

**A STUDY ON VARIATION IN HYDRAULIC CONDUCTIVITY OF A SOIL
AFTER PASSING WASTE WATER THROUGH IT**

MAJOR PROJECT REPORT

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OF

MASTER OF TECHNOLOGY

IN

ENVIRONMENTAL ENGINEERING

Submitted by:

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CANDIDATE’S DECLARATION

I, Dushyant Singh, Roll No. 2K17/ENE/06 student of M. Tech (Environmental Engineering), hereby declare that the Major project report titled “A STUDY ON VARIATION IN HYDRAULIC CONDUCTIVITY OF A SOIL AFTER PASSING WASTE WATER THROUGH IT” which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title of recognition.

Place: Delhi

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Date: 05 JULY,2019

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CERTIFICATE

I hereby certify that the Minor project report titled “A STUDY ON VARIATION IN HYDRAULIC CONDUCTIVITY OF A SOIL AFTER PASSING WASTE WATER THROUGH IT” which is submitted by DUSHYANT SINGH, 2K17/ENE/06, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students 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

Date: 05 JULY, 2019

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ABSTRACT

Waste water from over the years has become one of the hazardous pollutants affecting the human life in urban areas. There has been an exponential growth of human population which has caused substantial rise in the dumping of Solid and Semi Solid Waste in open area along with rapid urbanization and industrialization, which is known to cause high Soil contamination and Water Pollution levels in Indian cities.

The Soil below any Landfill Site undergoes many Physical, Chemical and Structural changes. The Objective of this study is to observe the changes in the properties of the soil and also the changes in the properties of waste water. The property of soil observed during this study was the Hydraulic Conductivity of the soil which was checked for fresh water on first day and then observed with wastewater for the next 3 days. The properties of wastewater observed were pH, Total Dissolved Solids, Total Suspended Solids, Dissolved Oxygen, COD and Hardness of the water.

The soil for this Observational Study was taken from the construction site in Delhi Technological University premises and the waste water was taken from hostel mess drain.

It is observed that the Leachate and waste water contribute significantly in the soil contamination and also the contamination of nearby natural drains and underground water. The test analysis shows that the hydraulic conductivity decreases with continuous passage of leachate or waste water through the soil.

Keywords: Waste Water, Leachate, Variation, Hydraulic conductivity.

CHAPTER 1

THEORETICAL BACKGROUND

1.1 Hydraulic Conductivity

In soils, the interconnected pores provide passage for water. A large number of such flow paths act together, and the average rate of flow is termed the coefficient of Hydraulic conductivity, or just Hydraulic Conductivity. It is a measure of the ease that the soil provides to the flow of water through its pores.

Hydraulic Conductivity (**k**) is an engineering property of soils and is a function of the soil type. Its value depends on the average size of the pores and is related to the distribution of particle sizes, particle shape and soil structure.

DARCY'S LAW

Darcy's law states that there is a linear relationship between flow velocity (**v**) and hydraulic gradient (**i**) for any given saturated soil conditions.

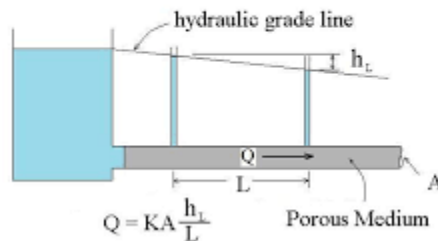


Figure 1.1 Darcy's Law

If the rate of flow is **q** (volume/time) through cross-sectional area (**A**) of the soil mass, Darcy's Law can be expressed as

$$v = q/A = k \cdot i$$

where **k** = Hydraulic Conductivity of the soil

$$i = h/L$$

h = difference in total heads

L = length of the soil mass

The flow velocity (**v**) is also called the Darcian velocity or the **superficial velocity**. It is different from the actual velocity inside the soil pores, which is known as the **seepage velocity**, **v_s**. At the particulate level, the water follows a tortuous path through the pores. Seepage velocity is always greater than the superficial velocity.

1.2 Methods of determination of Hydraulic Conductivity

1.2.1 Direct methods

a. Constant head Hydraulic Conductivity test

Constant Head Flow

Constant head permeameter is recommended for coarse-grained soils only since for such soils, flow rate is measurable with adequate precision. As water flows through a sample of cross-section area **A**, steady total head drop **h** is measured across length **L**.

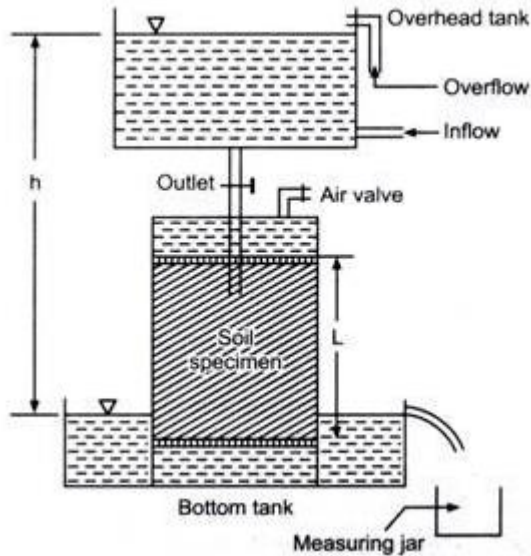


Figure 1.2 Constant Head Hydraulic Conductivity Test

Hydraulic Conductivity **k** is obtained from:

$$k = \frac{qL}{Ah}$$

b. Variable head Hydraulic Conductivity test

Falling head permeameter is recommended for fine-grained soils.

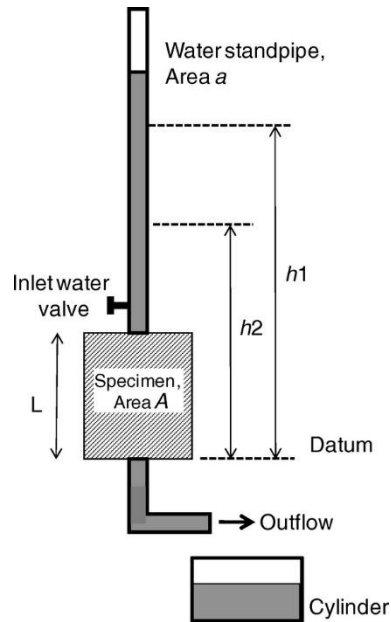


Figure 1.3 Falling Head Hydraulic Conductivity Test

Total head h in standpipe of area a is allowed to fall. Hydraulic gradient varies with time. Heads h_1 and h_2 are measured at times t_1 and t_2 . At any time t , flow through the soil sample of cross-sectional area A is measured. The permeability is given by

$$K = 2.303 \frac{aL}{At} \log \frac{h_1}{h_2}$$

c. Capillarity Hydraulic Conductivity test

This test is used to find Hydraulic Conductivity of medium and Capillary rise in it.

It is suitable for Partially Saturated soil.

In this test, partially saturated sample of soil is placed in a cylindrical glass tube having diameter of 4cm and length of 35cm.

1.2.2 Indirect Methods

a. Kozeny Carman equation

The Kozeny-Carman equation works well for describing coarse-grained soils such as sand and some silts. For these cases, the coefficient of Hydraulic Conductivity bears a linear relation to $e^3/(1+e)$.

Kozeny and Carman proposed the below expression for predicting the Hydraulic Conductivity of porous media:

$$k = \frac{\gamma}{\mu} \frac{1}{C_{K-C}} \frac{1}{S_o^2} \frac{e^3}{1+e}$$

where γ = unit weight of permeant, μ = viscosity of permeant; C_{K-C} = Kozeny-Carman empirical coefficient; S_o = specific surface area per unit volume of particles (1/cm); and e = void ratio. When the permeant is water at 20°, $\gamma/\mu = 9.933 \times 10^4$ l/cm·s.

b. Allen Hazen equation

In sands, Hydraulic Conductivity can be empirically related to the square of some representative grain size from its grain-size distribution. For filter sands, Allen Hazen in 1911 found that $k = 100 (D_{10})^2$ cm/s where D_{10} = effective grain size in cm.

c. Consolidation equation

$$K = C_v \cdot m_v \cdot \gamma_w$$

C_v = Coefficient of consolidation (m²/sec)

m_v = Coefficient of volume compressibility (m²/kN)

1.3 Properties of Soil

1.3.1. Void ratio (e) is the ratio of the volume of voids (V_v) to the volume of soil solids (V_s), and is expressed as a decimal.

$$e = \frac{V_v}{V_s}$$

1.3.2. Porosity (n) is the ratio of the volume of voids to the total volume of soil (V), and is expressed as a percentage. $n = \frac{V_v}{V} \times 100$

Void ratio and porosity are inter-related to each other as follows: $e = \frac{n}{1-n}$

1.3.3. Degree of Saturation: The volume of water (V_w) in a soil can vary between zero (i.e. a dry soil) and the volume of voids. This can be expressed as the **degree of saturation (S)** in percentage. For a dry soil, $S = 0\%$, and for a fully saturated soil, $S = 100\%$.

