STUDY OF GEOTECHNICAL PROPERTIES OF SOIL CONTAMINATED WITH OIL

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SUBMITTED BY

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CANDIDATE'S DECLARATION

I do hereby certify that the work presented in the report entitled "**STUDY OF GEOTECHNICAL PROPERTIES OF SOIL CONTAMINATED WITH OIL**" in the partial fulfillment of the requirement for the award of the degree of "Master of Technology" in Geotechnical Engineering submitted in the Department of Civil Engineering, Delhi Technological University, Delhi is an authentic record of my own work carried out under the supervision of Prof. A.K Gupta, Department of Civil Engineering. The work is original and not copied from any other source without proper citation. The work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

Place: Delhi (RITU DAHIYA)
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CERTIFICATE

I hereby certify that the Project Dissertation titled "**STUDY OF GEOTECHNICAL PROPERTIES OF SOIL CONTAMINATED WITH OIL"** which is submitted by **RITU DAHIYA (2K17/GTE/15)**Civil Engineering Department**,** Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi

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ABSTRACT

Soil contamination is brought about by the human made synthetic substances or other modification in the normal soil condition. It is commonly brought about by agricultural synthetics, industrial exercises, or inappropriate transfer of waste. Examples of various contaminants of soil are oil hydrocarbon, industrial waste, pesticides, industrial solvents, and other significant metals. Any movement of substances that prompts numerous type of soil pollution (compaction, erosion, and so forth.) may in a round about way compound the contaminating impacts in that soil remediation becomes progressively difficult. Soil Remediation done on these soil relies on the degree of soil contamination and this can bestbe considered by checking the impact of contamination on different properties of soil. Oil spillage insoil can happen because of numerous reasons. This results in soil layer development blended with oil. Spilled oil impacts and changes the different properties of soil. Soil was mixed with different percentages of two types of oil i.e. Diesel oil and motor oil. The result of permeability test done on such soil contaminated with oil resulted in lower permeability value and for motor oil the decrease was more than that for diesel contaminated soil. The effect of time was also studied on the permeability of soil contaminated with oil. After four days of continuous flow through the sample it was seen that value of permeability further decreased due to reason of accumulation of finer particles on the upper portion of sample which decreased the flow and due to gas molecules being accumulated in the sample which were mixed in the water.

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CHAPTER 1

INTRODUCTION

1.1 Background

Soil contamination is brought about by nearness of man made synthetic materials or different adjustments in the original soil condition . It is brought about by industrial synthetic substances, agricultural exercises and ill advised transfer of waste . The most regularly included synthetics are solvents, lead, oil hydrocarbons, pesticides and other substantial metals . Oil spillage happens because of war, mining, transportation of oil, mishaps, stockpiling and disastrous events . Oil in the wake of discharging into soil dwells in its pore space, changing the conduct of the soil . Oil spillage into soil results in pollution and there is a requirement for bioremediation . An essential advance for doing bioremediation is a comprehension on how the geotechnical properties of the soil are influenced by the oil leakage .

Soil remediation to be done on such soils relies on the degree of soil contamination and this can be found out by checking the impactof oil on geotechnical properties of soil . Bioremediation of soils contaminated with unrefined petroleum includes hydrocarbon eating microscopic organisms utilizing oil which are present in water (Kogbara, 2008) . At the point when water moves to an at first dry tainted soil, the rate of oil consumption by the microscopic organisms increments as it benefits from supplements that are present in the water . It is in this manner appropriate to know hydraulic conductivity of water in the soil contaminted with oil .

Treatment methods for the contaminated soil included bioremediation, soil washing and incineration . Soil contamination is affected by the type of contaminant as well as the soil's properties. Hence, an adequate understanding of the geotechnical characteristics of soils contaminated byoil is imperative. Sand and clay mixtures are used as soil liners for landfill. When clay is scarce, a mixture of sand and clay is used. Soil mixtures are commonly those of sand, kaolinite and bentonite or sand and bentonite. When sand is mixed with natural clay and bentonite, the mixture can be used as a water barrier in landfills . Evaluation of the effect of oil on contaminated soil using crude oil or its oilproduct as its representative was important as it could aid in decisions on using the material for alternative purposes like construction of slabs and support of structures. Bioremediation of crude oil contaminated soils involves hydrocarbon utilising bacteria degrading oil in the presence of water (Kogbara, 2008). When water moves to an initially dry contaminated soil, the rate of oil degradation by the bacteria increases as it feeds on nutrients that dissolve in water. It is therefore pertinent to determine the hydraulic conductivity of water in the oil contaminated soil, in order to suggest area of contaminated soil with increased bacterial degradation of oil. Incineration is an alternative to bioremediation (Khamehchiyan et al, 2007); in this case, the soil is excavated and burnt in an incinerator.

Different properties which are affected by the oil contamination are as follows:

1. Atterberg Limits
2. Coefficient of Permeability
3. Shear Characteristics
4. Max dry density and OMC of soil

The Purpose of this research is-

1. To perform the Compaction test to determine γ_d and OMC of soil.
2. To draw the Particle size analysis curve of soil.

3. To investigate the Atterbergs'limit of uncontaminated soil.
4. To determine the hydraulic characteristics of soil using different percentage of oil contamination.
5. To determine the effect of time on change of hydraulic characteristics of soil.

CHAPTER 2

LITERATURE REVIEW

"The way where oil influences a soil would decide the methodology of dealing with the contaminated soil with the point of placing it into different use". "Oil contamination has transformed into an important issue, and there is prerequisite for remediation of the soil contaminated with oil. A comprehension on how oil influences the geotechnical properties of soil is an essential advance in planning a powerful remediation framework.

Khosravi et. al. stated that, The varieties in discoveries on impact of oil on the geotechnical properties of soil are because of variety in oil and soil mineralogy . The examination on different properties of soil contaminated with oils is a significant zone of research . Hardly any investigations are accessible around there and this section audits past examinations .

Benson and Daniel (1990)

Hydraulic conductivity diminished in light of the fact that delicate soil clods were available in the polluted soil. The delicate soil lumps were delicate and effectively compressible when the soil were compacted, bringing about decreased hydraulic conductivity. For the most part as max dry density and OMC diminished in the soil, the hydraulic conductivity diminished.

Puri et al. (1994)

Maximum dry unit weight for a given compactive effort happened at around a similar level of saturation not depending on whether oil or water was utilized as the pore liquid. The shear quality parameters of sand are unfavorably influenced by oil contamination. The hydraulic conductivity of water is subject to the consistency of the contaminant oil when different factors, for example, initial density of sand, temperature, technique for test arrangement and permeant continue as before.

Al-Sanad et al. (1995)

He examined the impact of oil contamination on sand of poor gradation. The soil was blended with 2, 4, and 6% of oil substance by dry weight and compacted with 4.5 kilogram rammer. Compaction done using 4.5 kg rammer gives higher soil densification than that of 2.5 kilogram of test rammer. There was a decline in the γ_d as the oil substance varied from 2 to 6% because of lubricating effect of oil on soil. γ_d increased as the oil substance varied from 0 to 2% on the grounds that the oil provided cohesion to soil at 2%. At the point when oil substance was above 2%, the oil gave less cohesion to the soil, bringing about decrease in γ_d.

Evans and Fang (1988)

They gave a technique to decide shear strength and hydraulic conductivity of soil contaminated with oil (or of soil with permeating contaminants mixed with water). It requires technique and equipment unique in relation to that required for ordinary triaxial strength and permeability testing. Strategy and hardware alterations are required to obtain saturation. Gradients of permeants utilized are greater than normally encountered in natural soil conditions. This outcomes in high effective pressure and differential consolidation.

