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Contamination of Fine Grained Soils by Oil Spillage: Effects and Remediation by Electrochemical Technique

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Abstract: *The effects of oil contamination on the geotechnical properties of clayey soil and the effectiveness of electrochemical method as a remediation technique for oil contaminated clayey soil are investigated in this study. Diesel engine oil is mixed with locally obtained clayey soils and the changes in the engineering and index properties of soil are determined. It is proposed to design and fabricate an electrochemical cell, 25cm square, made of acrylic sheets. The electrodes are be fabricated using an inert material such as graphite and a DC power supply is used to provide the necessary potential across the electrodes. The contaminated soil was treated under the current generated by a constant potential. The changes in soil properties such as pH, oil content, Atterberg limits and shear strength with the addition of oil are extensively investigated.*

Keywords: *Clayey soil, Diesel engine oil, graphite electrodes, D C supply, Acrylic box*

1. INTRODUCTION

Oil contamination poses a severe threat to the environment and is considered as a hazardous pollutant to soil. Numerous studies over the past have proven that, contamination with oil products causes significant changes in soil properties, which make them unsuitable for construction purposes. Chances of oil pollution occur in terrestrial and marine environments, especially during exploration, transportation and processing of oil. Some of the geotechnical problems associated with construction over oil contaminated sites include excessive settlement of tanks and breakage of pipelines. In recent years many soil remediation technologies have been studied and practiced all over the world. The techniques using for remediation depend on type of soil, contaminant and economy. In the case of fine grained soil contaminated by oil products, conventional remediation techniques like chemical oxidation, soil washing etc. are not practical in all times. Electrochemical technologies prove to be an effective remedy to remove pollutants from the soil. This method is an advanced chemical oxidation process which can be applied in a very effective way for water and soil treatment from wastes which cannot be easily decomposed by biological processes. These methods are based on using electrochemical and electro kinetic processes occurred in the soil under the electric current generated by a constant potential. The principles of electrochemical treatment method involve applying a low direct current or a low potential gradient to electrodes inserted in the low permeable soils that cannot readily drained. The use of this technique involves an approach with minimum disturbance to the surface while treating subsurface contaminants and improving the engineering characteristics of subsurface soils (Mosavat et al. 2012). Higher efficiency, environmental safety and applicability to a wide range of contaminants are main advantages of this technology. Restoration of contaminated site to the original site, this is the most important aspect of soil remediation. However this is not fully practical in field, we can remove the contaminant to a level, safe to human and environment and also can restore the properties of soil not fully but some extend (Claudio Cameselle et al.,2013). Electrochemical treatment is comparatively a new technology and being investigated for different types of contaminants as an insitu soil remediation and treatment method.

2. OBJECTIVES & SCOPE OF THE WORK

The primary objectives of the study are:

- To investigate the effect of soil contamination by diesel engine oil on the geotechnical properties of the clayey soil

- To check the effectiveness of electro kinetic remediation for remediation of oil contaminated clayey soil
- To study the changes in the composition, physico-chemical and engineering characteristics of clayey soils treated using electro kinetic remediation

The scope of the work done is as follows

- Engineering & index properties of uncontaminated soil
- Effects of varrying percentage of diesel engine oil on the strength characteristics of soil
- Effects of parameters such as pH , soil moisture content etc..in a rectangular electrochemical cell of 25 x 25 x 25 cm

3. MATERIALS & METHODOLOGY

The materials used for conducting the experiments are explained in details as below.

3.1. Soil

The soil used for experimental work has been collected from Nadakkavu, Calicut area. The samples (fig 1) were obtained from the depth of 20 m below the existing ground elevation. Wet soil sample (fig 2) is kept on a water dish for 2 weeks to check for the presence of oil. The clay is classified as CH according to the IS Soil Classification System

Figure1. *Air dried Soil samples*

Figure2. *Wet soil kept in water*

3.2. Oil

To contaminate the soil artificially, the Mak Auto XL 15W-40 diesel engine oil (Bharath Petroleum, Diesel Oil) was used. The properties of diesel oil are shown in Table1

Table1. *Physical Properties of Diesel Oil*

Characteristics	IS 1448	Typical Figures 15W-40
Appearance	--	Clear & Bright
Colour, Visual Observation	--	Brown
Density @15°C, gm/ml	P:16	0.8896
K.V at 100° C, cSt	P:25	14.20
Copper Corrosion@ 100° C for 3 hrs	P:15	1a
Flash Point, (COC), °C	P:69	232
Viscosity Index	P:56	147
Pour Point, °C	P:10	-24

3.3. Electrochemical Cell

In order to conduct the experimental investigation, of electrochemical soil decontamination from oil a three - dimensional experimental setup was developed and several laboratory tests were performed. Experimental setup consists of a rectangular reactor 25cm long, 25 cm wide and 25 cm high, made up of 1cm thick transparent acrylic sheets, a pair of graphite electrodes, a stabilized DC power supply (providing 12V and 0.5A). Contaminated soil was tested under a constant voltage of 12 V (specific voltage 0.6 V/cm, since centre to centre distance between electrodes is 20cm).

