indicates that the soil is well graded. The percentage passing the British Standard (BS) No. 200 (0.075 mm) sieve is 55.5% and according to AASHTO, this soil is a fine-grained because over 35% of its particles are finer than BS No. 200 sieve opening. The plasticity index of the soil sample is greater than 11% and thus according to AASHTO system, the fines are clayey.

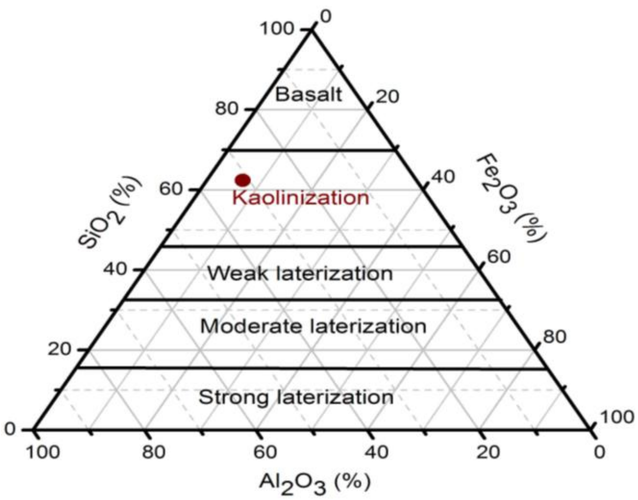


Fig. 1. Al_2O_3-SiO_2-Fe_2O_3 ternary plot for the soil sample

Table 1. Properties of the Uncontaminated Soil

	Properties	Value / Description
Gradation / Classification	Gravel (>4.75 mm), %	0.5
	Sand (0.075 - 4.75 mm), %	44.0
	Silt and Clay (<0.075 mm), %	55.5
	AASHTO Soil Classification System	A-7-6 (7)
	Unified Soil Classification System	CL - Sandy clay
Physical	Colour	Brown
	Natural Moisture Content (%)	15.6
	Specific Gravity	2.51
	Liquid Limit (%)	41.0
	Plastic Limit (%)	23.0
	Plasticity Index (%)	18.0
	Maximum Dry Unit weight (kN/m^3)	18.2
	Optimum Moisture Content (%)	15.3
	Coefficient of Permeability (cm/s)	8.24×10^{-6}
Strength	Unsoaked CBR (%)	16
	Soaked CBR (%)	10

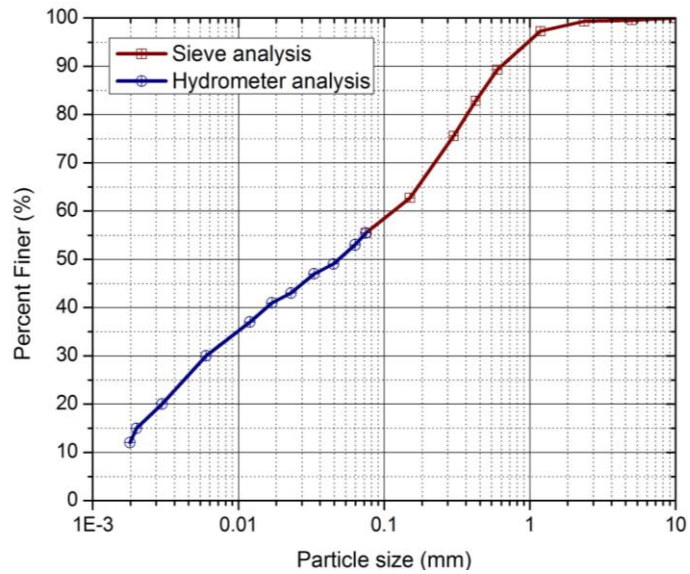


Fig. 2. Particle size distribution of natural soil

3.3 Waste Engine Oil Contamination of Soil

3.3.1 Specific Gravity

The specific gravity of the soil sample is 2.51. A graphical presentation of the variation of specific gravity of the soil with the waste engine oil content in the soil is shown in Fig. 3. As the percentage of waste engine oil admixed with the soil sample increased, the specific gravity of the mixture decreased. This is attributed to the lower specific gravity of the waste engine oil.