Ratnaweera and Meegoda (2006)

A number of UCS test was done on 3 fine grained soil with 3 chemicals and a CD triaxial test wasdone on granular soil with one substance. Changing measurements of 3substances - 1-propanol, acetone and glycerol were blended with water to set up the required pore liquids for the 3 fine grained soil. Glycerol was used with the granular soil. UC tests demonstrated that stress-strain conduct and shear strength diminished with increasing contamination of clayey soil; there was just a minimal decrease for the clayey silt. For granular soil, residual shear values when plotted against its critical void ratio, a group of curves that could be distinguished by their pore liquid viscosities was acquired. For a given value critical void ratio, the residual shear strength qualities diminished as pore liquid consistency expanded.

Khamehchiyan et al. (2007)

They expressed that oil caused a decrease in the measure of water that encompassed sand and clay particles. The main contact of the soil was not with the water but was with the oil. Soil contaminated with oil deforms as plastic or liquid within the availability of water. This was not much when oil substance expanded, subsequently, plastic limit and liquid limit decreased.

Ahmed et al. (2009)

Consolidation tests were completed on the readied sand samples contaminated with oil. The impacts of oil rate on sudden collapse settlementand the modulus of deformation are considered and displayed. The utilized sand was siliceous sand of Egyptian deserts. Sand was tried for 3 diverse relative densities; 20%, 50% and 80%. Kerosene, used oil and solar oil were used intesting which have different values of viscosities. For different oil type, the tried examples were set up by blending clean sand with four diverse oil rates by weight of the dry sand; 2%, 5%, 10% and 15%. As the rates of a similar oil gets higher sudden collapse settlement diminishes. For unadulterated sand and sand oil blends, sudden collapse settlement diminishes with increase of value of sand relative densities. Increment of oil content, for the various oils utilized shows decrease in value of soil modulus of elasticity (E_s) for various sand relative densities.

Rahman et al. (2010)

They examined the impact of contamination of oil on the geotechnical properties of basaltic soil. The soil were of silty and loam textures. XRD examination showed that the soil had quartz, clay minerals and feldspar of kaolinite and contained little measure of goethite and gibbsite (Gibbsite contains aluminum metal while goethite contains iron). Atterberg's Limits were resolved for different percentage of oil contamination as per BS 1377 (1990). It demonstrates decrease inplastic limit and liquid limit as oil content increases. This was on the grounds that oil consumed more space without adding more union to the soil.

Ijimdiya (2012)

They researched the impact of contamination of oil on grain size distribution. The soil utilized was reddish dark colored and gotten from a borrow pit at Shika, Zaria, Nigeria. The soil had a lot of kaolinite mineral and 87% silt. Different percentage of oil (1%, 2%, 3%, 4%, 5% and 6%) were blended with the dry soil. The soil contaminated with oil was gone through 2.4 to 0.075 mm sieve sizes and weight of soil on each sieve was calculated. The particle size analysis curve moved from fine to coarse as percentage of oil increased. The investigation demonstrated that an expansion in oil percentage moved the grain size distribution curve from fine to coarse.

Khosravi et al. (2013)

The study considered the impact of contamination of oil on Atterberg's limit by mixing a low plastic clay containing kaolinite with oil substance of 2, 4, 6, 12 and 16% by dry load of the soil. Plasticity index and liquid water content of soil expanded as the oil substance expanded in the soil from 0 to 12%. In any case, there was a decrease in the previously mentioned parameters from 12 to 16% oil percentage on the grounds that the oil diminished the soil cohesion.

Murray R&D Technical Report P1-398/TR/2

The procedure is consistent with that adopted in the Environment Agency R&D Contract Project No. P1-3398 'Validation of the Accelerated Permeability Test as an Alternative to the British Standard Triaxial Permeability Test'. The basic test does not include measurements to assess the incremental volume and moisture content (or density) changes of the specimen during the test, or determination of the degree of saturation from B value determinations. Calculate the coefficient of permeability in the vertical direction, k_v (in m/s), from the equation

$$k_v = \frac{1.63 \times q \times L \times R_t \times 10^{-4}}{A\left(p_1 - p_2\right) - p_e}$$

here,

q = the mean rate of flow through the soil specimen (in mL/min),

L is the length of the specimen prior to testing (in mm)

(p_1-p_2) is the pressure difference between the pressure applied to the top and base pressure lines (in kPa)

p_e is the pressure loss in the system (in kPa) for the rate of flow q, obtained from the calibration graph.

R_t is the temperature correction factor for the viscosity of water.

Summary of Literature Review

1. The literature review showed that oil contamination caused reduction of fine aggregate as evident in the shifting of the aggregate size distribution curve from finer to coarser.
2. The Atterberg's limits increased or decreased depending on the kind of soil that was contaminated with oil.
3. Max γ_d andOMC increased or decreased depending on the kind of soil that was contaminated with oil.
4. The hydraulic conductivity of soils contaminated with oil decreased.

CHAPTER 3

MATERIAL AND METHODS

3.1 Material and Equipments used

The different methods and materials used to fulfill the objectives of this research work .The material and equipment used are as follows.

The soil that is used for the work is taken from DTU ground which is near the main gate. There are two types oil used for this research work which are as follows:

1. Diesel oil
2. Motor oil

3.2 Properties of different oil used

Properties	**Diesel**	**Motor Oil**
Density (kg/m^3)	820	861
Viscosity (m^2/s)	2.87×10^{-6}	19.8×10^{-6}
Final boiling point (^{o}C)	349.8	370

3.3 Classification of Soil

Classification of soil is **CL-ML**. The soil is collected from DTU grounds from a depth of .6 m. A sample of this soil was enclosed by plastic sheet for water content determination which was secured with tape to not to lose the water content which was then tried forthe normal water content. The normal water content of soil was 17.46%. The **CL-ML** soil characterized by Indian Soil Classification System (IS 1498(1970)) with LL =

25.51% and plastic limit 19.45% was taken from DTU Campus which went through 4.75 mm IS sieve. The soil ought to be free from grass roots and other natural material and it was dried in oven for 24 hours before performing any tests.

As per Casagrande's plasticity chart following calculation was done to reach at CL-ML classification of soil.

$$PI = .73\ (LL-20)$$
$$= .73\ (25.51-20) = 4.022$$

As the plasticity index comes out to be between 4%-7% soil is classified as CL-ML.

3.4 ExperimentsPerformed

3.4.1 GrainSizeAnalysis

The Grain Size Analysis was done in accordance with IS: 2720 (Part 4) – 1985 (Reaffirmed-2006) to determine the particle size distribution of soil. 115 grams sample was taken for sieve analysis. The sample was first dried in oven at 105^0C temperature. A solution was prepared with sodium hexameta phosphate (33grams) and sodium carbonate (7 grams). 115 grams of soil was then added in this solution and stirred for 10 mins. This solution was kept overnight to break the lumps of soil.

The soil was then sieved through 75 micron IS sieve and the weight retained on sieve is collected in a dish and dried in oven. Dry sieve analysis was done for this sample which retained on 75 micron sieve. The material passing through IS sieve 75 micron is used for doing hydrometer analysis. Observation table of both hydrometer analysis and dry sieve analysis is given in appendix. Following is the result of sieve analysis.

