EFFECT OF WASTE ENGINE OIL CONTAMINATION ON GEOTECHNICAL PROPERTIES OF CLAY SOIL

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Abstract
The effects of waste engine oil (WEO) contamination on geotechnical properties of clay soil was investigated. Laboratory testing of clay soil from Eagle Island area of Port Harcourt was carried out. Tests carried out included Specific gravity, Atterberg properties, Compaction, California Bearing Ratio (CBR), Linear shrinkage and tri-axial compression in both clean and contaminated clay soils. Varying percentages of (0%, 3%, 6%, 9% and 12%) of WEO were mixed with clay soil as a simulation of the contamination. Results show that the Specific gravity and Plastic Limits (PL) decreased as the content of used engine oil increased. The values of the Linear Shrinkage, Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) increased as the content of the waste engine oil increased but experienced a decrease at 6% contamination. The values of Shear Strength and CBR decreased as the content of the contamination increased but experienced an increase at 9% WEO content, thereafter a decrease commenced again.

Key Words: Clay soil, waste engine oil, geotechnical properties contamination.
1. INTRODUCTION:
The indiscriminate location of auto maintenance workshops and operation of industrial and home generators has resulted in massive pollution of soils in such locations. The waste engine oil penetrate deep down affected soils by the effect of gravity. Several works have been carried out on WEO and crude oil contaminated soils.

[1] investigated the effects of Crude Oil Low Point Pour Fuel Oil (LPFO) and Vacuum Gas Oil contamination on the geotechnical properties of sand, clay and lateritic soils. They established that shear strength of clay soil increased with LPFO contaminations at 2% and 4% LPFO, however, at 6% LPFO contamination and 2-6% LPFO contamination, the shear strength of clay increased.

The CBR values for the clay soil decreased with LPFO contamination. Other deleterious changes included an increase in consolidation settlement for LPFO contaminated laterite. The consolidation settlement of the contaminated clay soil generally decreased with all contaminants.

[2], examined the compressibility of contaminated fine-grained soils by consolidation test. [3], also carried out geotechnical investigation of oil contaminated Kuwaiti Sand as a result of the destruction of Kuwaiti’s oil production facilities at the end of the Gulf war. The results of their findings revealed a reduction in permeability and strength and an increase in compressibility with oil contamination.

[4], studied the effect of motor oil contamination duration on over consolidated clay and reported decreases in Atterberg properties, unconfined compression strength but increases in the permeability, compression and swell potential of the contaminated soil. Furthermore, they observed that motor oil contamination led to close packing of the clay particles.

[5] and [6] corroborated this view. They also concluded that the compression behaviour of montmorillonite indicated that the particles tend to coagulate and to behave like granular materials in the presence of organic contaminants. [7], observed that Liquid Limit and consolidation parameters of highly plastic clay tend to decrease in the presence of organic pollutants.

The engineering properties of oil contaminated sand were investigated by [8]. They reported decreasing values of strength, permeability, MDD, OMC and Atterberg Limits values with increase in contaminant content.

Tests to determine the geotechnical properties of oil contaminated sands were carried out by [9] and [10]. Results indicated that the compaction characteristics are influenced by oil contamination. The suitability of petroleum contaminated soils in road construction was studied by [11]. They found out that in construction application including stabilizing the soil with cement, mixing it with crushed stone aggregate for use in road bases or sub bases, and using it for as a fine aggregate replacement in hot mix asphalt concrete, there was good potential for use in road construction.

[12], investigated the effect of waste engine oil contamination on the plasticity, strength and permeability of lateritic clay. They concluded that (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) Optimum Moisture Content and Maximum Dry Density, unit weight of the contaminated soil decreased with increasing percentage of waste engine oil in the soil.

(iii) Surprisingly, CBR (soaked and un-soaked) values of the contaminated soil were greater than those of the uncontaminated soil. (iv) The permeability of the soil decreased with increasing content of the waste engine oil. (v) They recommended stabilizing the waste engine oil contaminated lateritic clay before using it for construction purposes.

[10] - [13] also studied the effect of waste engine oil contamination on different types of soil. [10] concluded that the Atterberg Limits of unconfined compressive strength of an over consolidated clay decreased while the coefficient of permeability increased with increasing motor oil content.[13] found out that the OMC,
MDD and unconfined compressive strength and CBR of a lateritic soil decreased with the waste engine oil content of the soil.

[14], investigated the effect of crude oil polluted soils and concluded that the Shear strength, permeability and OMC and MDD of the crude oil polluted soils decreased as the content of the crude oil increased. However, the CBR increased as the crude oil content increased. Therefore crude oil polluted soils can be used as base and sub base for roads and air-field construction.

[15], investigated the geotechnical properties of waste engine oil contaminated laterites. The result showed a general decrease in OMC, Liquid limits and Permeability. They observed an increase in shear strength, MDD and CBR.

This study investigated the effects of waste engine oil on geotechnical properties of clay soils.

