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Influence of Engine Oil on Geotechnical Properties of Cohesive Soil

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Abstract

In the absence of regulations in some developing countries that enforce cleaning of site from any possible contamination, construction engineers find themselves reluctant to deal with contaminated sites. In this paper, the effect of engine oil on some geotechnical properties of soil was investigated. Non contaminated soil samples (reference) and those mixed with 5%, 10%, and 15% (by weight) of engine oil were laboratorial examined. The tests included Atterberg limits, specific gravity, density-moisture relationship, unconfined test, shear strength, and California Bearing Ratio (CBR). Results showed that liquid limit and plasticity index decreased while plastic limit increased as the percentage of the contaminant increased. Specific gravity, maximum dry density and optimum moisture content were also found to be decreased in response to the increase of the engine oil. The unconfined compressive strengths of the contaminated specimens was found to be lower than that of the reference soil specimen. Both cohesion and internal friction angle were significantly decreased as a result of using engine oil as contaminant in the soil used. The CBR value of the contaminated specimen having 15% engine oil was lower by approximately 65% compared to that of the non-contaminated specimen.

Keywords: cohesive soil, engine oil, geotechnical properties, contamination

1.0 INTRODUCTION

The oil and its derivatives are considered as contaminants for terrain. These contaminants can penetrate soil into various depths depending on permeability of soil, viscosity of the contaminant and others. In Iraq, the main source of electricity power is the traditional generators that daily consume thousands of liters of engine oil. In addition, the use of small and mid-size generators is very public in houses and factories in Iraq because of the significant shortage of electricity supply. For example, a small city like Samawa (population of about 250,000) has two electrical power plants of 700 MW for each and hundreds of mid-size generators (0.5 to 1 MW) and thousands of small house generators.

Due to the absence of regulations that control the transportation of engine oil and the disposal of the used engine oil, the contamination of soil by engine oil represents an environmental disaster in Iraq. It is very normal to see big spots of land around the generators that is contaminated by engine oil. Lately, many projects like roads and lightly loaded structures were constructed on soils contaminated by engine oil. Considering that soil investigation sometimes did not include the contaminated soil in the site, the geotechnical properties of the contaminated soil become a matter of interest for the construction engineers and contracting companies.

The alteration in the geotechnical properties of soil resulted in loss some of the bearing capacity of soil and increase in the settlement of the foundation under structures which consequently causing losing the function or failure of the structure [1]. The most common types of soil contamination are fertilizers, pesticides, petroleum hydrocarbon, heavy metals, volatile organic compounds and organic compounds. The sources of contaminants are the oil fields, thermal power plants, or in most cases the contaminants are resulted accidently from the spill of oil during the transportation as leakage from the pipelines and storage tanks or during oil drilling processes. The attention of researcher was focused on investigated the effects of such contaminants on the geotechnical properties of soil due to the large volume and types of contaminants resulted from the oil industries. Large quantities of industrial wastes are generated every year due to growing of industries and these wastes are harm to the human being health and the environment components [2,3].

The occurrence of contaminations in soil are not challenge for the environmentalists only but also cause a deterioration of geotechnical properties of soil. Cohesive soils which are electro-chemically active and affected whenever the environment is contaminated by wastes [4, 5]. The flow of contaminant in the soil or in groundwater depends on many factors such as the permeability of soil and adsorption properties of the soil solids [6]. The extent of contaminant in the soil depends on the properties of soil and chemical composition of the contaminant [7].

Abdul Rasool [8] investigated the influence of kerosene contamination on the geotechnical properties of clayey silt soil. Results showed significant effects for kerosene on the physical and mechanical properties of soil. Khamehchiyan et al. [9] investigated the geotechnical properties of clayey and sandy soils contaminated by crude oil. The results indicated noticeable reduction in the shear strength, the dry density, optimum

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moisture content and Atterberg's limits with increasing the content of crude oil in the soil. Karkush et al. [10] investigated the effects of four types of contaminants on the geotechnical properties of clayey soil. The four contaminants are kerosene, ammonium nitrate, copper and lead, each of them was mixed with soil in two percentages (10 and 25) %. Results showed diverse effects for these contaminants on the geotechnical properties of clayey soil. Karkush and Resol [11] investigated the geotechnical properties of sandy soil contaminated with oil ,the results of tests showed that the fuel oil has significant impacts on the mechanical properties of soil and slight effects on the chemical and physical properties of soil. Increasing the percentage of contaminant causes a slight decrease in the liquid limit and particle size distribution, on the other hand it causes a considerable decrease in the consolidation and shear strength parameters. George et al. [12] conducted an experimental work to study the effect of diesel engine oil on the geotechnical properties of soil, the results showed negative effects of engine oil on the geotechnical properties of a clayey soil sample.