Table 1 Percentage of different types of soil

Type of soil	Percentage
Gravel	2
Sand	27
Silt	53
Clay	18

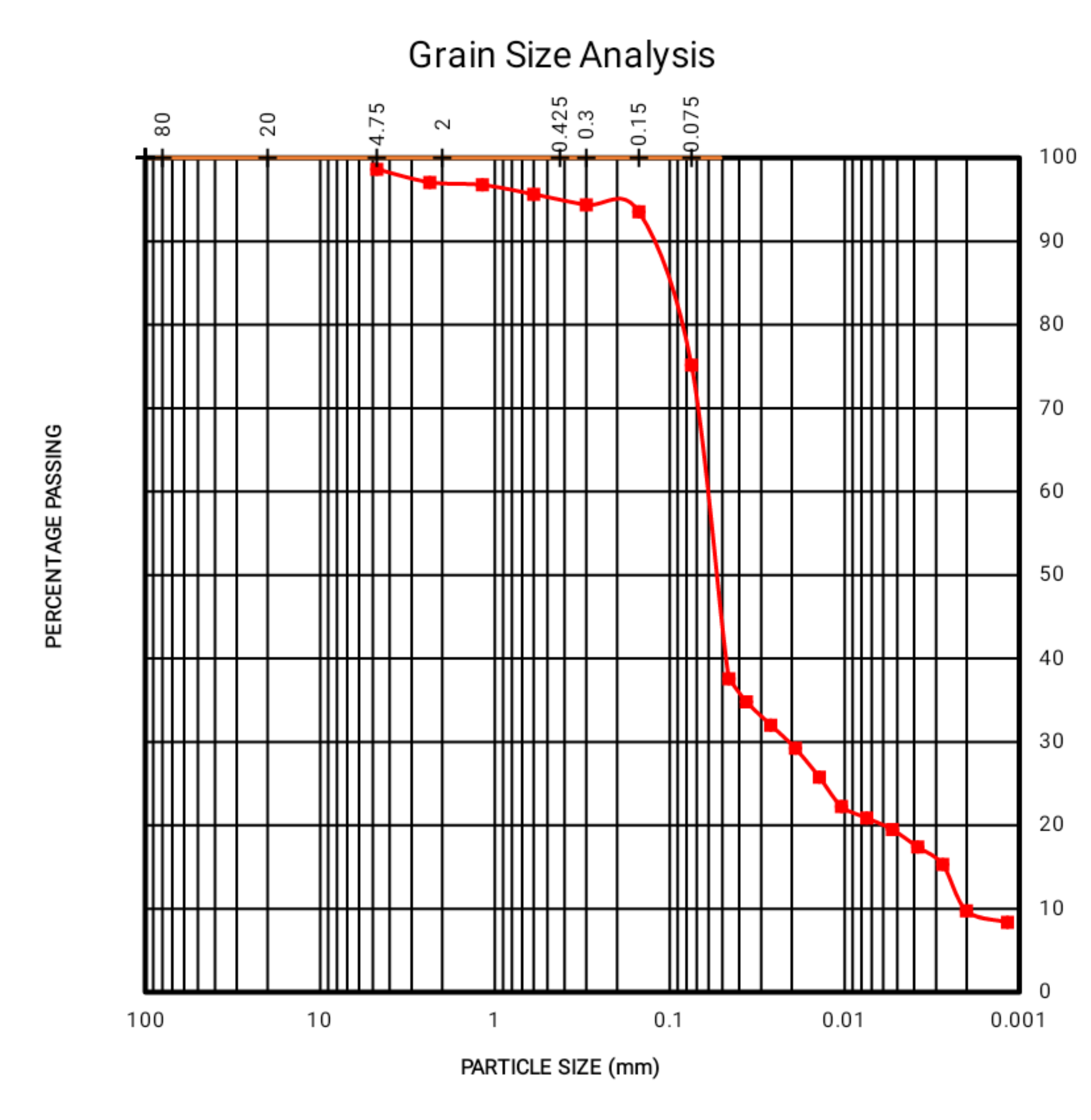

Fig. 3.1 - Grain Size Analysiscurve of soil

Fig. 3.2 - Hydrometer Analysis of soil

3.4.2 Consistency Limits

3.4.2.1 Plastic Limit test

Thread rolling Method was done in accordance with IS: 2720 (Part 5) – 1985 (Reaffirmed 2006) to determine the Plastic limit of the soil. In this method the water content at which soil just crumbles when rolled into a dia. of 3 mm were noted. The rate of rolling was between 60 to 90 strokes for every min. The plastic limit observed is 19.45%.

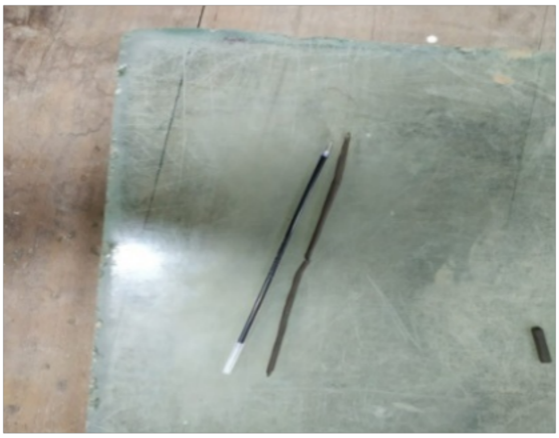

Fig. 3.3 - Plastic limit test

3.4.2.2 Liquid Limit test

Casagrande method is used to determine the Liquid limit of soil samples in accordance with IS: 2720 (Part 5) – 1985 (Reaffirmed 2006).

250 gm of soil passing through 425µ sieve is taken, enough water was added and soil was mixed for approx 3 minutes. This soil was put in Casagrande cup and it is ensured that height of sample put in cup is 1 mm at its thickest, then the soil pat is struck off with flat spatula and was cut by a groove of standard dimension (11 mm wide top, 2 mm bottom, and 8 mm deep). The cup is lifted and dropped by turning crank at a rate of approx. 2 revolutions per sec. No. of blows required for the soil to flow together by a distance of 2 mm is noted. 4 samples of soil were tested and a plot of water content vs. $Log_{10}N$ is plotted and water content corresponding to 25 no. of blows were noted. The liquid limit observed is 25.51%.

