EFFECT OF LEACHATE ON THE COMPACTED SOIL AS A LINER MATERIAL

A Dissertation submitted in partial fulfilment of the requirement for the Award of degree of

MASTER OF TECHNOLOGY
IN
GEOTECHNICAL ENGINEERING

BY

RIBBOM BASAR
(2K15/GTE/15)

Under the guidance of

Dr. Ashok Kumar Gupta (Professor)
Department of Civil Engineering
Delhi Technological University
Delhi

DELHI TECHNOLOGICAL UNIVERSITY

(FORMELY DELHI COLLEGE OF ENGINEERING)

DELHI-110042

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CANDIDATES'S DECLARATION

I do hereby certify that the work presented is the report entitled **"Effect of leachate on the compacted soil as a liner material"** in the partial fulfilment of the requirements for the award of the degree of "Master of Technology" in Geotechnical Engineering submitted in the Department of Civil Engineering, Delhi Technological University, is an authentic record of my own work carried out from January 2017 to July 2017 under the supervision of Dr. Ashok Kumar Gupta (Professor), Department of Civil engineering. I declare that this thesis submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the institute.

I have not submitted the matter embodied in the report for the award of any other degree or diploma.

Date: 05/07/2017

Ribbom Basar
2K15/GTE/15

CERTIFICATE

This is to certify that above statement made by the candidate is correct to best of my knowledge.

Dr. Ashok kumar Gupta
(Professor)
Department of Civil Engineering
Delhi Technological University

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ABSTRACT

With the increase of waste generation and the need of the containment of waste to avoid ground water contamination effective liner system are inevitable. Due to shortage of the suitable material or its non availability, it is necessary to develop certain alternative material for the liner system. In this project, local soil of DTU is proposed for the liner system. The properties of the soil are altered by adding bentonite to get the desired least permeability. Further, the effect of leachate on the proposed soil is studied. A column study is being carried out to study short term effect of leachate on the soil. First a short term test is carried out by mixing the soil with leachate for 2-3 days and then finding out the change in properties. Secondly, a long term test was carried out using a column study in which the soil is compacted at its MDD and OMC and the leachate is permeated and kept for a month or two. Then the change in the properties is determined. Change in the properties, change in internal structure if any, and change in the hydraulic conductivity of the soil is determined. Atterberg limit test to determine the change in properties was done and XRD to find the change in internal structure was done and falling head test for the hydraulic conductivity. It can be seen that leachate does change the properties of the soil, internal structure and also the hydraulic conductivity.

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NOTATIONS

Notations	Description
k	Coefficient of permeability
LL	Liquid limit
PL	Plastic limit
GCL	Geosynthetic clay liner
CCL	Compacted clay liner
FML	Flexible membrane liner
MSW	Municipal solid waste
ML	Silty soil with low plasticity
OMC	Optimum moisture content
MDD	Maximum dry density
NTU	Nephelometer turbidity unit
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
Zn	Zinc
Mg	Magnesium
Na	Sodium
Ca	Calcium
Cr	Chromium
Mn	Manganese
Fe	Iron
Co	Cobalt
Ni	Nickel
Cu	Copper
As	Arsenic
Cd	Cadmium
Pb	Lead
DO	Dissolved oxygen
ICP-MS	Inductively coupled plasma- Mass spectrometry
XRD	X-ray diffraction technique

CHAPTER 1

INTRODUCTION

With increase in the waste day by day for disposal the suitable arrangement of a landfill is also must, which will be safe against soil and ground water contamination. Though it is desirable to construct the landfill away from water reservoir due to increase possibility of contamination but due to unavoidable circumstances like lack of land space and increase waste, many a times it can't be avoided. With passing of time there is generation of harmful gases and liquid called leachate, which may flow with the water towards the ground water or low lying water reservoir and contaminate it.

For the landfill to be effective in constraining the waste and its harmful products, it should be built with strong liner system which is also called as engineered landfill. The main purpose of the liner system is to impede waste contaminants from leaving the site that may contaminate ground water. The main two function of a liner system are,

i. To impede the movement of the pollutant in to the subsoil.

ii. Attenuation of the dissolved or suspended pollutants particles so that the contaminants present in leachate will be within acceptable range.[1]

The first function of the liner which is mentioned above is attained by constructing the liner system with material of low permeability. The attenuation capability depends on the mass of the liner system and chemical composition of the material used. Though Soil have a great capacity to absorb materials of various types, but most of them cannot provide an impervious boundary. A larger thickness of a soil layer below the waste can also result in a lower movement of a contaminant through the liner. A soil liner with a minimum percentage of clay i.e. 25-28% is a good liner material. The clay-size of small fraction i.e. less than 0.002 mm has a comparatively larger surface area, and the physico-chemical interactions between soil particle influences the mechanical behaviour of a clayey soil. Soils used as liners also must have acceptable engineering properties. The soil consistency differs with moisture content, and the degree of hydration of clayey soils has a direct effect upon the liner's compressive strength. The plastic limit and the liquid limit are also valuable in assessing the engineering characteristics of soils. Soil permeability is the quantitative analysis of the ability of the soil to transmit the liquid. The permeability is dependent on both the soil properties and leachate properties. A good liner will usually possess a hydraulic conductivity (k) of 1×10^{-7} cm/s or less when it is tested with a simulated or actual waste fluid.[1]

1.1 LINER SYSTEM:

The landfill liner system is mainly of three types viz.

1.1.1. SINGLE LINER SYSTEM –

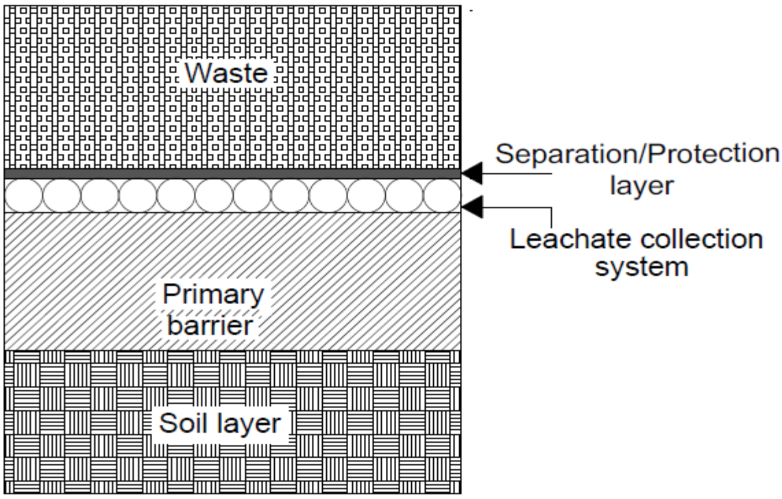


Fig. 1: Single liner system

Single liner system primarily consists of Primary barrier which may be of compacted clay layer, a geosynthetic clay liner, or a geomembrane. It is provided for non-toxic waste like construction and demolition debris where there is less probability of soil contamination beneath it. It requires less expenses i.e. cheaper and also require less money for maintaining the landfill liner.

1.1.2. DOUBLE LINER SYSTEM –

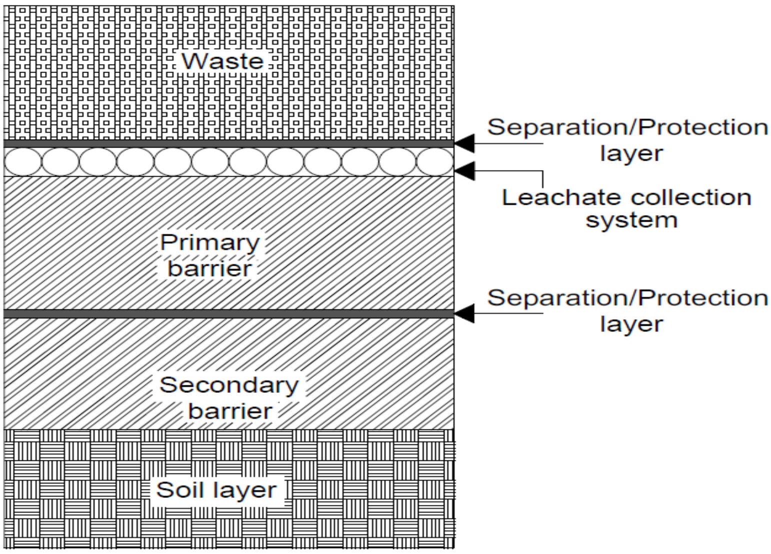


Fig. 2: Double liner system.

A double liner system mainly consists of a Primary barrier and a Secondary barrier. These barriers may be a composed of two single liners which are parted by a protection or separation layer, two composite liners separated by a separation or protection layer, or a single and composite liner separated by a separation or protection layer. The function of the upper layer also called as the primary barrier is generally to collect the leachate, while the second liner below i.e. the secondary liner or barrier performs the function of leak-detection system and also as a support to the primary liner. Double-liner systems are generally used for landfill for municipal solid waste which can contain toxic metals and also in every hazardous waste landfills.[4] Providing more than a single barrier can increase the capacity of liner system in safeguarding the soil and ground water beneath it.

1.1.3. COMPOSITE LINER SYSTEM –

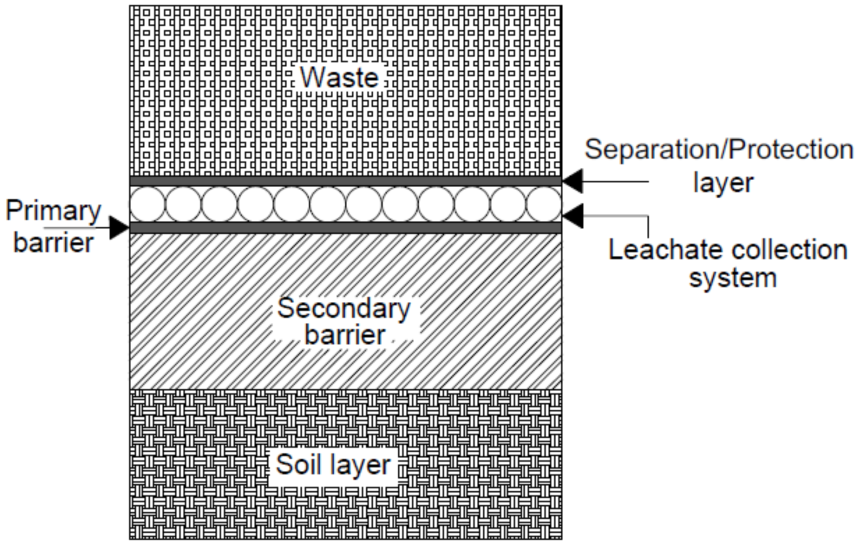


Fig. 3: Composite liner system.

The composite liner consists of a primary barrier and secondary barrier attached to one another with no separation layer. They are provided as one. Primary barrier is generally of geosynthetics like geomembrane combined with a liner of Clay or GCL. Composite liner systems are far better at limiting the migration of leachate than a single Clay liner or single geomembrane layer. Therefore, they are provided in landfills where there are more chances of leachate generation like MSW landfills

1.1.4. MULTIPLE LINER SYSTEM –

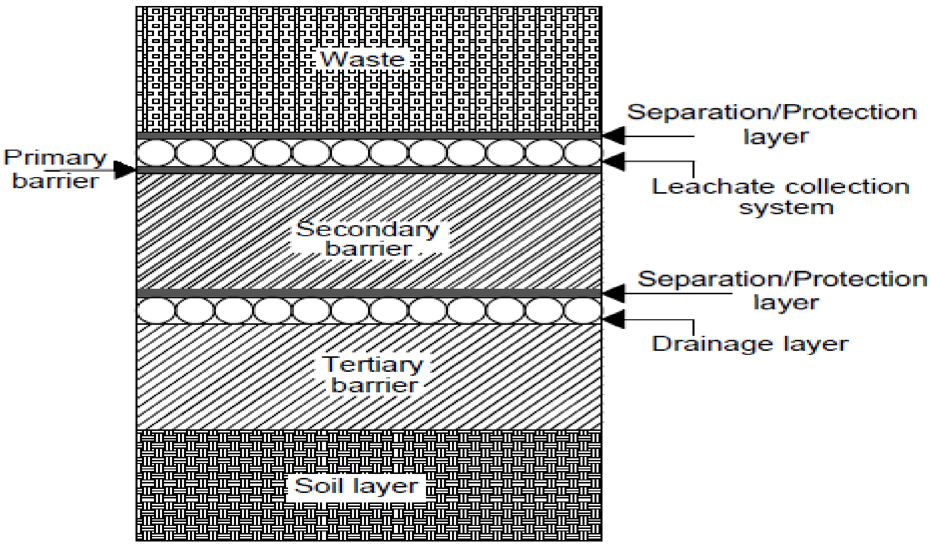


Fig.4: Multiple liner system.

In multiple liner system with primary and secondary barrier there is an addition of one more barrier called as tertiary barrier. The primary and secondary barrier are provided as one without any separation layer as in a composite layer. The primary layer be a Flexible membrane liner and secondary be CCL or GCL. Tertiary liner material is either clay or GCL or flexible membrane liner. These liner system are provided where the waste is highly toxic and also the nearby ground water or surface water is at high risk of contamination.

1.2 LINER COMPONENTS:

As there are various layer in a liner systems, various materials can be chosen for different layer for different functions.

1.2.1. CCL:

The main characteristics property of the clay for which it is best as a liner material is its low hydraulic conductivity which is in the range of 10^{-10} m/s. The thickness of the clay layer to be provided in a landfill liner depends on the level of toxicity of the waste material, characteristics of the soil geology beneath and the liner type which has to be installed. The effectiveness of compacted clay liners can be reduced to an extent by fractures caused by freezing and thawing cycles, drying, and the presence of various chemicals. Generally, it is said that approximately 30 cm of clay layer is enough to impede the flow of leachate but, additional clay has to be added so as a precautionary measure in case of any loss of effectiveness of clay layer. Clay liners efficiency can be enhanced or maximised by compacting the clay with a roller few inch by inch. Desiccation or drying of the clay should be avoided during construction which will or may results in cracks that can reduce its efficiency. Clay should be always compacted at the wet side of optimum as it is more efficient and act as an effective barrier. Liners should be made of a single clay type rather than different types because it perform better this way.

1.2.2. GCL:

GCL are used as a substitute to CCL because of its greater resistance to temperature changes and also it has less hydraulic conductivity compared to CCL. GCL are manufacture by sandwiching the sodium bentonite clay or any other material of very low permeability in between two geosynthetic layer. The geosynthetics used are generally geotextiles as the main function is to minimise the migration of harmful liquids. They are held together by stitching, needling or use of chemical adhesives. In GCL, clay is the primary component as a barrier material as geotextile generally add shear strength. GCL liners requires less installation time as compared to CCL and also the efficiency of the liners is less affected by the freezing and thawing cycles.

1.2.3. GEOMEMBRANE:

Geomembranes are the synthetic membrane which are manufactured by using plastic materials like Polyvinyl Chloride (PVC), High density polyethylene (HDPE) etc. They are used as a liner material because of its very low permeability and greater strength and, resistant to chemicals. They are also called as flexible membrane liners (FML).

1.2.4. GEOTEXTILES:

Geotextiles are the synthetic fabric which have multiple application like for separation, reinforcement, filter, protect and drain. In liners of landfill, geotextiles are used as a protection layer as well filter so as to avoid the passage of minute soil and waste particles into the leachate collection system and also to protect the geomembranes against punctures. These materials allows only the passage of water and traps the particles in the leachate to diminish the clogging of the leachate collection layers.[4]

1.2.5. GEONET:

A geonet is a synthetic material which consists of net-like integrally connected blanket which can be used to replace sand and gravel for the layer of leachate collection. Geonets are costlier and also are very much susceptible to clogging by tiny particles which can be the reason to prefer sand and gravel instead of geonet. This clogging could weaken the performance of the geonet and thereby leachate collection system. However, geonets transfer liquid more quickly than gravel and sand.

1.2.6. SAND AND GRAVEL:

Sand and gravel are generally used as a drainage layer or a gas collection layer as they are highly permeable and easily allows the movement of fluids through it.

1.3 FACTORS AFFECTING THE SELECTION OF A BARRIER LAYER:

There are various factors which can lead to the selection of a particular barrier type and the composites. They are –

1. CLIMATE:

The climate of a region can affect the selection of the material that can be used in the barrier layer and also the thickness of the barrier layer to be provided. For example,

- The region where there is problem of frost action CCL should be avoided, instead GCL or GM should be used. And, if due to unavoidable condition CCL is used, the thickness provided should be such that the water permeating should not be freezed.