2.0. EXPERIMENTAL WORK

2.1 Materials

<u>Soil Used</u>

Clean (not contaminated) soil disturb samples were obtained from the area surrounding the main electrical power plant in Simawa City. The samples were obtained at a depth of 2 m below the natural ground level which is the normal depth of shallow foundation in Simawa city. The odor of the soil samples was checked to ensure that the samples are not contaminated by engine oil. Then all samples were immersed in distilled water to clean any possible contamination. The soil samples were consequently dried and stored for the proposed lab tests.

Grain size distribution and some geotechnical properties of soil used in the experimental program are shown in Fig, 1 and Table 1, respectively. As it can be seen that the soil used is classified as OM according to unified soil classification system.

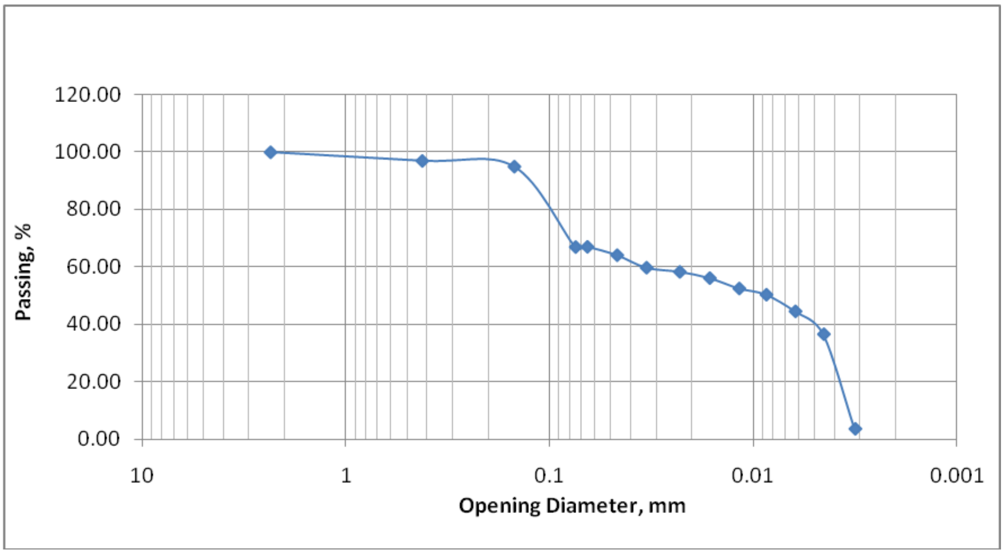

Fig 1. Grain size distribution of soil used

Table 1. Some geotechnical properties of soil used

PROPERTY	VALUE	TYPE OF TEST	STANDARD
L.L %	44	Atterberge limits	*ASTM 4318*
P.L%	15		
P.I	29		
G.S	2.71	Specific gravity of solids	*ASTM D854*
Sand content %	33	grain size distribution test	*ASTM D422- ASTM D421*
Clay and silt %	67		
γdry(gm/cm^3)	1.64	Field Unit weight	(ASTM-D2937
γwet(gm/cm^3)	1.73		
CLASSIFICATION OF USED SOIL	OL	(USCS)	

Engine Oil

Engine oil used in this study was provided by the main electrical station of Simawa city. properties of the used engine oil as provided by the supplier are depicted in Table 2.

Table 2. Engine oil properties

Density(kg/m^3) @ 15 C̈	API @ 15.6 C̈	FLASH POINT C̈	VISCOSITY @50 C̈	Sulfur wt%	W&S(V%)
960.3	15.6	94	220.6	4.414	0.03