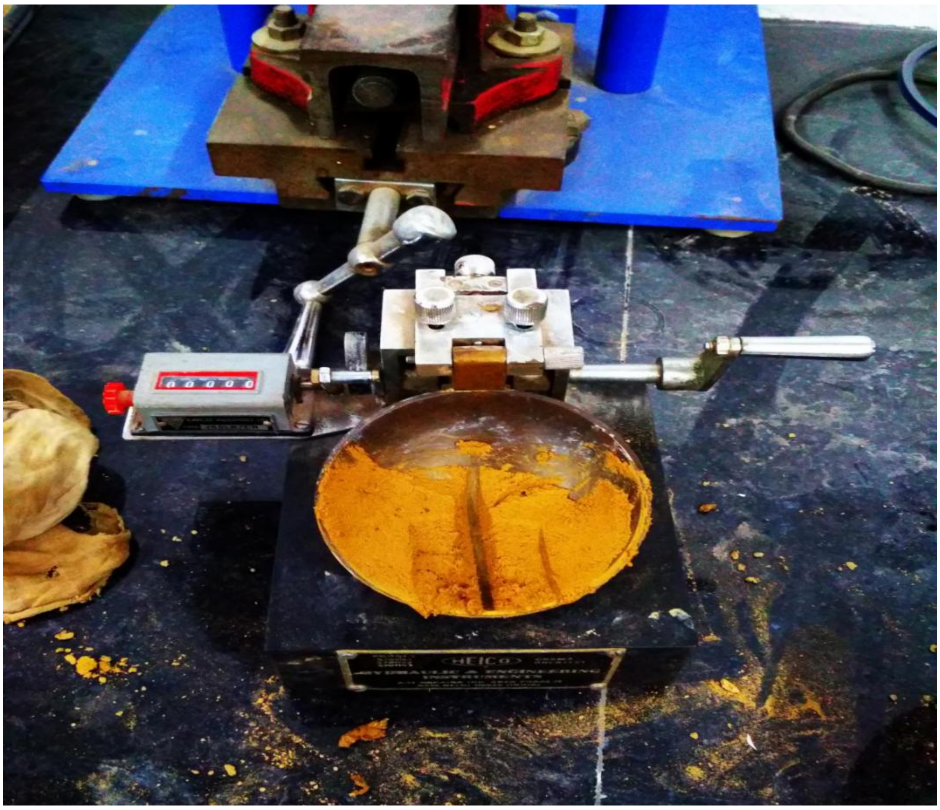

Fig.3.4 - Liquid limit test Apparatus

Table 2 – Liquid Limit observation table

No of blows	Water Content
30	24.5
17	26.6
10	31.2
7	36.4

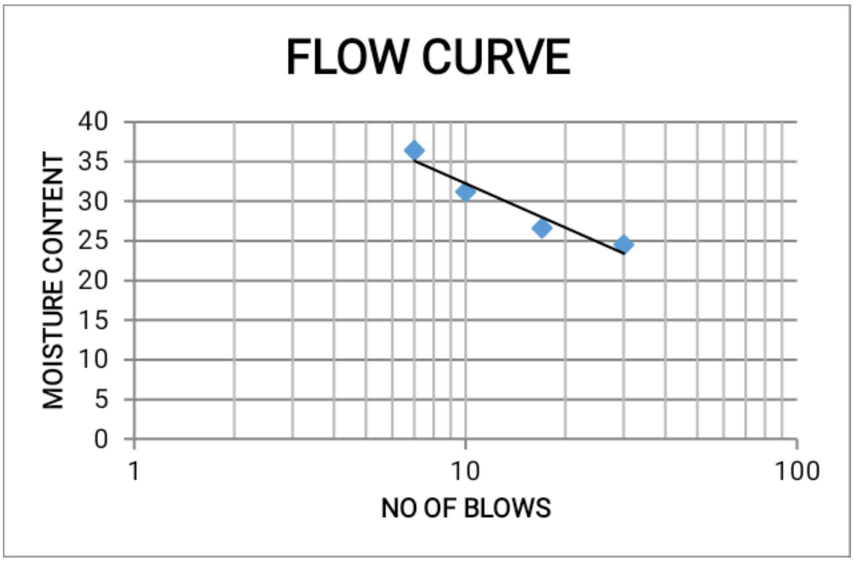

Fig.3.5 - Flow Curve

3.4.3 Standard Proctor Compaction Test

This test was performed to find out themax γ_d and OMC of soil as per IS : 2720 (Part VII) (Reaffirmed 2011). 7 kg oven dried soil sample passing IS sieve 20 mm was taken. Soil was compacted in 3 different layers in compaction mould while giving 25 blows to each layer by rammer of weight 2.6 kg which is dropped from a height of 310 mm from the top surface of soil. The blows were distributed uniformly over the surface of each layer. The observation table is given in appendix 4.

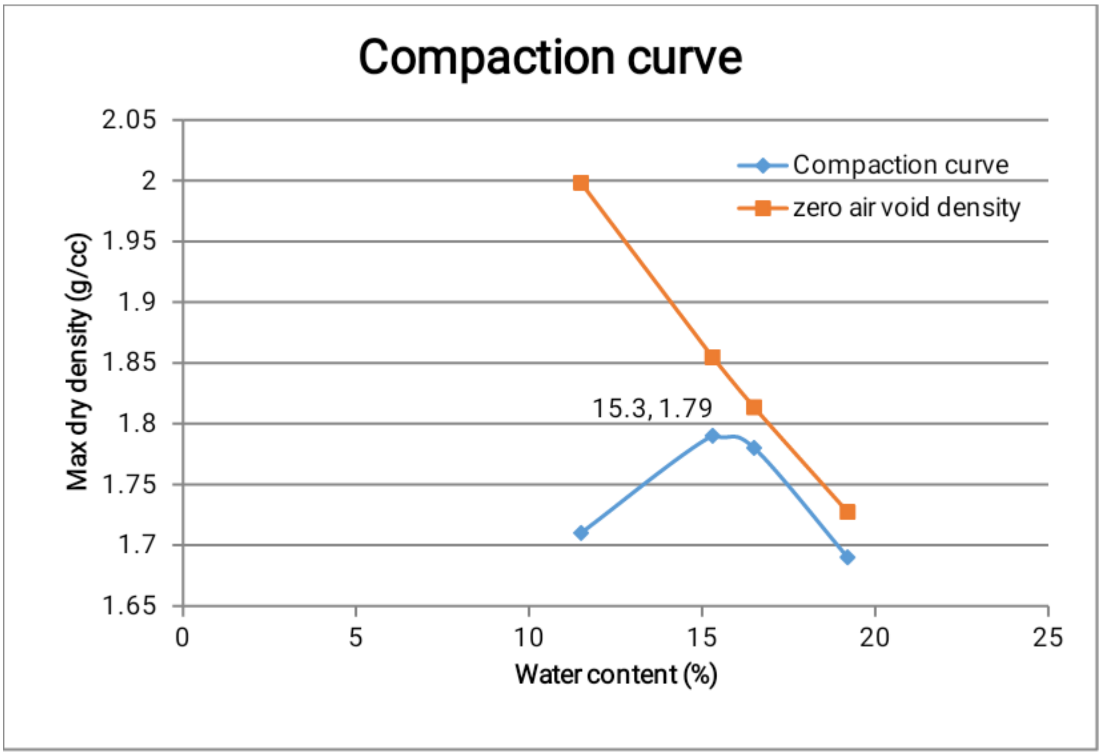

Fig.3.6 - Compaction Curve

From the graph we can calculate that

OMC = 15.3%

Max γ_d= 1.79 gm/cc

or 17.56 KN/m^3

3.4.4 Specific Gravity Test

Specific Gravity test of soil was done to know the specific gravity of soil. Pycnometer method used as per **IS 2720 1980 (Part 3).** First the weight of empty pycnometer is determined (W_1) in dry condition. Then the sample of dry soil is placed in the pycnometer and its weight with the soil is determined (W_2). The remaining volume of the pycnometer is then gradually filled with distilled water. The entrapped air was removed by vigorous shaking. The wight of the pycnometer, soil and water is obtained (W_3) carefully. Lastly the bottle is emptied thoroughly cleaned and filled with distilled water and its weight is taken (W_4). The specific gravity of soil is reported as 2.66.

Table 3 – Observation table - Specific gravity

Weight of dry empty pycnometer (W_1) (g)	700
Weight of dry soil + pycnometer (W_2) (g)	857
Weight of dry soil + pycnometer + water (W_3) (g)	1673
Weight of water + pycnometer (W_4) (g)	1575

CHAPTER 4

METHODOLOGY

4.1 Accelerated Permeability Tests

The test is conducted for measurement of permeability of DTU soil with different percentage of oil contamination using **Triaxial Apparatus**. The following outlines the test procedure to be adopted in the Accelerated Permeability Tests (AP tests) in determining the permeability of soils.

