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Evaluation of Geotechnical Properties of Oil Contaminated Laterite Soil

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***Abstract*— Soil can be contaminated by oil spills, leakages from pipe, during transportation or accidental etc. This project aims to investigate the impact of oil contamination on the geotechnical properties of laterite soil in the Ambalamugal region. The oil contamination in this locality is due to underground pipe leakage from oil refinery which can alter its engineering properties of soil affecting the stability of structures built upon it. Through a comprehensive laboratory and field study, this research assesses the changes in properties such as Permeability, Compaction, Specific gravity and Compressibility of laterite soil due to oil contamination. The contaminated sample is prepared by mixing soil with crude oil in amount of 4%, 8 %, 12%, 16 % by dry weight. Various remediation techniques can also be suggested to understand their influence on soil behavior. The findings from this study will provide valuable insights for geotechnical engineers working in contaminated soil for construction projects in oil-affected areas.**

***Keywords*— Oil Contamination, laterite soil, stabilization**

I. INTRODUCTION

The contamination of soil and water by crude oil is increasing due to oil drilling, leakage from pipes, from mechanical workshops, accidental Spillages etc. Oil pollutes water resources and when it percolates through the soil, it contaminates soil and ground water. The engineering properties of soil will get adversely affected due to oil contamination making it unsuitable for construction. Lateritic soils are widespread in tropical areas and they are highly weathered soil. Laterite soils inhibits the properties of both cohesive and non-cohesive soil, it primarily depends upon the particle size of soil. These soils develop through a process called laterization, where intense weathering and leaching lead to the removal of soluble minerals, leaving behind residual concentrations of iron and aluminum. Laterite soils can vary in composition and properties depending on factors such as climate, parent rock material, and vegetation. As oil contamination poses significant challenges to soil integrity, understanding how it influences parameters such as shear strength, compaction, and permeability is crucial for environmental assessment and remediation efforts. This investigation aims to unravel the complexities of geotechnical behavior in oil-contaminated laterite soil, shedding light on potential implications for infrastructure stability and environmental sustainability. As laterite soils play a significant role in various engineering applications, understanding the alterations induced by oil contamination is crucial for assessing the potential impact on foundation stability, soil compaction, shear strength, and permeability.

II. LITERATURE REVIEW

J R Oluremi, A P Adewuyi, A A Sanni (2015) "Compaction characteristics of oil contaminated Residual Soil" This study examined the effect of oil contamination on the strength properties of lateritic soil. Here the lateritic soil samples were artificially contaminated with the crude oil in the range 0% to 8% of the dry weight of soils and laboratory tests like sieve analysis, Atterberg's limits, compaction, CBR and UCS were done. The result shows that the plastic and liquid limits of the soils decreased as the crude oil content increased. This indicates a potential adverse effect on the soil's plasticity and moisture retention capabilities as contamination intensifies. Maximum Dry Density (MDD) decreased and Optimum Moisture Content (OMC) increased. Also, unconfined compressive strength (UCS) of samples increased with oil content up to 2% and thereafter decreased with further contamination. These alterations suggest a potential shift in the soil's compaction behaviour due to crude oil influence. Interestingly, the unconfined compressive strength (UCS) initially increased with oil content up to 2%, indicating a strengthening effect, but subsequently decreased with further contamination. This nuanced response underscores the complex interplay between oil content and the soil's mechanical properties. The study's findings contribute valuable insights into how crude oil contamination can alter the fundamental strength characteristics of lateritic soil, providing a basis for understanding the soil's behavior under varying levels of hydrocarbon influence.

Araz Salimnezhad, Hossein Soltani Jigheh, Ali Abolhasani Soorki (2020) "Effect of oil contaminated and bioremediation on geotechnical Properties of highly plastic clayey soil" This study discusses the change in properties of oil contaminated plastic clayey soil and effect of bioremediation. Here soil properties like maximum dry density (MDD), optimum moisture content (OMC), unconfined compressive strength (UCS), shear strength, swelling pressure, and coefficient of consolidation on contaminated and bio remediated soil samples were investigated. Bioremediation reduced soil contamination by about 50%. Moreover, in comparison with contaminated soil, bioremediation reduced the MDD, UCS, swelling index, free swelling etc. And also increased OMC, shear strength, cohesion, internal friction angle etc. As a result, oil contamination affected the mechanical properties of soil negatively, but bioremediation improved these properties. In a broader context, oil contamination induced a universal decrease in permeability and strength across all soil samples. These findings underscore the multifaceted and adverse effects of crude oil on soil properties, emphasizing the importance of understanding and mitigating such environmental impacts. Bioremediation emerges as a crucial intervention, successfully reducing soil contamination levels by approximately 50%. A comparative analysis between contaminated and stabilized soil samples resolves significant transformations. Bioremediation leads to a reduction in MDD, UCS, swelling index, and free swelling when compared to the contaminated soil. These decreases suggest an amelioration of soil compaction and swelling tendencies, indicating an overall positive influence on the geotechnical characteristics.