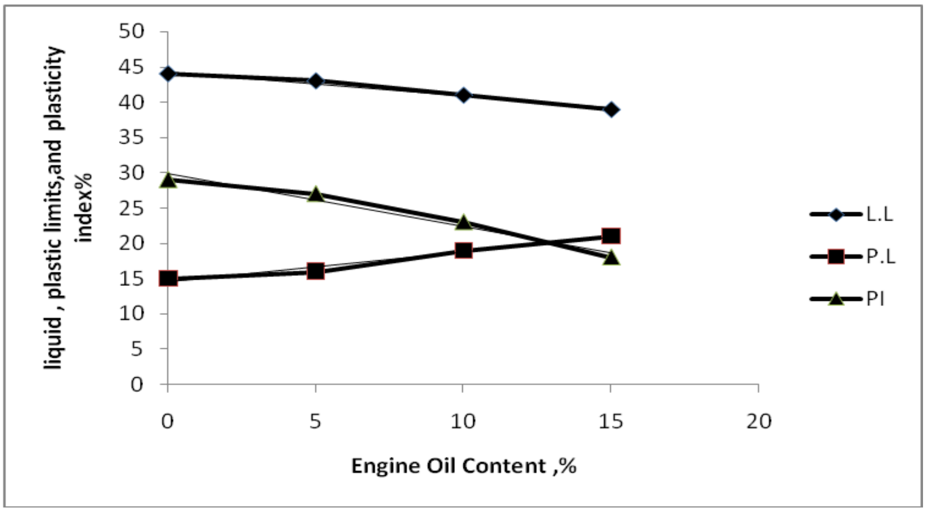

Fig 2. Effect of various engine oil contents on liquid limit, plastic limit, and plasticity index of soil used

Preparation of Soil Specimens

The clean disturb soil was used to prepare reference soil specimens. The contaminated samples were prepared by mixing the clean soil with engine oil. Three levels of engine oil corresponding to (5%, 10%, and 15% by weight) were thoroughly mixed with clean soil using a mechanical mixer to prepare the contaminated specimens. Disturbed and remolded of reference and contaminated specimens were prepared for the purpose of determination of engine oil on geotechnical properties of soil used.

2.2 Tests

The geotechnical properties of the reference and contaminated specimens were examined by carrying out many tests including Atterberg limits, specific gravity, Proctor tests, unconfined tests, shear strength, and California Bearing Ratio (CBR). Remolded reference and contaminated specimens were used for unconfined and shear strength tests while disturbed specimen were used to carry out the remaining tests. All tests were performed according to ASTM. Table 1 shows the performed tests and the corresponding specification used in the experimental program. The remaining tests including Proctor tests, unconfined tests, shear strength tests and CBR were performed as per ASTM D-698, D-2166,D-3080, and D1883-99, respectively

3.0 RESULTS AND DISCUSSION

3.1 Effect of Engine oil on Atterberg Limits

The effect of various engine oil contents on liquid limit, plastic limit and plasticity index of the soil used is shown in Figure 2 . It is evident that the increase in contaminant percentage resulted in a decrease in liquid limit and an increase in plastic limit. Consequently, the plasticity index of the contaminated soil was significantly decreased as the content of the engine oil increased. The presence of 15% of engine oil in the soil increased the plastic limit from 15% to 21%. According to Modified Unified Classification System of Soil, the soil used was changed from OL to CL owing to the addition of engine oil. It can be proposed that the presence of oil engine led to flocculation of clay particles which subsequently resulted in the decreasing and increasing of liquid and plastic limits, respectively.

3.2 Effect of Engine Oil on Specific Gravity

The specific gravity of the reference (not contaminated) samples and those contaminated with various levels of engine oil is depicted in Table 3. It clearly seen that the specific gravity linearly decreased owing to the increase of the percentage of engine oil. The increase of percentage of the contaminant from 0 to 15% resulted in decreasing the specific gravity from 2.71 to 2.66. This decreased can be mainly attributed to the low specific gravity of engine oil which resulted in lowering the specific gravity of the contaminated soil.

Table 3. Index Properties of Soil Samples

OIL (%)	MDD(g/cm^3)	O.M.C(%)	L.L (%)	P.L (%)	P.I (%)	GS
0	1.712	24.6	44	15	29	2.71
5	1.619	23	43	16	27	2.69
10	1.580	22.1	41	19	23	2.67
15	1.460	17.8	39	21	18	2.66