1. The procedure is consistent with that adopted in the Environment Agency R&D Contract Project No. P1-3398 "Validation of the Accelerated Permeability Test as an Alternative to the British Standard Triaxial Permeability Test" .
2. In the AP test, the preparation of specimens, equipment to be used and testing requirements shall be in accordance with ***BS1377: 1990*** other than as detailed in the following .
3. The basic test does not include measurements to assess the incremental volume and moisture content changes of the specimen during the test, or determination of the degree of saturation from B value determinations .
4. It should be noted that the procedures for assessing volume and moisture content change of the specimen during the test are prone to errors using conventional laboratory equipment and require very careful appraisal of the data to obtain meaningful results .

4.1.1 Experimental setup

1. Mould specification:

Diameter	38 mm
Height	76 mm

2. Rubber membrane
3. O-Rings
4. Frictionless end plates of 38 mm diameter
5. Porous end stones
6. Triaxial cell

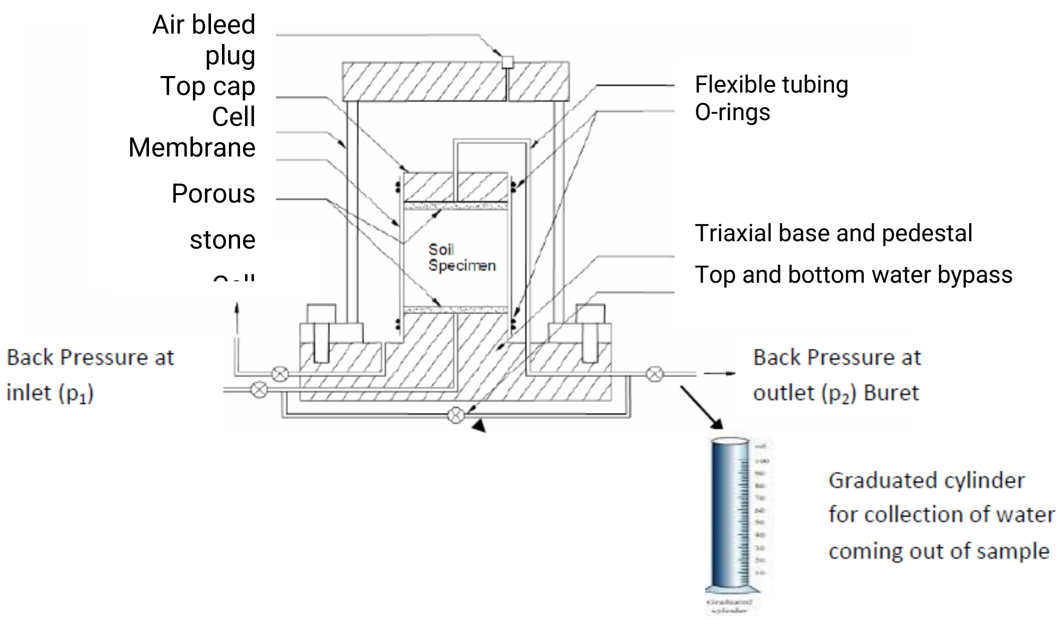

Fig. 4.1 – Line diagram showing experimental setup

Fig. 4.2 – Mould

Fig. 4.3 - Triaxial cell with mounted sample

Fig. 4.4 - Sample Extruder

Fig. 4.5 - Soil Sample

Fig. 4.6 - Length of sample 76 mm

Fig. 4.7 - Triaxial cell connected to pneumatic control panel

4.1.2 Sample Preparation

Soil sample to be used is divided into 7 equal parts and then oil was added according to weight of soil. Part one of soil was left as it is, it is the soil with 0% oil contamination. Other 6 parts of soil were mixed with oil no. 1 and oil no. 2 with different percentage of each oil i.e. 1%, 2%, and 3% respectively in a mixer so that soil is mixed throughly.

1. For sample preparation soil with different contamination of oil was taken as per its max dry density.
2. Then optimum water is added to soil and mixed thoroughly.
3. Soil is filled in the mould in two layers having internal diameter of 38 mm and height 76 mm and each layer was compacted with a hammer.
4. The soil specimen was placed in sample extruder and sample was

extracted with the help of plunger.

5. This process was repeated with each sample of soil containing different percentages of diesel oil and motor oil.

Measured sample height = 76mm

Measured specimen diameter = 38mm

4.1.3 Setting up the sample in triaxial apparatus

1. Place the sample in Triaxial cell.
2. Care must be taken to prevent any part of the cell from disturbing the sample while it is being setup, for example, by knocking against bottom of the loading piston.
3. A separate base porous disc is used in the triaxial test, the saturated disc was slided onto a layer of water on the triaxial base pedestal without entrapping air. Any surplus water standing on the disc is removed, ensuring that the pores remain saturated. A filter paper is put on the porous disc and it is ensured that filter paper is saturated with water too.
4. The specimen is placed on the disc without any delay and without entrapping air. The saturated porous disc along with filter paper towards the side of soil sample is placed, with excess water removed, on top of the specimen.
5. The soaked rubber membrane is placed over the specimen, after allowing surplus water to drain off, using a membrane stretcher. An unused leak-free membrane shall be used for every test.
6. The cell must be properly set up and uniformly clamped down to prevent any release of pressure or leakage of water during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are correctly placed.
7. When the sample is setup water is admitted and the cell is filled until water escapes from the air bleed valve, at the top, which is

then closed.

8. The piston lock is then moved down by handle until it is just in touch with the pressure plate on the top of the sample, and locked at this position before testing.
9. Ensure that the specimen axis is vertical and that the top drainage line do not interfere with fitting the cell body.
10. Pressure setup is used to apply cell pressure and back pressure to the sample.
11. All the valves of Triaxial cell are closed firstly. Application of Back pressure and Cell pressure is done.

Back Pressure (p_1)	343.35 kPa
Cell Pressure	441.45 kPa
p_1	Inlet back pressure
p_2	Outlet back pressure 101.325 kPa

CHAPTER 5

OBSERVATION AND CALCULATION

5.1 Observations and calculations

In the AP test, the preparation of specimens, equipment to be used and testing requirements shall be in accordance with ***BS1377: 1990*** and following formula is used for calculating the permeability value of soil is as follows.

$$k_v = \frac{1.63 \times q \times L \times R_t \times 10^{-4}}{A\left(p_1 - p_2\right) - p_e}$$

Where,

k_v = permeability coefficient (m/s)

A = Cross sectional area of specimen (mm^2)

p_1 = Back pressure at inlet (kpa)

p_2 = Back pressure at outlet (kpa)

q = Rate of outflow from outlet valve (ml/min)

L = Height of specimen (mm)

R_t = Temperature correction factor for water viscosity

p_e = Pressure loss in the system (kpa) for th rate of flow obtained from calibration graph.