-In places where there is a problem of temperature variations, CCL should not be provided as temperature variation will lead to cracking of the clay liner and thereby the liner system will fail and will be not able to do the intended function

2. THE AMOUNT OF DIFFERENTIAL SETTLEMENT:

The settlement can in large affects the selection of right material for the line system. For example,

-The landfill with high probability of settlement CCL should not be provided because the settlement will lead to cracking and thereby failure of the clay liner.

-Geogrids should be installed after the expected settlement as it is very weak in tension strength. So, instead geomembranes can be provided as it has good tensile strength.

3. The susceptibility of the cover soil to puncture and erosion.

4. The quantity of water seeping through the liner.

5. The necessity for collection of the gas generated by waste.

6. Slope steepness.

7. BENEFIT/COST TERMS:

It will affect the selection as follows,

-Of all the single layer systems, the GM alone perform better than the CCL by 77% on benefit/cost basis. Also GCL performs better than CCL by 27%.

-Among the composites, GM/GCL performs better than GM/CCL by 13% on benefit/cost terms.

-In triple layer systems, the differences of performances are relatively small like 6%.

1.4 OBJECTIVE:

The present study is carried out with the following objectives

1. To examine the effect of leachate on compacted soil liner material which includes the effect on soil structure and overall performance of the liner system.

2. To evaluate the effects of leachate on hydraulic conductivity of liner material.

3. The effect of leachate on physical properties of the soil.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a review of important literature pertaining to the history and theory of effects of leachate on liner material and also theory of landfill liner systems. It also includes review on the methods of testing the compatibility of clay liners with the leachate. A review of permeability test using leachate is also described.

1. **Eklund, A. G. (1985)**. "A Laboratory Comparison of the Effects of Water and Waste Leachate on the Performance of Soil Liners"**.** In this paper, study was conducted to determine the performance of two compacted native soils and the soils with commercial additive and was exposed to specific paper mill waste leachates. Short term and long term compatibility study was done to see the effect of leachate on the soil physical properties, chemical and also the internal and external structure of the soil. Comparison tests was performed to measure the hydraulic conductivity were to determine the behavioural differences of the candidate soil liners with the waste leachate and water. Test results obtained indicated that the two soils tested were effective in containing the paper mill waste leachates. One soil physically contained the waste leachates by providing an impermeable barrier ($k = << 10^{-7}$cm/s). The other soil, while not providing as strong a physical barrier, ($k = 10^{-7}$ cm/s), did contain the leachate through chemical attenuation of the trace contaminants in the leachate. It was also seen that the soil added with beneficent was superior compared to the virgin soil alone. The authors concluded that, both the mechanisms of containment will be effective in providing protection of groundwater resources below a non-hazardous waste landfill.

2. **Bowders et al (1986).** "Methods for Testing the Compatibility of Clay Liners with Landfill Leachate"**.** In this study, the compatibility of compacted clay liners with landfill leachate was evaluated with laboratory permeability tests. Authors suggested that, compaction mould permeameters was to be used for laboratory-compacted specimens of clay subjected to low overburden pressure and Flexible wall permeameters for laboratory-compacted specimens subjected to relatively high overburden pressure and for undisturbed specimens of clay obtained from the field. For dilute leachates, batch equilibrium tests was recommended before a permeability test was initiated so that the tendency for the soil to adsorb materials in the leachate can be evaluated. Authors also concluded that if the index properties are unaffected by the leachate then it is unlikely that the permeability will be affected. They suggested this tests to reduce the required no. of permeability tests. Lastly they presented a decision tree as an aid to select the best testing program.

3. **Fang, H.Y., Evans, J.C. (1988)**. "Long-Term Permeability Tests Using Leachate on a Compacted Clayey Liner Material"**.** In this study, the results of laboratory tests on a compacted clayey liner material using landfill leachate was presented. Laboratory permeability tests were conducted with continuous permeation for a period of three to six months in triaxial cell permeameters. The soil samples were obtained from a borrow pit in eastern Pennsylvania and was proposed for use as a compacted liner material. Soil tests, like Atterberg Limits, gradation, compressive strength, and compaction tests were conducted on samples exposed to both water

and leachate. Also, tests were conducted on bentonite-clay mixtures to illustrate the behavioural difference between high-swelling and non-high-swelling clays. It was found that permeation of the clayey liner material with landfill leachate did not significantly change permeability of the material, also the physical properties remained relatively unchanged. In contrast, it was seen that the test results conducted on bentonite-clay mixtures resulted in more significant changes. Therefore it was concluded that leachate permeation of natural silty clays of low activity, can result in insignificant change in engineering properties. In contrast, leachate permeation of a high swelling sodium montmorillonitic soil could result in significant changes.

4. **Gordon et al (1989)**. “Hydraulic conductivity of three landfill clay liners”. In this study, the authors have presented the data collected by lysimeters for 5-7 years from three landfills lined with clay. The information was used to calculate the hydraulic conductivity along with estimated leachate head levels using Darcy’s law. The three landfills were Marathon county landfill, Portage county landfill, sauk county landfill. The materials used fo the construction of the three landfill were residual clay weathered from metamorphic rocks, residual clay weathered from granitic bedrock, residual clay weathered from dolomite respectively. The thickness of the liners were 1.22 m, 1.5 m, 1.5m respectively. Results shows that the hydraulic conductivities calculated were always below 1×10^{-7} cm/s and generally ranges between 1×10^{-8} cm/s to 1×10^{-9} cm/s. The authors concluded from the data collected that hydraulic conductivities in liner system can be achieved less than 1×10^{-7} cm/s by using thick clay liners with standard compaction. They also concluded that to measure directly the hydraulic conductivities of liners exposed to leachate lysimeters should be installed at all sites.

5. **Mohamed et al (1994).** “Geo-Environmental assessment of a micaceous soil for its potential use as an engineered clay barrier”. This study was carried out to find the ability of natural micaceous clay soil found in Stanleyville, southern Ontario to be a potential liner material. Mineralogical study was carried out by using XRD analysis. Batch equilibrium tests were conducted to study the absorption and desorption capacity of the soil. Leaching column test were also conducted to examine the PH buffering capacity of the soil. The results from the batch test shows that compacted soil adsorbed less Pb^{2+} and Zn^{2+} as compared to the soil used in batch test. Results also shows that there is less adsorption of Pb^{2+} and Zn^{2+} in mixed solution than that each as solo ion. A very little change was seen in the hydraulic conductivity of the soil sample. The experimental results reveals that the soil has high PH buffering capacity. It was concluded that the soil can function as a natural liner material, if the finer part of the soil is used.

6. **Ganjian et al (2004)**. “Selection of cementitious mixes as a barrier for landfill leachate containment”. In this study, an alternative material i.e concrete, which has been considered as waste by their primary producers was introduced as a liner material. Various cementitious mixes were made and analysed. The results shows that most of the waste minerals and cementitious mix satisfied the requirement of a barrier system. Results also shows that these materials have decent chemical buffering capacity. The work also shows that the material can be combined by careful selection and screening to produce low permeability cementitious mix which will be highly resistive to organic acids. Study concluded that various selection of mixes

can be proposed and made from locally available material which will satisfy the requirement of a good liner material.

7. **Frempong, E.M., Yanful, E.K., (2005).** "Geo-environmental assessment of two tropical clayey soils for use as engineered liner materials". In this study, two soil from Ghana was analysed for its potential as a landfill liner material. The hydraulic conductivity of the soils before and after the leachate permeation was examined. Also the effect on mineralogy, geotechnical properties and chemical composition was examined. The results shows that there were no adverse effect on the strength properties of soil. The study concluded that the two soil can be used as an effective liner material.

8. **Jang, Y.S., Kim, Y.I., (2007)**. "Influence of accumulated leachate on settlement and in-situ geotechnical properties of a landfill site". In this study, effect of leachate on the settlement of the clay soil below and also stability of the landfill was analysed. Authors have compared the geotechnical properties of soil determined from the laboratory with that of the properties determined from site. They have also compared he consolidation data of both the laboratory and field measurement. Results shows that the settlement is least effected at the beginning but after certain stage settlement increases which is due to the increase in effective load of waste which become greater than the pre-consolidation pressure. They have also back calculated the C_C (compression index) from the settlement they measured to predict the settlements.

9**. Frempong, E.M., Yanful, E.K., (2008)**. "Interactions between three tropical soils and municipal solid waste landfill leachate". This study was carried out to investigate the potential of three tropical soil from Ghana, West Africa as a liner material. The objective was to examine the effect of leachate on the hydraulic conductivity and also mineralogical and chemical composition of soil. The effect on the soil properties before and after leachate permeation was examined. The capacity of the soil to retain toxic metals were also examined. Batch sorption test and diffusion test was carried out to examine the attenuation capacity of the soil. Results shows that new minerals were formed. Hydraulic conductivity was slightly affected. Study also shows that there was sorption of Cl^- ion which was considered as non- reactive. The study concluded that the soil can be used as a potential landfill liner material.

10**. Patil et al (2009). "**Alternative materials for Landfill liner and Covers"**.** In this study, Kolar soil and Granite polish wastes were used as basic materials and are proposed as an alternative for the clay soil. The properties of these materials were altered by adding sodium bentonite to attain the required properties of a competent material for landfill liners and covers. Also, the performance of these materials was tested under different physicochemical environments. It was observed that the permeability of these materials decreases with increase in sodium bentonite. Ilkal granite polish waste with 4% sodium bentonite added and Kolar soil with 10% of sodium bentonite reduces the permeability of the soils to the desired value to use as a material for landfill liner and cover when water (pH = 7) was used as a pore fluid. It was observed that permeability changes with change in pH value. It was found that increase in permeability is high in alkaline medium for both the study materials. But increase in the permeability of Ilkal granite polish waste was marginal. Recommended quantity of sodium bentonite to be added to Ilkal granite polish waste was 4% and that for Kolar soil was 14% to use them as a competent material for landfill liner and cover.

11. **Bradshaw, S.L., Benson, H.B., (2014)**. “Effect of municipal solid waste leachate on hydraulic conductivity and exchange complex of geosynthetic clay liners”. In this study, effect of synthetic leachate and real leachate on the hydraulic conductivity and ion exchange capacity of GCL was evaluated. To see the effect of confining stress on the hydraulic conductivity and cation exchange of the liner, permeability test were conducted with different confining stress. For comparison, hydraulic conductivity test was conducted using leachate with two different conditions, i.e. GCL which is not exposed to the subgrade-hydration and GCL prehydrated with deionized water. Five liquids as a permeant liquids were used for the hydraulic conductivity test, i.e. type II deionized water, Typical real leachate (TRL), typical synthetic leachate (TSL), strong real leachate (SRL), strong synthetic leachate (SSL). Various test conditions were created viz. GCL hydrated with different materials like on torpedo sand, red wing clay, cedar rapids clay, boardman silt for different time period like 30-90 days at different confining stresses like 70, 270, 520 kPa permeated with the five permeant liquids. Results shows that the hydraulic conductivity slightly decreases in the beginning and after that remain steady up to certain volume and then increases slowly up to 40 PVF and then become steady again. From cation exchange results it was seen that the conc. of Na was decreasing and that of Ca, Mg, and K were increasing which suggested that Ca, Mg and K were replacing the Na ion from bentonite. Results also suggested that this cation exchange were affecting the hydraulic conductivities. Another result shows that the GCL which was hydrated and was permeated using synthetic leachate had higher hydraulic conductivities compared to GCL permeated only with synthetic leachate without hydration. Results of the stress variation test shows that the permeability of GCL decreases with increasing confining stress.

Concluding Remarks: From the literature reviewed in this chapter, it can be seen that the research has mostly been carried out using the native soil as a liner material which in this project will be also be pursued. Though many studies have been carried out regarding proposing a newer material for a liner material, but limited studies have been carried out regarding the soil mixed with additives. So, in this project study have been carried out for the soil of Delhi adding bentonite clay. The study carried out in literature above regarding additives mixture is that they have narrowed down the additive percentage to one, but in this project additives are added with soil with two nearest percentages giving least permeability and compared.

CHAPTER 3

EVALUATION OF SOIL PROPERTIES

The soil which is proposed for the liner system to be mixed with clay is DTU soil. The soil was collected from a site near lake inside of DTU campus. Various test was carried out on the soil to determine its type.

3.1 INDEX PROPERTIES OF SOIL:

3.1.1 GRAIN SIZE DISTRIBUTION:

In a given soil sample, the determination of the percentage of the various sizes of soil grains is the Grain-size distribution. To find the distribution of the grain size of the given sample, two tests are generally performed i.e. Sieve Analysis and Hydrometer Analysis. The distribution of particle sizes larger than 75 µm is determined by sieve analysis, while the distribution of particle sizes smaller than 75 µm is determined by hydrometer analysis. Sieve analysis was conducted by taking the sample of 100 g and wet sieve analysis was done. First the 100 gm soil was taken in 75 µ sieve and then washed with water. This washing is done till the water which comes out of the sieve is clear. After that the soil which is retained on the sieve is taken in a dish and oven dried and then taken for sieve analysis and the soil which passes from the sieve is taken for hydrometer analysis.

Photograph No. 1: Process of wet sieve analysis

3.1.1.1: SIEVE ANALYSIS -

For sieve analysis the portion of the 100 gm soil which retained on 75 µ is oven dried and then taken for sieve analysis. Sieves of size 4.75mm, 2mm, 1mm, 425µ, 300 µ, 212µ, 150µ and 75 µ were taken and arranged in descending order of sizes from top to bottom.

Photograph No. 2: Arrangement of sieve on the sieve shaker

The soil retained on each sieve was taken and weighed and the amount retained was noted. The observation carried out is given in appendix I. The cumulative percentage of weight of soil was plotted against the soil particle on a Semi-log graph as shown in fig. no. 1. Using this curve, called as the grain size distribution curve, the C_u (Coefficient of uniformity) and C_c (coefficient of curvature) can be computed.

3.1.1.2 HYDROMETER ANALYSIS –

- The soil passing through 75 µ sieve through wet analysis is collected and then the analysis is carried out.
- Sodium hexa metaphosphate is mixed with the soil so that the soil particles remain as a single entity.
- The reading is taken at time 0.5 min, 1 min, 2 min, 4min, 8min, 15 min, 30 min, 63 min, 113min, 240 min, 513min, 1408min. The hydrometer is calibrated before every

reading i.e. it is kept in a cylinder containing distilled water. The observation carried out is given as in appendix I.

- The particle size distribution curve obtained is as shown in the fig. below. This is the combined graph of both the sieve analysis and hydrometer analysis.

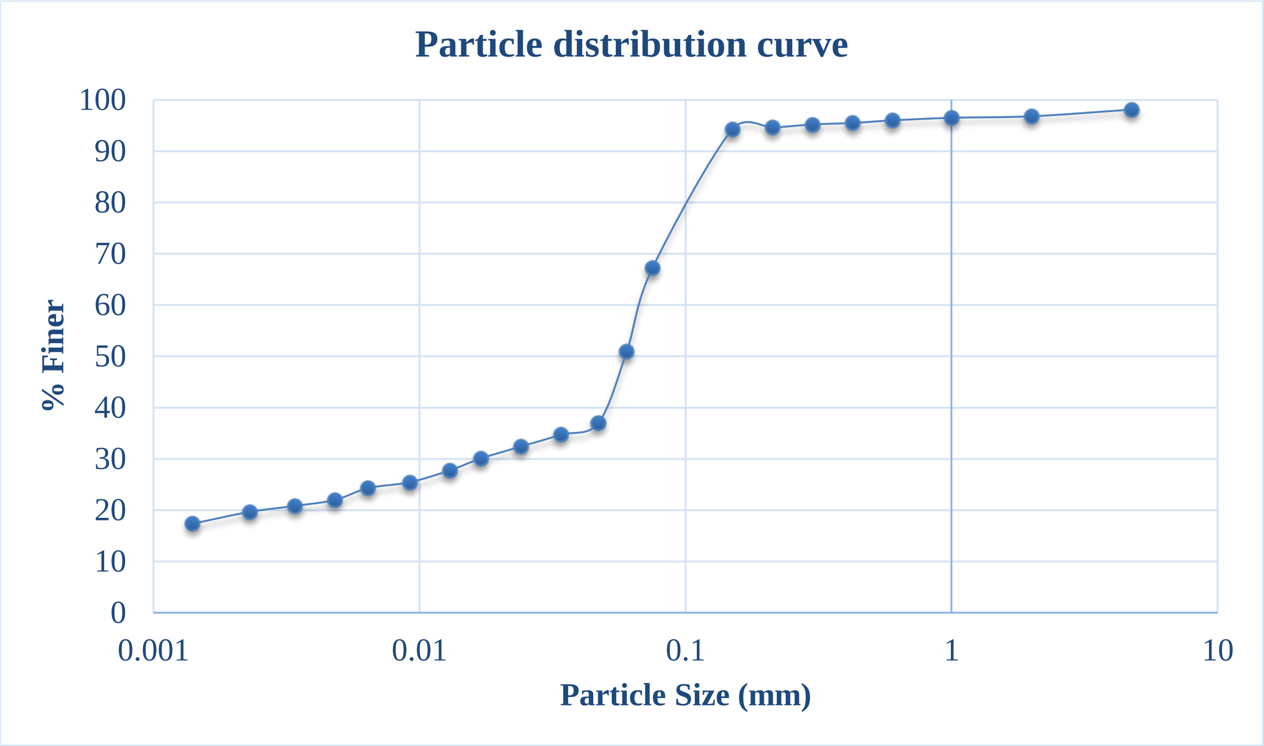


Fig 5: Particle size distribution curve

3.1.2. ATTERBERG LIMIT**:**

3.1.2.1 LIQUID LIMIT -

The soil sample was taken and tested for the liquid limit by cone penetrometer test.