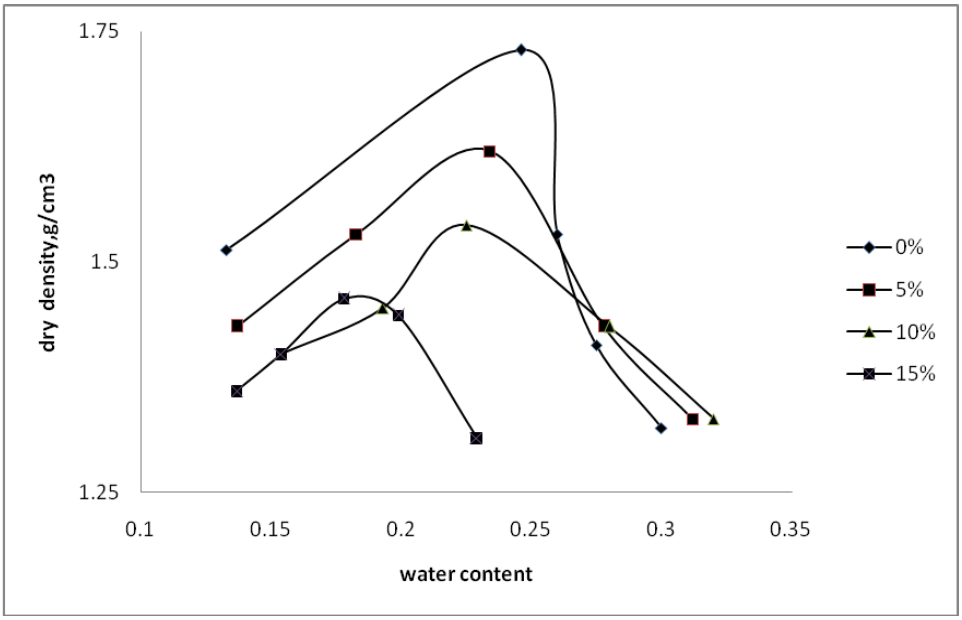

Fig 3. Density-moisture relationships of the reference and contaminated soil samples.

3.3 Effect of Engine Oil on Proctor values

Figure 3 shows the Density-moisture relationship of the reference and contaminated soil samples. The figure is clearly shown that the maximum dry density decreased as the percentage of the contaminant increased. The maximum dry density was decreased from 1712 kg/m^3 to 1460 kg/m^3 owing to the increase of percentage of the contaminant from 0% to 15%. In other words, the presence of 15%of engine oil resulted in a decrease of the maximum dry density of the used soil by approximately 15%. This rational decrease in the maximum dry density is attributed to the density of the engine oil which is relatively low compared to that of the soil. In addition, the presence of engine oil may be prevented moisture to make film around clay particles which hindered the electrostatic bonds between clay particles.

Figure 3 also shows the effect of various levels of the contaminant on the optimum moisture content. As it can be seen in figure 3, the optimum moisture content decreased as the dosage of the contaminant increased. In response to the 15% increase in engine oil level, the optimum moisture content (OMC) decreased from 24.6% to 17.8%. The observed decrease in OMC can be attributed to the reduction in ability of soil to absorb the water owing to the presence of engine oil. The decrease in the optimum moisture content was in parallel to that of the maximum dry density.

3.4 Effect of Engine Oil on Unconfined Compressive Strength

Figure 4 shows results of unconfined compression tests carried out on the reference and contaminated soil specimens. The relationship between the axial load and axial strain clearly reveals that the axial load was deceased while the axial strain was increased in response to the increase of dosage of engine oil. The relationship between the dosage of the engine oil and the unconfined compressive strength is shown in Fig. 5. The unconfined compressive strength decreased from 49.2 kPa for the reference soil specimen to 38 kPa for the contaminated soil specimen having 15% of engine oil.

The loss in the compressive strength owing to the presence of engine oil can be attributed to the loss of cohesion between the soil particles which may decrease the ability of soil to resist the applied forces.

