A Review on Effect of Crude Oil on the Geotechnical Properties of Soil

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Abstract - *Soil properties are affected by past land use, current activities on the site, and nearness to pollution sources. Accidental spills and leaks of crude oils is a common occurrence which results in partial or full replacement of the soil pore fluid by oil, thereby changing the shear strength and stress-strain behavior of soils. The addition of hydrocarbon into the granitic and metasedimentary soils has clearly affected the engineering properties of the contaminated soils. The increase in the hydrocarbon contents in soils caused the reduction of the water content at the liquid limit and plastic limit. The paper aims at reviewing the works of researchers on different types of soils and studies of the effects of crude oil contamination on the various geotechnical properties of soil.*

***Key Words*: Crude oil, Contamination, Atterberg Limits, Permeability, Angle of Internal Friction, Optimum Moisture Content , Remediation**

1. INTRODUCTION

Soils are formed by the decomposition of rock and organic matter over many years. Soil properties vary from place to place with differences in bedrock composition, climate, and other factors. At times, the amounts of some soil elements and other substances may exceed levels recommended for the health of humans, animals, or plants. Certain chemical elements occur naturally in soils as components of minerals, yet may be toxic at some concentrations. Other potentially harmful substances that may end up in soils through human activities are Lead paint, Fertilizers, Pesticide, Petroleum spills, crude oil, and High concentrations of organic chemicals, petroleum crude, petrochemical products, and industrial solvent.

Crude oil is one of the most common soil contaminants. Over two million tons of oil are produced all over the world every day, and about 10 percent is entering the environment due to pipeline breaks, leakage from reservoir tanks, tanker accidents, discharge from coastal facilities, and offshore petroleum productions. Several hydrocarbon components in crude oil are toxic and have a certain degree of water solubility. Oil contamination presents many hazards to wildlife, such as the poisoning of animals that are high in the food chain when they eat large amounts of other organisms that have taken oil into their tissues; the interference with breeding behaviors by making animals too ill to breed; the irritation or ulceration of the skin, mouth, or nasal cavities; damage to red blood cells; damage to the adrenal tissue of birds, which interferes with their ability to maintain their blood pressures and the concentrations of fluids in their bodies, and leads to a decrease in the thickness of eggshells.

1.1 What Happens to Contaminants in Soils?

Once contaminants are in soils, where they go and how quickly they travel depends on many factors. Some organic (carbon-based) contaminants can undergo chemical changes or degrade into products that may be more or less toxic than the original compound. Note that chemical elements (such as metals) cannot break down, but their characteristics may change so that they can be more or less easily taken up by plants or animals. Different contaminants vary in their tendency to:

- End up in water held in the soil or in the underlying groundwater (by leaching through the soil);
- Volatilize (evaporate) into the air; or
- Bind tightly to the soil.

The characteristics of the soil also affect the fate of contaminants and whether they can be readily taken up by plants or animals. Site management and land use (such as gardening practices) can affect some soil characteristics. Important soil characteristics that may affect the behavior of contaminants include:

- Soil mineralogy and clay content (soil texture);
- pH (acidity) of the soil;
- Amount of organic matter in the soil;
- Moisture levels;
- Temperature; and
- Presence of other chemicals.

2. EFFECT OF OIL CONTAMINATION ON GEOTECHNICAL PROPERTIES OF SOIL

2.1 Angle of internal friction

Sanad et al., [1] studied the geotechnical properties of oil contaminated Kuwaiti sand and observed that the friction angle generally decreases with oil contamination with the maximum reduction occurring with heavy crude oil. This reduction was noticeable at all relative densities from loose to very dense sand conditions. Kermani et al., [2] studied the influence of oil contamination on lean Clay and noticed that there was increase in internal friction angle and decrease in cohesion and inferred that under high normal stresses, the contaminated soil will be more resistant than the clean soil. On the other hand, because cohesion is the principal factor in slope stability, trenches made in the contaminated soil will be less stable.

2.2 **Max dry density**

Bignell at al., [3] found that the maximum dry density for well graded sandy soils increased as oil content increased up to a particular values, then followed a decreasing trend beyond that particular oil percentage. Rahman et al [4] suggests that the moisture content required to achieve maximum dry density decreased when oil content increased in contaminated soil. The researchers inferred that this variation was due to the fact that oil has partially occupied the inter-particles spaces and the occurrence of oil has changed the soil to a state of looser material than an uncontaminated soil. Also studies by Sanad et al., [1] on modified Proctor compaction tests on Jahra sand and mixing it with 2%, 4%, and 6% by weight of heavy crude oil indicated that with the presence of oil up to 4% better compaction characteristics were achieved. With 4% oil the maximum dry density and optimum moisture content were 1,940 kg/m3 and 6.9%, respectively which might be due to the lubricating effect caused by the presence of oil, which facilitates compaction and reduces the amount of water needed to reach maximum density. However, with further increase of the oil content to 6%, the sample showed inferior compaction characteristics.