Figure3. *Acrylic box(25cmx25cmx25cm)*

Figure4. *A pair of graphite electrodes*

Figure5. *Electrochemical cell with D.C power supply*

3.4. Experimental Investigation Performed

In first phase, the physical properties of soil such as, Atterberg's limits, specific gravity, particle size distribution, differential free swell, maximum dry density, optimum moisture content values are determined.

4. RESULTS & DISCUSSIONS

The research has just started and the major results obtained is highlighted in Table 2.

Table.2 *Results obtained from the tests conducted.*

NAME OF TEST	TEST RESULT
Specific gravity	2.46
Combined sieve and sedimentation analysis	D10 = 0.002mm D30 = 0.1mm D60 = 0.3 mm Cu = 150 Cc = 16.67
Atterberg limits Liquid limit Plastic limit Plasticity index **UCC** **Consolidation**	 35.5% 16.32% 19.18% q_u=0.65 kg/cm^2 1^0compression ratio=0.85 2^0compression ratio=0.19
Free swell index	0%
Modified proctor test OMC Dry density	 16.8% 1.76 g/cc

4.1. Liquid Limit

IS: 2720(PART 5) -1985 specifies test procedure for conducting liquid limit. The liquid is the water content at which the soil changes from liquid state to plastic state..

Liquid limit = 35. 5%

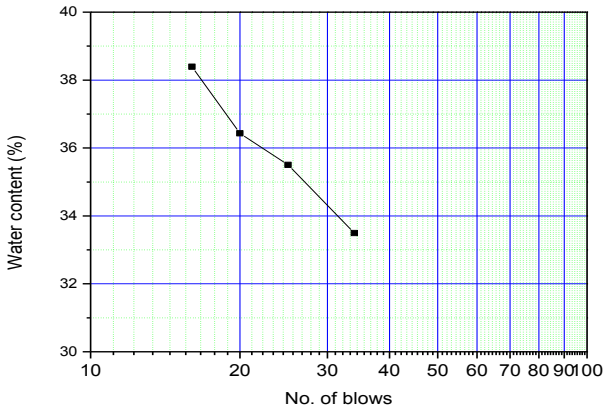

Figure6. *Graph of liquid limit*

4.2. Plastic Limit

The test procedure is described in IS: 2720(PART 5) -1985. The plastic limit is the water content below which the soil stops behaving as aplastic material. Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit;

Ip = wL – wP

Plastic limit = 16.32%

Plasticity index = 19.18%

So based on soil classification related to plasticity index, Ip > 17 is highly plastic soil

4.3. Specific gravity of the soil

IS: 2720 (Part III/Sec 1) – 1980 contains the test procedure for finding specific gravity of soil. The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water.

Specific gravity obtained by pyconometer test = 2.46

4.4. Particle size distribution

IS :2720 (Part 4) – 1985 specifies test procedure for determining particle size distribution .it is found out by two methods, first is sieve analysis which is done for coarse grained soils only and the other method is sedimentation analysis used for fine grained soil sample.

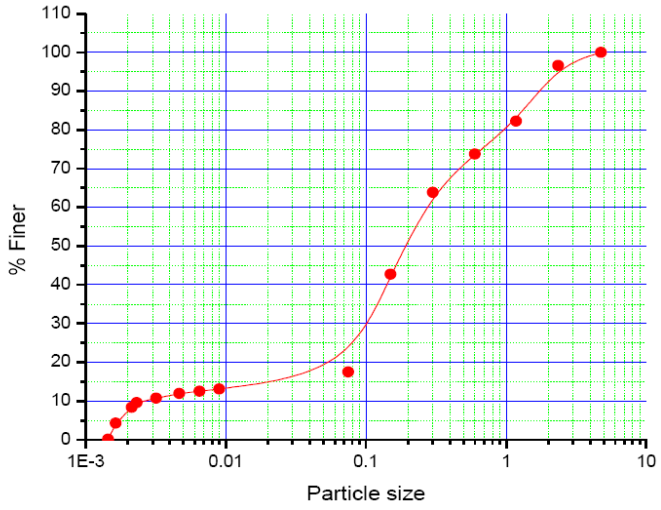

Figure7. *Combined sieve and seimentation analysis curve*

D10 = 0.002mm D30 = 0.1mm D60 = 0.3 mm Cu = 150 Cc = 16.67

4.5. Free Swell Index Test

As per IS: 2720 (Part 40) - 1977 specifies test procedure. Free swell or differential free swell also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water.