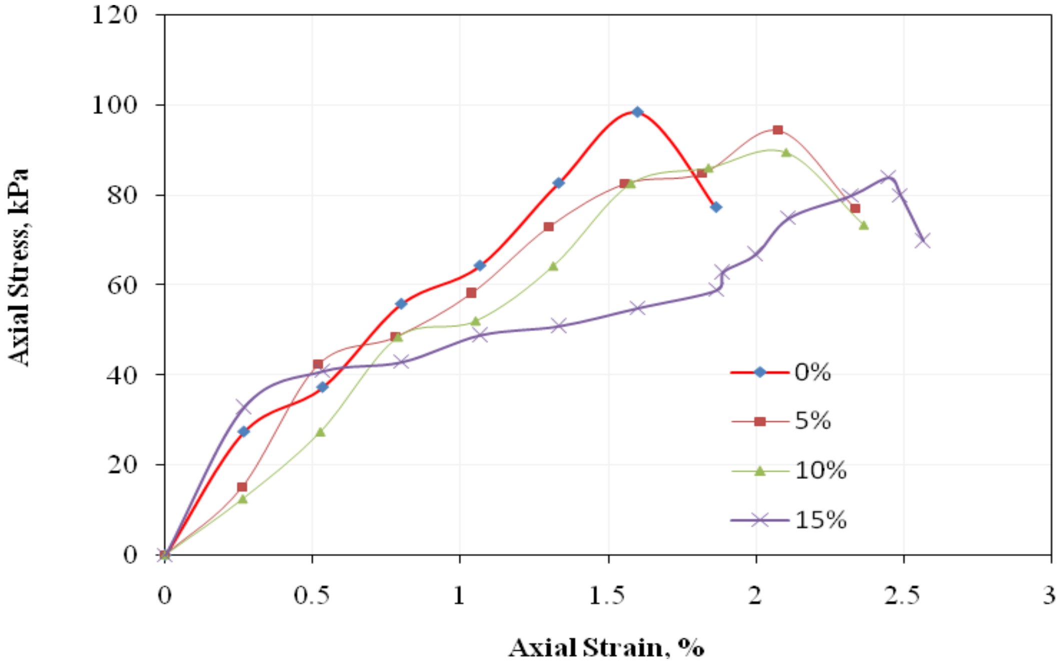

Fig. 4. Unconfined compression tests of reference and contaminated soil specimens.

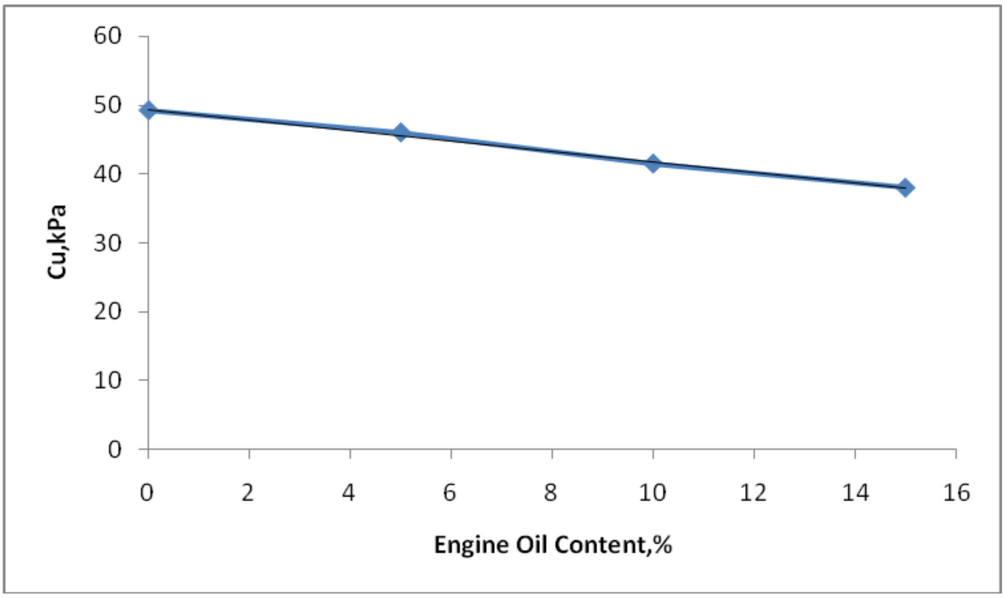

Fig. 5. Effect of engine oil dosage on unconfined compressive strength .

3.5 Effect of Engine Oil on Shear Strength Parameters

Shear strength tests were performed on remolded samples of the reference and contaminated soil and results are presented in Figure 6. Table 4 shows the values of internal friction angles and cohesion of the reference and contaminated soil samples based on results of the shear strength tests hown in Figure 5. It is seen that both cohesion and the internal friction angle decreased as the dosage of the contaminant increased. It was noted that the cohesion of the contaminated specimen having 15% engine oil was less by about 62.5% compared to that of the reference specimen. The internal friction angle was dramatically decreased by about 52% as a response to the presence of 15% engine oil in soil specimens.The engine oil seems to hinder the electrical bonds between the soil particles which probably resulted in the dramatic loss of cohesion. The decrease in the internal friction angle can be attributed to the lubrication effect of engine oil that significantly decreased the friction between soil particles.

