International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 10, October-2015

# Investigation on the Effects of Hydrocarbon Spillage on Soil Properties

Jesna Joseph
Department of Civil Engineering
Saintgits College of Engineering
Kottayam, Kerala, India

Hari G
Professor, Department of Civil Engineering
Saintgits College of Engineering
Kottayam, Kerala, India

***Abstract*— Every year, several onshore and offshore oil spills occur around the world, and these oil spills contaminate the soil. The physical and mechanical property of the ground gets altered as a result of contamination. Increasing petroleum exploration refining and other allied industrial activities have led to the wide scale contamination of soil. Amongst diesel and petrol, the consumption of diesel is higher. Therefore, diesel was selected as the pollutant and its effect on engineering properties of soil was studied. The present study focuses on evaluation of uncontaminated and contaminated soil with different concentration of diesel (8%,12%,16%,20% and at fully saturation by dry weight of the soil) were determined on samples of lateritic soil, sandy soil and clayey soil and the test results are compared to determine the effects of diesel contamination on some of the geotechnical properties. The testing included basic properties, Specific gravity, Atterberg limits, compaction, direct shear, and triaxial test and permeability tests. The results showed that the diesel contaminated soil samples have adverse effects on the geotechnical properties of the soil. The liquid limit, plastic limit and of the soil decreased as its diesel content increased. Strength and permeability of the soil decreased as its diesel content increased. If the foundation design for structures to be erected on hydrocarbon polluted soil does not consider the reduction in angle of internal friction and shear strength, this will ultimately affect the stability of shallow foundations, slopes, and other structures.**

***Keywords*— Diesel; Contaminated soil; Geotechnical properties; Laboratory studies;; Shear strength parameters***

## I. INTRODUCTION

Humans are, unintentionally or intentionally contaminating soils from different sources. The contaminated soils are not only a challenge for the environmentalists but also for the geotechnical engineers. The surface and subsurface environment is becoming increasingly contaminated because of disposal of chemicals and waste materials produced as a result of rapid industrialization and various other human activities. All types of pollution have direct and indirect effect on soil/sub-soil. The pendulum swings from oil exploration, production, processing and transportation from one end to refining, storage (surface and subsurface) transportation and distribution leads to the chance of leakage and spillage. Petroleum contamination may also occur on right of way of the road due to leakage of diesel products from leaking oil tankers, spills due to vehicular accidents, buried pipelines, acquired properties such as rail yards an abandoned oil storage sites. Oil spills in most cases are accidental; during transportation both on the land and sea; as leakage from storage tanks; or during oil drilling processes. There are also cases where oil might be spilled purposely as what was happened in the Persian Gulf War in 1991.

Environmental pollution with petroleum and petrochemical products has been recognized as one of the most serious current problems especially when associated with accidental spills on large scale. Every year, several onshore and offshore oil spills occur around the world, and these oil spills contaminate the soil. The Subsurface contamination is a widespread problem all over the world. The physical and mechanical property of the ground gets altered as a result of contamination. Increasing petroleum exploration refining and other allied industrial activities have led to the wide scale contamination of soil.

Hydrocarbon leaks and spills have become of great concern in most of the oil producing countries of the world. Among the contaminants, the hydrocarbons are a major source of soil pollution; petrol and diesel being the chief contributors. A vast majority of the population use these two commodities. Amongst diesel and petrol, the consumption of diesel is higher. Therefore, diesel is selected as the pollutant and its effect on engineering properties of soil is studied. The impact of these leaks and spills on the environment cannot be overlooked or disregarded. Hydrocarbon contaminated has not just affected the quality of the soil but will also alter the physical properties of oil-contaminated soil. The physical properties of the oil-contaminated soil will also control the stability of slopes as well as the bearing capacity of foundations and other structures. Because of the sensitivity of structures bearing capacity changes have more significant effects on foundation. It can result in structural or functional failure of existing structures, especially when the contamination causes a significant increase in the soil's plasticity; loss of its bearing capacity; increase its settlement, and/or prevent drainage of water or other liquid. For proposed structures, it can cause an abandonment of the site having the contaminated soil, a reduction in the scope of the project or an increase in its project cost. Therefore it is necessary to applying soil remediation or stabilization technologies before construction. This study focuses on evaluation of uncontaminated and contaminated soil samples of lateritic soil sandy soil and clayey soil to determine the effects of diesel contamination on some of the geotechnical properties .The testing included basic properties, Specific gravity, Atterberg limits, compaction, direct shear, triaxial and permeability tests of artificially contaminated sand, clay and laterites.