Values observed

- P_2 = 101.325 kpa

- A =1134.11 mm^2
- P_e= 0 kpa
- q = ml/min (as read from graph)
- L = 76 mm
- R_t = 1 (as no effect of temperature on viscosity of water is observed)

5.2 Calculations:

5.2.1 Permeability value calculation for uncontaminated soil

The equation is as given below

$$k_v = \frac{1.63 \times q \times L \times R_t \times 10^{-4}}{A\left(p_1 - p_2\right) - p_e}$$

Putting all the values in above equation we get the permeability for uncontaminated soil as

Different values are

q = 2.193 (as read from fig. 5.1)

L = 76 mm

p_1 = 343.35 kpa

$$k_v = \frac{1.63 \times 2.193 \times 76 \times 10^{-4}}{1134.11 \times (343.35 - 101.325)}$$

$$k_v = 9.89 \times 10^{-8} m/s$$

5.2.2 Permeability value calculation for contaminated soil with Diesel oil

For soil with 1 % contamination of diesel oil

Different values are

q = 1.4667 (as read from fig. 5.1)

L = 76 mm

p_1 = 441.45 kpa

$$k_v = \frac{1.63 \times 1.4667 \times 76 \times 10^{-4}}{1134.11 \times (441.45 - 101.325)}$$

$$k_v = 4.707 \times 10^{-8} m/s$$

For soil with 2 % contamination of diesel oil

Different values are

q = 0.7224 (as read from fig. 5.1)

L = 76 mm

p_1 = 441.45 kpa

$$k_v = \frac{1.63 \times 0.7224 \times 76 \times 10^{-4}}{1134.11 \times (441.45 - 101.325)}$$

$$k_v = 2.135 \times 10^{-8} m/s$$

For soil with 3 % contamination of diesel oil

Different values are

q = 0.4291 (as read from fig. 5.1)

L = 76 mm

p_1 = 441.45 kpa

$$k_v = \frac{1.63 \times .4291 \times 76 \times 10^{-4}}{1134.11 \times (441.45 - 101.325)}$$

$$k_v = 1.38 \times 10^{-8} \, m/s$$

5.2.3 Permeability value calculation for contaminated soil with Motor oil

For soil with 1 % contamination of motor oil

Different values are

q = 1.017 (as read from fig. 5.2)

L = 76 mm

p_1 = 441.45 kpa

$$k_v = 3.26609 \times 10^{-08} \, m/s$$

For soil with 2 % contamination of motor oil

Different values are

q = .3958 (as read from fig. 5.2)

L = 76 mm

p_1 = 441.45 kpa

$$k_v = 1.27111\times 10^{-08} \text{ m/s}$$

For soil with 3 % contamination of diesel oil

Different values are

q = 0.1358 (as read from fig. 5.2)