Mashalah Khamehchiyan, Amir Hossein Charkhabi, Majid Tajik (2007) "Effects of Crude oil contamination on geotechnical properties of clayey and sandy soils". This study discusses the effect of crude oil on the geotechnical properties of soil. Various laboratory tests like Atterberg's limits, compaction test, Permeability test etc. were conducted. Here the soil samples were mixed with crude oil in the amount of 0,4,8,12 and 16% by weight of dry weight of dry soil sample. The result shows that the Atterberg's limit decreases with increasing oil contamination in clayey soil, it is due to the nature of water in the clayey minerals. Also, increasing crude oil content in soil sample causes a reduction in maximum dry density and optimum water content. Oil contamination induces a reduction in permeability and strength of all the soil samples. The results unveil notable changes in Atterberg's limits, specifically a decrease with escalating crude oil contamination in clayey soil. This decline can be attributed to the interaction between crude oil and the clayey minerals, influencing the nature of water present in the soil. Moreover, an increase in crude oil content correlates with a reduction in both maximum dry density and optimum water content of the soil samples. This suggests that the introduction of crude oil hampers soil compaction and alters its moisture characteristics. Crucially, oil contamination induces a consistent reduction in permeability and strength across all soil samples. The diminished permeability implies a decrease in the soil's ability to allow fluid flow, while the reduction in strength underscores compromised mechanical properties. These findings collectively emphasize the adverse effects of crude oil on the fundamental geotechnical aspects of soil. Understanding the alterations in Atterberg's limits, compaction characteristics, permeability, and strength provides valuable insights into the challenges posed by oil-contaminated soil. This knowledge is instrumental in developing strategies for remediation and environmental management, ensuring informed decision-making when dealing with soils impacted by crude oil contamination.

Opeyeni E Oluwatuyi, Oluwapelumi O Ojuri, Arman Khoshghalb (2020) "Cement - Lime stabilization of crude oil contaminated kaolin clay". This study examines the effect of cement-lime stabilization on the geotechnical properties of crude oil contaminated kaolin clay. Lime and cement were mixed and added to the crude oil contaminated kaolin clay at different percentages (5%, 10%, 15%, and 20%). Parameters like consistency limits, unconfined compressive strength (UCS), and direct shear of the untreated and stabilized soil is investigated. The result shows that increasing cement -lime content increases the UCS values and the compression indices from consolidation test decreased. The study shows the effectiveness of cement-lime mix in stabilizing the contaminated kaolin clay and the possible use of stabilized contaminated kaolin clay as an alternative construction material. The results unveil a positive correlation between increasing cement-lime content and enhanced UCS values, signifying improved strength characteristics in the stabilized soil. Additionally, the consolidation tests reveal a reduction in compression indices, indicating decreased compressibility and improved load-bearing capacity. These findings collectively affirm the effectiveness of cement-lime mixtures in stabilizing crude oil-contaminated kaolin clay, presenting a promising avenue for the use of stabilized contaminated clay as an alternative construction material. This dual benefit of remediating contaminated soil while repurposing it for construction aligns with sustainable practices, demonstrating the potential of this stabilization technique to contribute to environmentally conscious geotechnical solutions.

III. MATERIALS AND METHODOLOGY

PART – I MATERIALS

A. Laterite Soil

Laterite soil is a unique type of soil characterized by its distinctive red color, attributed to the high concentration of iron and aluminum oxides. This soil type is commonly found in tropical and subtropical regions, thriving in warm climates with abundant rainfall. For this study the soil sample is collected from Ambalamugal region in Ernakulam district. It was collected from a depth of 50 cm as underground pipes are usually given in 50 cm depth.

Table 1: Geotechnical Properties of soil used

Properties	Value
Specific gravity	2.35
Liquid limit (%)	25%
Plastic limit (%)	30%
Plasticity index (%)	5%
Unconfined compressive strength (kN /m2)	184.5
Optimum moisture content (%)	16
Coefficient of permeability (cm/s)	$9.46x10^{-3}$

B. Petrol

Petrol, also known as gasoline, is a vital and widely used liquid fuel in internal combustion engines. It is derived from crude oil through a refining process. Composed of hydrocarbons, petrol is a mixture of various liquid compounds with different boiling points. We collected the petrol for contaminating the soil artificially from the refinery retail outlet, we collected an amount of 4%, 8%, 12% & 16% to the dry weight of the sample for contaminating.