Photograph No. 3: Process of liquid limit test using cone penetrometer

The result obtained are shown in appendix II. The graph obtained is as shown in the fig.no. 2 below. The Liquid Limit from graph is plotted as 28.6%.

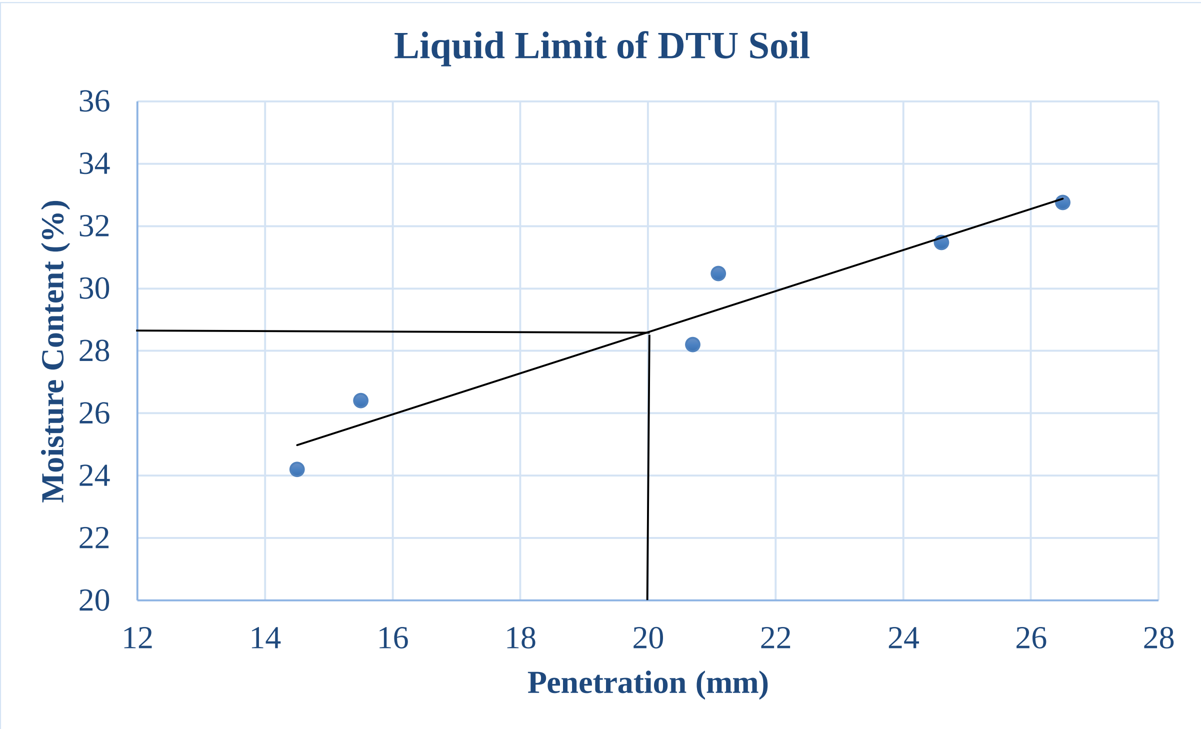


Fig 6: Graph for liquid limit determination of DTU soil

3.1.2.2 PLASTIC LIMIT -

The plastic limit is the water content of the soil sample at which a thread of the soil sample of 3 mm will just crumble. The plastic limit (PL) of the soil is computed as 21.67% as shown in appendix II. Hence the Plasticity Index is 6.93.

3.1.3 COMPACTION CHARACTERISTICS:

Standard proctor test was conducted to find the maximum dry density (MDD) and optimum moisture content (OMC) of the soil. Soil was taken and water was mixed and then the soil was compacted in the mould with 25 no. of blows in three layers with a rammer weighing 2.5 kg from a fall of 310 mm. At least five test was done to determine the OMC and MDD of the soil. With every test a soil sample was taken out from the centre and kept in oven for water content determination.

Photograph No. 4: Process of compaction test

A graph was plotted between the water content (WC) and the density of the soil. The observations are as shown in appendix III. From the graph as shown in fig. below, the optimum moisture content is 13.5% and MDD is 1.87 g/cc.

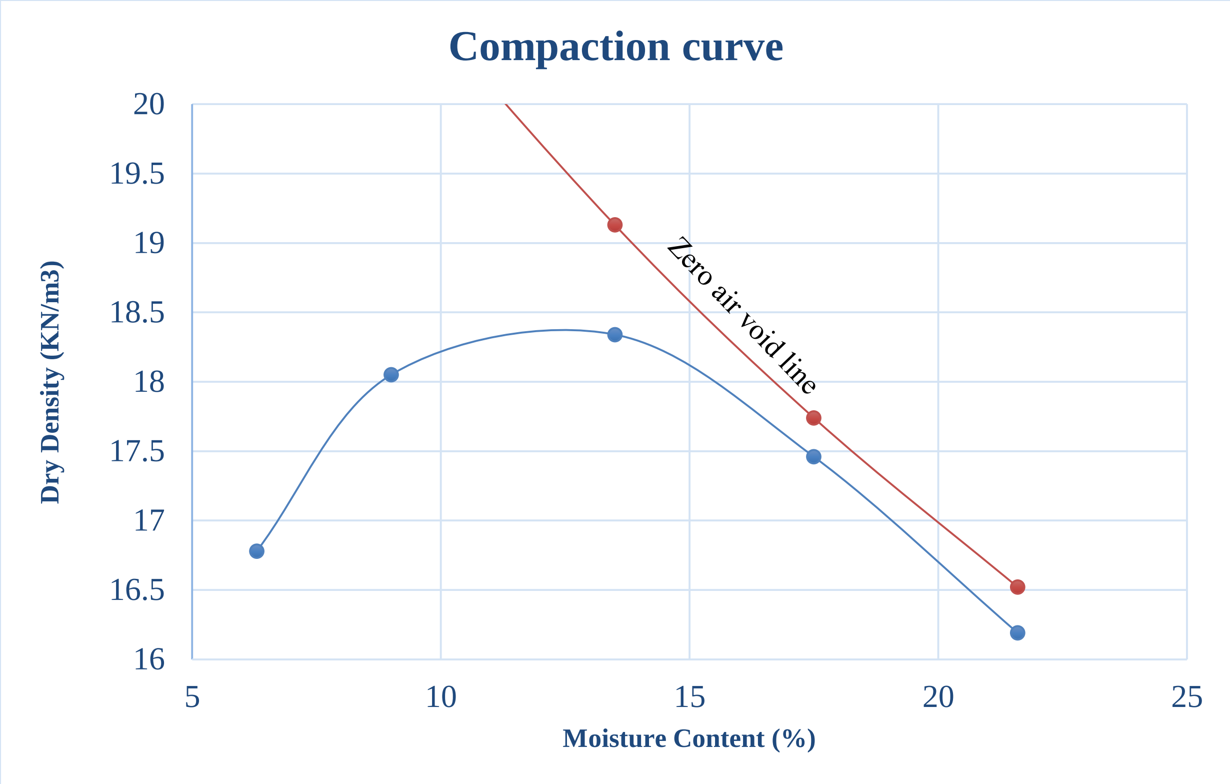


Fig 7: Graph between dry density and water content

3.2 SOIL CLASSIFICATION:

- Since more than 50% soil passes through 4.75mm sieve so, the soil will be classified as Sand.
- Again the soil passing through 75µ is more than 12% so classification will be done by using liquid limit (LL) and plastic limit (LL).
- By plotting the liquid limit (LL) and plasticity index (PI) on the plasticity chart, the point comes below A-line, so it will be classify as Silt.
- As the liquid limit is below 35 so the soil will be of low plasticity (ML).
- So, it was concluded that the soil sample is "Silty Sand" and hence was classified as the same.

3.3 ATTERBERG LIMIT TEST FOR SOIL MIXED WITH BENTONITE:

3.3.1 BENTONITE CLAY:

3.3.1.1 LIQUID LIMIT –

Liquid limit test was carried out for bentonite clay. The observation are as shown in appendix IV. The graph obtained is as shown below. From graph, the liquid limit (LL) of bentonite clay is plotted as 250.09%

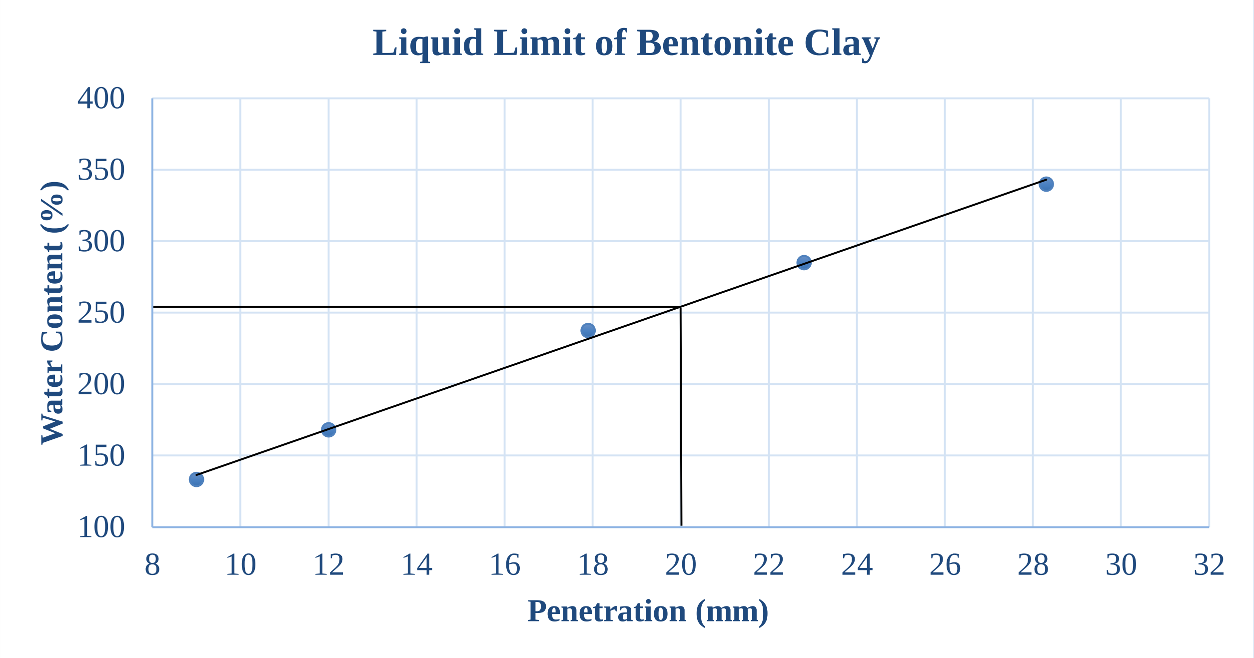


Fig 8: Graph for liquid limit determination of bentonite clay

3.3.2 SOIL MIXED WITH 3% BENTONITE CLAY:

3.3.2.1 LIQUID LIMIT –

Liquid limit test was carried out for soil mixed with 3% bentonite clay. The observation are as shown in appendix V. The graph obtained is as shown below. From graph, the liquid limit is 32.1 %

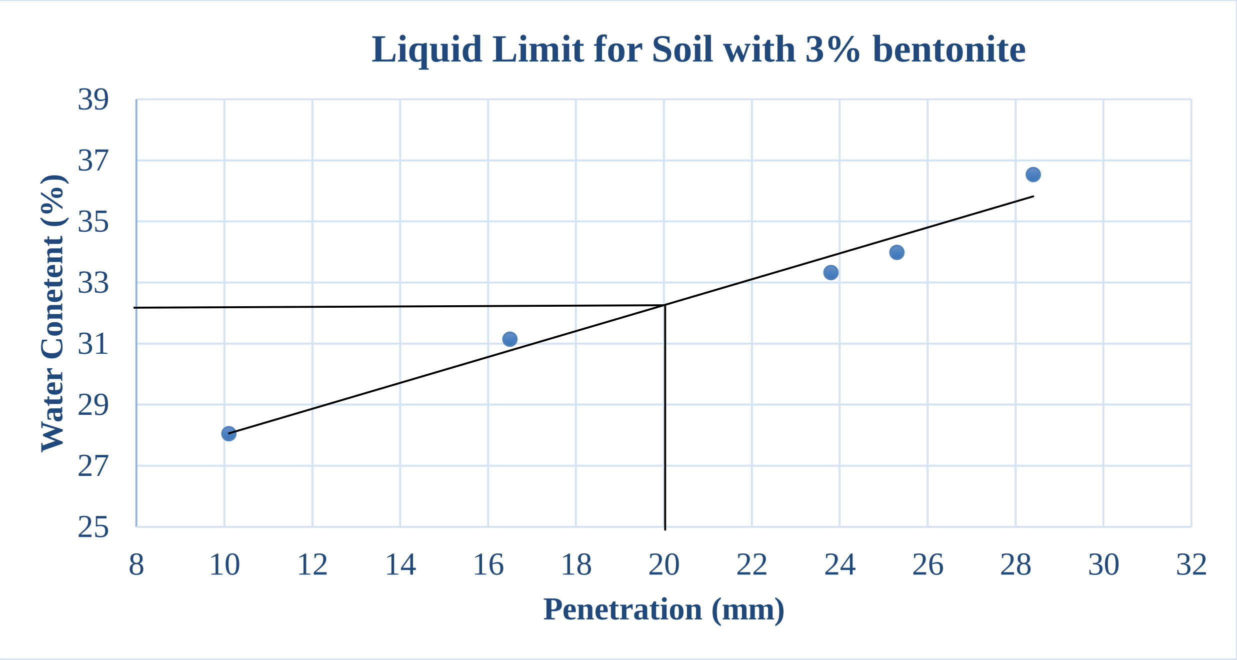


Fig 9: Graph for liquid limit determination of soil with 3% bentonite

3.3.2.2 PLASTIC LIMIT –

The plastic limit is the water content of the soil sample at which a thread of the soil sample of 3 mm will just crumble. The plastic limit (PL) of the soil is computed as 18.8%, as shown in appendix V. Hence the Plasticity Index is 13.3.

3.3.3 SOIL MIXED WITH 5% BENTONITE CLAY:

3.3.3.1 LIQUID LIMIT –

Liquid limit test was carried out for soil mixed with 5% bentonite clay. The observation are as shown in appendix VI. The graph obtained is as shown below. From graph it can be seen that the liquid limit is 35.8 %.