L = 76 mm

p_1 = 441.45 kpa

$$k_v = 0.43612\times 10^{-08} \text{ m/s}$$

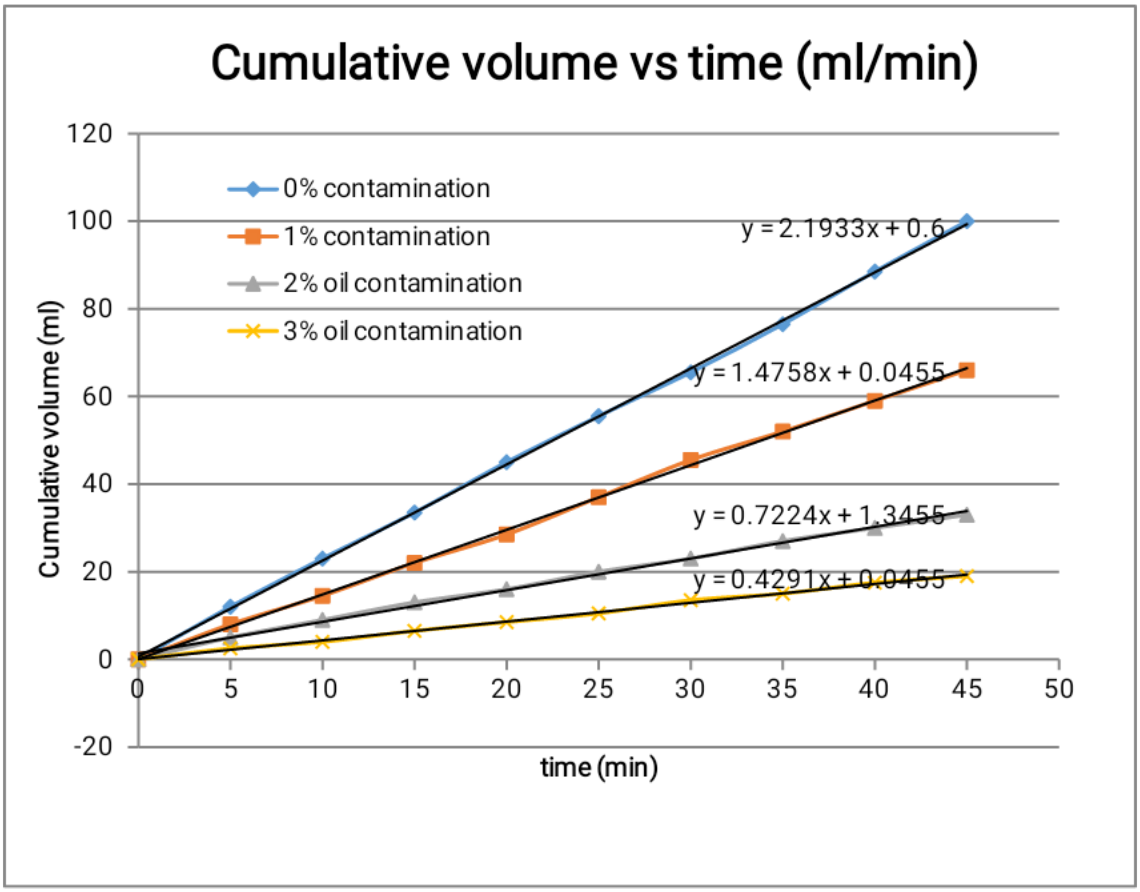

Fig. 5.1- Graph volume vs time for diesel contaminated soil

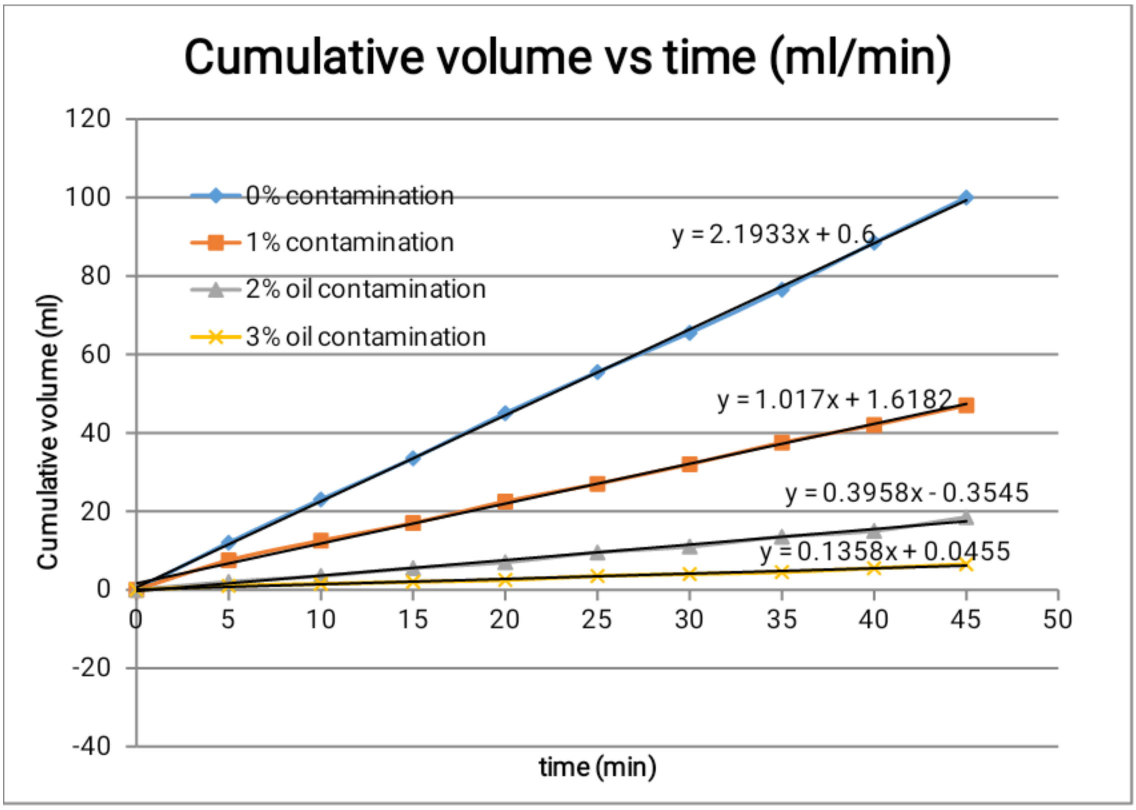

Fig. 5.2 - Graph volume vs time for motor oil contaminated soil

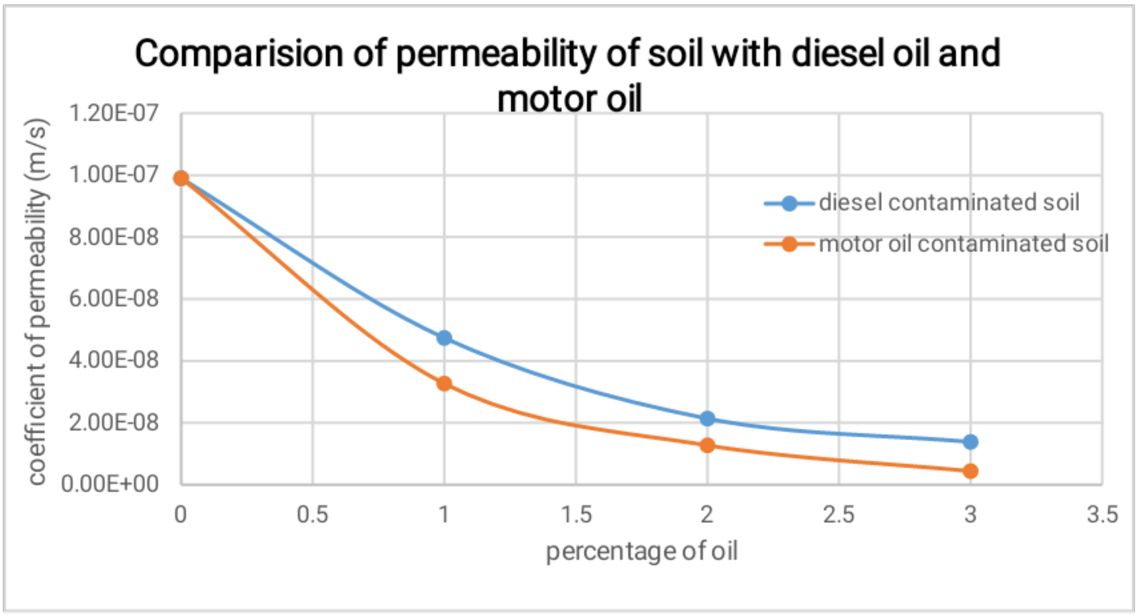

Fig. 5.3 :Permeability of soil with different oil percentage of both oil

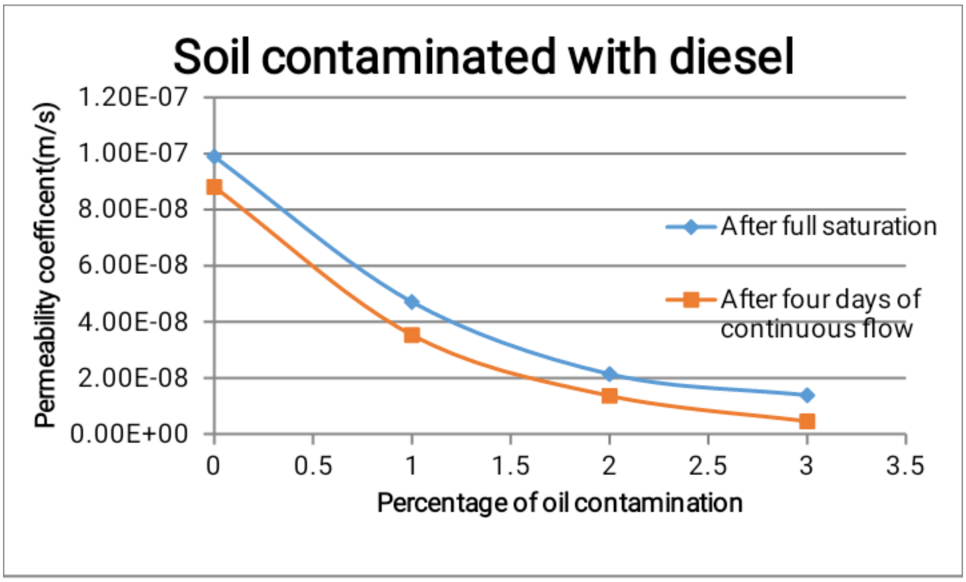

Fig. 5.4 :Effect of time on Permeability of soil contaminated with diesel

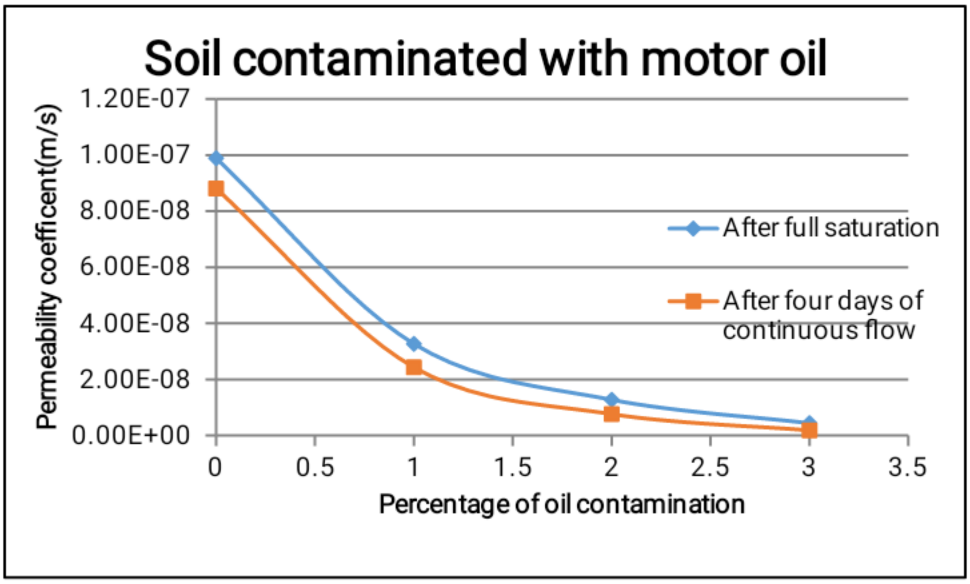

Fig. 5.5 : Effect of time on Permeability of soil contaminated with motor oil

CHAPTER 6

RESULT AND CONCLUSION

6.1 Conclusions

Following results and conclusions can be drawn from the research work done for this thesis.