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PART – II METHODOLOGY

A. Site Scouting

The site selected for this study is Ambalamugal region in Ernakulam district. The soil in this locality is contaminated due to the underground pipe leakage from the oil refinery situated here. This caused pollution in water in nearby wells and also the soil in this locality.

B. Material Procurement

Soil sample was collected from the decided site up to a depth of 50 cm. Generally, the underground pipes of oil refineries are provided in 50 cm depth, so the soil is collected from this depth. It was kept for air drying in open air.

C. Lab Analysis in Raw and Contaminated Soils

To evaluate the changes in geotechnical properties several laboratory tests like Atterberg's limit, Specific gravity, California Bearing Ratio (CBR), Standard proctor test and Permeability tests were done in both raw soil and artificially contaminated soil by 4%, 8%, 12% and 16%. Similarly, same tests were done for the stabilized soil and result is been analyzed.

D. Result Interpretation

After the lab analysis we have to analyze the results obtained and then compare it with the range, the contaminated soil results are compared with the raw soil to find the changes in the properties of soil before and after contamination. Similarly, comparison for stabilized soil results is also to be done to know the property changes.

IV. LABORATORY ANALYSIS

A. Specific Gravity

Specific gravity test was conducted on both raw soil and contaminated soil. figuring out the weight ratio between a specific volume of soil and a volume of water of same weight. The void ratio, porosity, saturation level, critical hydraulic gradient, and other parameters are determined using the specific gravity of the soil particle.

B. Compaction

The natural and contaminated samples underwent standard Proctor tests with 4,8,12 and 16%. It was carried out to determine the highest dry density and ideal soil moisture content. In this test, the pore fluid is a mixture of water and oil. Therefore, when determining the water content, we also need to consider the oil's evaporation while it's in the oven.

C. Unconfined Compressive Strength (UCS) Test

Both uncontaminated and contaminated soil were subjected to unconfined compressive strength testing. The ideal moisture content and maximum dry density were used for the experiments.

D. Permeability test

Permeability test were conducted in both contaminated and uncontaminated soil samples. It was done using permeameter. The rate of settlement of clay layer and the shear strength of soil also depend upon the permeability of soils.

E. California Bearing Ratio (CBR) Test

Tests for the California Bearing Ratio (CBR) were done on both uncontaminated and contaminated soil. It was completed with a CBR device. This device measures the soil's penetration and force when it is compacted at the ideal moisture content. The graph was used to compute the CBR value.

V. RESULTS AND DISCUSSIONS

A. Specific Gravity

The results of the specific gravity are shown in the Fig.1. It is observed the specific gravity value gets reduced by increasing oil percentage. Table.2 shows the value obtained for various soil samples.

Table.2 Effect of petrol specific gravity

Oil Percentage (%)	Specific gravity
0	2.35
4	2.17
8	2.16
12	2.14
16	2.12

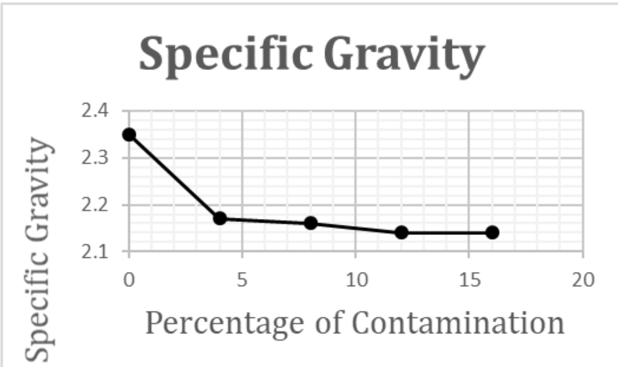

Fig.1 Effect of petrol on specific gravity

B. Compaction

Table.3 displays the compaction test results. As seen in Fig. 2, the compaction curves for both natural and polluted soils are plotted.

Table.3 Effect of petrol on OMC and MDD

Oil Percentage (%)	OMC	MDD
0	16	1.8
4	14	1.71
8	12	1.706
12	10	1.69
16	8	1.67

The value of optimum moisture content and maximum dry density is reduced with increasing contamination.

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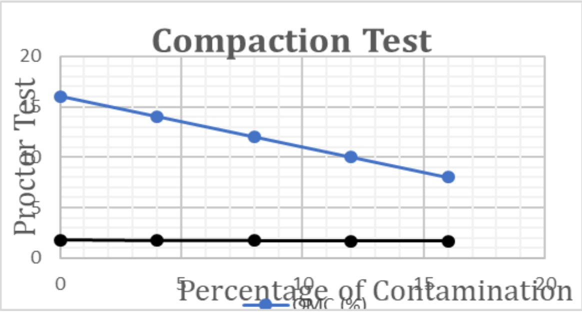

Fig.2 Effect of petrol on OMC and MDD

Additionally, oil can fill in soil pore spaces, minimizing the quantity of water needed to achieve maximum compaction and consequently lowering OMC.