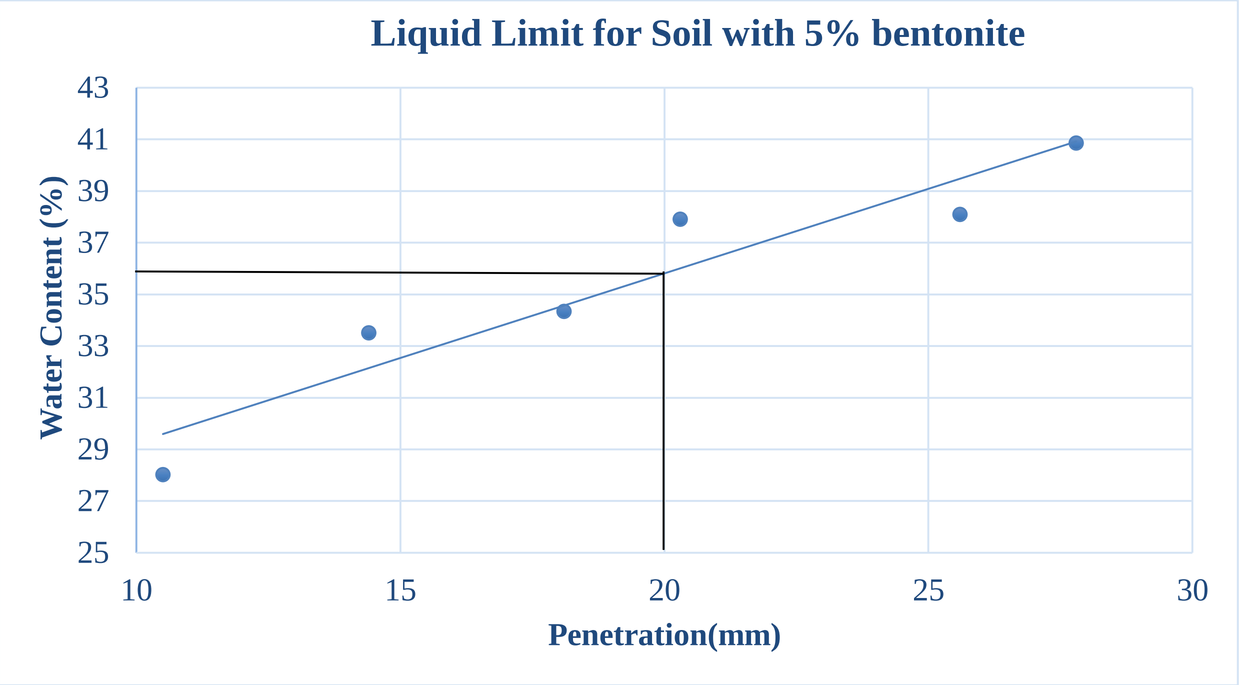


Fig 10: Graph for liquid limit determination of soil with 5% bentonite

3.3.3.2 PLASTIC LIMIT –

The plastic limit is the water content of the soil sample at which a thread of the soil sample of 3 mm will just crumble. The plastic limit (PL) of the soil is computed as 19.81%, as shown in appendix VI. Hence the Plasticity Index is 15.99.

CHAPTER 4

EXPERIMENTAL INVESTIGATIONS

4.1 LEACHATE CHARACTERISTICS

The leachate was collected from OKHLA landfill, DELHI. Various tests were conducted on the leachate to determine its various constituents like sulphates, nitrites, chlorides, heavy metal and also to determine its BOD, COD and TS. A brief of the various test performed are given as follows.

4.1.1 PH TEST:

- The PH of the leachate was found out by using digital PH meter. A PH meter is an instrument which measure the hydrogen ion concentration in a liquid, indicating its alkalinity or acidity.
- Before measuring the PH of the leachate digital meter is calibrated/standardised using acetic acid-sodium acetate buffer reagent.
- 1.5 ml of acetic acid is taken and then diluted up to 100 ml. for sodium acetate solution, 0.64 g is taken and then dissolved in the water and diluted upto 100 ml.
- Now, take 36.2 ml of the sodium acetate sol. In to a flask and then add 14.8 ml of acetic acid sol. And the mixture is diluted up to100 ml.
- The leachate was poured in a dish and digital meter is placed in it to measure the PH of the leachate.
- It was found out to be 7.9 which is almost neutral or we can say slightly alkaline.

4.1.2 TURBIDITY:

- Turbidity is a qualitative characteristics of a solution which refers to the opacity of the solution. Turbidity is due to the suspended solid particles, which obstruct the passage of light through the solution or the sample. Turbidity shows the presence of suspended and dispersed solids like silt, organic matter, algae, clay etc.
- Turbidity is the comparison of the measurement of the intensity of light scattered by the waste water sample under defined condition with respect to a standard reference solution under same condition. The higher is the scattering light intensity higher is the turbidity.
- Apparatus required for the test are turbidity meter, funnel, sample cells, std. flasks, wash bottle and chemicals required are hexamethylene tetramine and hydrazine sulphate.
- For the test firstly, reagents like hydrazine sulphate, hexamethylene tetramine has to be prepared. For hydrazine sulphate reagent, 1gm of hydrazine sulphate is taken and put in a 100 ml flask and distilled water is filled up to 100 ml. For hexamethylene tetramine reagent, 10 gm of hexamethylene tetramine is taken in a 100 ml flask and distilled water is filled up to 100 ml.

- A standard 400 NTU solution is to be prepared for the calibration of the turbidity meter. For this, 5 ml of hydrazine sulphate reagent and 5 ml of hexamethylene tetramine reagent is to be taken in a 100 ml flask and allow it to mix for 24 hrs. After that fill the flask with distilled water till 100 ml mark. Standard solution is ready.
- For calibration, sample cells are filled with distilled water and the 400 NTU standard solution and put in the turbidity meter.
- Then the test sample is filled in the sample cell and put in the turbidity meter for the measurement.
- The turbidity of the leachate sample is 324 NTU.

4.1.3 TOTAL SOLIDS:

- Total solids includes both dissolved and suspended solids. Dissolved solids are those which are totally dissolved in the waste water and cannot be filtered in nature. Suspended solids are the one which are filterable and also remain in suspension in waste water.
- The sample is well mixed and 50 ml is poured in the porcelain dish and put in the oven for the evaporation of the liquid. The weight of the dish with the sample and after evaporation is weighed. The increase in the weight of the dish shows the total dissolved solid. The calculation is as shown in appendix XI

Photograph No. 5: dish with leachate kept in oven for determination of dissolved solids

- The sample is well mixed and filtered through filter paper. The weight of the clean filter paper is weighed. The particles retained on the filter paper is dried and weighed. The change in weight (increases) of the filter paper is the total suspended solids.

Photograph No. 6: Arrangement to find suspended solids.

- Apparatus required for the test are Evaporating dish, oven, flask, filter paper, forceps, dish tongs, analytical balance and graduated cylinders.
- Total dissolved solid of the waste water is 13940 mg/L and suspended solid is 1860 mg/L.

4.1.4 SULPHATES:

- Sulphates is broadly distributed in nature and may be present in the waste water in thousands of concentration. These are of grave concern regarding handling of wastewater as it can cause corrosion of the sewer by forming hydrogen sulphide in anaerobic condition and also foul odour.
- Sulphates are measured by turbidimeter method. The principle behind the test is that barium sulphate precipitates in a colloidal form in presence of NaCl, HCL, and glycerol.
- The absorbance capacity of the $BaSo_4$ formed is measure with the help of spectrophotometer set at 420 nm and then the concentration of sulphates ion is found out by using a standard curve.
- Apparatus required are UV-visible spectrophotometer, sample tubes, flask, beaker, spatula, measuring cylinder, wash bottle, and the chemicals required are Isopropyl alcohol, glycerol, conc. HCL, NaCl, $BaCl_2$ (barium chloride), sodium sulphate and distilled water.
- For the test, conditioning reagent is prepared taking 25 ml glycerol in a beaker then add 15 ml of conc. HCL and 50 ml of 90% isopropyl in the beaker. Weigh 37.5 gm of NaCl and dissolve in distilled water and then mix all the solution up to 250 ml.
- Standard sulphate solution is prepared by taking 1.479 gm of anhydrous sodium sulphate and then dissolving it with distilled water. Put this solution in a 1000 ml beaker and increase the volume to 1000 ml by adding distilled water.
- For preparing the samples for testing take six 50 ml flask. In first four, add std. sulphate solution like 10 ml, 20ml, 30ml, and 40ml. in fifth add the leachate and the sixth one is

the blank sample. Add 5 ml of the conditioning reagent to all the flask. Fill the volume to 50 ml.

- Now one by one put the sample in sample tubes and place it in UV- spectrophotometer for measurement of absorbance. The observation is as given in appendix XII.
- The sulphates content of the leachate sample is 1712.28

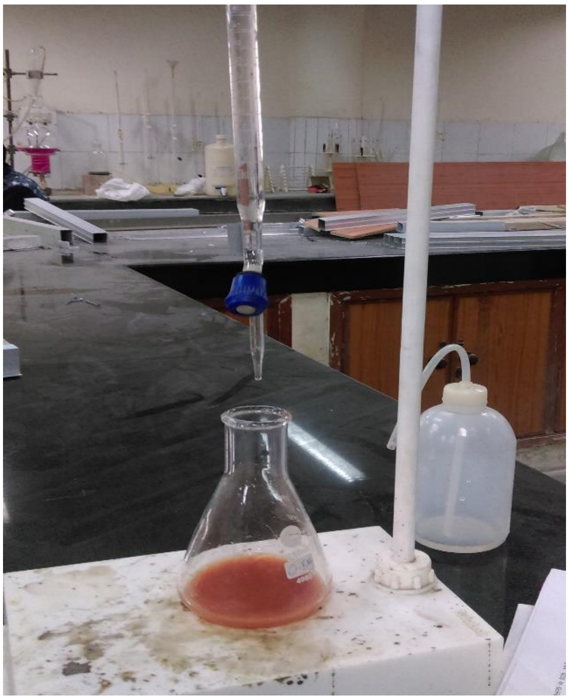
4.1.5 PHOSPHATES:

- Phosphates is present in leachate mainly due to detergents in which phosphate is used for water softeners. Though it is non-toxic both for plants and animals but for characterisation of leachate its presence should be determined.
- Phosphates are measured by using spectrophotometer. The principle behind the test is that molybdophosphoric acid is formed and which is further reduced to molybdenum blue, an intensely coloured complex.
- Apparatus required are spectrophotometer using 650 nm wavelength, measuring cylinder, wash bottle, flask and the chemicals required are ammonium molybdate, stannous chloride, conc. H_2SO_4.
- For the test, reagent like aluminium molybdate is prepared by taking 175 ml of water and then dissolving in it 25 g of aluminium molybdate. Another solution of conc. H_2So_4 is formed by taking 280 ml of it in 400 ml of water and then after cooling, mixing the aluminium molybdate sol. To the sulphuric acid solution and then increase the water up to 1L.
- Stannous chloride reagent is prepare by mixing 2.5 g of stannous chloride in 100 ml of glycerine and is heated.
- Phosphate solution is prepared by mixing in 1 L of water 0.286 g of KH_2Po_4 which is a 200 mg/L stock solution. We need 20 mg/L stock solution for which we have to dilute 100 ml of the solution to 1 litre and again repeat two times.
- Five Standard phosphate solution has to be prepared for the test in measuring cylinders of 100 ml and one blank solution. Put in sequence like 2 ml, 4 ml, 6 ml, 8 ml, 10 ml of the phosphate solution in the five cylinders and dilute all of them to 40 ml.
- For blank put 25 ml of water which will be later treated with colour developing reagent along with other five solution cylinders
- Colour development procedure is used for the presence of phosphate. Take in flask 25 ml of the sample which need to be analysed. 1 ml of aluminium molybdate solution is added in the flask containing sample. Again add 2 drops of stannous chloride in the flask and mix. A blue colour will developed if phosphate is present.
- Now, put the samples in sample cell and then in spectrophotometer one by one and note the absorbance. The absorbance is as given in appendix XIII.
- The phosphate content of the leachate sample is 845.2 mg/L.

4.1.6 CHLORIDES:

- Chlorides are widely present in environment as salt of calcium, sodium and potassium.

- Determination of presence of chloride can be done by using silver nitrate solution to titrate the sample. The silver nitrate then reacts with chloride ion and form a red silver chromate solution.



Photograph No.7: leachate sample after titration with silver nitrate

- Apparatus required for the test are burette, pipette, conical flask, beaker, wash bottle and the chemicals required are Silver nitrate, phenolphthalein indicator, sodium chloride, potassium chromate.
- Standard sodium chloride solution is prepared by taking 1.648 g of NaCl in a beaker and water is added and mix well. It is then transferred to a 100 ml flask and water is added till the 100 mark.
- Silver nitrate solution is prepared up to 0.0282 N by taking 4.791 g of silver nitrate and mix with water.
- Potassium chromate indicator is prepared by taking 25 g of potassium chromate in a beaker containing distilled water and then add few drops of $AgNO_3$ till slight red precipitates is formed. After 12 hrs dilute the filtered solution to 1000 ml.
- Chloride content in leachate is determined by taking 20 ml of leachate in conical flask and then adding 1 ml of potassium chromate indicator after which a yellow colour is formed.
- Using silver nitrate solution titrate the sample after which colour will be brick red. Note the amount of silver nitrate required. Repeat for at least three times.
- Perform the same procedure for a blank solution. The observation are given in appendix XIV.
- The chloride content of leachate are 15995 mg/L.

4.1.7 BOD:

- BOD i.e. biochemical oxygen demand is the amount of biological oxygen required for the organic matter decomposition at a temp. of 20° C and time of 5 days.
- Determination of BOD is a chemical process in which the dissolved oxygen required by the aerobic organism to break down the organic matter in a stipulated time at certain temp. is determined.
- The principle behind the test is measuring the DO before and after 5 days of incubation at 20° C. the difference in DO gives the BOD.
- Apparatus required for the test are BOD incubator, burette, flask, pipette, graduated cylinders, wash bottle and chemicals required are potassium iodide, sodium azide, sodium thiosulphate, ammonium chloride, calcium chloride, ferric chloride, magnesium sulphate potassium hydroxide, Conc. Sulphuric acid, starch indicator etc.
- Various reagents are prepared viz. for manganous sulphate solution take 364 g of monohydrous manganese sulphate and dissolve it in 1000 mL of water.
- For alkaline iodide sodium azide solution take 700 g of potassium hydroxide and 150 g of potassium iodide and mix in 1000 ml distilled water. And then take 10 g of sodium azide and mix in 40 ml of water and add this solution to the above alkaline iodide solution.
- For sodium thiosulphate stock solution, take 25 g of sodium thiosulphate and dissolved in 1000 ml distilled water. 1 g of Sodium hydroxide is added for its preservation.
- Starch indicator is prepared by dissolving 2 g of starch in 100 ml of hot water.
- Calcium chloride solution is prepared by taking 27.5 g of anhydrous calcium chloride and make a solution of 100 ml with distilled water.
- Sample is tested by taking four 300 ml glass stoppered bottle for sample and blank. Put 10 ml of sample in two bottles and fill up to the mark. The remaining 2 bottles is filed with distilled water.
- Keep one blank and one sample bottle in incubator for 5 days at 20° C temp.

Photograph No. 8: Blank sample and leachate sample kept in BOD incubator

- Then one by one add all the reagent in the remaining one sample bottle. Add 2 ml of manganese sulphate and the 2ml of alkaline iodide azide and then 2ml of conc. Sulphuric acid.


Photograph No.9: Cloudy formation after addition of reagents to the sample

- After addition of reagent take 203 ml of the sample in a flask and titrate with sodium thiosulphate until the yellow colour is fades.
- Then add 1 ml of starch solution upon which sample will turns to blue colour. Titrate the sample again till it become colourless.
- The volume of sodium thiosulphate required is the amount of DO in mg/L. after 5 days repeat the same procedure for the sample kept in incubator. The observation is as given on appendix XV.
- The BOD of the given sample is 2600 mg/L.

4.1.8 COD:

- COD i.e. chemical oxygen demand is the amount of oxygen required to chemically oxidise the organic matter in the waste water.
- The principle behind the test is that potassium dichromate in presence of sulphuric acid, silver sulphate and mercury sulphate gets oxidised. So the amount of dichromate consumed equals the amount of oxygen for organic oxidation.
- Apparatus required are COD digester, burette, pipette, wash bottle, conical flask and the chemical required are sulphuric acid, potassium dichromate, silver sulphate, ferrous ammonium sulphate, mercury sulphate, ferroin indicator and distilled water.

- Standard potassium dichromate reagent is prepared by taking 4.913 g of potassium dichromate, 33.3 g of mercury sulphate and 167 ml of sulphuric acid in a beaker and mix and then dilute it to 1000 ml.
- Sulphuric acid reagent is prepared by taking 5.5 g of silver sulphate crystal and then adding to it 500 ml of sulphuric acid and leave it for 24 hrs.
- Std. ferrous ammonium sulphate solution is prepared by taking 39.2 g of ferrous ammonium sulphate crystal and then diluting it to 1000 ml.
- Now for testing the sample, take three COD tubes and then fill two of them with 2.5 ml sample and one with blank. Then add 1.5 ml of potassium dichromate solution to each three tubes.
- Then add 3.5 ml of sulphuric acid. Now place the tubes in digester for 2 hrs at 150 °C. After that take the sample for titration by ferrous ammonium sulphate solution with ferroin as an indicator which will turn the sample in bluish green colour.
- After titration in the end colour changes to reddish brown.
- Repeat the same for blank. The observation is as given in appendix XVI.
- The COD of the leachate sample is 6400 mg/L.

