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OIL SPILLS AND THEIR EFFECT ON THE PROPERTIES OF SOIL

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Abstract— The world is encountering oil pollution due to many reasons such as leakage of oil due to tanker accidents, transportation on land and sea, and during the process of oil drilling. This oil spill has a negative effect on the environment and on the ecological life and it may also change the geotechnical properties of the soil. The aim of this work was to study the effect of crude oil i.e. Kerosene and Diesel on the properties of the soil. Three different types of soils were selected on the basis of their grain size distribution and their initial physical properties of the selected soils such as optimum moisture content, maximum dry density, and shear strength, grain size distribution, and permeability were determined. A number of samples were prepared by mixing the soil with different percentages of crude oil products (kerosene and diesel) and their effects were studied by conducting different experiments such as permeability test, proctor compaction test, direct shear test .When normal stress were low the percentage of diesel and kerosene in soil was increased, the shear strength increased then it decreased .When normal stress was high as the percentage of diesel and kerosene in soil increased, this resulted in the decrease in shearing strength where as permeability decreased in all the samples with the addition of addition of diesel and kerosene.

Keywords— Oil Spill, Diesel, Kerosene, Permeability, Shear Strength

I. INTRODUCTION

Petroleum products can be released into the soil environment via spill, leakage, transport, or other incidents which adversely affect agricultural, residential or recreational land use. Since oil pollution is a great environmental threat as it can pollute neighbouring soil, surface and ground water, it may damage ecosystems and negatively affect health of plants, animals and human being. Therefore it's important to study its effect on the ground and soil. In past few years, many researchers have been studying the effect of oil spills on the properties of soil and their effect on the engineering applications. Oil spill may be caused due to many reasons such as transportation on land and sea, ship accidents and due to drilling of oil processes. The aim is to develop an understanding of the behaviour of the soil subjected to oil product contamination and thus resulting change in their physical properties. The outcome of this study can be the guidance for geotechnical designers and soil researchers to improve their understanding of the soil behaviour subjected to the addition of crude oil products like kerosene and diesel.

II. LITERATURE SURVEY

Purj (2000) studied the effect of oil contamination on the compaction characteristics, shear strength, one dimensional compression and hydraulic conductivity of sand [1]. It was found that when crude oil was used as a pore fluid, the maximum dry unit weight of sand was about 6 percent higher when compared with water as the pore fluid. This was explained as oil is more effective in reducing the friction between the soil particles resulting in a reduction in the spacing between the soil grains. Therefore an increase in the dry unit weight for a given compaction effort would be found. The peak shear strength, the angle of internal friction and the hydraulic conductivity was found to decrease as the percentage of oil saturation increased. Tests were conducted at different relative density of compaction of 40%, 65%, and 80%. It was noticed that for a known amount of oil saturation the decrease in the angle of internal friction was more pronounced for samples at a higher relative density. This would be effect the stability of onshore and offshore structures and slopes. For the permeability test, three types of motor oils with different viscosities as well as crude oil were used. The hydraulic conductivity was seen to decrease with the increase in the degree of oil saturation, with the increase in the relative density of the sand and with the increase in the viscosity of the oil contaminant.

Three oil sand materials were tested for their shear strength properties using triaxial compression and direct shear test [2]. Results obtained using the triaxial test showed that the angle of internal friction equal to zero which suggested that the sample behaved cohesive in nature and no interparticle contacts in oil-sand samples. While the direct shear test showed an increase in the friction angle and a lower cohesive values. The results also showed a higher friction angle values for the oil sand sample at 20 degree Celsius than at 30 degree Celsius. The results of the shear strength obtained would be useful in calculating the bearing capacity of oil sand material under trucks and shovels in the field.

The behavior of three fine grained soils and a granular soil with the addition of glycerol, propanol and acetone have been studied [3]. The three chemical were mixed with water to prepare the required amount of pore fluid. It was shown using the unconfined compression test that the shear strength and stress strain behavior of clay decreased by contamination and a marginal reduction for the silty soil was observed. The stress strain behavior has shown softening with the increase in the concentration of the pore fluids. The reduction that was observed in the shear strength and the stress strain behavior in the low and high plastic clays was due to the reduction in the frictional contacts at the particle contacts. This was also believed to be caused by a change in mineral pore fluid mineral interactions.

Gueddouda et al.(2008) studied the effect of the addition of a small amount of bentonite on sandy soil [4]. They concluded that the maximum dry unit weight, permeability and angle of internal friction decreased while the cohesion increased due to the addition of bentonite.