C. Unconfined Compressive Strength (UCS) Test

Results obtained for unconfined compressive strength of both contaminated and uncontaminated soil sample as shown in Table.4

Table.4 Effect of petrol on unconfined compressive strength test

Oil Percentage (%)	Unconfined compressive strength (kN/m²)
0	184.5
4	119
8	162.5
12	158
16	126

Fig. 3 shows the unconfined strength of both uncontaminated and contaminated soil.

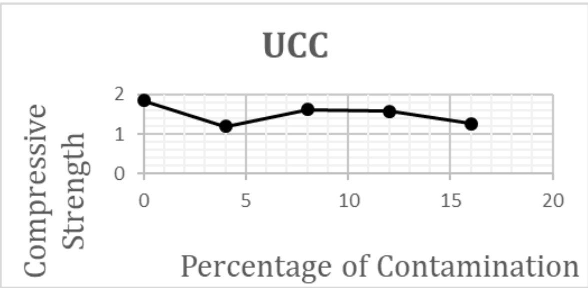

Fig.3 Effect of petrol on unconfined compressive strength

The unconfined compressive strength decreases as the oil content rises. This might be because of the coating, which lessens the friction between the soil particles and weakens their binding, decreasing strength, or it could be because of the pore pressure. Additionally, analysis reveals that the least strength is shown by 4% contamination. When it reaches 8%, it increases slightly before beginning to decline once more. It might be caused by variations in the morphological properties of the soil.

D. Permeability

The coefficient of permeability values falls as the percentage of oil pollution rises. This decrease is shown in Table 4.

Table.5 Effect of petrol on unconfined compressive strength test

Oil Percentage (%)	Coefficient of permeability (Cm/s)
0	9.46×10^{-3}
4	9.46×10^{-3}
8	7.21×10^{-3}
12	6.66×10^{-3}
16	5.82×10^{-3}

Because petrol may have filled up some of the vacuum spaces in the soil, the ease with which water moves through the soil has decreased, resulting in a reduction in the soil's permeability.

E. California Bearing Ratio (CBR) Test

The CBR value of the soil also decreases with increase in oil content. The values obtained for various oil percent is given in Table.5

Table.5 Effect of petrol on unconfined compressive strength test

Oil Percentage (%)	CBR (%)
0	9.46×10^{-3}
4	9.46×10^{-3}
8	7.21×10^{-3}
12	6.66×10^{-3}
16	5.82×10^{-3}

Fig.4 shows the CBR value of raw soil and contaminated soil.

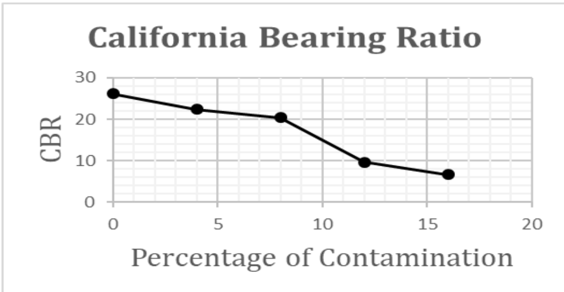

Fig.4 Effect of petrol on CBR values

This decrease in CBR value could be the result of lubrication, which makes soil particles glide over one another more easily and reduces the soil's capacity to withstand pressure.

VI. CONCLUSION

As observed from the results of this study, following conclusions can be drawn:

• The specific gravity of the soil decreased with increasing contamination.

• The value of Atterberg's limits of raw soil is obtained as liquid limit as 30% and plastic limit as 25%. But, for petrol contaminated soil the results are not obtained, it may be due to

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the difference in the morphological characteristics of studied soil.

• Unconfined compressive strength is decreased with increase in oil content, this may be due to the coating, which reduces the friction between soil and weakening their bonding which reduces the strength and also it may be due to the pore pressure.

• Maximum dry density and optimum moisture content reduced with increase in oil percentage, it may be due to the soil particles which reducing their ability to pack together during compaction, which results in lower MDD. And oil can occupy pore spaces in the soil, reducing the amount of water can be added to achieve maximum compaction, hence lowering OMC.

• CBR of the soil also decreases with increase in oil content, because of the lubrication causes the soil particles to slip away and this reduces its ability to withstand pressure.

• Oil contamination reduces the permeability of soil, it may be due to the petrol may occupy in the pores and reduces the flow of water through them.

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