4.1.9 HEAVY METALS:

- Major heavy metals like Cd, Fe, Pb, Mn, Cu, Hg, As, Cr, Ni and many more comes from industrial source, mining and extraction, smelting and processing, volcanic eruption, fossil fuel combustions, erosion, agriculture and metallurgical industries.
- There are various methods or techniques to measure the heavy metals or trace elements like ICP-MS (Inductively coupled plasma mass spectrometry), ICP-OES (Inductively coupled plasma optical emission spectrometry), FAAS (Flame atomic absorption spectrometry), GFAAS (Graphite furnace atomic absorption spectrometry).
- The method used for the project is ICP-MS, where the sample are atomised by plasma source after which the ions are detected by mass spectrometer. It is a multi- element technique.
- The detection limit of ICP-MS is up to part per thousand. Samples can be introduced in two forms, Viz. liquid and aerosol. Solid samples are either dissolved or are converted to aerosol.
- The output given by the system is as shown in table below.

The physico chemical properties of the leachate are given in the table below,

Table No. 1: Physico-chemical properties of leachate

PARAMETER	UNIT	VALUE
PH	No unit	7.9
Colour	-	Dark brown
Turbidity	NTU	324
Total dissolved solids	mg/L	13940
Total suspended solids	mg/L	1860
Sulphate (SO_4^{2-})	mg/l	1712.28
Phosphate(PO_4^-)	mg/l	845.2
Chloride (Cl^-)	mg/l	15995
BOD_5	mg/l	2600
COD	mg/l	6400
Mg	mg/l	68.43
Ca	mg/l	140.5
Cr	mg/l	0.26
Mn	mg/l	0.33
Fe	mg/l	11.19
Co	mg/l	0.12
Ni	mg/l	0.5
Cu	mg/l	0.46
Zn	mg/l	1.68
As	mg/l	0.03
Cd	mg/l	0.05
Pb	mg/l	0.57

4.2 HYDRAULIC CONDUCTIVITY TEST:

The hydraulic conductivity test of the virgin DTU soil and the soil mixed with 3% and 5% bentonite clay was carried out. The test as carried out was falling head permeability test.

Photograph No. 10: Process for sample preparation for hydraulic conductivity test.

- The soil was compacted in the mould at its MDD. A total of 1.87 kg of soil was taken and mixed with 15 % of water which is the OMC.
- The air void was removed and compacted soil was saturated for many days.
- The saturation day for the virgin soil was 3 days whereas it took 10-15 days for the soil mixed with bentonite to saturate.
- The observation as shown in appendix X shows that the virgin soil itself has a low permeability in the range of 10^{-6} and after mixing with 3% bentonite clay its permeability decreases in the range of 10^{-8}.
- It can be seen from the observation that there is not much variation in between 3% and 5% mixed soil.

4.3 COLUMN STUDY

A short term and long term column study of the effect of leachate on the soil was conducted in which the soil from DTU campus is mixed with 3% and 5% bentonite clay for low permeability. The soil is then compacted in the acrylic sheet made mould in its maximum dry density. The leachate is then poured into the mould to permeate and react with the soil.

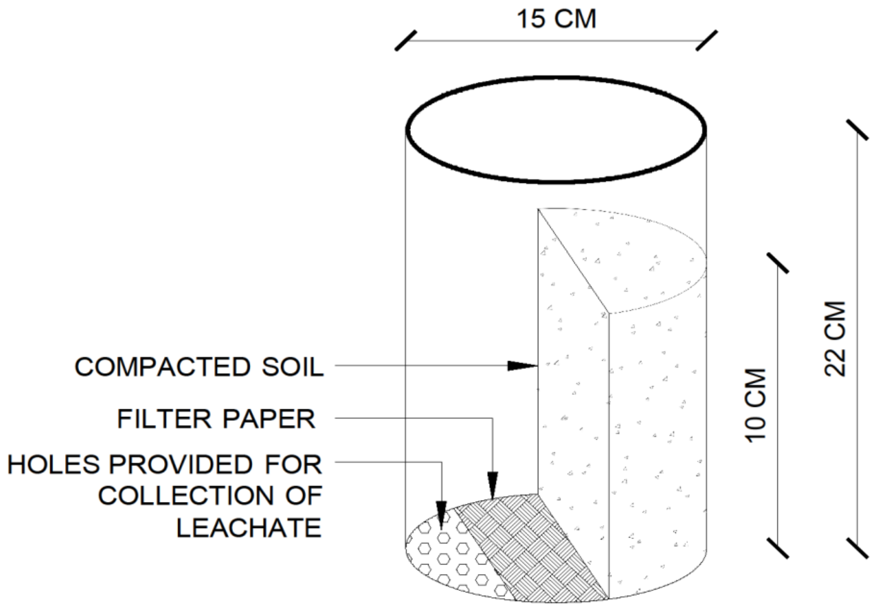


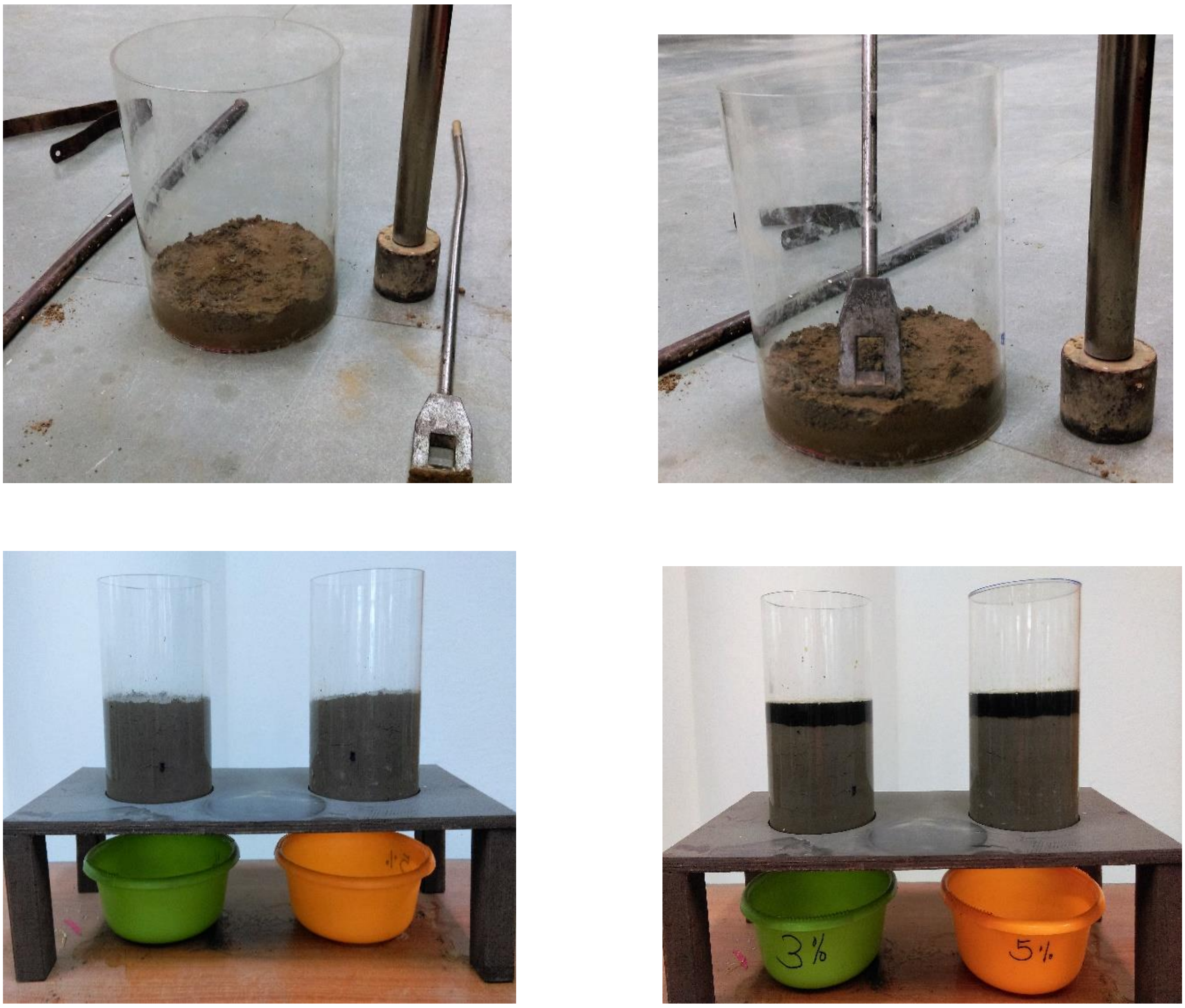
Fig.11: A schematic diagram of the column study

The fig. above is the schematic diagram of the arrangements of the test.

The soil was analysed as an alternative to the clay layer in the liner system as a liner material. Since the soil is a silty sand, its permeability is more than the required. So a few percentage of clay is mixed with the soil to decrease its permeability to be used as a liner material. With clay solely as the liner material, there are certain problem like cracking which can be avoided if it is replaced by a soil which has less problem due to wetting and drying.

After the soil is subjected to leachate there may be change in the properties of soil which can be analysed later by checking the change in Atterberg limits and also the internal structure. Two test are carried out i.e. short term and long term test. In the short term the soil is subjected with leachate for few days and for long term the soil is subjected to leachate for months. Leachate if contain organic matter can affect the soil properties a lot.

The fig. below shows the set up of the study and how the soil is compacted in the mould gradually upto its MDD.



Photograph No. 11: Sample preparation and setup of the column study

4.3.1 SHORT TERM TEST:

In this study, the soil is subjected to leachate for a few days and the effect is seen. The liquid limit (LL) and plastic limit (PL) of the soil mixed with leachate is taken and then oven dried. The soil sample is then tested for the Atterberg limits. The soil was also tested for the presence of organic matter. The test result as shown in appendix IX shows that there is very little presence of organic matter which tells us that there won't be prominent change in the properties of soil. The change in Atterberg limit were also done to confirm the prediction according to presence of organic matter and shown in appendix VII and VIII.

4.3.1.1 ORGANIC MATTER TEST FOR SOIL CONTAMINATED WITH LEACHATE FOR FEW DAYS:

The soil was tested for the presence of organic matter (OM) in the soil after the permeation of leachate. The test result as shown in appendix IX shows that there is very little presence of organic matter which tells us that there won't be prominent change in the properties of soil but will affect though little.

4.3.1.2 ATTERBERG LIMIT TEST FOR SOIL WITH 3% BENTONITE CONTAMINATED WITH LEACHATE FOR FEW DAYS:

4.3.1.2.1 LIQUID LIMIT TEST -

Liquid limit test was performed for soil mixed with 3% bentonite clay. The observation are as shown in appendix VII. The graph obtained is as shown below. From graph the liquid limit is plotted as 33%.

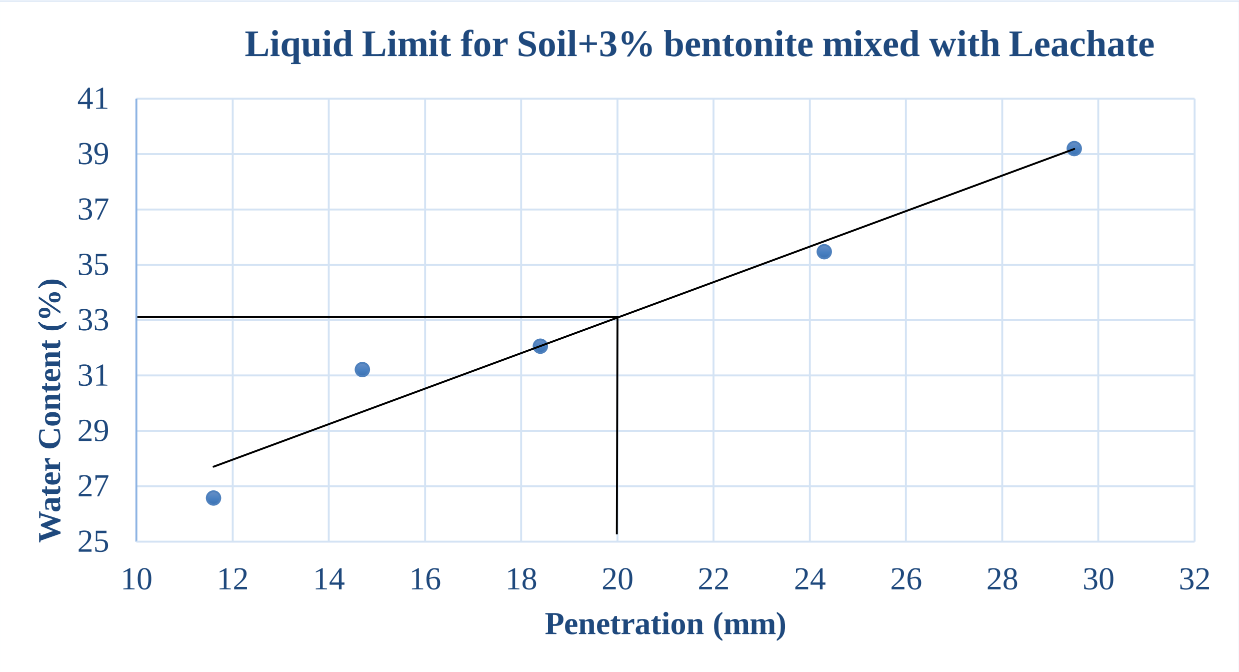


Fig 12: Graph for liquid limit determination of soil with 3% bentonite after permeation of leachate for few days.

4.3.1.2.2 PLASTIC LIMIT TEST –

The plastic limit is the water content of the soil sample at which a thread of the soil sample of 3 mm will just crumble. The plastic limit (PL) of the soil is computed as 19.35%, as shown in appendix VII. Hence the Plasticity Index is 13.65.

4.3.1.3 ATTERBERG LIMIT TEST FOR SOIL WITH 5 % BENTONITE CONTAMINATED WITH LEACHATE FOR FEW DAYS:

4.3.1.3.1 LIQUID LIMIT TEST -

Liquid limit test was carried out for soil mixed with 3% bentonite clay. The observation are as shown in appendix VIII. The graph obtained is as shown below. From graph, the liquid limit is plotted as 36.6%.

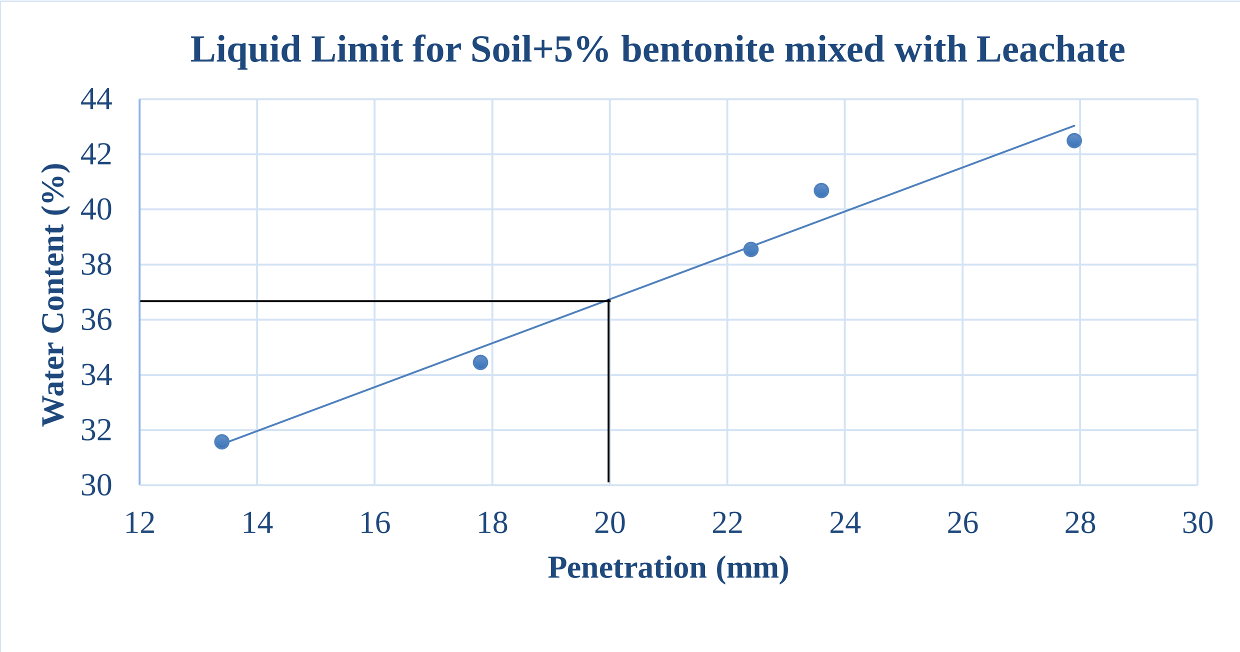


Fig 13: Graph for liquid limit determination of soil with 5% bentonite after permeation of leachate for few days.