3.3.2 Atterberg Limits

Liquid and plastic limits were the Atterberg limits determined for the uncontaminated and contaminated soil samples. The plasticity index was obtained by subtracting the plastic limit from the liquid limit. Fig. 4 graphically illustrates how the liquid and plastic limits and plasticity index varies with the percentage of waste engine oil in the soil sample. As the percentage of waste engine oil increased, the liquid limit and plasticity index of the contaminated soil increased while the plastic limit decreased. The addition of waste engine oil to the soil is thought to cause an inter layer expansion within the clay minerals, which may have accounted for the change in its plasticity [17]. The increase in the plasticity index of the soil sample as its waste engine oil increased indicates that the contaminated soil becomes less workable. Figs. 5(a) and 5(b) show plasticity charts with the incorporation of AASHTO and USC systems, respectively. Although the AASHTO classification of the uncontaminated and contaminated soil samples remained unchanged (A-7-6), the uncontaminated soil (classified as clay of low plasticity - CL) got transformed after the addition of 10% waste engine oil to a soil classified as CH, according to USC system.

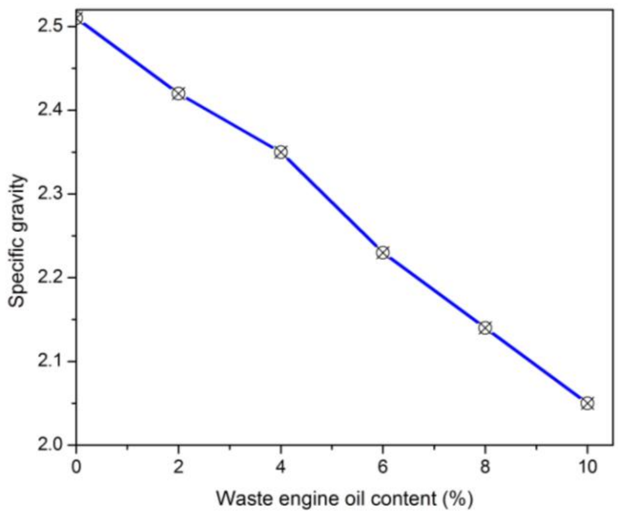


Fig. 3. Variation of specific gravity with waste engine oil content

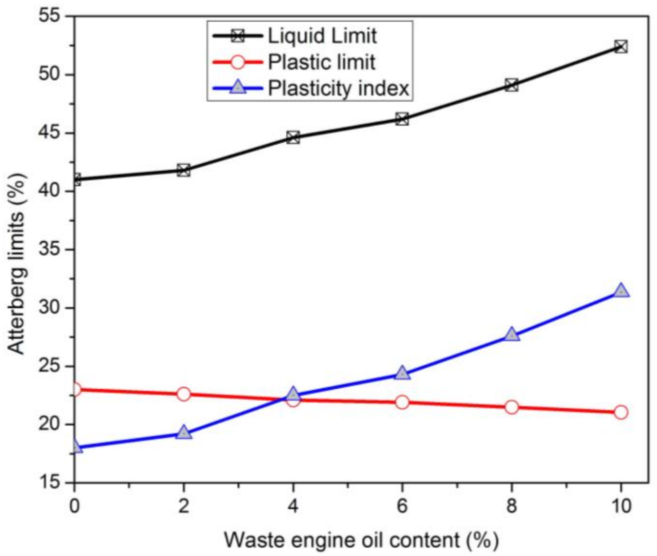
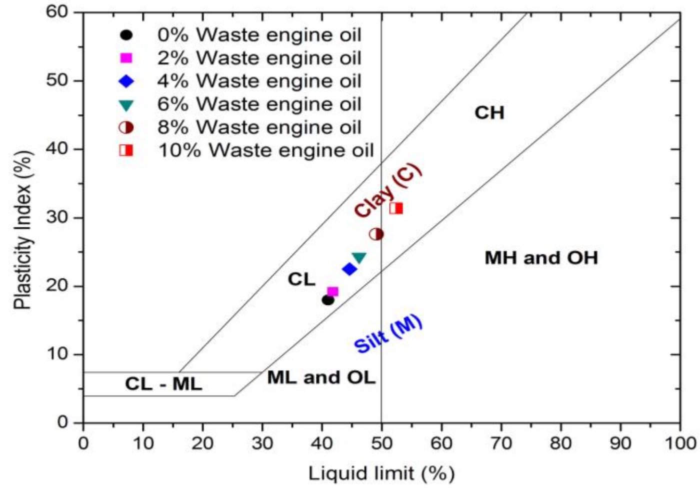
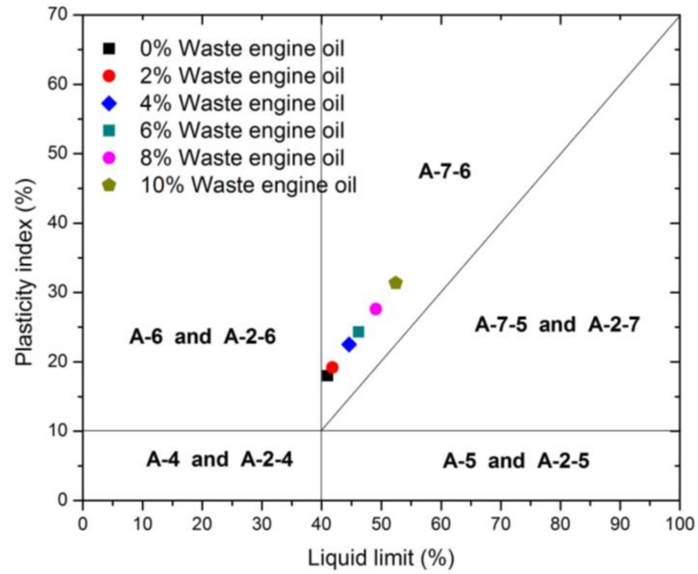