1.3.4. Air content (a_c) is the ratio of the volume of air (V_a) to the volume of voids.

$$a_c = \frac{V_a}{V_v}$$

1.3.5. Percentage air voids (n_a) is the ratio of the volume of air to the total volume.

$$a_c = \frac{V_a}{V} * 100$$

1.3.6. Water Content: The ratio of the mass of water present to the mass of solid particles is called the **water content (w)**, or sometimes the **moisture content**.

$$w = \frac{W_w}{W_s}$$

Its value is 0% for dry soil and its magnitude can exceed 100%.

1.3.7. Specific Gravity: The mass of solid particles is usually expressed in terms of their **particle unit weight (γ_s)** or **specific gravity (G_s)** of the soil grain solids

$$\gamma_s = \frac{W_s}{V_s} = G_s \cdot \gamma_w$$

Where γ_w = Unit weight of water

For most inorganic soils, the value of G_s lies between 2.60 and 2.80. The presence of organic material reduces the value of G_s .

1.3.8 Dry unit weight γ_d is a measure of the amount of solid particles per unit volume.

$$\gamma_d = \frac{W_s}{V}$$

1.3.9 Bulk unit weight is a measure of the amount of solid particles plus water per unit volume.

$$\gamma \text{ or } \gamma_t = \frac{W}{V}$$

1.4. Atterberg Limits

1.4.1 Plastic Limit:

This limit which is between the plastic and semi-solid state of the soil. it's determined by rolling out a thread of the soil on a flat surface that is non-porous. it's the minimum water content at that the soil simply begins to crumble whereas rolling into a thread of roughly 3mm diameter. Plastic limit is denoted by w_p .

1.4.2 Liquid Limit:

It is the water content of the soil between the liquid state and plastic state of the soil. It may be outlined because the minimum water content at that the soil, although in liquid state, shows little cutting strength against flowing. it's measured by the Casagrande's equipment and is denoted by w_L .

1.5 Specific gravity

Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water.

1.5.1 Equipment

- Pycnometer
- Sieve(4.75 mm)
- Oven
- Weighing balance
- Glass rod

1.5.2 Procedure

1. Dry the pycnometer and then weigh it with its cap (W_1).
2. Take about 100g to 300 g of oven dried soil passing through 4.75mm sieve into the pycnometer and weigh again (W_2).
3. Add water to cover the soil and screw on the cap.
4. Shake the pycnometer well to remove entrapped air .
5. After the air has been removed, fill the pycnometer with water uptill brim and weigh it (W_3).
6. Wash the pycnometer thoroughly.
7. Fill the pycnometer completely with water upto brim with cap screw on.
8. Weigh the empty pycnometer after drying it thoroughly (W_4).

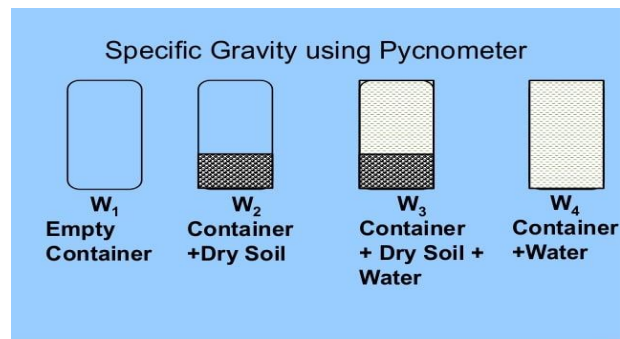


Figure 1.4 Procedure of experiment



Figure 1.5 Pycnometer device

1.5.3 Specific gravity calculation

The Specific gravity of soil solids (G_s) is calculated using the following equation.

$$\text{Sp. Gravity } (G_s) = \frac{(W_2 - W_1)}{((W_2 - W_1) - (W_3 - W_4))}$$

1.6 Maximum dry density and Optimum moisture content :

The maximum dry density of a material for a specific compactive effort is the highest density obtainable when the compaction is carried out on the material at varied moisture contents.

Optimum moisture content: The optimum moisture content for a specific compactive effort is the moisture content at which the maximum density is obtained.

When placing soils as fill materials, it is important to achieve suitable compaction, primarily in order to reduce the susceptibility of a soil to settlement. The ability to attain acceptable levels of compaction is reliant on the moisture content of the soil being placed along with the compactive effort achievable from the plant used. In order to monitor compaction of soils placed on site, in-situ density testing is frequently undertaken. Results of this in-situ testing are compared to theoretical maxima derived in the laboratory on samples of the material being placed. Sub-samples of a material are compacted into a mould using a specified compactive effort provided by one of a 2.5kg (light) rammer, a 4.5kg (heavy) rammer or a vibrating hammer.

The dry density is calculated for each moisture content and plotted against this moisture allowing a curve to be drawn through the resultant points. The peak of this curve provides the theoretical maximum dry density and the optimum moisture content at which to place the soil to obtain this density. If required air void content as a guide as to the level of compaction that can be expected.

1.7 Waste Water Quality Parameters

1.7.1 TOTAL DISSOLVED SOLIDS (TDS)

TDS or total dissolved solids, show the concentration of dissolved materials in wastewater. TDS is made of inorganic salts, as well as a small quantity of organic material. Not unusual vicinity inorganic salts water consists of calcium, magnesium, potassium and sodium, which can be known as cations, and carbonates, nitrates, bicarbonates, chlorides and sulphates, that are known as anions.

Total Dissolved Solids correspond with conductivity and affects pH. The taste of water is changed by the presence of dissolved solids in the water. The higher the TDS, higher is the conductivity and the lower is the pH, towards acidity.

Palatability of Drinking Water

Table 1.1 TDS Palatability

Less than 300 mg/L	Excellent
Between 300 and 600 mg/L	Good
Between 900 and 1200 mg/L	Fair
Between 600 and 900 mg/L	Poor
Greater than 1200 mg/L	Unacceptable

Table 1.1 TDS Palatability

1.7.2 pH

The concentration of hydrogen ion in system is denoted by pH. Distilled water will have pH of 7 which means it has an amount of 10^7 hydronium ions same as hydroxide ion concentration. Rain water etc have certain amount of acidity due to carbonic acid by carbon dioxide.

The pH of water determines the ability of the ions to interact thus increasing the solubility of the solvents or decreasing it. For example, the type of chlorine or abundance of Phosphorus is determined by the pH of a water body. High pH is not good for use neither does low pH as it involves the dissolution of heavy metals.

1.7.3 DISSOLVED OXYGEN (DO)

Dissolved oxygen refers to the amount of free, non-compound element in water or alternative liquids. It's a vital parameter in assessing water quality thanks to its influence on the organisms living at intervals a body

of water. In earth science (the study of lakes), dissolved O_2 is a vital issue second solely to water itself. A dissolved oxygen level that's too high or too low will hurt aquatic life and have an effect on water quality. Non-compound O_2 , or free element (O_2), is component $\{O_2 \text{ gas}\}$ that's not secure to the other element. DO is that the presence of those free O_2 molecules at intervals water. The secure element molecule in water (H_2O) is during a compound and doesn't count toward dissolved element levels.