4.3.1.3.2 PLASTIC LIMIT TEST –

The plastic limit is the water content of the soil sample at which a thread of the soil sample of 3 mm will just crumble. The plastic limit (PL) of the soil is computed as 20.34, as shown in appendix VIII. Hence the Plasticity Index 16.26.

4.3.2 LONG TERM TEST:

The soil is compacted in the mould at its MDD and leachate is poured into it. Here long term is as compared to the short term duration (3 days) i.e. 1-2 months. Though the leachate should be kept in contact with the soil for at least 6 months but this short days is to get an idea of the leachate- soil compatibility.

4.3.2.1 ORGANIC MATTER TEST FOR SOIL CONTAMINATED WITH LEACHATE FOR FEW MONTHS:

The soil was tested for the presence of organic matter after the permeation of soil with leachate for 1-2 months. The observations are as shown in appendix XVII. The results indicated presence of organic matter in few amount. Since organic matter is present though in small amount, it will affect the Atterberg limit.

4.3.2.2 ATTERBERG LIMIT TEST FOR SOIL WITH 3% BENTONITE CONTAMINATED WITH LEACHATE FOR FEW MONTHS:

4.3.2.2.1 LIQUID LIMIT TEST -

Liquid limit test was performed for soil mixed with 3% bentonite clay and was kept in a cylindrical mould for permeation of leachate. The observation are as shown in appendix XVIII. The graph obtained is as shown below. From graph, the liquid limit is plotted as 36.9%.

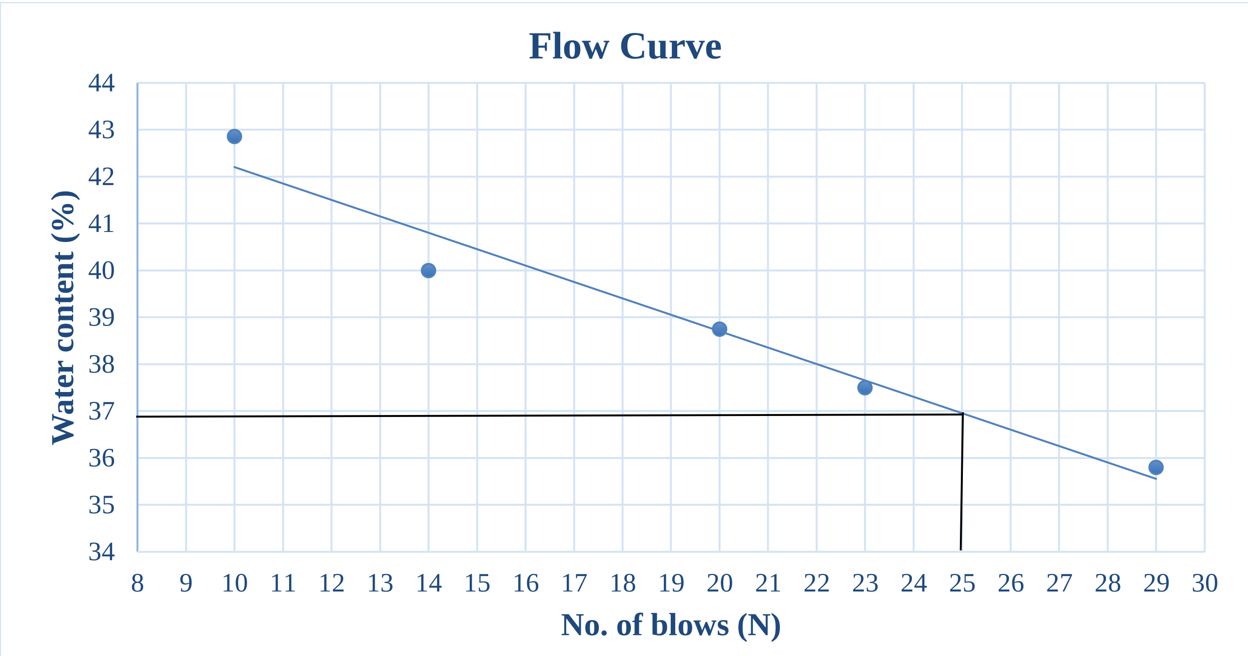


Fig 14: Graph for liquid limit determination of soil with 3% bentonite after permeation of leachate for few months.

4.3.2.2.2 PLASTIC LIMIT TEST –

The plastic limit is the water content of the soil sample at which a thread of the soil sample of 3 mm will just crumble. The plastic limit (PL) of the soil is computed as 21.05%, as shown in appendix XVIII. Hence the Plasticity Index is 15.85.

4.3.2.3 ATTERBERG LIMIT TEST FOR SOIL WITH 5 % BENTONITE CONTAMINATED WITH LEACHATE FOR FEW MONTHS:

4.3.2.3.1 LIQUID LIMIT TEST -

Liquid limit test was carried out for soil mixed with 5% bentonite clay and was compacted in a cylindrical mould at its MDD and OMC and is permeated with leachate. The observation are as shown in appendix XIX. The graph obtained is as shown below. From graph, the liquid limit is plotted as 38%.

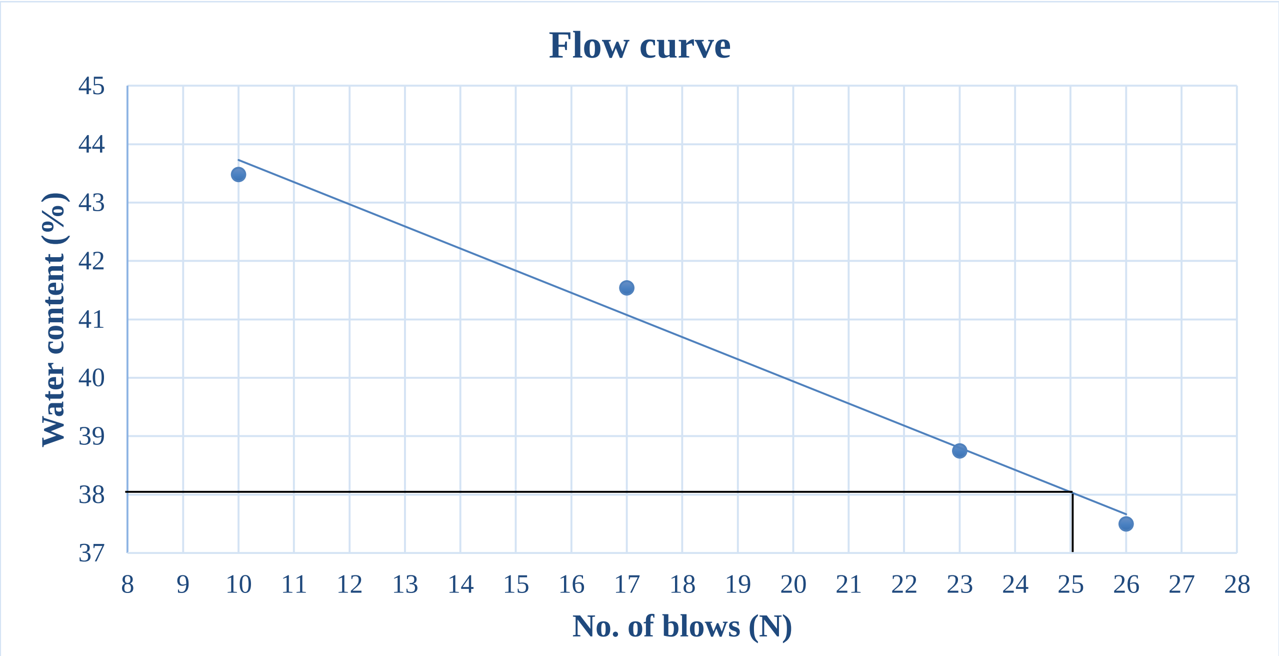


Fig 15: Graph for liquid limit determination of soil with 5% bentonite after permeation of leachate for few months.

4.3.2.3.2 PLASTIC LIMIT TEST –

The plastic limit is the water content of the soil sample at which a thread of the soil sample of 3 mm will just crumble. The plastic limit (PL) of the soil is computed as 21.74%, as shown in appendix XIX. Hence the Plasticity Index is 16.26.

CHAPTER 5

EXPERIMENTAL RESULTS

5.1 EFFECT ON PHYSICAL PROPERTIES OF SOIL MIXTURE

5.1.1 ORGANIC MATTER TEST IN CONTAMINATED SOIL:

The presence of organic matter in the soil subjected to leachate was find out by muffle furnace test. This test was done to get an idea about the effect on the geotechnical properties of the soil. If there is ample amount of organic matter then there will be a change in the properties of soil and if the organic matter is present in low or negligible amount then there will be no or very little amount of change in the properties of soil. The test results are as shown in appendix XVII. And presented in chapter above.

5.1.2 ATTERBERG LIMIT TEST IN CONTAMINATED SOIL:

The change in the liquid limit (LL) and plastic limit (PL) of the soil was found out after the soil was subjected to leachate for many days. This test was done to see changes in the properties of soil due to leachate. The effect of leachate on the properties of soil is on the basis of presence of organic matter. Initially in the soil there were no organic matter and after the permeation there is certain amount of organic matter. The results obtained are already shown in above chapter.

5.2 EFFECT ON INTERNAL STRUCTURE OF SOIL MIXTURE

To see any change in the internal structure of soil XRD test was done on various soil samples taken before and after the introduction of leachate to the soil. The XRD results have shown that there is change in the structure of the soil after the leachate is subjected.

5.2.1 XRD OF DTU SOIL

The Diffractograms generated from XRD unit is as shown. The peak values, spacing, lattice parameter are calculated to know which type of crystal lattice is present and also the lattice parameter is compared with that of reference element and determined.

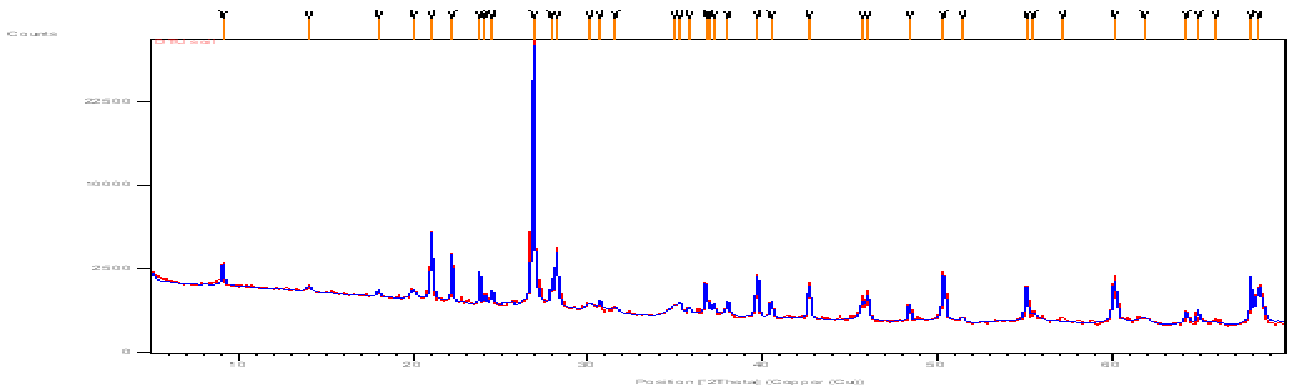


Fig 16. : Diffractograms of DTU soil

Table 2: Calculation table to find lattice paramet**er**

2Θ	Θ	Θ (rad)	sin Θ	sin2 Θ	Ratio	whole no.	whole no.× 2	index	d (A°)	a
9.0863	4.5432	0.0793	0.0792	0.0063	1	1	2	110	9.7248	13.75
14.0417	7.0209	0.1225	0.1222	0.0149	2.37	2	4	200	6.302	12.6
18.0274	9.0137	0.1573	0.1567	0.0245	3.89	4	8	220	4.9167	13.91
19.9972	9.9986	0.1745	0.1736	0.0301	4.78	5	10	310	4.4366	14.03
21.0798	10.5399	0.1839	0.1829	0.0335	5.32	5	10	310	4.2111	13.32
22.2272	11.1136	0.1939	0.1928	0.0372	5.9	6	12	222	3.9963	13.84
23.8105	11.9053	0.2078	0.2063	0.0426	6.76	7	14	321	3.7339	13.97
24.1216	12.0608	0.2105	0.2089	0.0437	6.94	7	14	321	3.6865	13.79
24.5472	12.2736	0.2142	0.2126	0.0452	7.17	7	14	321	3.6236	13.56

From the calculation table, it can be concluded that the crystal structure is BCC (body centered cubic) as the whole no. came out to be 7, so it has to be multiplied by 2. By comparing the lattice parameter with that of reference it was seen that the parameter does not resemble the known elements. This may be due to the reaction between the soil and leachate and forming new compound.

5.2.2 XRD OF SOIL WITH 3% BENTONITE SUBJECTED TO LEACHATE

The Diffractograms generated from XRD unit is as shown. The peak values, spacing, lattice parameter are calculated to know which type of crystal lattice is present and also the lattice parameter is compared with that of reference element and determined.

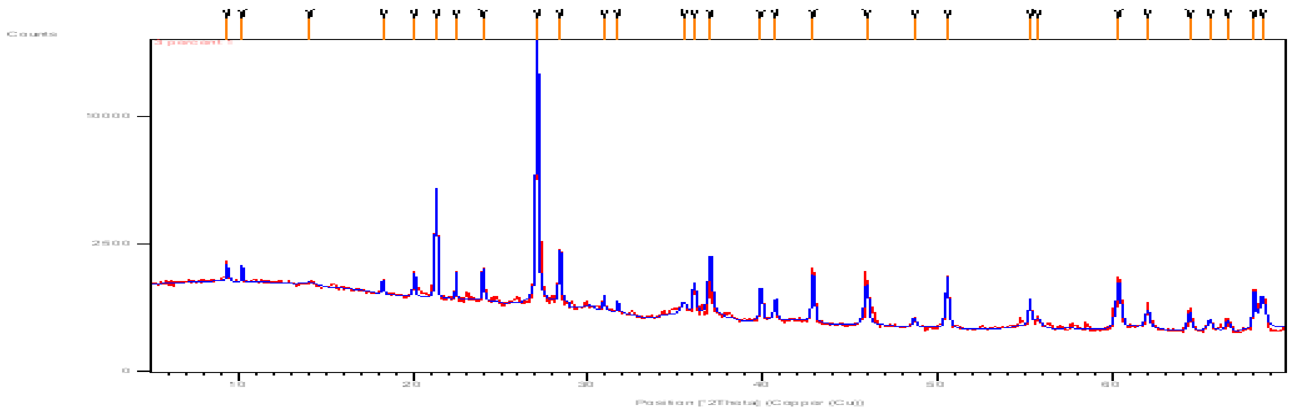


Fig.17: Diffractograms of Soil after leachate permeation (1st layer)

Table 3: Calculation table to find lattice parameter

2Θ	Θ	sin Θ	sin2 Θ	Ratio(N)	Whole no.	whole no.× 2	miller indices	d (A°)	a
9.3577	4.67885	0.081570607	0.006653764	1	1	2	110	9.4433	13.35
10.2192	5.1096	0.089061184	0.007931894	1.192091353	1	2	110	8.6491	12.23
14.0642	7.0321	0.122425399	0.014987978	2.252556357	2	4	200	6.2919	12.58
18.2791	9.13955	0.158839619	0.025230025	3.791842454	4	8	220	4.8495	13.72
20.0656	10.0328	0.17421192	0.030349793	4.56129693	5	10	310	4.4216	13.98
21.33	10.665	0.185066337	0.034249549	5.147394653	5	10	310	4.1623	13.16
22.464	11.232	0.19478219	0.037940101	5.702050995	6	12	222	3.9547	13.69
24.0154	12.0077	0.208043143	0.043281949	6.504881965	7	14	321	3.7026	13.85
27.0997	13.54985	0.234291283	0.054892405	8.249827533	8	16	400	3.2878	13.15

From the calculation table, it can be concluded that the crystal structure is BCC (body centered cubic) as the whole no. came out to be 7, so it has to be multiplied by 2. By comparing the lattice parameter with that of reference it was seen that the parameter does not resemble the known elements. This may be due to the reaction between the soil and leachate and forming new compound.