## II. MATERIALS USED

In the present investigation three set of soil samples taken for the study were lateritic soil, sandy soil and clayey soil. Lateritic soil was obtained from a construction site near Thengana, Kottayam District Kerala. Sandy soil was collected from Mundupaalam stream near St Mary's Catholic Church Mundupaalam, Kottayam District Kerala. Clayey soil was obtained from Kinakary, Alappuzha District Kerala ware taken to carry out the study. These soil samples were collected from 0.5m depth. Samples were collected in sacks while some were stored in a water-tight container for laboratory determination of their natural moisture content. The soil samples collected in sacks and transported to the laboratory. After transferring to the geotechnical lab it was air dried for about 24 hrs and sieved through 20mm IS sieve. Index properties and engineering properties of the soil were determined for uncontaminated soil passing 20 mm IS sieve. Then the contamination of the soil with varying percentages of diesel was carried out in the laboratory. Each sample is divided into five parts and they are dried in oven at 105° C then mixed with diesel in the amount of 8%,12%,16%,20% and at fully saturation by weight of dry soil sample. The mixed samples were kept for curing in an air tight plastic bag.

## III. RESULTS AND DISCUSSION

The soil samples collected from different locations were taken for the present study. Chemical characteristics such as pH, were determined for fresh soil samples. Experiments were conducted to determine properties of soil were specific gravity, field density, Atterberg limits, direct shear test, triaxial test, and compaction. First these samples are kept for oven drying and further experimental investigations are carried out after artificially contaminating the soil with varying percentage of diesel. The results are interpreted in the form of tables and graphs. Finally comparison is made in between contaminated and uncontaminated soil.

TABLE I. PROPERTIES OF THE SOILS TESTED

| PARAMETER | LATERITIC SOIL | SAND SOIL | CLAY SOIL |
|---|---|---|---|
| Field moisture content(%) | 8.6 | 19.1 | 123.8 |
| Field density(g/cc) | 1.92 | 1.97 | 1.43 |
| Specific gravity | 2.69 | 2.58 | 2.69 |
| Grain size analysis Gravel (%) (4.75 mm-80 mm) | 31.92 | 3 | 0 |
| Sand (%) (0.075 mm-4.75 mm) | 48.06 | 93 | 13.75 |
| Fines (%) (< 0.075 mm) | 20.02 | 4 | 86.25 |
| Atterberg Limits (%) Liquid Limit ($W_L$) | 74.8 | - | 9 1 |
| Plastic Limit ($W_P$) | 41.2 | - | 40 |
| Plasticity Index (%) | 33.6 | - | 51 |
| Optimum Moisture Content (%) | 16.1 | 12.1 | 25.27 |
| Maximum dry density (g/cc) | 1.83 | 1.88 | 1.31 |
| Angle of internal friction Ø | 39.96 | 39.6 | 8.53 |
| Cohesion (kN/m²) | 14 | 0 | 19 |

TABLE II. CHEMICAL PROPERTIES OF SOIL

| PH | LATERITE | SAND | CLAY |
|---|---|---|---|
| Uncontaminated soil pH | 5.70 | 6.56 | 6.98 |
| Contaminated soil pH | 7.53 | 7.63 | 7.62 |

TABLE III. PROPERTIES OF DIESEL

| | |
|---|---|
| Density | 0.74 g/cc |
| Specific Gravity | 0.82 |
| Viscosity | 5.5 centistokes |

*A. Effects Of Diesel On Lateritic Soil*

Direct Shear Tests

Shear test were carried out to find the effect of diesel contamination on strength parameters of soils. The tests were performed in a square shear box (6 cm×6 cm) with a constant rate of shear strain equal to 0-2mm/min at a normal load of 0.35,0.5,0.75,1,1.25,1.5 kg/cm² as per IS 2720 (Part 39)-1987. The tests were carried out on artificially contaminated lateritic soil with increasing percentage of diesel (8%,12%,16%,20% and 22% ).