1.7.4 CHEMICAL OXYGEN DEMAND (COD)

Chemical Oxygen Demand (COD) is technique for figuring how much oxygen would be exhausted because of bacterial activity. While the BOD data is obtained using a variety of microbes and different microorganisms in an endeavor to copy what might occur in a characteristic stream over a period of five days, whereas the COD test utilizes a solid substance oxidizing specialist (potassium permanganate) to artificially oxidize the natural material in the presence of extreme physical conditions like heat and corrosion. The COD test has the benefit of not being affected by toxic materials, as well as requiring just a few hours for test completion, rather than five days for the BOD test. It has the impediment of being totally impractical, yet is considered to yield an outcome that might be utilized to understand the actual amount of oxygen that is the need of waste water for complete oxidation. The COD test is frequently used along with the BOD test to evaluate the measure of non-biodegradable natural issue in a wastewater.

Chemical Oxygen Demand is the total oxygen required for oxidation of all the oxidisable products be it organic or inorganic. COD can be an indicator of the total industrial load of the river and hence of the industrial pollution.

In normal cases it is observed that COD is 1.3 to 1.5 times the BOD available. At the point when the consequence of a COD test is more than twice that of the BOD test, there is valid justification to associate that a critical part with the natural material in the example isn't biodegradable by normal microorganisms. So the input via industries is significantly high which is increasing COD.

1.7.5 BIOCHEMICAL OXYGEN DEMAND (BOD)

BOD is a measure of the dissolved oxygen consumed by microorganisms during the oxidation of reduced substances in waters and wastes. BOD directly affects the amount of DO in rivers, streams and water bodies. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less O_2 is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen aquatic organisms which become stressed, suffocate and die. Resources of BOD

embody leaves and woody particles; useless plant life and animals; animal manure; effluents from pulp and paper turbines, urban storm water runoff, wastewater treatment flowers, feedlots and meals-processing vegetation; failing septic structures; and wastewater treatment flowers. The discharge of wastes with high levels of BOD can cause water quality problems such as severe dissolved oxygen depletion and fish kills in the receiving water bodies. Chlorine can also affect BOD measurement by inhibiting or killing the microorganisms that decompose the organic and inorganic matter in a sample. In chlorinated waters, including those underneath the effluent from a sewage remedy plant, it's far vital to neutralize the chlorine with sodium thiosulphate.

1.7.6 HARDNESS

This is the presence of multivalent cations in the water such as calcium, magnesium, iron etc. This may be due to the geological features of catchent area. It may also be due to drainage from mines. The iron produces extraordinarily high hardness readings. For these reasons, hardness is an important water quality indicator.

For the most elements, however, hardness is a mirrored image of the quantity of calcium and magnesium coming into the flow via the weathering of rock including limestone (CaCO_3). when limestone is weathered, it dissolves into Ca^{2+} and CO_3^{2-} . Calcium is an important nutrient that is used by plants and animals. Carbonate buffers the stream's pH. Although these two ions are advantageous to a stream, they can cause problems in residents.

Foaming agents comprising of those in soaps and detergents do no longer paintings as nicely in hard water. Also, hard water has a tendency to leave tough, scaly calcium deposits on faucets. This is the reason for many people installing water softener systems in their homes.

CHAPTER 2

LITERATURE REVIEW

Stern and Shackelford (1998) studied the Hydraulic Conductivity of three sand – clay soil mixtures (sand mixed with bentonite, sand mixed with attapulgite clay and bentonite), with water and CaCl₂ solution relative to water decreases from 150 to 4.1 as the percentage of attapulgite clay relative to bentonite in the admixture for a sand – clay soil mixture containing 20% clay soil increases from 50% to 100%.

Anandarajah (2003) investigated the various mechanisms of increase in Hydraulic Conductivity by leaching, when a water saturated clayey soil is leached with an organic fluid such as heptane. Based on theoretical and experimental data, it has been shown that the formation of macro cracks is the most possible mechanism of Hydraulic Conductivity increase.

Maurya et. al (2007) studied the leaching losses, movement and distribution of carbofuran in three different soils (black, laterite and saline-alkaline soil) by soil column. It is found that the leaching loss in the soil are laterite soil > black soil > saline-alkaline soil and that higher quantities of carbofuran were retained in the upper layers.

T. Thyagaraj et. al (2019) studied that compacted clays in landfill applications are subjected to both physico-chemical changes and wet-dry cycles. Physico-chemical interactions occur at the microstructural level between the clay particles and chemical constituents such as brine solutions or leachates generated from the landfill waste. Further, the volumetric changes during wetting and drying also cause the microstructural changes to compacted clays. The microstructural changes due to physico-chemical interactions and wet-dry cycles are reflected at the macrostructural level and govern the macro-behaviour of compacted clays.

Bowders et. al (1987) studied the hydraulic conductivity of two soils (kaolinite and illite – chlorite) to form dilute organic chemicals (methanol acetic acid, heptane and trichloroethylene). Liquid and plastic limits were also determined. The studies supported the hypothesis : (i) if an organic liquid does not affect

sedimentation characteristics or Atterberg limits (compared to water), the liquid will not affect the hydraulic conductivity of compacted clay; (ii) if the liquid does not affect sedimentation velocity or Atterberg limits, the liquid may or may not affect 'k' and that hydraulic conductivity testing is needed to determine whether 'k' will be affected.

Acar and Ghosh (1987) investigated the role of soil activity in miscible organic fluid permeation (acetone) by conducting hydraulic conductivity tests on compacted soil specimens (Georgia Kaolinite, Na-montmorillonite and a fine sand) prepared at activities of 0.36 to 1.39 and a fine fraction of 25%. It is found that the ratio of the final (acetone) to initial (water) absolute hydraulic conductivity displayed a decreasing trend, with increasing activity. This indicated that miscible organic fluids are not expected to lead to dramatic increases in laboratory determined hydraulic conductivity of high-activity soils. Further, it is suggested that volume changes, rather than, internal fabric changes emerge as the critical factor controlling the structural stability of compacted soils, with high activity values.

Abduljawwad and Al-Amoudi (1995) investigated the behaviour of salt – cemented sabkha soil by considering the effect of brine and distilled water on its properties. Results indicated that the percolation of distilled water through the sabkha causes destruction of natural cementation, leading to collapse, increase in Hydraulic Conductivity, reduction in strength and increase in settlement.

Bachewar and Mehta (2001) investigated the physico – chemical characteristics of the effluent from a drug industry located in Nanded district of Maharashtra. The waste effluent generated during various manufacturing process of bulk drug was characterized for different water quality parameter. The toxic effect of waste effluent was evaluated with respect to soil quality. It is concluded that SAR value of the soil was very high and cannot be recommended for any agricultural use.

Tremblay et. al (2002) added separately 13 organic compounds to two soils and two types of cement to determine the implication of the nature of organic matter on soil. It appears that organic acids, mixed with soil and cement that produce a pH lower than 9 in the pore solution, prevent the development of the cementing products because the pH is too low to allow secondary mineral formation. Finally, the pH and SO₄ concentration of the pore liquid are good indicators of the effectiveness of the cementing process.

Janardanan (1989) studied the change in Hydraulic Conductivity of magnesium montmorillonite and kaolinite clay caused by the reaction between clays and various organic permeants (acetic acid, aniline, methanol and xylene). They have observed that the clay Hydraulic Conductivity has increased by an order of two or three than the original Hydraulic Conductivity due to clay permeant-chemical reaction. They showed that loss of mass through dissolution of clay mineral particles by permeant, increase the effective pore space and thus increases in Hydraulic Conductivity.

Jo et. al (2005) conducted long-term hydraulic conductivity tests on geosynthetic clay liners (GCLs) using single-species salt solutions (NaCl, KCl or CaCl₂). It is reported that permeation with CaCl₂ solutions resulted in an increase in the hydraulic conductivity of one order of magnitude or more. In contrast, permeation of 100 mM NaCl or KCl solutions or de-ionized (DI) water resulted in no appreciable change in hydraulic conductivity.

Kim et al (1997) studied the effective porosity and seepage velocity in column test on compacted clay. A series of column and tank tests were conducted using bromide to estimate seepage velocity through compacted clays. Bromide concentration in effluent and sectioned core pore water were measured. Seepage velocity estimated from the concentrated depth profile data obtained from sectioned core pore water was 50% greater than the estimated breakthrough curve data. The hydrodynamic dispersion coefficient had a linear relationship with the seepage velocity.