The XRD of the 2nd layer from the column is taken for analysis.

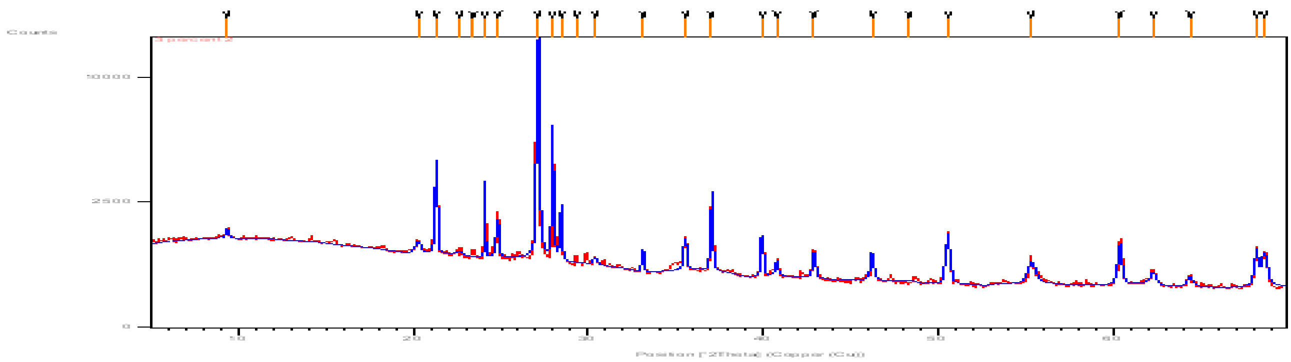


Fig.18: Diffractograms of Soil after leachate permeation (2nd layer)

Table 4: Calculation table to find lattice parameter

2Θ	Θ	sin Θ	sin2 Θ	Ratio	whole no.	whole no. × 2	index	d (A°)	a
9.361	4.6805	0.081599309	0.006658447	1	1	2	110	9.44	13.35
20.2725	10.13625	0.175989568	0.030972328	4.651584217	5	10	310	4.3769	13.84
21.3169	10.65845	0.184953991	0.034207979	5.137530959	5	10	310	4.1648	13.17
22.653	11.3265	0.19639967	0.03857283	5.793066877	6	12	222	3.9221	13.59
23.3902	11.6951	0.20270355	0.041088729	6.170917603	6	12	222	3.8001	13.16
24.0639	12.03195	0.208457106	0.043454365	6.526200964	7	14	321	3.6952	13.83
24.7908	12.3954	0.214656914	0.046077591	6.920170589	7	14	321	3.5885	13.43
27.1282	13.5641	0.234533062	0.055005757	8.261048747	8	16	400	3.2844	13.14
27.9563	13.97815	0.241551851	0.058347297	8.762898429	9	18	411	3.1889	13.53

From the calculation table, it can be concluded that the crystal structure is BCC (body centered cubic) as the whole no. came out to be 7, so it has to be multiplied by 2. By comparing the lattice parameter with that of reference it was seen that the parameter does not resemble the known elements. This may be due to the reaction between the soil and leachate and forming new compound. It is same as almost same as the first layer.

5.2.3 XRD OF SOIL WITH 5% BENTONITE SUBJECTED TO LEACHATE

The Diffractograms generated from XRD unit is as shown. The peak values, spacing, lattice parameter are calculated to know which type of crystal lattice is present and also the lattice parameter is compared with that of reference element and determined.

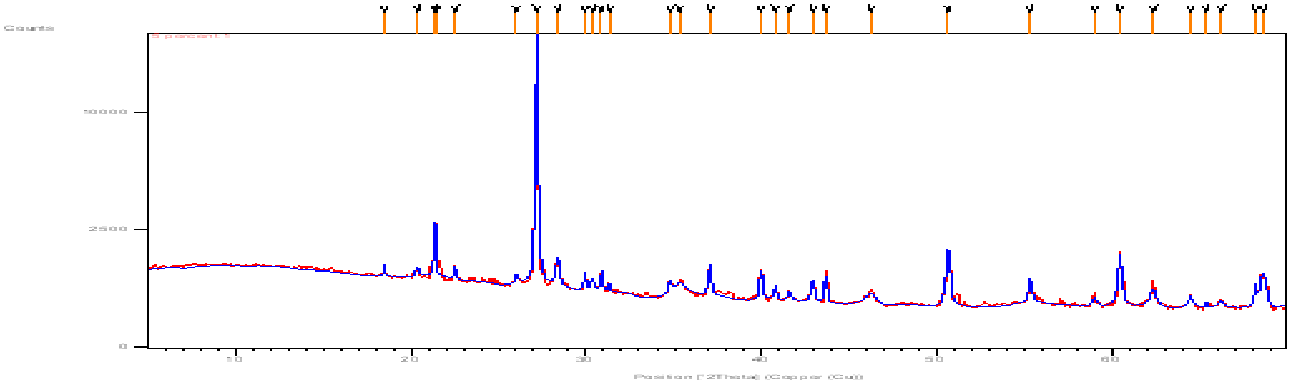


Fig.19: Diffractograms of Soil after leachate permeation (1st layer)

Table 5: Calculation table to find lattice parameter

2Θ	Θ	sin Θ	sin2 Θ	Ratio	whole no.	whole no. × 2	index	d (A°)	a
18.4782	9.2391	0.160554796	0.025777842	1	1	2	110	4.7977	6.78
20.3473	10.1737	0.176632955	0.031199201	1.210310785	1	2	110	4.361	6.17
21.3745	10.6873	0.185448808	0.03439126	1.334140377	1	2	110	4.1537	5.87
21.4913	10.7457	0.186450303	0.034763716	1.348589036	1	2	110	4.1314	5.84
22.5241	11.2621	0.195297445	0.038141092	1.479607614	2	4	200	3.9443	7.89
26.007	13.0035	0.225010575	0.050629759	1.964080546	2	4	200	3.4234	6.85
27.1798	13.5899	0.234970774	0.055211265	2.141810929	2	4	200	3.2783	6.56
28.3887	14.1944	0.245212633	0.060129235	2.332593794	3	6	211	3.1414	7.69
29.9423	14.9712	0.258333485	0.06673619	2.588897415	3	6	211	2.9818	7.3

From the calculation table, it can be concluded that the crystal structure is BCC (body centered cubic) as the whole no. came out to be 7, so it has to be multiplied by 2. By comparing the lattice parameter with that of reference it was seen that the parameter does resemble the known elements like Ca, Cl. But most of the known elements does not resemble. This may be due to the reaction between the soil and leachate and forming new compound.

The XRD of the 2nd layer is taken for analysis,

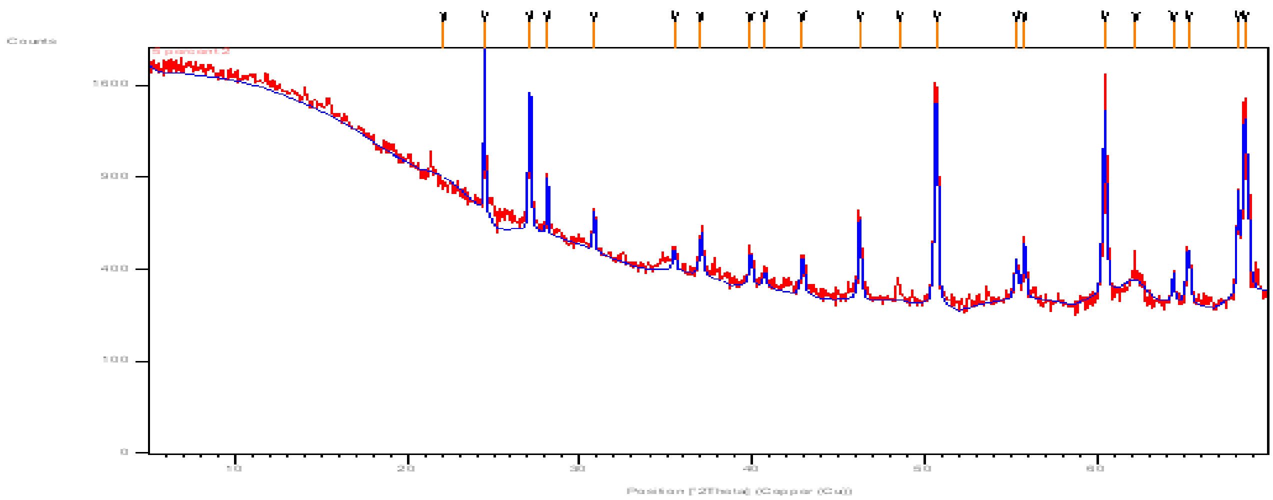


Fig.20: Diffractograms of Soil after leachate permeation (2nd layer)

Table 6: Calculation table to find lattice parameter

2Θ	Θ	sin Θ	sin2 Θ	Ratio	whole no.	whole no. × 2	index	d (A°)	a
22.1403	11.0702	0.192	0.0369	1	1	2	110	4.0118	5.67
24.482	12.241	0.212	0.0449	1.22	1	2	110	3.6331	5.14
27.1208	13.5604	0.2345	0.0549	1.49	2	4	200	3.2853	6.57
28.1179	14.0589	0.2429	0.059	1.59	2	4	200	3.171	6.34
30.8154	15.4077	0.2657	0.0706	1.91	2	4	200	2.8993	7.1
35.4733	17.7367	0.3046	0.0928	2.51	3	6	211	2.5285	6.19
37.0497	18.5249	0.3177	0.1009	2.73	3	6	211	2.4245	5.94
39.9066	19.9533	0.3413	0.1165	3.16	3	6	211	2.2573	5.53

From the calculation table, it can be concluded that the crystal structure is BCC (body centered cubic) as the whole no. came out to be 7, so it has to be multiplied by 2. By comparing the lattice parameter with that of reference it was seen that the parameter does resemble the known elements like Ca, Cl. But most of the known elements does not resemble. The second layer is almost same as that of the first layer. This may be due to the reaction between the soil and leachate and forming new compound.

5.3 EFFECT ON HYDRAULIC CONDUCTIVITY OF SOIL MIXTURE

After the permeation of soil with leachate, the effect of leachate on the hydraulic conductivity of the soil is determined. It can be seen that when the soil was permeated with water its hydraulic conductivity came out to be in the range of 10^{-8} for soil with 3% clay and 10^{-9} for soil with 5% clay. After permeation with leachate, the hydraulic conductivity increases in the range of 10^{-6} as shown in appendix XX. The increase in the permeability is may be due to presence of organic matter which decrease the specific surface area of the soil to react with the leachate.

Chapter 6

CONCLUSION

DTU soil was analysed as a competitive liner material by adding 3% and 5% of bentonite to the soil for reducing the hydraulic conductivity. After addition of bentonite clay the hydraulic conductivity of the soil mixture reduces from 10^{-6} to 10^{-8} and 10^{-9}. So it can be seen that little amount of bentonite can reduces the hydraulic conductivity of the soil. The mixed soil was then compacted and was permeated with leachate and further, was taken for analysis. Various test were conducted like Atterberg limit test, XRD analysis, Hydraulic conductivity test. After evaluation of all the results following conclusion was obtained.

- Leachate permeation affects the properties of soil mixture. It increases the liquid limit and plastic limit. It is may be due to that, after permeation of leachate organic matter is found which increase the water holding capacity of the soil. Increase in liquid limit indicates the increase in the hydraulic conductivity.
- Interpretation of the XRD data shows that elements like Ca and Cl can be traced in the soil after the permeation of leachate. Most of the elements like Pb, Cd, Zn, Cu, Mn, Cr, Fe, As could not be traced. This is may be due to reaction with soil and formation of new compounds.
- Leachate does affect the hydraulic conductivity of the soil by increasing the conductivity from 10^{-9} to 10^{-6} which is slightly less than the required hydraulic conductivity. This may be due to investigation error. This increase in the conductivity is is may be due to the decrease in the double layer thickness of the clay particles.

So from the results it can be concluded that, after the permeation of leachate, there is an increase in the hydraulic conductivity, which suggests that the soil used as a liner material should be prepared using compaction control.

Future scope:

- Long term effect like 6 months or more, of leachate can be analysed.
- Effect on shear strength of compacted soil and subsequently on its stability can be determined.
- Effect on thickness of double layer of the clay soil particles can be studied.
- Variety of Permeates like synthetic liquid can be used to see their effect on soil as a liner material.

Appendix I

Grain Size distribution (Sieve + Hydrometer)

Table 7: Observation Table for Sieve Analysis

Sieve Size (mm)	Mass of soil retained (gm)	Percentage retained	Cumulative percentage retained	%Finer
4.75	1.9	1.9	1.9	98.1
2	1.3	1.3	3.2	96.8
1	0.3	0.3	3.5	96.5
0.600	0.5	0.5	4	96
0.425	0.5	0.5	4.5	95.5
0.300	0.3	0.3	4.8	95.2
0.212	0.6	0.6	5.4	94.6
0.150	0.3	0.3	5.7	94.3
0.075	27.1	27.1	32.8	67.2

Table 8: Observation Table for Hydrometer Analysis

Time (min)	R_h (mm)	Temp. (°C)	Corrected R_h (mm)	He (cm)	D (mm)	% Finer
0.5	21.5	30	22	11.3	0.06	50.90
1	15.5	30	16	13.9	0.047	37.02
2	14.5	30	15	14.4	0.034	34.70
4	13.5	30	14	14.6	0.024	32.39
8	12.5	30	13	15	0.017	30.08
15	11.5	30	12	15.4	0.013	27.76
30	10.5	30	11	15.9	0.0092	25.45
63	10	30	10.5	16.1	0.0064	24.29
113	9	29	9.5	16.6	0.0048	21.98
240	8.5	32	9	17	0.0034	20.82
513	8	32	8.5	17.3	0.0023	19.66
1408	7	35	7.5	17.6	0.0014	17.35

Appendix II

Atterberg limit test of DTU soil

Table 9: Observation table for Liquid Limit of DTU soil

Determination no.	1	2	3	4	5	6
Penetration (mm)	14.5	15.5	20.7	21.1	24.6	26.5
Wt. of empty dish (gm)	12.3	10.4	9.9	12.1	12.1	12.1
Wt. of dish+wet soil (gm)	31.8	24.3	37.2	25.8	30.9	51
Wt. of dish+dry soil (gm)	28	21.4	31.2	22.6	26.4	41.4
Water Content (%)	24.2	26.4	28.2	30.48	31.47	32.76

Table 10: Observation table for Plastic Limit of DTU soil

Determination no.	1
Wt. of empty dish (gm)	6
Wt. of dish+wet soil (gm)	27.9
Wt. of dish+dry soil (gm)	24
Water Content (%)	21.67

From graph,

Liquid limit = 28.6%, Plastic limit = 21.67 %

Appendix III

Compaction Test

Volume of mould, V (cc) = 1000

Table 11: Observation table for compaction test

Determination No.	1	2	3	4	5
Wt. of Mould (gm), M_1	5265	5265	5265	5265	5265
Wt. of Mould+Compacted Soil(gm), M_2	7084	7269	7390	7362	7274
Bulk Density (gm/cc)	1.82	2.00	2.13	2.10	2.01
Wt. of cup (gm), m_1	10.6	12.4	10.8	12.2	9.9
Wt. of cup+wet soil (gm), m_2	29.3	46.4	44.4	55.2	50.5
Wt. of cup+dry soil (gm), m_3	28.2	43.6	40.4	48.8	43.3
Moisture Content (%)	6.3	9.0	13.5	17.5	21.6
Dry Density (g/cc),	1.71	1.84	1.87	1.78	1.65
Dry Density (kN/m^3)	16.78	18.05	18.34	17.46	16.19
Dry Density(S=1)	22.25	20.97	19.13	17.74	16.52

Appendix IV

Liquid Limit test of Bentonite clay

Table 12: Observation table for Liquid Limit of bentonite clay

Determination no.	1	2	3	4	5
Penetration (mm)	9	12	17.9	22.8	28.3
Wt. of empty dish (gm)	10.1	44.6	47.3	43.8	27.5
Wt. of dish+wet soil (gm)	22.7	57.2	63.5	59.2	40.7
Wt. of dish+dry soil (gm)	15.5	49.3	52.1	47.8	30.5
Water Content (%)	133.3	168.1	237.5	285	340