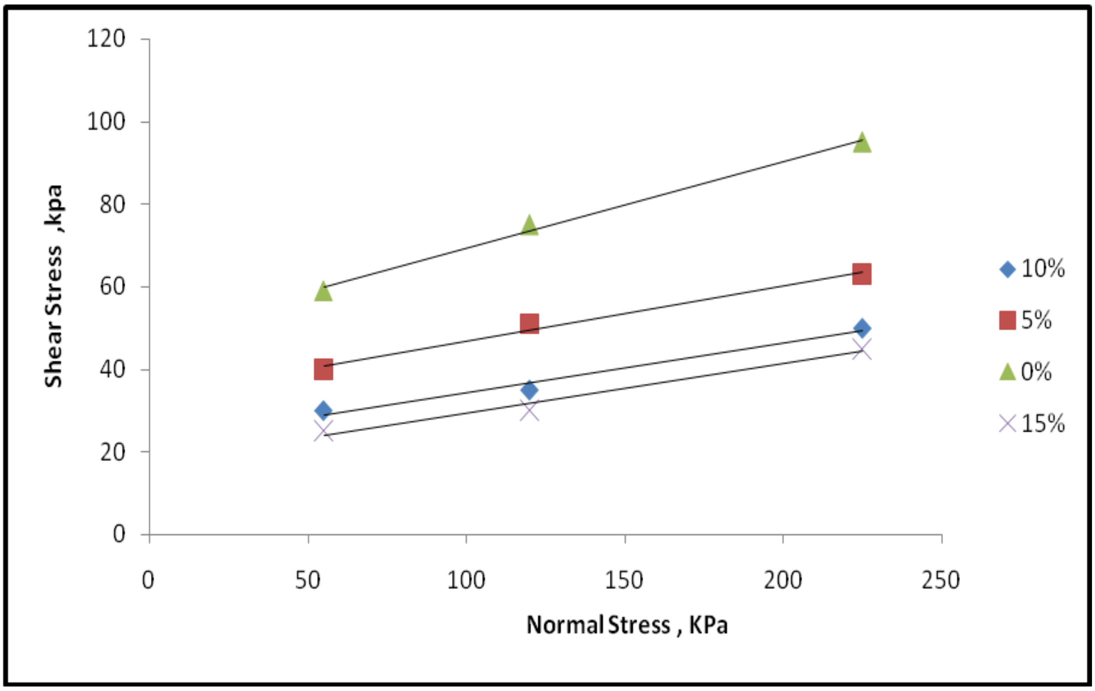

Fig. 6. Variation of unconfined compressive strength with engine oil content

Table 4. Shear parameters of reference and contaminated samples

Engine oil %	C kPa	φ
0	48	32
5	34	28
10	23	19.6
15	18	15.3

3.6 Effect of Engine Oil on CBR values

The load –penetration relationship of CBR tests performed on soil specimens contaminated with 0%, 5%, 10%, and 15% of engine oil are shown in Figures 7, 8, 9, and 10, respectively. The four figures show that for a constant penetration of 7.5 cm (3 inches), the applied load was decreased as the dosage of the engine oil increased. Figure 11 shows the CBR values of the reference and contaminated soil specimens. It can be seen that the CBR value was significantly reduced (from 8.8% to 5.6%) owing to the contamination by 15% of engine oil. The rate of reduction in CBR values was higher between 10% and 15% of engine oil compared to that between 0% and 5%. The negative effect of the engine oil on the structure of soil particles and its effect on the attraction between the soil particles may be the reasons behind the reduction in CBR values.

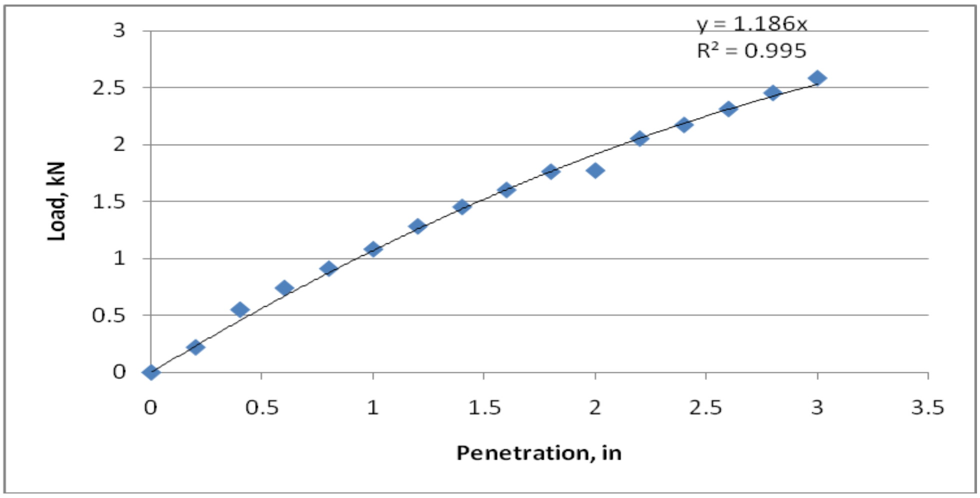

Fig. 7. CBR results of reference soil specimen .