Free swell index = $\frac{Vd - Vk}{Vk}$x100 =0%

Where,

Vd = volume of soil specimen read from the graduate cylinder containing distilled water.

Vk = volume of soil specimen read from the graduate cylinder containing kerosene

4.6. Light Compaction Test

IS: 2720 (Part 7) - 1983 explains the procedure for light Compaction. The degree of compaction of a given soil is measured in terms of its dry density.

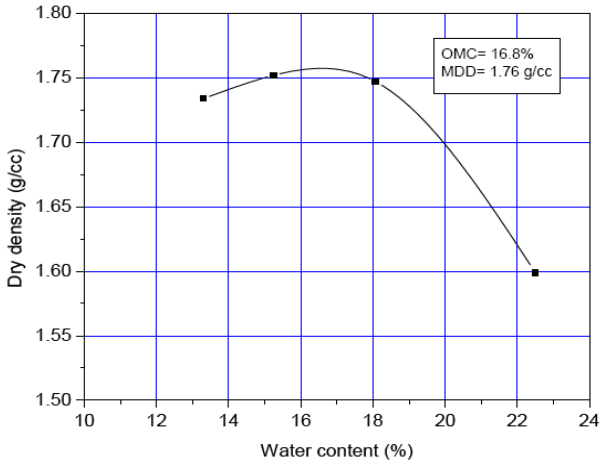

Figure8. *Dry density Vs Water content curve*

Dry density = $\frac{\gamma_b}{1+\omega}$

Where, γ_b = bulk density

ω = water content

No of layers = 3, No of blows = 25, Hammer weight = 2.6 Kg

Hammer drop = 310 mm, Mould volume = 1000cc

Optimum moisture content = 16.8% and Maximum dry density =1.76 g/cc

4.7. Unconfined Compression Test

In unconfined compression test a cylindrical specimen is tested under the axial compressive stress only without any lateral stress.UCC is a measure of a cohesive soil.

unconfined compression strength q_u = 0.65 kg/cm^2

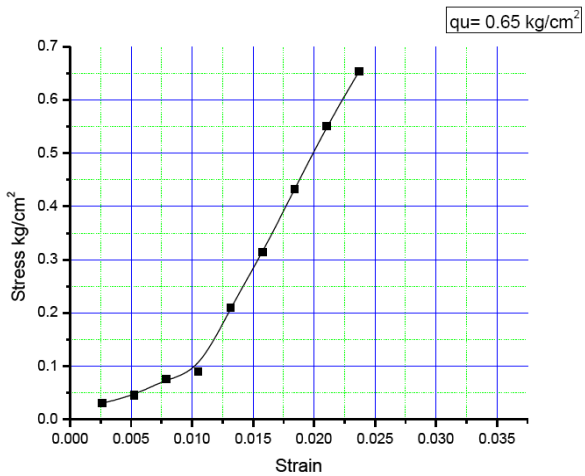

Figure9 .*Stress -Strain curve*

4.8. Consolidation Test

The consolidation test is conducted in a laboratory to study the compressibility of a soil. This test is essentially required to estimate total settlement of foundation, time required for total settlement ,time required for any percentage of total settlement and pre-consolidation pressure. The results obtained from dial gauge Vs log t graph is as follows

1^0compression ratio=0.85

2^0compression ratio=0.19

5. CONCLUSIONS

1. Study of effecet of oil contamination on marine clays is not well evaluated in India. This study will be benefitted to engineers before going to any construction in an oil field.
2. Electrochemical Remediation Technique is an emerging technology and its application has a very wide range
3. Electrochemical technologies prove to be an effective remedy to remove pollutants from the soil. This method is an advanced chemical oxidation process which can be applied in a very effective way for water and soil treatment from wastes which cannot be easily decomposed by biological processes.
4. These methods are based on using electrochemical and electro kinetic processes occurred in the soil under the electric current generated by a constant potential

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