Fig. 1. Angle of internal friction of contaminated lateritic soil

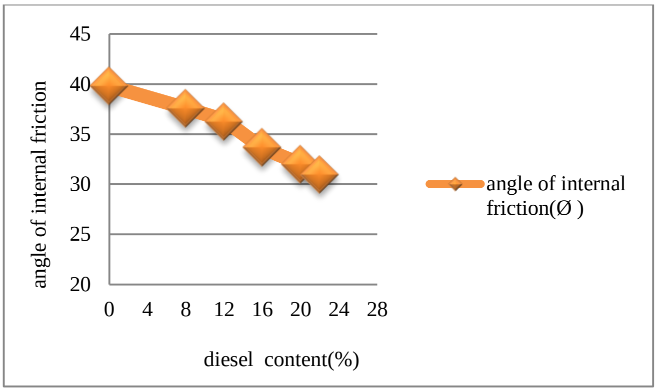
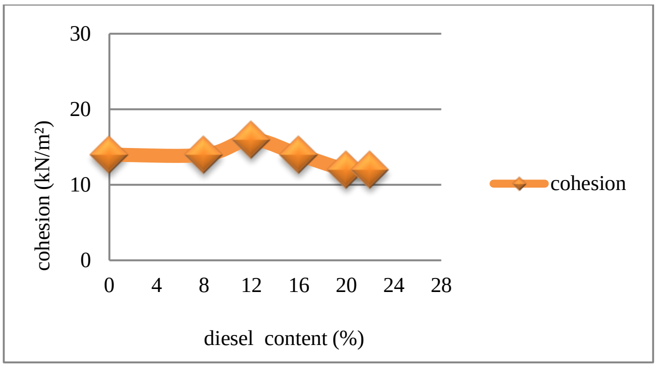


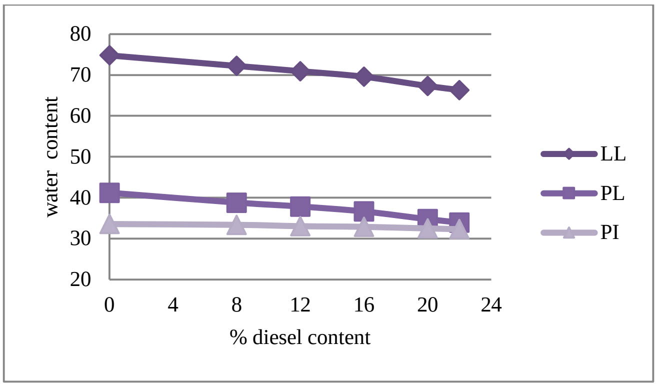

Fig. 2 Cohesion of contaminated lateritic soil




Effects of Diesel on Consistency Limits

Liquid limit and plastic limit of virgin and contaminated lateritic soil were found as per IS: 2720 (Part V)-1985. Liquid limit (LL) and plastic limit (PL) of soil increased with addition of contaminant. The decrease in plasticity index (PI) of contaminated soil is the indication of problematic nature of soil. Fig 3 shows the variation of consistency limit of virgin and contaminated soil. Liquid limit in soil increases whereas plasticity index is found to decrease with the increase in percentage of diesel in the soil.

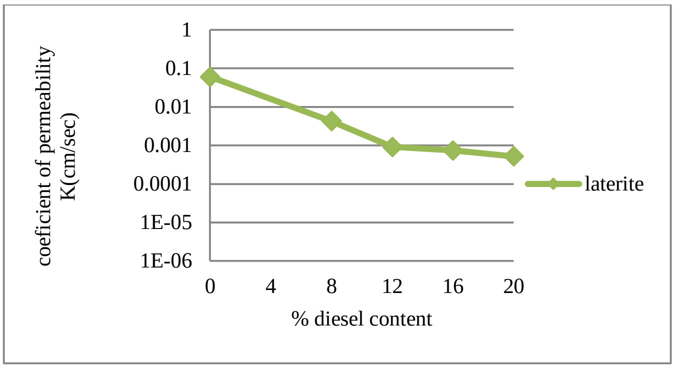
Fig. 3 Atterberg limits of Contaminated Lateritic soil




Effects of Diesel on Hydraulic Conductivity

Variable head permeability tests were carried out on the lateritic soil samples with increasing percentage of diesel content. Fig 4 shows an inverse correlation between permeability and diesel content.