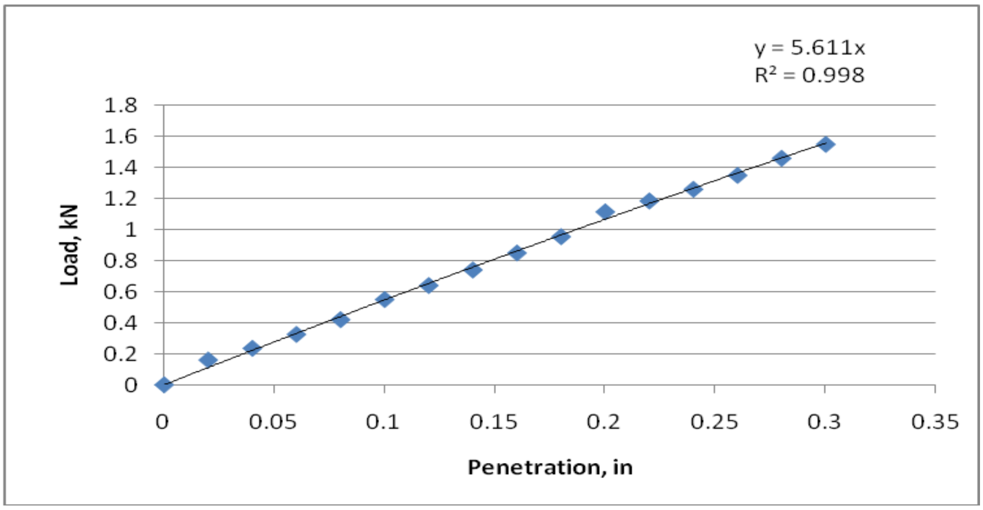

Fig. 8. CBR results of contaminated soil sample having 5% engine oil

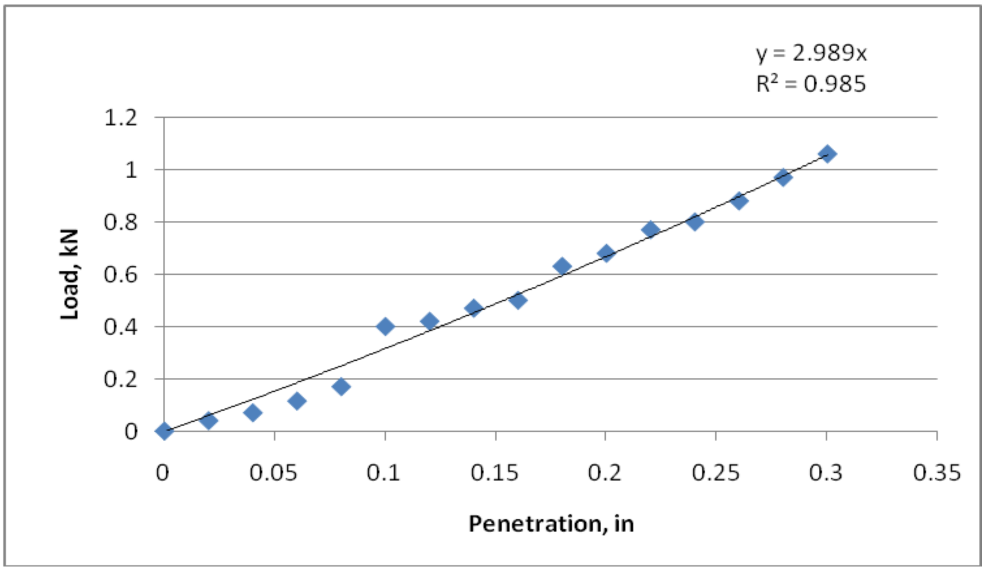

Fig. 9. CBR results of contaminated soil sample having 10% engine oil .