2. MATERIALS AND METHOD

2.1 MATERIALS

The clay soil used was collected from about 12 m depth below the surface at Eagle Island area of Port Harcourt, Southern Nigeria. The soil samples for the natural moisture content determination were stored in a water-tight container. The samples for other tests were stored in sealed plastic bags before being transported to the laboratory. The waste engine oil used was obtained from an auto mechanic workshop at Mile 3 area of Port Harcourt. It was brown in colour and had a pungent odour.

The water used was obtained from the Civil Engineering Laboratory of the Rivers State University of Science and Technology Port Harcourt. The water met the Standard Organisation of Nigeria requirement.

2.2 METHODS

Since the clay was wet, it was not possible to immediately mix it with the WEO. The soil sample was divided into four parts and each part was mixed with (0%, 3%, 6%, 9% and 12%) of the WEO, measured by dry weight of the soil. The clay soil was therefore separated, air dried for 48 hours and then later oven dried at 50°C to ensure zero moisture content. The mixing of the WEO with the dry clay soil sample was mechanically carried out. The mixed samples were then stored in a sack for 72 hours to allow for proper mixing and to attain a homogeneous mixture. The enclosure in the sack prevented the evaporation of the WEO prior to carrying out the test.

3. RESULT AND DISCUSSIONS

Table 1 shows the results of the physiochemical analysis of the WEO and the Standard values of an uncontaminated engine oil. All the parameters of the WEO tested did not conform to the acceptable standards indicating contamination.

<table>
<thead>
<tr>
<th>S/No</th>
<th>Parameter</th>
<th>Test Method</th>
<th>Result</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Appearance</td>
<td>Visual</td>
<td>Dull Black</td>
<td>Bright</td>
</tr>
<tr>
<td>2</td>
<td>Colour</td>
<td>ASTMD 6040-40 [16]</td>
<td>4.9</td>
<td>2.0</td>
</tr>
<tr>
<td>3</td>
<td>Specific Gravity @ 15°C</td>
<td>IP 160 [17]</td>
<td>0.9283</td>
<td>0.85-0.90</td>
</tr>
<tr>
<td>4</td>
<td>Acidity (mgKOH/g)</td>
<td>ASTMD 664 [18]</td>
<td>0.24</td>
<td>0.1</td>
</tr>
<tr>
<td>5</td>
<td>TAN (mgKOH/g)</td>
<td>ASTMD 974 [19]</td>
<td>0.48</td>
<td>0.2</td>
</tr>
<tr>
<td>6</td>
<td>Flash Point (°C)</td>
<td>IP 34 [20]</td>
<td>278</td>
<td>270</td>
</tr>
<tr>
<td>7</td>
<td>Cloud Point (°C)</td>
<td>IP 219 [21]</td>
<td>-11</td>
<td>-15 to -35</td>
</tr>
<tr>
<td>8</td>
<td>Pour Point (°C)</td>
<td>ASTM D5949 [22]</td>
<td>-7</td>
<td>&lt; -16</td>
</tr>
<tr>
<td>9</td>
<td>Total Sulphur (%)</td>
<td>ASTM 5453 [23]</td>
<td>10.92</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>Water Content (%)</td>
<td>IP 74 [24]</td>
<td>0.4</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>
3.1 SPECIFIC GRAVITY

Fig. 1 shows the plot of the average Specific Gravity versus the WEO contamination content. The specific gravity of the clay soil decreased as the WEO content increased. This is attributed to the lower specific gravity of the waste engine oil [12].

![Figure 1: Average Specific Gravity against Percentage contamination](image)

3.2 ATTERBERG LIMITS

From Fig. 2 it can be noticed that the Liquid Limit (PL) and Plasticity Index (PI) increased with an increase in WEO content up till 3% contamination. Thereafter the values of the PL and PI started to decrease with increase in WEO contamination. The Plastic Limit (PL) decreased as the WEO content increased. At 3% WEO contamination the LL started to increase before commencing another decrease at 6% WEO contamination. [12] observed in a previous study that the addition of WEO to the soil is thought to cause
inter layer expansion within the clay minerals, which may have accounted for the change in its plasticity. The increase in Plasticity Index of the soil up to 3% WEO content indicates that the contaminated soil becomes less workable up to 3% WEO content and thereafter workability starts to increase. The increase in Plasticity Index between 0-3% as the WEO increased indicates that the contaminated soil up till 3% becomes less workable.

3.3 LINEAR SHRINKAGE

Fig. 3 show an increase in Shrinkage Limit as the WEO content in the clay soil increases up till 6% WEO contamination. Thereafter the Shrinkage Limit tends to decrease with an increase in WEO content in the soil. The initial increase in the Linear Shrinkage is due to the fact that the pore spaces are occupied by water and used WEO. With the increase in the content of WEO, the ratio of the
WEO to that of water in the pore spaces also increased, therefore the rate of evaporation of the WEO during drying also increased. However, above 6% contamination, even though rate of WEO evaporation increased, there was more crude oil in the pore space than water.