Kolstad et. al (2004) have discussed the ionic strength and relative amounts of monovalent and divalent cations (RMD) in multispecies solutions affect swelling and hydraulic conductivity of nonhydrated geosynthetic clay liners (GCLs) containing sodium bentonite. Aqueous solutions of LiCl, NaCl, CaCl₂ and MgCl₂ salts were used. It is found that hydraulic conductivity is found to be directly related to RMD, with RMD having a greater effect on hydraulic conductivity in weaker solutions.

Rakhshandehroo et. al (2001) studied the hydraulic conductivities of cationic surfactant modified soil mixtures with different fine contents (6, 12, 18 and 24 %) either untreated or treated in batch systems with

hexadecyltrimethylammonium (HDTMA). It is found that the 0.7 and 1.0 CEC treated soils showed equal or higher conductivities compared to 0.1 and 2.3 CEC treated soils. Further, the 0.7, 1.0 and 2.3 CEC treated soils also showed higher compressibility.

Bady and Rowe (1996) investigated the transportation of contaminants (chloride and sodium) underlain by an unsaturated stone collection layer, for three different flow rates ranging between 2.5 and 0.017 m/annum. Experimental observations were accurately predicted using one-dimensional advective – diffusive - dispersive theory. Based on the experimental and modelling results, there was some swelling of the compacted silt layers. This implies that contaminant transport due to matric suction was small when compared to the contaminant migration due to advection and advection diffusion.

Foreman and Daniel (1986) studied the variation in hydraulic conductivities of three compacted clays permeated with water, methanol and heptane and concluded that the Atterberg limits of three clays changed significantly when pore fluid was changed from water to either methanol or heptane and when clays were permeated with concentrated organic chemicals, the hydraulic conductivity varied significantly with the type of permeants. They found that organic chemicals reduced or eliminated the plasticity of the soil.

Steele and Hu (1987) have presented a summarized form of the effect of pore-fluid on soil/water behaviour. It has been concluded that (i) pore fluid affect the index properties and it is also affected by soil types and temperature, (ii) volume change of soil is also influenced by pore fluids. Polluted pore fluid (pH = 2 or pH = 11) produces larger volume changes especially on bentonite some acids, such as aniline, acetic acid and carbon tetra chloride show greater volume changes than other acids, in soils (iii) consolidation and other engineering behaviours of soils are all influenced by pore fluids.

Boardman et. al (2004) studied the influences of iron (III) and lead (II) contaminants on lime – stabilized clay. It has been concluded that the contaminants had a large effect on the initiation and development of the lime-clay reactions both during short term modified cation and during the longer-term solidification.

Rowe et. al (2002) measured the complex Hydraulic Conductivity of a natural clayey till (Halton till) before and after permeating with four different ionic contaminant solutions (CaCl₂, MgCl₂, NaCl and acetic acid) to examine the effects of contaminant type and concentration on the complex Hydraulic Conductivity of contaminated soil. The results provide the evidence that the complex Hydraulic Conductivity of soils may be used to identify changes in soil pore - water chemistry, which has the potential for use in the detection of soil contamination.

Yang and Barbour (1992) studied the impact of soil structure and confining stress on the hydraulic conductivity of clays in brine environment and they observed that increase in hydraulic conductivity that occurred during brine permeation can be prevented by increasing the level of confining stress.

Katsumi et. al (2007) studied the long – term hydraulic conductivity of a non prehydrated geosynthetic clay liners (GCLs) permeated with two types of solutions, namely, (i) chemical solutions consisting of a single species and multispecies of NaCl, CaCl₂ or KCl and (ii) real leachates sampled from waste containment facilities in Japan. It is concluded that the hydraulic conductivity test with chemical inorganic solutions when compared to those with waste leachates, the hydraulic conductivity of GCL permeated with chemical solution was almost the same within the electric conductivity of 0 – 25 S/m as that permeated with waste leachates having similar electric conductivity.

Review Summary

The Literature Review highlights the importance of both Solid Waste Management and Wastewater disposal. The studies conducted in the past show that the Capacity of a soil to handle solid waste and pass Leachate through it changes significantly with the time depending on the characteristics of both the Leachate or waste water and the characteristics of Soil. The Properties of the soil such as the Void Ratio and the Hydraulic Conductivity of the soil change with time.

The Objective of this study is to observe the Variation in the Hydraulic Conductivity of the Soil before and after passing Waste Water through it and the Variation is studied for 3 days.

CHAPTER 3

METHODOLOGY AND TECHNIQUES

3.1 FALLING HEAD HYDRAULIC CONDUCTIVITY TEST



Figure 3.1 Falling Head Hydraulic Conductivity Test

Procedure for falling head Hydraulic Conductivity test

1. Remove the collar of the mould. Measure the internal dimensions of the mould. Weigh the mould to the nearest gram for Hydraulic Conductivity test of soil.
2. Clamp the mould between the base plate and the extension collar, and place the assembly on a solid base.
3. Take about 2.5kg of the soil sample, from a thoroughly mixed wet soil, in the mould. For Hydraulic Conductivity test of soil compact the soil at the required dry density.
4. Remove the collar and base plate. Trim the excess soil level with the top of the mould.

5. Clean the outside of the mould and also find the mass of the soil in the mould.
6. Take a small specimen of the soil in a container for the water content determination.
7. Hydraulic Conductivity test of soil is determined by saturating the porous disc (stones).
8. Place a porous disc on the drainage base and keep a filter paper on the porous disc.
9. Remove the dummy plate and place the mould with soil on the drainage base after inserting a washer in between.
10. Clean the edges of the mould and place a filter paper, a porous stone and fix the drainage cap with the use of washers.
11. Allow some fresh water to be flown through the sample of soil for around 1 hour in order to completely saturate the soil sample.
12. When the sample is saturated, close both the top and bottom outlets.
13. Connect the stand pipe of diameter 7mm to the inlet at the top. Fill the stand pipe with fresh water sample.
14. Allow the fresh water from the stand pipe to flow through the soil specimen.
15. Starting from the height h_1 , the time required for the head to drop to h_2 is noted. Similarly, the head drop upto h_3 is noted in the same time.
16. The Hydraulic Conductivity of the soil is then calculated using the formula.
17. The same test procedure is repeated during Day 2, Day 3 and Day 4 using waste water sample and the corresponding difference in the heads is noted.
18. The Hydraulic Conductivity of the soil is calculated using the formula and the Variation in the Hydraulic Conductivity is noted from Day 1 to Day 4.

$$K = 2.303 \frac{aL}{At} \log \frac{h_1}{h_2}$$



Figure 3.2 Falling Head Hydraulic Conductivity Mould

3.2 FIELD DENSITY OF SOIL BY CORE CUTTER METHOD

Cylindrical core cutters of 130mm long and 100mm diameter are used for testing the in-situ compaction of cohesive and clay soils placed as fill. By using core cutter method, bulk density of soil can be quickly calculated and by determining the moisture content of the soil the dry density of the fill can be calculated and hence the voids percentage. A high percentage of voids indicates poor compaction of soil. A cylindrical core cutter is a seamless steel tube. For determination of the dry density of the soil, the cutter is pressed into the soil mass so that it is filled with the soil without disturbing the core contents. The cutter filled with the soil is lifted up. The mass of the soil in the cutter is determined. The dry density is obtained as

$$\text{Dry Density} = \frac{\gamma}{1 + w}$$

where,

γ = Field Density of the wet soil in the cutter

w = water content.

Equipment for Core Cutter Method

1. Cylindrical core cutter, 100mm internal diameter and 130mm long

2. Steel rammer, mass 9 kg, overall length with the foot and staff about 900mm.
3. Steel dolley, 25mm high and 100 mm internal diameter
4. Weighing balance, accuracy 1g.
5. Palette knife
6. Straight edge, steel rule etc

Procedure of Core Cutter Method

1. Determine the internal diameter and height of the core cutter to the nearest 0.25mm
2. Determine the mass (M_1) of the cutter to the nearest gram.
3. Expose a small area of the soil to be tested. Level the surface, about 300mm square in area.
4. Place the dolley over the top of the core cutter and press the core cutter into the soil mass using the rammer. Stop the pressing when about 15mm of the dolley protrudes above the soil surface.
5. Remove the soil surrounding the core cutter, and take out the core cutter. Soil soil would project from the lower end of the cutter.
6. Remove the dolley. Trim the tip and bottom surface of the core cutter carefully using a straight edge.
7. Weigh the core cutter filled with the soil to the nearest gram (M_2).
8. Remove the core of the soil from the cutter. Take a representative sample for the water content determination.
9. Determine the water content.