Kalkan (2009) studies the effect of silica fume on the geotechnical properties of finely grained soil exposed to freeze and thaw[5]. The main goal of his research was to reduce the effects of thawing and freezing cycle on the strength and permeability. He concluded that the silica fume decreased the liquid limit, plasticity index, maximum dry unit weight, permeability and increased the plastic limit, optimum moisture content, unconfined compressive strength. He found that the cause for the increase in optimum moisture content is due to the change in the surface area of composite samples and the reason for the decrease in dry density is due to the addition of high quantity of silica fume with low density where the voids of the composite samples were filled. Added to that, the permeability effect was significantly observed when silica fume content reached 25 percent, after that it has a less effect. The reason for this decrease in permeability was because the addition of high amount of silica fume to the finely grained soil particle would fill the void and cause a chemical reaction in the composite sample.[6]

III. METHODOLOGY AND RESULTS

A. Soil Classification

In the first, the soil classification was done. Sieve size distribution was used to measure the gradation of the sand. The sieves are selected according to ASTM D-422 standard specifications. A known weight of the sample was passed through various known sieve sizes of 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm, 0.212mm, 0.15mm, 0.106mm, and 0.075mm.The retained sand on each sieve was weighted using a balance and converted to a percentage of the total soil sample. By this method the maximum soil diameter was found and we could now differentiate between the different soils samples according to their grain size distribution. This was done for the three different soils and they were classified using the Unified Soil Classification System as shown in Table 1.

TABLE I
RESULTS OBTAINED FROM THE SIEVE SIZE ANALYSIS TEST

	Soil-1	**Soil-2**	**Soil-3**
D60	0.350	0.5	0.43
D30	0.20	0.42	0.32
D10	0.19	0.17	0.15
Cu	1.55	2.96	1.88
Cc	0.92	0.91	0.89
Soil Classification	Poorly graded soil (SP)	Poorly graded soil (SP)	Poorly graded soil (SP)

From the values obtained it was noticed that all of the values of Cu were less than 6 and all the values of Cc were less than 1. Therefore, it was concluded that the three soil samples were poorly graded soils with different gradations.

B. Soil Compaction

In all experiments, the maximum dry unit weight and the optimum moisture content was chosen to be the base parameters. The standard proctor compaction test was used. This test determines the optimum amount of water to be mixed with soil in order to obtain maximum compaction for a given soil sample. A known quantity of water was added and mixed thoroughly in soil. The soil was placed into a compaction mold having a volume of 0.0009438 m^3. The soil was compacted in three layers with each layer being compacted by 25 blows with a 24.4 N hammer dropped from a height of 305 mm, subjecting the soil to a total compactive effort of about 600 $kN\text{-}m/m^3$. The wet unit weight of compaction was calculated as weight of the compacted soil over volume of the mold. The resulting dry unit weight was determined by taking a sample from the compacted sand and it was left to dry in an oven for 24 hours. By knowing the moisture content, the dry unit weight was calculated. The procedure was repeated for a number of water content to get a relation between the dry unit weight and water content. Thefollowing data was obtained.

TABLE II
RESULTS OBTAINED FROM THE STANDARD PROCTOR COMPACTOR TEST

	Maximum Dry Unit Weight(kN/m^3)	Optimum Moisture Content
Soil-1	16.4	4%
Soil-2	15.9	15%
Soil-3	16.66	13%

C. Shear Strength

The shear strength of a soil is an important property as it determines the bearing capacity of the soil. The soil was compacted in 3 layers compaction tool. The shear box was put into the machine and a normal stress was applied to it. Each prepared soil sample was tested using normal stresses of 27, 50 and 05 kN/m^2 and from this three results were obtained and a graph was drawn for the normal stress versus the shear stress. This test was repeated for the three samples by varying the amount of kerosene and diesel as 0%, 5%, 10% and 15% by weight of the dry soil samples. When normal stress were low, the shear strength increased with the increase in the amount of diesel and kerosene. The increase in shear strength becomes less when more than 10%of crude oil product was added. The maximum increase in shear strength was at 10 %of crude oil product being added. As shown in Table III and Fig.1 for soil-1

TABLE III
SHEAR STRENGTH RESULTS OF SOIL-1 (DIFFERENT % OF DIESEL)

	Shear Strength(kPa)			
Normal Stress (kPa)	0%	5%	10%	15%
27	21.00	23.30	25.10	23.60
55	39.90	42.00	44.60	41.86
105	80.00	81.90	83.50	78.8

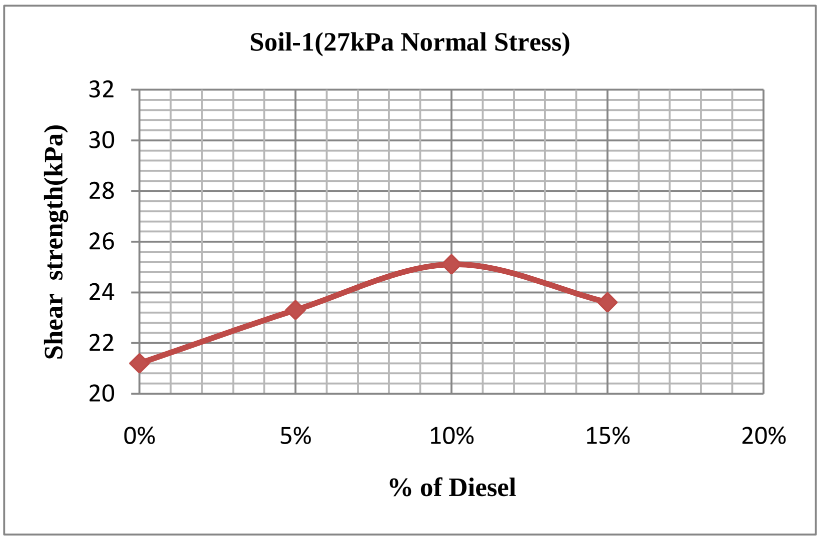


Fig. 1 Effect of Diesel on Shear Strength for Soil-1 at different normal stresses