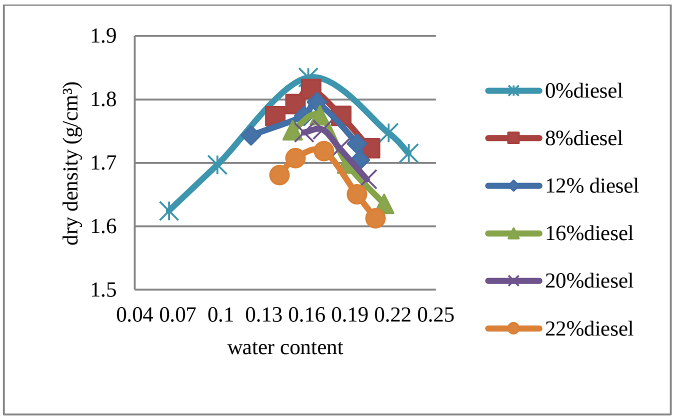
Fig. 4 Permeability of contaminated Lateritic soil




Effects of Diesel on Compaction

Standard Proctor test is carried out to find out the optimum moisture content (OMC) and maximum dry density (MDD) of soil as per IS 2720(part 7)-1973 with increasing percentage of diesel (8%,12%,16%,20%,22%).

Fig. 5 OMC and MDD of contaminated lateritic soil



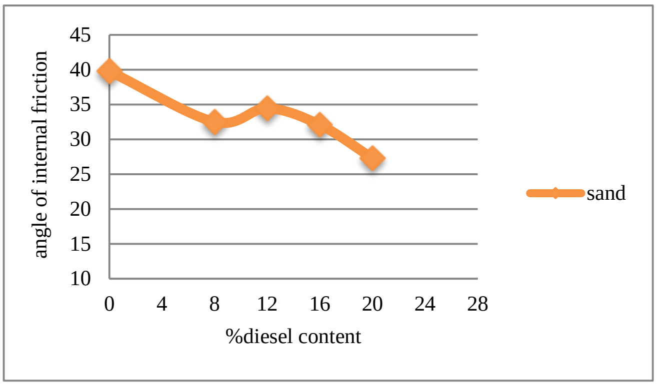
ISSN: 2278-0181
Vol. 4 Issue 10, October-2015

*B. Effects of Diesel on Sandy Soil*

Direct Shear Tests

Shear test were carried out to find the effect of diesel contamination on strength parameters of soil. The tests were carried out on artificially contaminated lateritic soil with increasing percentage of diesel (8%,12%,16% and20%).

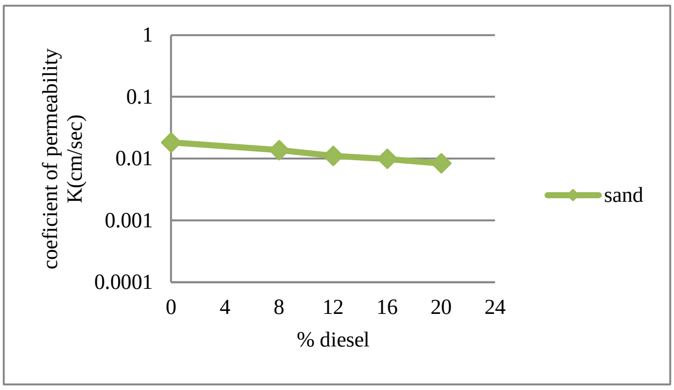
Fig. 6 Angle of internal friction of contaminated sand




Effects of Diesel on Hydraulic Conductivity

Variable head permeability tests were carried out on the sandy soil samples with increasing percentage of diesel content. Fig 7 shows an inverse correlation between permeability and diesel content. . IS 2720 (Part 17)-1986 has been followed for the test.

Fig. 7 Permeability of Contaminated Sand




C. *Effects of Diesel on Clayey Soil*

Triaxial Test

The triaxial compression is mainly used to determine the shear strength parameters and stress-strain behaviour of cohesive soil. The experiments were carried out in a standard triaxial apparatus as per IS:2720(part 11)-1971.In the present study the specimens were prepared with increasing percentage of diesel content (8%,12%,16%,20%,35%). Fig 8 and 9 shows the addition of diesel decrease the value of angle of internal friction and cohesion of the soil