3.3 WATER CONTENT OF SOIL BY OVEN DRY METHOD

The oven dry method is widely used laboratory method determine the water content or moisture content of given soil sample. It gives very accurate results.

Equipments for Oven Dry Method

1. Oven
2. Soil Containers (Cups)
3. Digital Weight Machine
4. Desiccator
5. Tongs

Procedure of Oven Dry Method

1. In first step, clean and dry the containers and weigh them and note down the mass of each container (M_1). Also note down the number of each container along with its weight.
2. Collect the soil sample from field. Remove the top layer of soil and collect the wet soil from bottom layers.
3. Fill the containers with required quantity of soil sample and weigh the each container and note down its mass (M_2).



Figure 3.3 Oven Dry Method

4. Place the containers in hot air oven, arrange temperature to $110^{\circ} \pm 5^{\circ}$ C and allow them to dry for 24 hours.
5. After 24 hours turn off the oven and take out the containers using tongs.
6. Cool down the containers in desiccator for one hour.
7. After that weigh containers and note down the mass (m_3) of each container.

Calculation Steps of Oven Dry Method

The data collected during the test is noted in below data sheet. From this data the water content of given soil sample is calculated by the below shown formula

$$w = \frac{M_2 - M_3}{M_3 - M_1} \times 100$$

Where M_1 = Mass of empty container with lid,

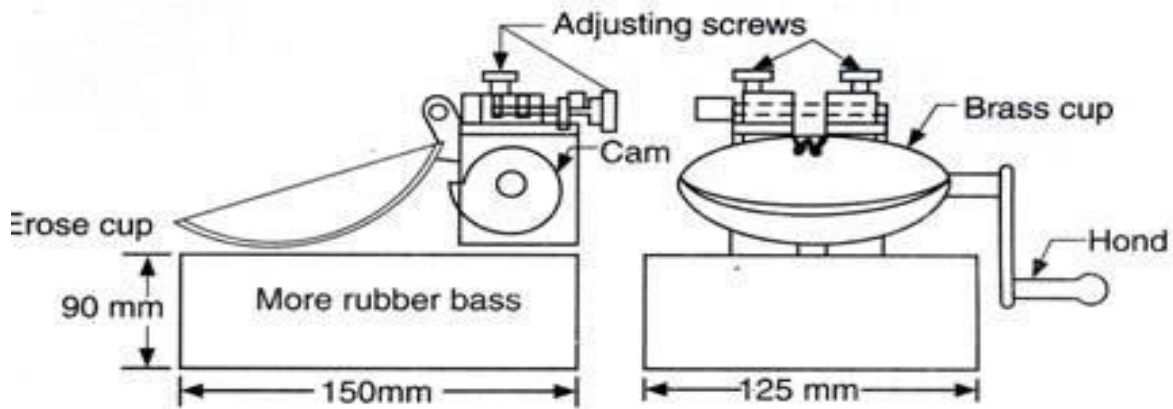
M_2 = Mass of the container with wet soil and lid,

M_3 = Mass of the container with dry soil and lid.

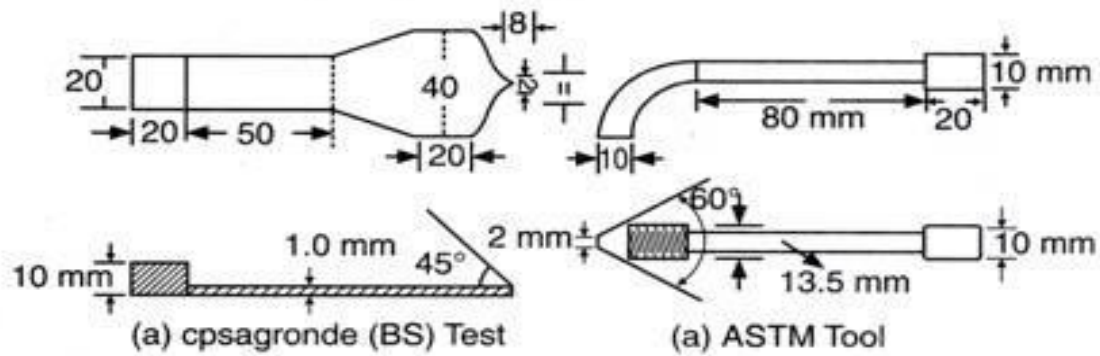
3.4 LIQUID LIMIT DETERMINATION

Procedure of Liquid Limit Determination

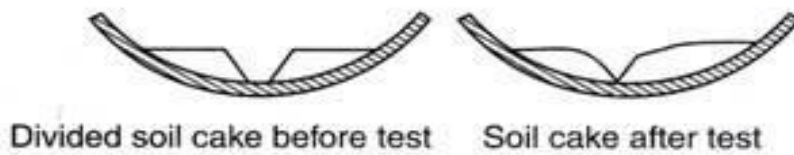
1. Adjust the drop of the cup of the liquid limit device by releasing the two screws at the top and by using the handle of the grooving tool or a gauge. The drop should be exactly 1 cm at the point of contact on the base. Tighten the screw after adjustment.
2. Take about 120g of the air-dried soil sample passing 425 micron IS sieve.
3. Mix the sample thoroughly with distilled water in an evaporating dish or a glass plate to form a uniform paste. Mixing should be continued for about 15 to 30 min, till a uniform mix is obtained.
4. Keep the mix under humid conditions for obtaining uniform moisture distribution for sufficient period. For some fat clays. This maturing time may be upto 24 hours.
5. Take a portion of the matured paste and remix it thoroughly. Place it in the cup of the device by a spatula and level it by a spatula or a straight edge to have a minimum depth of the soil as 1cm at the point of the maximum thickness. The excess soil, if any should be transferred to the evaporating dish.
6. Cut a groove in the sample in the cup by using the appropriate tool. Draw the grooving tool through the paste in the cup along the symmetrical axis, along the diameter through the centre line of the cup. Hold the tool perpendicular to the cup.
7. Turn the handle of the device at a rate of 2 revolutions per second. Count the number of blows until the two halves of the soil specimen come in contact at the bottom of the groove along a distance of 12mm due to flow and not by sliding.
8. Collect a representative sample of the soil by moving spatula width-wise from one edge to the other edge of the soil cake at right angles to the groove. This should include the portion of the groove in which the soil flowed to close the groove.
9. Remove the remaining soil from the cup. Mix it with the soil left in evaporating dish.
10. Change the water content of the mix in the evaporating dish either by adding more water if the water content is to be increased or by kneading the soil, if the water content is to be decreased. In no case the dry soil should be added to reduce the water content.
11. Repeat the steps 4 to 10 and determine the number of blows (N) and the water content in each case.
12. Draw the flow curve between $\log N$ and w , and determine the liquid limit corresponding to $N=25$.



(i) - Liquid limit apparatus



(a) Growing tools



(c) Closing of groove

Figure 3.4 Liquid Limit Apparatus

3.5 PLASTIC LIMIT DETERMINATION

Procedure of plastic limit

1. Select a 1.5 to 2.0 g from the plastic-limit specimen and form the selected portion into an ellipsoidal mass.
2. Roll the soil mass by one of the following methods (hand or rolling device):

Method: Roll the mass between the palm or fingers and the ground-glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The thread shall be further deformed on each stroke so that its diameter reaches 3.2 mm, taking no more than 2 min.

Normally 80-90 stroke per minute is recommended. Count a stroke as one complete motion of the hand forward and back to the starting position. The rate of rolling shall be declined for very fragile soils.



Figure 3.5 Plastic Limit Determination



Figure 3.6 Plastic Limit Thread

3.6 Wastewater Quality Parameters

3.6.1 Analysis method for pH

It is measured on a scale of 1 to 14. Excess of free hydronium ion renders the nature acidic (i.e. $\text{pH} < 7$), while more hydroxide ions are expressed as alkaline (i.e. $\text{pH} > 7$).

Apparatus required:

Electrometric method: Glass electrode, reference electrode (mercury/calomel or silver/silver chloride) and a pH meter.