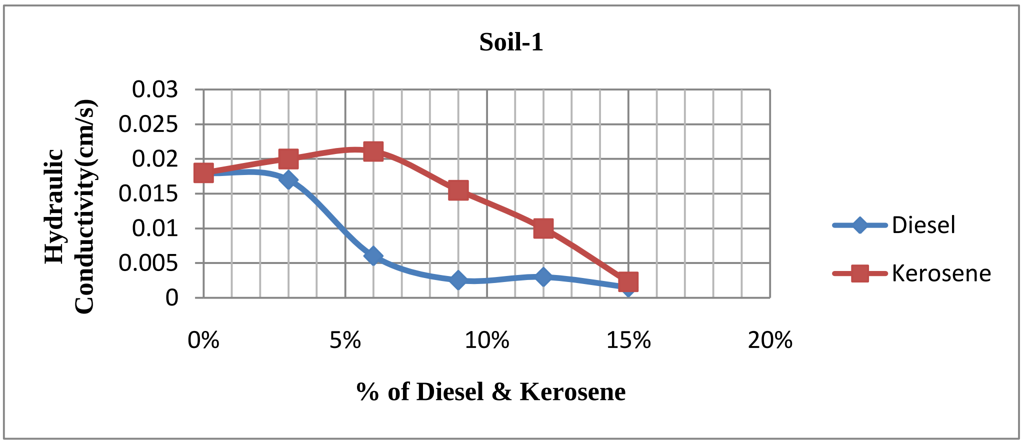
D. Permeability

Permeability of the soil is defined as easiness in which water flows through a specified soil. The pore sizes and their connectivity is what determine whether the soil has a high or low permeability. The constant head test and the falling head test. In this study, the constant head method was used since the soil is a granular. During the experiment, the prepared soil sample was added and compacted in three layers inside the apparatus. By knowing the volume of the apparatus, a known mass of the prepared soil sample was found from the soil dry unit weight. This soil was forced inside the apparatus to fill its volume and to get an equilibrium compaction for all the tests. Then the apparatus was connected to the two outlets of the manometer. Filter was added on each of the outlet in order to prevent the soil from flowing through the manometer. After getting the constant conditions, the heads at the manometer and the time it takes to pass through the soil were recorded and the quantity of discharged water is measured. Recording and measuring the results was done three times for each test at different timings. From this the coefficient of permeability was determined. This test was carried out for the three soil sample separately with different percentages of crude oil products (kerosene and diesel) of 0%, 3%, 6%,9% ,12%,15% by weight by the dry soil samples.

Constant head permeability test were carried out on soil-1. The results have shown an inverse correlation between permeability and crude oil products content. The rate of reduction of permeability was faster for the sand by the addition of diesel than by the addition of kerosene. The maximum change in permeability was noticed between 0% and 5% diesel; after the addition of 5% diesel onward, it was noticed that the effect of diesel on permeability was very small. On the other hand, the change in permeability was very small when kerosene was added up to 5%; with an increase in amount of kerosene of more than 5%, a large drop in the permeability was observed. The decrease in hydraulic conductivity was a result of the trapped diesel and kerosene that occupied the pore spaces of the soil; the pore volume of the soil would decrease and this would result in a decrease in permeability as shown in Table IV and Fig.2 for soil-1.

TABLE IV
PERMEABILITY RESULTS OF SOIL-1 WITH DIFFERENT % OF DIESEL AND KEROSENE ADDED

DIESEL						
PERMEABILITY(cm/s)	0%	3%	6%	9%	12%	15%
	0.018	0.017	0.006	0.0025	0.003	0.0015
KEROSENE						
PERMEABILITY(cm/s)	0%	3%	6%	9%	12%	15%
	0.018	0.020	0.0211	0.0155	0.01	0.0023



IV. CONCLUSIONS

From the results, it was seen that at low normal stress, as the percentage of diesel and kerosene crude oil products added to in the soil is increased, the shear strength increases up to a certain percent and then it decreases. At high normal stress, as the percentage of crude oil products added to the soil is increased, the shear strength decrease. It was noticed that as we increase the normal stress, the shear strength of the soil would show more noticeable reduction. A slightly greater decrease in the friction angle was noticed for the addition of kerosene than that with the addition of diesel. A slightly greater value of apparent cohesion was noticed for the addition of kerosene than that with the addition of diesel. A slightly greater decrease in shear strength was noticed for the addition of kerosene than that with the addition of diesel.

The results have shown an inverse correlation between permeability and crude oil products content which means that the addition of diesel and kerosene has caused a reduction in the permeability of the sand. The maximum change in permeability was noticed between 0% and 5% diesel and kerosene. The rate of reduction of permeability was faster for the soil by the addition of diesel than by the addition of kerosene.

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