1. The soil used was of DTU campus. For different percentage of oil used it was seen that overall permeability of soil decreased.

2. The decrease for motor oil contaminated soil was more than that of the diesel contaminated soil, it is due to the fact that motor oil had greater viscosity than diesel oil and permeability decreases with the increase in viscosity of permeant liquid.

3. The same samples were checked for permeability coefficient values after 4 days of saturation and effect of time was determined on permeability value. After four days of continuous flow through the sample it was seen that value of permeability further decreased due to reason of accumulation of finer particles on the upper part of sample which decreased the flow and due to gas molecules being accumulated in the sample which were mixed in the water.

6.2 Future Work Recommendations

1. Different types of soils can be tested for different oil contamination.
2. Soil can be tested with other contaminants to check its effect on the properties of soil.
3. This permeability test can be done with different moulding water content and the effect of same on the permeability value can be studied.
4. With the measurement of permeability, the measurement of shear stress can also be done in triaxial apparatus.
5. This method can further be modified and used to check volume change relationship with load and the shear characteristics of soil.
6. This method can be used to find out permeability of unsaturated soil.
7. This method is done using distilled water in uncontaminated and oil contaminated soil. The same can be done with different types of liquids such as brine solution and benzene solution to find out the effect of same in case of clay liner system.

APPENDIX

A 1 - Grain size analysis table

Table 2 - Sieve analysis table

No.	Sieve size	Retained mass (g)	Cumulative retained	Retained (%)	Cumulative passing (%)
1	4.75	1.56	1.56	1.4	98.65
2	2	1.82	3.38	1.6	97.07
3	1	0.35	3.73	0.3	96.77
4	0.6	1.30	5.03	1.1	95.64
5	0.3	1.47	6.5	1.3	94.37
6	0.15	0.96	7.46	0.8	93.54
7	0.075	21.23	28.69	18.4	75.14

A 2 - Hydrometer Table

Table 3 - Hydrometer Table

Elapsed time (min)	Hydrometer Reading, R_h	Correction	Corrected hydrometer reading	Effective Depth, H_e (mm)	Particle size, D (mm)	Percentage finer (%)	Temp	n_t
0.5	28.00	-1	27	79.63	0.0459	37.58	33.00	0.714
1	26.00	-1	25	99.97	0.0364	34.79	33.00	0.714
2	24.00	-1	23	105.17	0.0264	32.01	33.00	0.714
4	22.00	-1	21	110.37	0.0191	29.23	33.0	0.71

							0	4
8	19.50	-1	18.5	116.87	0.0139	25.75	33.00	0.714
15	17.00	-1	16	123.37	0.0104	22.27	33.00	0.714
30	16.00	-1	15	125.97	0.0075	20.88	33.00	0.714
60	15.00	-1	14	128.57	0.0053	19.48	33.00	0.714
120	13.00	-1	12.5	132.47	0.0038	17.4	33.00	0.714
240	12.00	-1	11	136.37	0.0027	15.31	33.00	0.714
480	8.00	-1	7	146.77	0.002	9.71	33.00	0.714
1440	7.00	-1	6	149.37	0.0012	8.35	33.00	0.714

A 3 - Liquid limit observation table

Table 4 - Liquid limit observation table

No of blows	Water Content
30	24.5
17	26.6
10	31.2
7	36.4

A 4 - Compaction characteristics observation table

Table 5 - Observation table for compaction test

S. No.	Moisture Content (%)	Weight of soil in mould (grams)	Volume of mould (cc)	Bulk density(gm/cc)	Dry Density (gm/cc)
1	11.5	1921	1000	1.921	1.71
2	15.3	2011	1000	2.011	1.79
3	16.5	2047	1000	2.047	1.78
4	19.2	2024	1000	2.024	169

A 5 - Permeability observation table of uncontaminated soil

Table 6 - Observation table for permeability of uncontaminated soil

Time (mins)	Cumulative vol (ml)	Incremental vol (ml)
0	0	0
5	12	12
10	23	11
15	33.5	10.5
20	45	11.5
25	55.5	10.5
30	65.5	10
35	76.5	11
40	88.5	12
45	100	12.5

A 6 - Observation table for permeability of 1% oil contaminated soil (Diesel)

Table 7 - Observation table for permeability of 1% oil contaminated soil

Time (mins)	Cumulative vol (ml)	Incremental vol (ml)
0	0	0
5	8	8
10	15	7
15	22	8
20	29	5
25	37	8
30	44	7
35	52	8
40	59	7
45	66	7

A 7 - Observation table for permeability of 2% oil contaminated soil (Diesel)

Table 8 - Observation table for permeability of 2% oil contaminated soil

Time (mins)	Cumulative vol (ml)	Incremental vol (ml)
0	0	0
5	5	5
10	9	4
15	13	3
20	16	3
25	20	4
30	23	3
35	27	4
40	30	3
45	33	3

A 8 - Observation table for permeability of 3% oil contaminated soil (Diesel)

Table 9 - Observation table for permeability of 3% oil contaminated soil

Time (mins)	Cumulative vol (ml)	Incremental vol (ml)
0	0	0
5	2.5	2.5
10	4	1.5
15	6.5	2.5
20	8.5	2
25	10.5	2
30	13.5	3
35	15	1.5
40	17.5	2.5
45	19	1.5

A 9 - Observation table for permeability of 1% motor oil contaminated soil

Table 10 - Observation table for permeability of 1% motor oil contaminated soil

Time (mins)	Cumulative vol (ml)	Incremental vol (ml)
0	0	0
5	7.5	7.5
10	12.5	5
15	17	4.5
20	22.5	5.5
25	27	4.5
30	32	5
35	37.5	5.5
40	42	4.5
45	47	5

A 10 - Observation table for permeability of 2% motor oil contaminated soil

Table 11 - Observation table for permeability of 2% motor oil contaminated soil

Time (mins)	Cumulative vol (ml)	Incremental vol (ml)
0	0	0
5	2	2
10	3.5	1.5
15	5.5	2
20	7	1.5
25	9.5	2.5
30	11	1.5
35	13.5	2.5
40	15	1.5
45	18.5	3.5

A 11 - Observation table for permeability of 3% motor oil contaminated soil

Table 12 - Observation table for permeability of 3% motor oil contaminated soil

Time (mins)	Cumulative vol (ml)	Incremental vol (ml)
0	0	0
5	1	1
10	1.5	0.5
15	2	0.5
20	2.5	0.5
25	3.5	1
30	4	0.5
35	4.5	0.5
40	5.5	1
45	6.5	1

A 12 – Observation table for permeability value of all samples after four days of continuous flow

Table 13 - Observation table for permeability for time effect

	Coefficient of Permeability m/s	
	After full saturation	**After four days of continuous flow**
Soil sample 1 (uncontaminated)	9.89E-08	8.81E-08
Soil sample with 1% diesel oil	4.71E-08	3.53E-08
Soil sample with 2% diesel oil	2.14E-08	1.36E-08
Soil sample with 3% diesel oil	1.38E-08	4.50E-09
Soil sample with 1% motor oil	3.27E-08	2.43E-08
Soil sample with 2% motor oil	1.27E-08	7.60E-09
Soil sample with 3% motor oil	4.36E-09	3.38E-09

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