Procedure:

□ Electrometric method:

The principle of pH determination is based on Electro Motive Force which involves the use of electrodes i.e. indicator electrode and a reference electrode. The water causes the flow of electrons and that generates voltage which is used to find the hydrogen ion concentration. High impedance voltmeter is used to calculate the pH as it is calibrated in such manner.

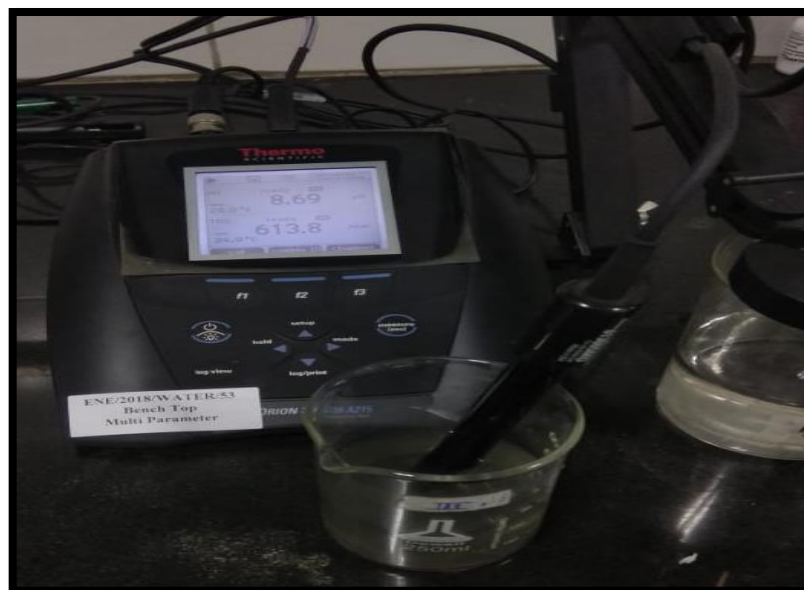


Fig. 3.7 Multi Parameter for pH and TDS

3.6.2 Analysis method for Hardness of water:

Hardness is caused by divalent cations such as calcium, magnesium, alkaline earth metal such as iron, manganese, calculated in terms as equivalent and then shifted to represent as CaCO_3 in mg/L. Carbonates and bicarbonates of calcium and magnesium cause temporary hardness. Sulphates and chlorides cause permanent hardness.

Principle: In alkaline conditions EDTA (Ethylene-diamine tetra acetic acid) and its sodium salts react with cations forming a soluble chelated complex when added to a solution. If a small quantity of dye such as Eriochrome black-T is added to an aqueous solution containing calcium and magnesium ions at alkaline pH of 10.0 ± 0.1 , it forms wine red colour. When EDTA is added as a titrant, all the calcium and magnesium

ions in the solution get complexed resulting in a sharp colour change from wine red to blue, marking the end point of the titration. Hardness of water prevents lather formation with soap rendering the water unsuitable for bathing and washing. It forms scales in boilers, making it unsuitable for industrial usage. At higher pH > 12.0, Mg^{++} ion precipitates with only Ca^{++} in solution. At this pH, murexide indicator gives a pink colour with Ca^{++} ion. When EDTA is added Ca^{++} gets complexed resulting in a change from pink to purple indicating end point of the reaction.

Apparatus required: Pipette, conical flask, Lab glassware-burette, pipette beakers etc.

Reagents:

- Buffer solution: 16.9 g of ammonium chloride and 1.25g of magnesium salt of EDTA is dissolved in 143ml of concentrated ammonium hydroxide and diluted to 250ml with distilled water.
- Eriochrome black-T indicator: 0.5 g of Eriochrome black-T indicator is dissolved in 100g of triethanolamine.
- Standard EDTA titrant: 0.01M or Ng ANALYTICAL REAGENT grade EDTA is dissolved in distilled water and diluted to 1000ml and is standardised in opposition to widespread calcium solution, 1ml = 1mg $CaCO_3$.

Procedure:

Exact 50ml of the well-mixed sample is pipetted into a conical flask, to which 1ml of ammonium buffer and 2-3 drops of Eriochrome black -T indicator is added.

The mixture is titrated against standard 0.01M EDTA until the wine red colour of the solution turns colourless at the end point.

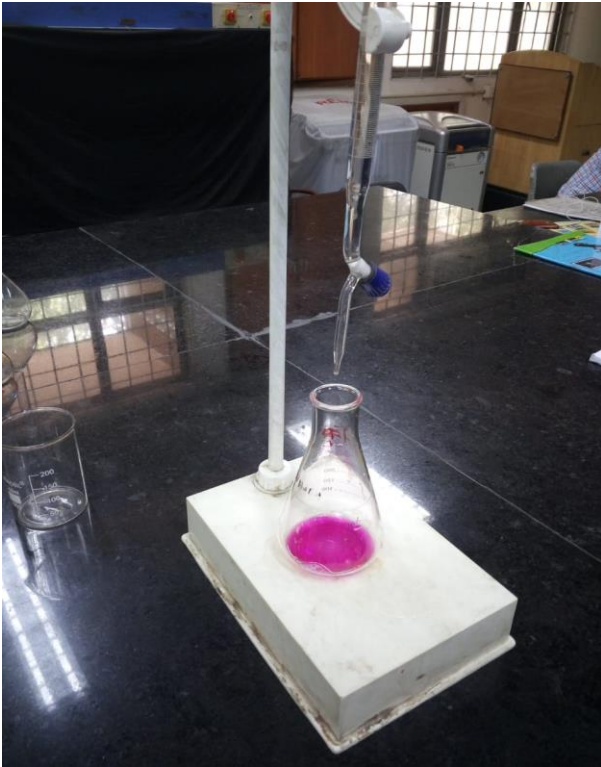


Fig.3.8 Titration Setup



Fig.3.9 Titration Equipments



Fig. 3.10 Titration Procedure

3.6.3 Analysis Method for Dissolved Oxygen (DO):

Membrane electrode method

Principle: The membrane electrode has a sensing element protected by an oxygen-permeable plastic membrane that serves as a diffusion barrier against impurities. Under steady conditions the electric current read is directly proportional to the D.O concentrations (electric current is directly proportional to the activity of molecular oxygen).

Apparatus required: Oxygen-sensitive membrane electrode and lab glassware.

Procedure: The calibrations are carried out following the manufacturer’s calibration procedure. The electrode is dipped into the sample, and the reading noted.



Fig. 3.11 Multimeter for DO Measurement

3.6.4 Analysis method for Total Dissolved Solids (TDS):

Waters with high dissolved solids typically are of inferior palatability and might induce an unfavorable physiological response in the temporary consumer. Dissolved solids are solids in dissolved state in solution.

Principle: The difference in the weight of total solids and the total suspended solids gives the total dissolved solids.

Apparatus: filtration apparatus, suction flask and pump, drying oven and Grooch crucible, Glass-fiber filter disks, membrane filter funnel.

Procedure: The difference in the weights of Total Solids (W_1) and Total Suspended Solids (W_2) expressed in the same units gives Total Dissolved Solids (TDS).

Calculation:

Total Dissolved Solids = $(W_1 - W_2) \times 1000$ (mg/L)

Sample volume (ml)

W_1 = Weight of total solids + dish

W_2 = Weight of total suspended solids

3.6.5 Analysis method for Chemical Oxygen Demand (COD):

Principle: A strong oxidising agent completely oxidises the organic compound present in the waste water. One of the oxidising agent is Potassium dichromate in acidic medium to release carbon dioxide and water. The excess potassium dichromate left will be found using titration via Ferrous Ammonium Sulphate (FAS) using ferroin indicator to determine the COD. The dichromate consumed gives the oxygen required for the oxidation of the organic matter.

Reagents:

- Standard potassium dichromate solution (0.250M): 12.25g of potassium dichromate is first dried at a temperature of 103 °C for about 2 hours and then it is dissolved in distilled water and made up to 1000ml.
- Standard ferrous ammonium sulphate (FAS) 0.25N: 98g of FAS is made soluble into a small amount of distilled water to which 20ml of concentrated sulphuric acid is poured and then made 1000ml using distilled water to obtain 0.25N of ferrous ammonium sulphate.
- Ferroin indicator
- Conc. sulphuric acid
- Silver sulphate crystals
- Mercuric sulphate crystals

Procedure:

- Add 15ml of conc. sulphuric acid to 0.3g of mercuric sulphate. To it a pinch of silver sulphate along with 5ml of 0.025M potassium dichromate is added and taken into a test tube.
- 10ml of the above sample (thoroughly shaken) is pipette out and digested to get the amount of FAS used.