2.3 Atterberg limits

Rahman et al., [4] has observed that the presence of oil has decreased the moisture contents of the liquid and plastic limits of the contaminated soils. This may be due to the presence of water around the charged clay particles getting replaced by nonpolarized liquid of oil. Oil would make earlier contact with clay particles, causing a removal of interaction between water and clay particles. Khamehchiyan et al., [5] observed a similar behavior for SM and CL soils. Meanwhile Shah et al., [6] showed that the contaminated soils increased the liquid and plastic limits and decreased the plastic index as compared to uncontaminated CL soils. Kermani et al., [2] studied the plastic limits on lean clay and observed that the property tend to increase distinctively as the oil content increases, the liquid limits increase with a light slope, and plastic index consequently decreases. Because crude oil covers clay particles and does not permit water molecules to reach the double-layer water, more water is needed for the soil to obtain plastic properties. This might be the reason for the increase in plastic limit. However, if the oil orients the soil particles, most of the water added to the soil during the test will join the free water layer. Because the flow characteristics of clay depend on free water, no distinctive increase in the liquid limit is observed. Finally, if most of the added water reaches the free water and not the double-layer water, the small difference between LL and PL, and consequently the small PI, would seem reasonable.

2.4 Permeability

Rahman et al., [4] observed that permeability of weathered basaltic soil was reduced as oil content increased. The decrease in permeability of the contaminated soils was likely associated with the clogging of some inter-particles spaces by oil. The researchers mentioned that the increase in oil content in contaminated soil will reduce the available inter-particles spaces for water seepage. Chang et al., [7] commented that oil occupies some pore space, it is expected that the permeability will decrease with increasing the oil content. Akinwumi et al., [8] observed that when the crude oil content increased, the permeability of the contaminated soil decreased. Crude oil becomes entrapped in the pore spaces that forms the pathway for water within the contaminated soil and consequently, reduced the pore sizes. The decrease in the permeability of the contaminated soil is attributed to the reduction in the pore space

2.5 Optimum moisture Content

Akinwumi et al., [8] noted that the OMC decreased as the crude oil content in the soil increased. Crude oil is hydrophobic and as it coats itself around individual clay particles, it disallows free water (water other than the adsorbed water) from interacting with the clay particles. This may be accountable for the reduction in the amount of water needed by the soil to reach its maximum unit
Kermani et al., [2] observed that lean clay- improvement in compaction characteristics can be attributed to the lubricating effects of the oil, which is due to the oil coating on the individual clay particles and the clay groups

3. METHODOLOGIES FOR REMEDIATION OF SOIL

Soil remediation methods can be divided into three parts; biological, physical and chemical which can be done ex situ or in situ depending on the type of method. Bioremediation is using microorganism to reduce or break down hazardous organic material to harmless compounds, such as CO_2 and water. Plants and their interactions with microorganisms (e.g. bacteria, fungi etc) can also help degradation or dissipation of organic pollutants in contaminated environments. There are a lot of studies which report remediation of petroleum polluted soil by the use of thermal decontamination, vapor extraction, surfactants or solvent flushing, chemical oxidation, steam stripping as well as biological treatment. Thermal methods showed great efficiency of 99%, in decontamination of organic polluted soils. Microwave heating technique as a thermal method has advantages of greater time and energy saving, selective and uniform heating compared to conventional thermal methods, which makes it attractive for industrial implementation. Soil washing is a promising remediation technique because in addition to treating oil contaminated soil it has the potential to remove heavy metals from soli as well [9] . Subcritical water extraction (SCWE)[10] also known as pressurized hot water extraction uses water heated from 100 ^{0}C to 274 ^{0}C under pressure to maintain it in its liquid form . The superheated and pressurized water is used as a solvent instead of organic chemicals. As the temperature is raised, the hydrogen bonding network of water molecules weakens resulting in a lower dielectric constant and simultaneously decreasing its polarity.

In the practical point of view, the selection of a suitable method for remediation of oil contaminated soils depends on several parameters including, type and concentration of contaminates, which may affect the remediation efficiency, as well as the area of polluted sites, time and cost. Furthermore, the environmental side effects of each method as an important factor should be considered.

3. CONCLUSIONS

Oil contamination leads to decreased permeability and strength. Heavy crude oils affect the strength parameters of sand more that light gas oil and benzene at all relative densities. The latter has very little effect. The plastic limits tend to increase distinctively as the oil content increases, the liquid limits increase with a very light slope, and the plastic index consequently decreases. As the oil contamination increases, the maximum dry density increases and the optimum water content decreases. In addition, a change in the shape of the compaction curves from bell-shaped for uncontaminated soil was detected. This change in soil properties will enhance its use in embankments.

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