Fig. 4. Variation of Atterberg limits with waste engine oil content



(a)



(b)

Fig. 5. Plasticity charts - (a) USC (b) AASHTO systems - showing the variation of the soil plasticity with its engine oil content

3.3.3 Compaction Characteristics

OMC and maximum dry unit weight were determined from standard proctor compaction test on the soil sample. Their variation with waste engine oil content in the soil sample is graphically illustrated in Fig. 6. As the waste engine oil content in the contaminated soil increased, both the OMC and maximum dry unit weight of the soil decreased.

For fine grained soils, the behaviour of the clay particles greatly influences the geotechnical engineering characteristics of the soil. The waste engine oil coats itself around individual clay particles, preventing free from interacting with the clay particles. This is thought to be responsible for the reduction in the amount of water needed by the soil to reach its maximum unit weight, as the waste engine oil content increased. The waste engine oil coated around the clay particles supposedly increased the thickness of the diffuse double layer. Therefore, the soil particles of the contaminated soil get less packed together despite using the same compaction energy as that used for the compaction of the uncontaminated soil. This consequently resulted in a decrease in the dry unit weight of the contaminated soil, as its waste engine oil content increased.

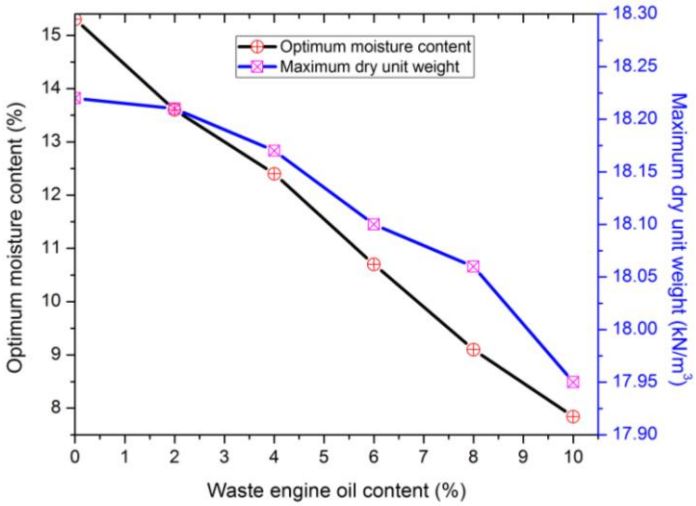


Fig. 6. Variation of compaction characteristics with waste engine oil content

3.3.4 California Bearing Ratio

Unsoaked and soaked CBR values of a soil are measures of its mechanical strength. Fig. 7 shows the variation of the unsoaked and soaked CBR of the soil with its waste engine oil content. It shows that unsoaked and soaked CBR values of the contaminated soil increased with increasing percentage of waste engine oil. However, these increases were experienced for upto 8% and 6% waste engine oil contents for the unsoaked and soaked CBR of the contaminated soil, respectively. These points suggest the limits to the increase in the CBR values for the soil sample. Beyond these limits, the effect of lubrication may have caused soil particles to slide easily over one another, accounting for the decrease in the capacity of the contaminated soil to bear pressure.