3.4 COMPACTION

Fig. 4 indicates that the MDD decreases as the WEO content increases up to 3% WEO contamination. Thereafter the MDD increases as the WEO content is increased up till 9% WEO contamination before it start again to decrease. Fig. 5 shows that the OMC increases as the WEO content increases up to 6% contamination. Thereafter it starts to decrease up till 9% before increasing. These results compare to the results from the investigation carried out by [12]. The behavior of the clay particles greatly influences the geotechnical properties of the soil. The WEO coats itself around the individual clay particles, preventing free interaction with clay particles. This is thought to be responsible for the reduction in the amount of water needed to reach its maximum unit weight as the WEO content is increased. The WEO coating around clay particles supposedly increased the thickness of the diffuse double layer. It follows that soil particles of contaminated soil gets less packed together despite losing some compaction energy as the one used for the compaction of the uncontaminated soil. This consequently results in a decrease in the dry unit weight of the contaminated soil as its WEO content is increased.
Fig. 4: Plot of Maximum Dry Density against WEO Contamination

Fig. 5: Plot of Optimum Moisture Content against % WEO contamination
3.5 SHEAR STRENGTH

Fig. 6 shows a decrease in the shear strength of the contaminated clay soil as the WEO content is increased up till 6% WEO contamination. Thereafter an increase in the shear strength as the WEO content increased was noticed, up till 9% when the shear strength started to decrease, with increase in WEO content. The variation in shear strength as the WEO content increased is similar to the trend observed by [1]. [1], however observed an increase in the shear strength of the WEO contaminated clay. The result of the present study is similar to [1] at between 6-9% WEO content contamination.

Between 3-6% WEO content contamination, the result (decreased shear strength) is similar to that obtained by [14] for crude oil polluted soils.

![Graph showing shear strength and stress at failure against % WEO Contamination](image)

**Fig. 6: Shear strength and stress at failure against % WEO Contamination**

3.6 CALIFORNIA BEARING RATIO

Fig. 7 illustrates the variation of the unsoaked and soaked CBR values of the clay soil with its WEO content contamination. Between 6-12% WEO content contamination, the CBR (unsoaked and soaked) increases as the WEO content is increasing. This result of the CBR values compares with that of the shear strength of the clay soil at all percentage WEO contamination. The increase in CBR values obtained in this experiment is consistent with the results of [12] and [14] between 4-10% WEO contamination. Above 12% WEO contamination, the effect of lubrication may have caused soil particles to slide easily over one another, accounting for the increase in the capacity of the contaminated soil to bear pressure.[12]. WEO content between 1-6% resulted in a general decrease in the compressibility of the clay soil which is reflected in the shear strength and CBR values of the WEO contaminated soil.

Between 6-12% contamination, WEO resulted in a general increase of compressibility of the clay soil. This is also similar to the results obtained by [1], which confirms that the shear resistance values of WEO contaminated lateritic clay increases with all the contaminants used.
4 CONCLUSION

From the above discussions, the following conclusions can be drawn.

(i) The specific gravity of the clay soil decreased with an increase in WEO content.

(ii) Contamination of the clay soil with increasing percentage of WEO resulted in progressive increase of Liquid Limit and Plasticity Index up to 3% contamination. Between 3 – 6% WEO contamination, the trend is reversed with Liquid Limit and Plasticity Index decreasing, while the Plastic Limit starts to increase. This implies that an increase in WEO contamination between 3-9% resulted in an increase in the soil cohesion to working and also reduction in adsorbed water [15].

(iii) The shrinkage limit increases as the WEO content is increased up till 6% WEO content, thereafter the Shrinkage Limit starts to decrease.

(iv) The MDD values of the WEO contaminated clay increases between 6-9% WEO content, prior to 6% WEO content, there was no improvement in the MDD.

(v) The shear strength and stress at failure of the clay soil decreased as the WEO content is increased up till 6% WEO content. Thereafter, it starts to increase as the WEO content is increased up till 9% when it commences a decrease again. This implies that between 6-9% WEO contamination, such contaminated soils can be used in engineering works to advantage.

(vi) Between 6-9% WEO contamination, the OMC reduced for al the samples. This is as a result of the lubrication ability of the WEO [15].

(vii) Between 0-6% WEO content, unsoaked and soaked CBR values decrease as the WEO content is increased. From 6% WEO content, the CBR values start to increase as the WEO content is increased. The decrease in the soaked and unsoaked CBR between
All dosages between (0-3%) of the WEO contaminants used with clay should clearly be avoided in road construction unless stabilization of the contaminated soil will prove worthwhile [1].

(viii) Any structure to be built near WEO contaminated clay soils should be adequately investigated as a result of the large variations in clay soil properties at various degrees of contamination.

5.0 RECOMMENDATION

0 – 3% WEO contamination will need to be investigated further since the result is not consistent with results of previous study.

6 REFERENCES