- The sample of 10 ml 0.25M FAS is titrated using ferroin indicator, till the colour turns from blue green to wine red indicating the end point.
- A reagent blank is also carried out using 10ml of distilled water.

3.6.6 Analysis method for Total Suspended Solids (TSS):

- To measure total solids, take a clean porcelain dish which has been washed and dried in a hot air oven at 105°C for one hour.
- Now weigh the empty evaporating dish in analytical balance. Let's denote the weight measured as (W₁).
- Now we should have to decide what should be the volume of sample to be taken for analysis.
- Volume may be estimated either from values of specific conductance or general thumb rule.
- In general, select a sample volume that will yield residue between 2.5 and 200 mg after drying.
- Using pipette transfer 75mL of unfiltered sample in the porcelain dish.
- Switch on the oven and allowed to reach 105°C. Check and regulate oven and furnace temperatures frequently to maintain the desired temperature range.
- Place it in the hot air oven and care should be taken to prevent splattering of sample during evaporation or boiling.
- Dry the sample to get constant mass. Drying for long duration usually 1 to 2 hours is done to eliminate necessity of checking for constant mass.
- Cool the container in a desiccator. Desiccators are designed to provide an environment of standard dryness. This is maintained by the desiccant found inside. Don't leave the lid off for prolonged periods or the desiccant will soon be exhausted.
- Keep desiccator cover greased with the appropriate type of lubricant in order to seal the desiccator and prevent moisture from entering the desiccator as the test glassware cools.
- We should weigh the dish as soon as it has cooled to avoid absorption of moisture due to its hygroscopic nature.
- Samples need to be measured accurately, weighed carefully, and dried and cooled completely.
- Note the weight with residue as (W₂).



Fig. 3.12 Crucible used for TSS

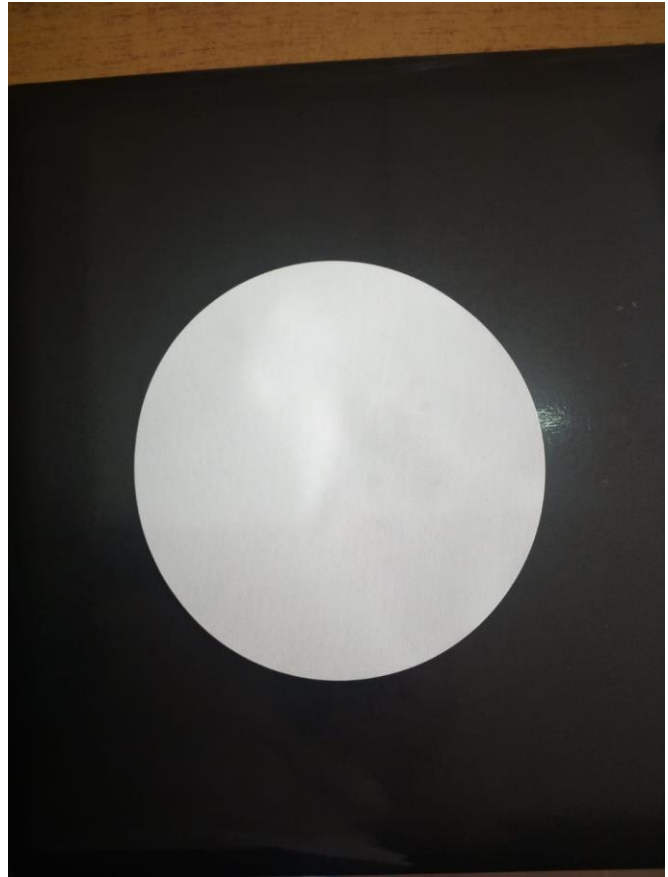


Fig. 3.13 Filter Paper used for TSS

CHAPTER 4

EXPERIMENTAL INVESTIGATION AND RESULTS

4.1 SIEVE ANALYSIS OF SOIL



Figure 4.1 Sieve Analysis

S.No.	Sieve Size(mm)	Weight Retained(G)	% Retained	% Finer
1	4.75	48.27	4.82	95.18
2	2.36	71.93	7.19	87.99
3	1.18	127.46	12.74	75.25
4	0.600	203.33	20.33	54.92
5	.425	168.12	16.81	38.11
6	.150	80.61	8.06	30.05
7	.075	124.2	12.42	17.63
8	PAN	176.35	17.63	-

Table 4.1 Sieve Analysis

Hence the soil used is classified as **Clayey Sand**.

4.2 CONSISTENCY LIMITS OF SOIL

Liquid Limit (w_L) = 39%

Plastic Limit (w_P) = 19%

Plasticity Index(I_p) = 20%

4.3 FIELD DENSITY OF SOIL BY CORE CUTTER METHOD

Sl. No.	Observations and Calculations	Determination No.		
		1	2	3
Observations				
1	Internal diameter	100	100	100
2	Internal height	127.5	127.5	127.5
3	Mass of empty core cutter (M_1)	950	950	950
4	Mass of core cutter with soils (M_2)	2513.5	2516	2515
Calculations				
5	$M = M_2 - M_1$	1563.5	1566	1565
6	Volume of cutter V	945	945	945
7	Water content	11.94%	11.94%	11.94%
8	Dry density using formula	1.48	1.48	1.48

Table 4.2 Field Density and Dry Density

Results of Core Cutter Method

Bulk density of the soil= 1.656 g/cc

Dry density of the soil= 1.48 g/cc.

4.4 WATER CONTENT OF SOIL BY OVEN DRY METHOD

Sl. No.	Observations and Calculations	Determination No.		
		1	2	3
Observation				
1	Container No.	1	2	3
2	Mass of empty container (M_1)	462	462	462
3	Mass of container + soil (M_2)	552	552	552
4	Mass of container + dry soil (M_3)	542.5	542.1	542.6
Calculations				
5	Mass of water $M_w = M_2 - M_3$	9.5	9.9	9.4
6	Mass of solids, $M_s = M_3 - M_1$	80.5	80.1	80.6
7	Water content = $(5)/(6) \times 100$	11.8	12.36	11.66

Table 4.3 Water Content

Water content of the given soil sample = 11.94%.

4.5 Wastewater Quality Parameters

Parameter	Before passing through soil	After passing through soil
pH	7.6	7.6
TSS(mg/l)	885	808
TDS(mg/l)	1146	978
Hardness(mg/l)	451	442
DO(mg/l)	5.66	5.58
COD(mg/l)	526	518

Table 4.4 Wastewater Quality Parameters

4.6 VARIABLE HEAD HYDRAULIC CONDUCTIVITY TEST OF SOIL

Test Sample 1

Length of specimen, $L = 127.5\text{mm}$

Diameter of specimen = 100mm

Volume of specimen = 1001.38cm^3

Diameter of stand pipe = 7mm

Area of stand pipe, $a = 38.48\text{ mm}^2$

Area of the specimen, $A = 78.54\text{ cm}^2$

Sl. No.	Observations and Calculations	Determination No.			
		Day 1 (FRESH WATER)	Day 2 (WASTE WATER)	Day 3 (WASTE WATER)	Day 4 (WASTE WATER)
Observation					
1	Initial Head h_1 (in cm)	125	125	125	125
2	Intermediate Head h_2 (in cm)	114.4	116.1	116.5	117.0
3	Final Head h_3 (in cm)	105.2	107.5	108.6	109.4
4	Time interval (in seconds)				
4.1	h_1 to h_2	240	240	240	240
4.2	h_2 to h_3	240	240	240	240
4.3	h_1 to h_3	480	480	480	480

Sl. No.	Observations and Calculations	Determination No.			
		Day 1	Day 2	Day 3	Day 4
Calculations					
1	$K = 2.303 \frac{aL}{At} \log \frac{h_1}{h_3}$	2.25×10^{-5}	1.96×10^{-5}	1.83×10^{-5}	1.73×10^{-5}