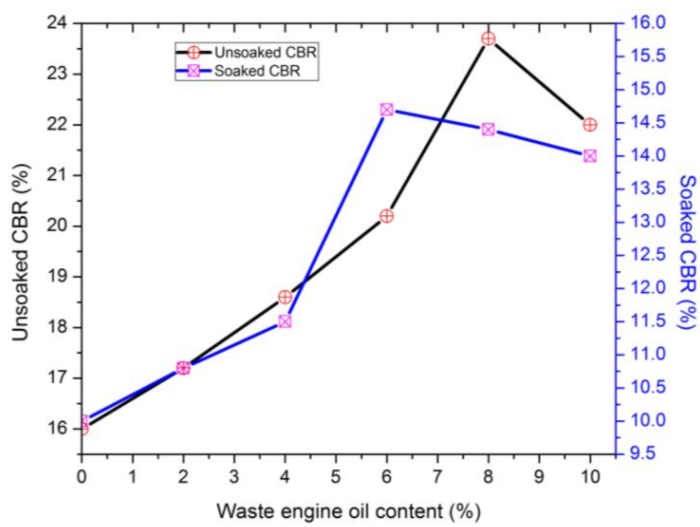


Fig. 7. Variation of CBR with waste engine oil content

3.3.5 Permeability Characteristics

A graphical illustration of the variation of the permeability of the soil with the waste engine oil content is shown in Fig. 8. The permeability of the contaminated soil decreased, as the percentage of waste engine oil in the soil increased. The waste engine oil must have occupied some of the void spaces within the soil, thereby reducing the ease with which water flows through the soil. The consequence of this result is that a soil contaminated with waste engine oil has the tendency to allow the formation of pool of water or streams above it. This in itself can magnify the effects of flood.

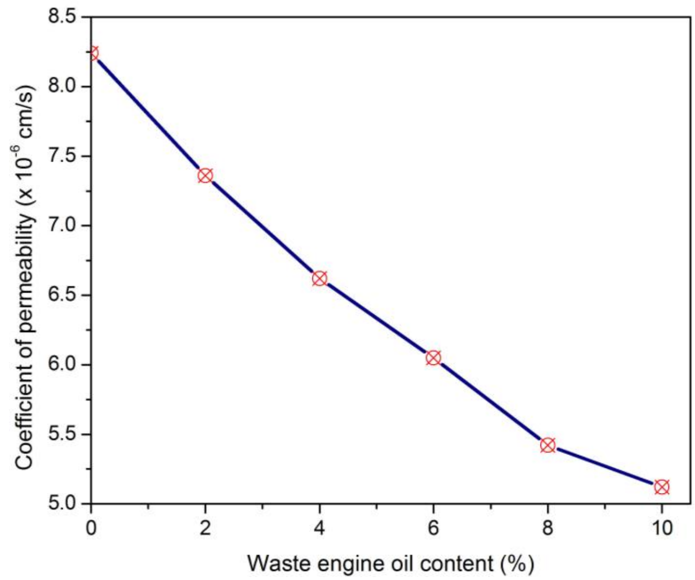


Fig. 8. Variation of permeability with waste engine oil content

4 Conclusions

From the results obtained, the following conclusions can be drawn:

(i) Contamination of the lateritic clay with increasing percentage of waste engine oil resulted in progressive increase in plasticity index of the soil. Thus, making the soil less workable.

(ii) The OMC and maximum dry unit weight of the contaminated soil decreased with increasing percentage of waste engine oil in the soil.

(iii) Surprisingly, the unsoaked and soaked CBR values of the contaminated soil were greater than those of the uncontaminated soil. However, their values were generally low.

(iv) The permeability of the soil decreased with increasing percentage of its waste engine oil content.

(v) It is necessary to stabilize the waste engine oil-contaminated lateritic clay before using it for construction purposes.

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