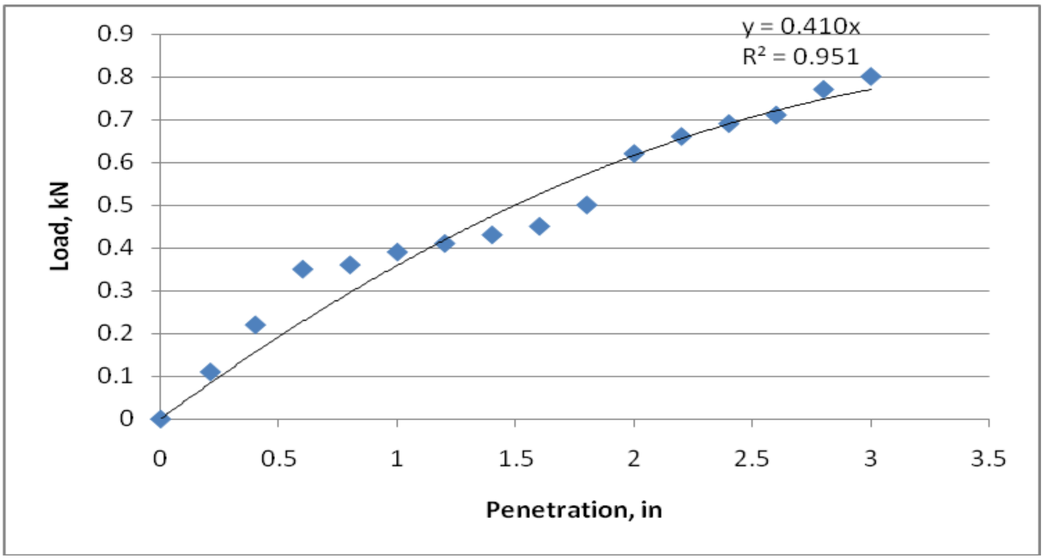

Fig. 10. CBR values of contaminated soil sample having 15% engine oil .

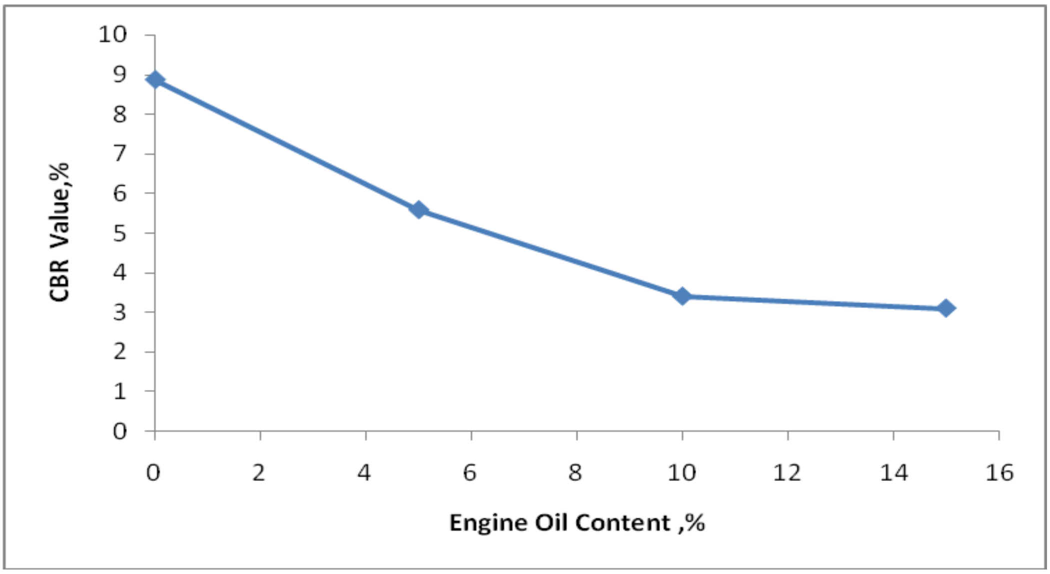

Fig.11. The CBR values of the reference and contaminated soil specimens.

4.0 CONCLUSIONS

Based on laboratory results of the effect of various levels of engine oil mixed with clay soil on the geotechnical properties including Atterberg limits, specific gravity, Proctor values, unconfined compression, shear strength values, and CBR values, the following conclusions were drawn:

1. The liquid limit was decreased and the plastic limit was increased as a response to the increase of percentage of engine oil. The plasticity index was decreased by approximately 38% owing to the increase of percentage of engine oil from 0% to 15%.
2. The specific gravity the contaminated soil specimen having 15% engine oil was found 2.66 while that of the reference soil sample (not contaminated) was 2.71
3. Both maximum dry density and optimum moisture content were found to be decreased as the percentage of the contaminant increased. The 15% of contaminant decreased the maximum dry density and optimum moisture content by 15% and 28%, respectively
4. The unconfined compressive strength was found to be decreased from 49.2 kPa for reference specimen to 38 kPa for the 15% contaminated soil specimen.
5. The shear strength values (cohesion and internal friction angle) were dramatically decreased owing to the incorporation of engine oil. The presence 15% of engine oil in the soil used reduced the cohesion from 48 kPa to 18 kPa and reduced the internal friction angle from 32 to 15.3.

6. The CBR value was decreased as the dosage of the engine oil increased. It was found that the rate of reduction in CBR value was decreased as the percentage of the contaminant increased.

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