Table 4.5 Hydraulic Conductivity of Sample 1

Test Sample 2

Length of specimen, L = 127.5mm

Diameter of specimen= 100mm

Volume of specimen = 1001.38cm³

Diameter of stand pipe = 7mm

Area of stand pipe, a = 38.48 mm²

Area of the specimen, A = 78.54 cm²

Sl. No.	Observations and Calculations	Determination No.			
		Day 1 (FRESH WATER)	Day 2 (WASTE WATER)	Day 3 (WASTE WATER)	Day 4 (WASTE WATER)
Observation					
1	Initial Head h ₁ (in cm)	125	125	125	125
2	Intermediate Head h ₂ (in cm)	114.8	116.4	116.6	116.7
3	Final Head h ₃ (in cm)	105.4	107.8	108.9	109.7
4	Time interval (in seconds)				
4.1	h ₁ to h ₂	240	240	240	240
4.2	h ₂ to h ₃	240	240	240	240
4.3	h ₁ to h ₃	480	480	480	480

Sl. No.	Observations and Calculations	Determination No.			
		Day 1	Day 2	Day 3	Day 4
Calculations					
1	$K=2.303\frac{aL}{At} \log \frac{h_1}{h_3}$	$2.22*10^{-5}$	$1.92*10^{-5}$	$1.79*10^{-5}$	$1.70*10^{-5}$

Table 4.6 Hydraulic Conductivity of Sample 2

CHAPTER 5

CONCLUSION

The soil was collected from a construction site in DTU premises and the waste water was collected from hostel mess drain. The soil was tested for Hydraulic Conductivity on Day1 using a fresh water sample. The Hydraulic Conductivity of the soil when tested with fresh water was found to be higher than the Hydraulic Conductivity of the soil when treated with waste water during the following days.

The Hydraulic Conductivity of the soil decreases slightly with the passage of time as the test is conducted from Day2 to Day 4 using the waste water and passing it through soil.

Apart from the Hydraulic Conductivity variation, the wastewater was also tested for variation. The pH, Hardness, COD and the Dissolved Oxygen did not show highly significant changes. But the Total Dissolved Solids and the Total Suspended Solids values were changed. Both of them showed decrease in value as compared to their initial values.

The Hydraulic Conductivity of soil is a characteristic of its water content and its density and hence these properties were not changed during the test analysis. The Field density was measured using Core Cutter and the density of the soil and the water content were kept same during the conduction of the tests as well.

The Hydraulic Conductivity of a soil is dependent on the density of fluid passing through it, the viscosity of fluid, the void ratio of soil and the particle size or the average or mean diameter of

particles. Hence, there was a significant change in the Hydraulic Conductivity of the soil when the Fresh Water on Day 1 was replaced with Wastewater on Day 2.

The decrease in the Hydraulic Conductivity of soil is an indicator that if the waste water is directly disposed off on land before giving it desired degree of treatment, then with the passage of time, the permeability of soil will decrease and it will lead to the contamination of the soil and the accumulation of waste water over the land surface.

So, for the land disposal of waste water, proper treatment of waste water up to desired degree should be done, otherwise it may lead to the contamination of land, surface water as well as the ground water.

REFERENCES

- Acar, Y.B., and Ghosh, A.(1987), “ Role of activity in hydraulic conductivity of compacted soils permeated with acetone”, *International Symposium on Environmental Geotechnology, Pennsylvanai, USA, Pennsylvania, Vol. I*, 391-412.
- Anandarajah, A. (2003), “Mechanism controlling permeability change in clays due to changes in pore fluid”, *Journal of Geotechnical and Geoenvironmental Engineering, ASCE*, **129** (2), 163 -172.
- Azam and Abduljauwad, S.N. (2000), “Influence of Gypsification on Engineering Behaviour of Expansive clay”, *Journal of Geotechnical and Geoenvironmental Engineering, ASCE*, **126** (6), 538 - 542.
- Bachewar and Mehta. (2001), “Assessment of waste effluent from drug industry and its influence on soil quality”, *Indian Journal of Environmental Protection*, **21**(9), 834-830.
- Boardman, D.I., Gkeadinning, S. and Rogers, C.D.E (2004), “The influences of iron (III) and lead (II) contaminants on lime – stabilized clay”, *Geotechnique*, **54** (7), 467 – 486.
- Bowders, J.J., Daniel, D.E. (1987), “Hydraulic conductivity of compacted clay to dilute organic chemicals”, ”, *Journal of Geotechnical Engineering, ASCE*, **113** (12), 1432 – 1448. .
- Chew, S.H., Kamruzzaman, A.H.M. and Lee, T.H. (2004), “Physico – chemical and Engineering Behaviour of Cement Treated Clays”, *Journal of Geotechnical and Geoenvironmental Engineering, ASCE*, **130** (7), 696 - 706.
- Foreman, D.E., and Daniel, D.E. (1986), “Permeation of compacted clay with organic chemicals”, *Journal of Geotechnical Engineering, ASCE*, **112** (7), 669 – 681.
- Janardanan, O., Uppot and Stephenson (1989), “Permeability of clays under organic permeants”, *Journal Geotechnical Engineering, ASCE*, **115** (1), 115 – 127.
- Jo, H.Y., Benson, C.H., Shackelford, C.D., Lee, J.M., Edil, T.B. (2005), “Long – term hydraulic conductivity of a geosynthetic clay liner permeated with inorganic salt solutions”, *Journal of Geotechnical and Geoenvironmental Engineering, ASCE*, **131** (4), 405 - 417.
- Katsumi, T., Ishimori, H., Ogama, A., Yoshikawa, K., Hanamoto, K. and Fukagawa, R. (2007),”Hydraulic conductivity of non prehydrated geosynthetic clay liners permeated with inorganic solutions and waste leachates”, *Soils and Foundations, the Japanese Geotechnical Society*, **47** (1), 79 – 96.
- Kim, Y.J. and Edil, B.T. (1997), “Effective porosity and seepage velocity in column test

on compacted clay”, *Journal of Geotechnical and Geoenvironmental Engineering, ASCE*, **123** (12), 1135 – 1141.

Klausner, Y. and Shainberg, I.

Kolstad, D.C., Benson, C.H. and Edil, T.B. (2004), “hydraulic conductivity and swell of non – prehydrated geosynthetic clay liners permeated with multispecies inorganic solutions”, *Journal of Geotechnical and Geoenvironmental Engineering, ASCE*, **130** (12), 1236 – 1249.

Martin, C.C. (1987), “Effect of pore-fluid on grain-size distribution”, *International Symposium on Environmental Geotechnology*, Pennsylvania, USA, Pennsylvania, Vol. II, 295-296.

Rakshandehroo, G. R., Wallace, R.B., Zhao, X., Boyd, S.A., Voice, T.C. (2001), “Hydraulic conductivities of cationic surfactant modified soil mixtures”, *Journal of Environmental Engineering, ASCE*, **127** (8), 724 – 729.

Rowe, R.K., Shang, J.Q. and Xie, Y. (2002), “Effect of permeating solutions on complex permeability of compacted clay”, *Canadian Geotechnical Journal*, **39**, 1016 - 1025.

Rowe, R.K and Badv.K. (1996), “ Chloride migration through clayey silt underlain by fine sand or silt”, *Journal of Geotechnical Engineering, ASCE*, **122** (1), 60- 68.

Steele, R. and Hu, Z.X. (1987), “Effect of pore-fluid on soil/water behaviour with examples”, *International Symposium on Environmental Geotechnology*, Pennsylvania, USA, Pennsylvania, Vol. II, 301-309.

Stern, R.T., Shackelford, C.D. (1998), “Permeation of sand – processed clay mixtures with calcium chloride solutions”, *Journal of Geotechnical Engineering, ASCE*, **124** (3), 231 - 241.

T. Thyagaraj, M. Julina (2019), “Effect of interacting fluid and wet-dry cycles of microstructures and hydraulic conductivity of compacted clay soil”, *Geotechnique Letters, ICE*, **9**, 1-24.

Tremblay, H., Duchesne, J., Locat, J. and Leroueil, S. (2002), “Influence of the nature of organic compounds on fine soil stabilization with cement”, *Canadian Geotechnical Journal*, **39**, 535 - 546.

Yang, N. and Barbour, S.L. (1992), “The impact of soil structure and confining stress on hydraulic conductivity of clays in brine environments”, *Canadian Geotechnical Journal*, **29**, 730 – 739.