Fig 8 Cohesion Values of Contaminated Clay

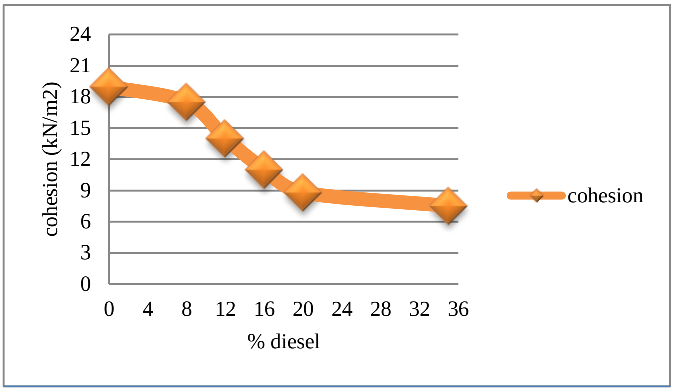
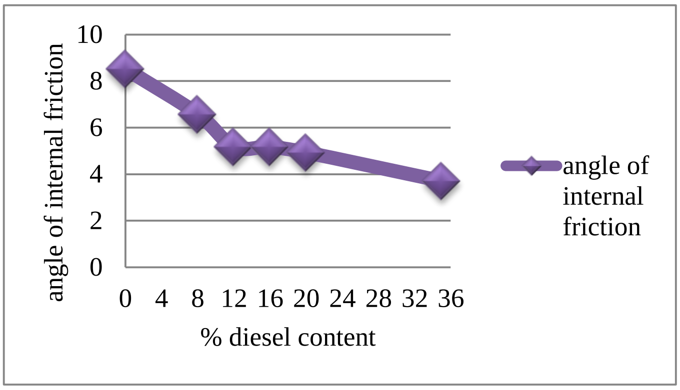


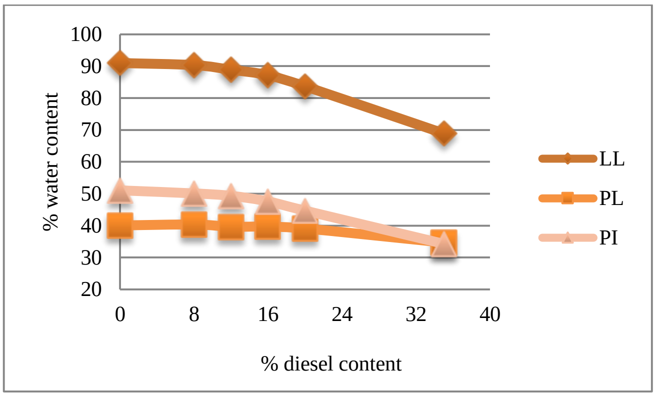

Fig. 9 Angle of Internal friction of Contaminated Clay




Effects of Diesel on Consistency Limits

Liquid limit and plastic limit of virgin and contaminated lateritic soil were found as per IS: 2720 (Part V)-1985. Liquid limit (PL) and plastic limit (LL) of soil increased with addition of contaminant. The decrease in plasticity index (PI) of contaminated soil is the indication of problematic nature of soil. Fig 10 shows the variation of consistency limit of virgin and contaminated soil. Liquid limit plastic limit and plasticity index is found to decrease with the increase in percentage of diesel in the soil.

Fig. 10 Atterberg Limits of Contaminated Clay



## CONCLUSION

In the present investigation laboratory studies were conducted to study the properties of uncontaminated and contaminated lateritic soil, sandy soil and clayey soil. Based on the experimental investigation the following are the some of the important conclusions.

1. Based on the results obtained after conducting comparative study on contaminated and uncontaminated soil the permeability of sand and lateritic soil is reduced with increasing diesel content since diesel gets entrapped in the pore spaces that forms the pathway for water within the contaminated soil and consequently, reduced the pore sizes

2. Addition of diesel to clayey soil and lateritic soil decreased the liquid limit, plastic limit and plasticity index of the contaminated soil. The decrease in the values of Liquid limit (PL) and plastic limit (LL) is due to the alteration of the cohesive bonds and forces that exists between the particles of the lateritic soil and clay.

3. Addition of diesel to the lateritic soil, sandy soil and clayey soil reduces the value of angle of internal friction. The decrease in the value of angle of internal friction is due to the infiltration of diesel into the lateritic soil; it occupies the voids between the particles of the lateritic soil and tends to form a film of coats around the lateritic soil particles.

4. The decrease in the cohesion of the lateritic soil and clayey soil is due to the reduced intermolecular cohesive forces.

5. The maximum dry density of lateritic soil dropped due to the lubrication effect of diesel.

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