From graph,

Liquid limit = 250.9 %,

Appendix V

Atterberg limit Test of Soil with 3% bentonite clay

Table 13: Observation table for Liquid Limit of DTU soil with 3% bentonite clay

Determination no.	1	2	3	4	5
Penetration (mm)	10.1	16.5	23.8	25.3	28.4
Wt. of empty dish (gm)	25.3	26.6	39.9	26.9	26.8
Wt. of dish+wet soil (gm)	46.3	48.5	61.1	54.1	48.1
Wt. of dish+dry soil (gm)	41.7	43.3	55.8	47.2	42.4
Water Content (%)	28.05	31.14	33.33	33.99	36.54

Table 14: Observation table for Plastic Limit of DTU soil with 3% bentonite clay

Determination no.	1	2
Wt. of empty dish (gm)	13.3	13.2
Wt. of dish+wet soil (gm)	14.4	14.7
Wt. of dish+dry soil (gm)	14.2	14.5
Water Content (%)	22.22	15.38

From graph,

Liquid limit = 32.1 %, plastic limit = 18.8 %

Appendix VI

Atterberg Limit Test of Soil with 5% bentonite clay

Table 15: Observation table for Liquid Limit of DTU soil with 5% bentonite clay

Determination no.	1	2	3	4	5	6
Penetration (mm)	10.5	14.4	18.1	20.3	25.6	27.8
Wt. of empty dish (gm)	14.5	35.3	26.7	14.1	15.8	26.8
Wt. of dish+wet soil (gm)	37.8	60	49	39.2	33.2	46.8
Wt. of dish+dry soil (gm)	32.7	53.8	43.3	32.3	28.4	41.0
Water Content (%)	28.02	33.51	34.34	37.91	38.09	40.85

Table 16: Observation table for Plastic Limit of DTU soil with 5% bentonite clay

Determination no.	1	2
Wt. of empty dish (gm)	12.5	13.2
Wt. of dish+wet soil (gm)	15.9	15.8
Wt. of dish+dry soil (gm)	15.3	15.4
Water Content (%)	21.43	18.18

From graph,

Liquid limit = 35.8 %, plastic limit = 19.81%

Appendix VII

Atterberg limit test of Soil+3% bentonite clay mixed with Leachate

Table 17: Observation table for LL of DTU soil+ 3% bentonite clay mixed with Leachate

Determination no.	1	2	3	4	5
Penetration (mm)	11.6	14.7	18.4	24.3	29.5
Wt. of empty dish (gm)	24.4	25.1	45.3	10.7	10.5
Wt. of dish+wet soil (gm)	50.6	47.8	72.9	38.2	41.4
Wt. of dish+dry soil (gm)	45.1	42.4	66.2	31.0	32.7
Water Content (%)	26.57	31.21	32.06	35.47	39.19

Table 18: Observation table for Plastic Limit of DTU soil+3% bentonite clay mixed with Leachate

Determination no.	1
Wt. of empty dish (gm)	27.3
Wt. of dish+wet soil (gm)	31
Wt. of dish+dry soil (gm)	30.4
Water Content (%)	19.35

From graph,

Liquid limit = 33%, plastic limit = 19.35%

Appendix VIII

Atterberg Limit Test of Soil+5% bentonite clay mixed with Leachate

Table 19: Observation table for LL of DTU soil+ 5% bentonite clay mixed with Leachate

Determination no.	1	2	3	4	5
Penetration (mm)	13.4	17.8	22.4	23.6	27.9
Wt. of empty dish (gm)	45.5	10.1	11.2	28.5	47.1
Wt. of dish+wet soil (gm)	70.5	30.0	32.4	52.7	75.6
Wt. of dish+dry soil (gm)	64.5	24.9	26.5	45.7	67.1
Water Content (%)	31.58	34.46	38.56	40.69	42.5

Table 20: Observation table for PL of DTU soil+5% bentonite clay mixed with Leachate

Determination no.	1
Wt. of empty dish (gm)	14.6
Wt. of dish+wet soil (gm)	21.7
Wt. of dish+dry soil (gm)	20.5
Water Content (%)	20.34

From graph,

Liquid limit =36.6%, plastic limit =20.34%

Appendix IX

Muffle Furnace method to find the Organic matter of soil

Table 21. Observation table for Organic matter determination

Determination no.	1	2
Wt. of empty dish (gm) (M_p)	53	50
Wt. of dish+dry soil (gm)(M_{pd})	88.45	90.74
Wt. of dish+burned soil (gm)(M_{pb})	88	89
Mass of dry soil (M_D = Mpd - M_p)	35.45	40.74
Mass of burned soil ($M_B = M_{pb} - M_p$)	35	39
Mass of organic matter($M_O = M_D - M_B$)	0.45	1.74
Organic matter	1.26	4.27

Calculation:

$$\text{Organic matter} = \frac{Mo \times 100}{M_D}$$

$$= \frac{0.45 \times 100}{35.45}$$

$$= 1.26$$

$$\text{Organic matter} = \frac{Mo \times 100}{M_D}$$

$$= \frac{1.74 \times 100}{40.74}$$

$$= 4.27$$

Appendix X

Hydraulic conductivity test

A. DTU soil

Table 22: Observation table for Hydraulic conductivity test of DTU soil

Determination no.	1	2	3
Initial reading	75	73	71.5
Final reading	73	71.5	70
Time(min)	30	30	30
Permeability k(cm/s)	1.22×10^{-6}	9.39×10^{-7}	9.59×10^{-7}
Avg. permeability k(cm/s)	1.04×10^{-6}		

B. Soil + 3% bentonite clay

Table 23: Observation table for hydraulic conductivity of soil with 3% bentonite clay

Determination no.	1	2	3
Initial reading	60	55	52
Final reading	55	52	51
Time(min)	48×60	48×60	48×60
Permeability k(cm/s)	4.1×10^{-8}	2.65×10^{-8}	9.16×10^{-9}
Avg. permeability k(cm/s)	2.56×10^{-8}		

C. Soil +5% bentonite clay

Table 24: Observation table for hydraulic conductivity of soil with 5% bentonite clay

Determination no.	1	2	3
Initial reading	80	78	76.5
Final reading	78	76.5	75
Time(min)	48×60	48×60	48×60
Permeability k(cm/s)	1.19×10^{-8}	9.16×10^{-9}	3.09×10^{-9}
Avg. permeability k(cm/s)	8.05×10^{-9}		

Appendix XI

Total solids

A. Total Dissolved solids

Table 25: Observation table for total dissolved solids

Description	**Weight**
Weight of clean porcelain evaporating dish (W_1) (gm)	65.315
Wt. of the dish and residue (W_2) (gm)	66.012
Wt. of residue (gm)	0.697
Volume of the sample (ml)	50
TDS (mg/L)	13940

Calculation:

1. Weight of residue (gm) = $W_2 - W_1$ = 66.012 – 65.315
   = 0.697 gm
2. Weight of residue (mg) = 0.697 × 1000
   = 697 mg
3. Total dissolved solids (mg/L) = 697/50 (mg/ml)
   = 13.94 × 1000
   = 13940 mg/L

B. Total suspended solids:

Table 26: Observation table for total suspended solids

Description	**Weight**
Weight of clean filter paper (W_1) (gm)	0.930
Wt. of filter paper and residue (W_2) (gm)	1.023
Wt. of residue (gm)	0.093
Volume of the sample (ml)	50
TSS (mg/L)	1860

Calculation:

1. Weight of residue (gm) = $W_2 - W_1$ = 1.023 – 0.930
   = 0.093 gm
2. Weight of residue (mg) = 0.093 × 1000
   = 93 mg
3. Total dissolved solids (mg/L) = 93/50 (mg/ml)
   = 1.86 × 1000
   = 1860 mg/L

Appendix XII

Determination of Sulphates

Table 27. Observation table for sulphates determination

Sample no.	Vol. of sample	Absorbance
Blank	0	0.041
Std. 1	10	0.101
Std. 2	20	0.264
Std. 3	30	0.503
Std. 4	40	0.689
Leachate sample	50	0.898
Test sample	25	0.732

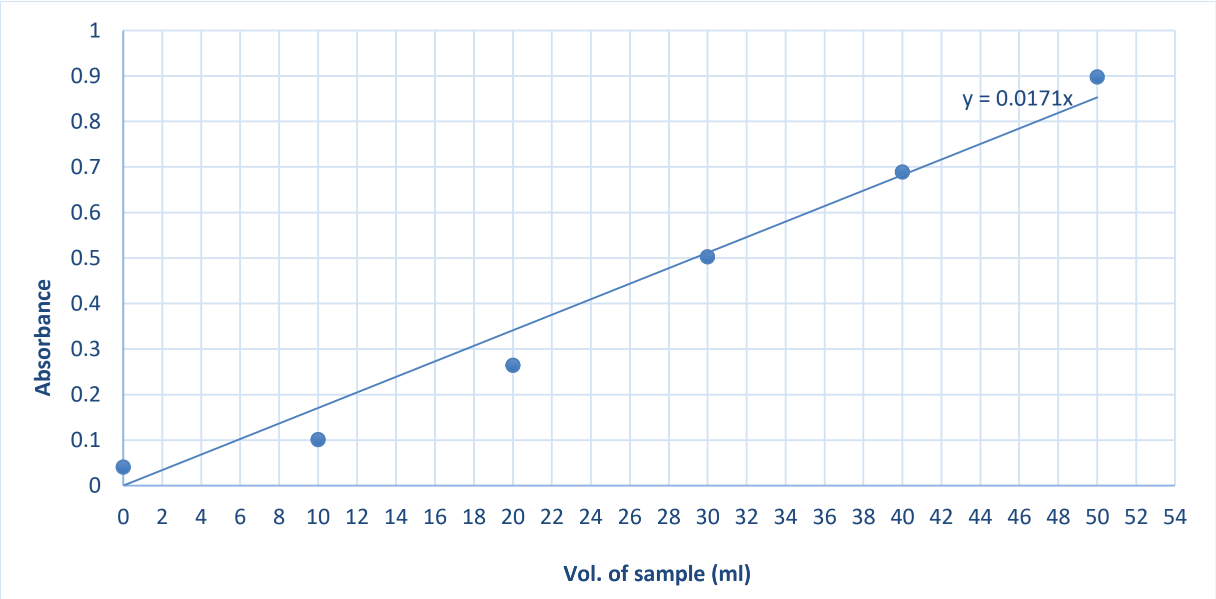


Fig.21: Calibration graph for sulphate determination

From calibration curve:

Y = mX + C, where Y = absorbance
m = slope of the line
X = concentration of sulphate in mg

Therefore,
0.732 = 0.0171 X
X = 42.807

$$\text{Conc. Of sulphates in mg/L} = \frac{42.807 \times 1000}{25} = 1712.28 \text{ mg/L}$$

Appendix XIII

Determination of Phosphates

Table 28: Observation table for phosphates determination

Sample no.	**Vol. of sample**	**Absorbance**
Blank	0	0.0012
Std. 1	2	0.002
Std. 2	4	0.003
Std. 3	6	0.075
Std. 4	8	0.080
Std. 5	10	0.102
Leachate sample	2	0.205

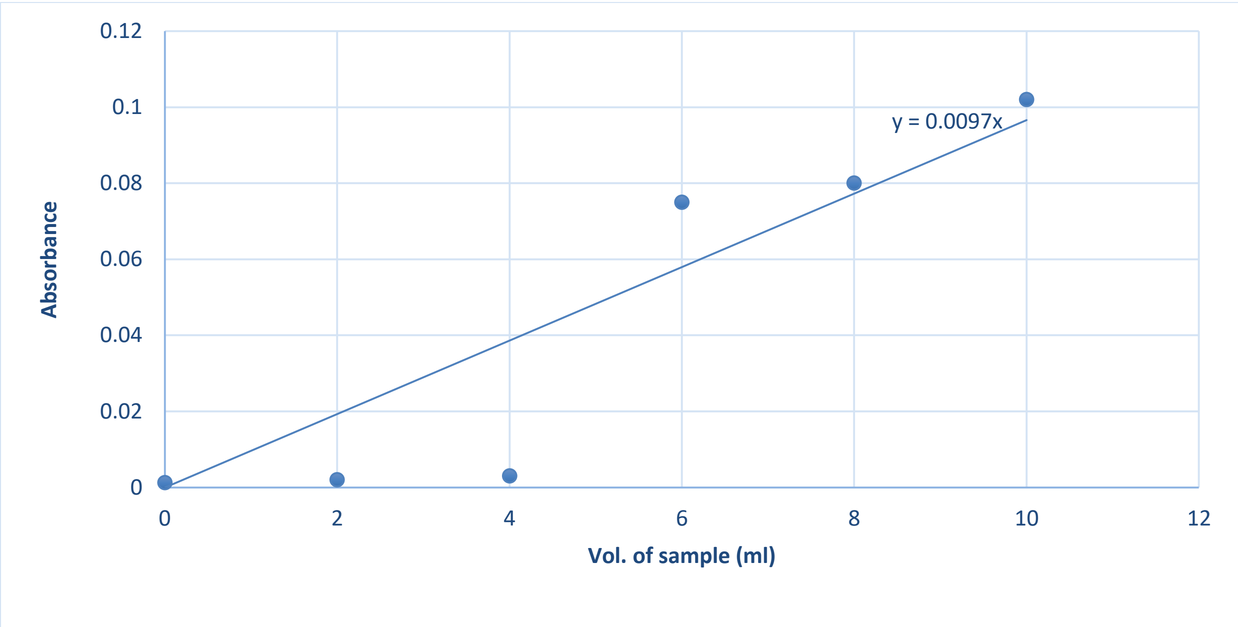


Fig.22: Calibration graph for phosphate determination

From calibration curve:

Y = mX + C, where Y = absorbance
m = slope of the line
X = concentration of sulphate in mg

Therefore,
0.205 = 0.0097 X
X = 21.13

Conc. Of sulphates in mg/L = $\frac{21.13 \times 1000}{25}$
= 845.2 mg/L

Appendix XIV
Determination of Chloride

Table 29: Observation table for chloride determination

Sl. No	**Vol. of sample (ml)**	**Burette reading (ml)**		**Vol. of EDTA (ml)**
		Initial	**Final**	
1	20	0	3.4	3.4
2	20	0	3.4	3.4
3	20	0	3.4	3.4
blank	20	0	0.2	0.2

Calculation:

Volume of silver nitrate for the sample (V_s) = 3.4 ml

Volume of silver nitrate for the blank (V_b) = 0.2 ml

Equivalent weight of chlorine = 35.45

Normality of EDTA = 0.0282 N

Volume of sample taken = 20 ml

Therefore,

$$\text{Chlorides} = \frac{(V_s - V_b) \times N \times 35.45 \times 1000}{20}$$

$$= \frac{3.2 \times 0.0282 \times 35.45 \times 1000}{20}$$

$$= 159.9504 \times 100(\text{D.F})$$

$$= 15995 \text{ mg/L}$$

Appendix XV

Determination of BOD

Table 30: Observation table for BOD determination

Trial no.	No. of days	Volume of sample (ml)	Burette reading (ml)		Volume of titrant	Dissolved oxygen (mg/L)
			Initial	Final		
Blank	0	200	0	8.1	8.1	8.1
1	0	200	0	4.5	4.5	4.5
2	0	200	0	4.5	4.5	4.5
Blank	5	200	0	8.0	8.0	8.0
1	5	200	0	3.1	3.1	3.1
2	5	200	0	3.1	3.1	3.1

Calculation:

Initial DO of the sample = 4.5

Final DO after 5 days of the sample = 3.1

Blank correction = 0.1

$$\text{Biochemical oxygen demand (mg/L)} = \frac{(D_0 - D_5 - BC) \times \text{volume of the diluted sample}}{\text{Volume of sample taken}}$$

$$= \frac{(4.5 - 3.1 - 0.1) \times 200}{10}$$

$$= 26 \times 100 \text{ (DF)}$$

$$= 2600 \text{ mg/L}$$

Appendix XVI

Determination of COD

Table 31: Observation table for COD determination

S no.	Sample	Volume of sample (ml)	Burette reading (ml) Initial	Final	Vol. of 0.1N FAS (mL)
1	Blank	2.5	0	15.1	15.1
2	1	2.5	0	14.9	14.9
3	2	2.5	0	14.9	14.9

Calculation:

Volume of FAS for blank (A) = 15.1 ml

Volume of FAS for sample (B) = 14.9 ml

Normality of FAS solution = 0.1 N

Volume of sample = 2.5 ml

$$\text{Chemical oxygen demand (mg/L)} = \frac{(A - B) \times N \times 8 \times 1000}{\text{Volume of sample taken}}$$

$$= \frac{(15.1 - 14.9) \times 0.1 \times 8 \times 1000}{2.5}$$

$$= 64 \times 100\ (DF)$$

$$= 6400\ mg/L$$

Appendix XVII

Muffle Furnace method to find the Organic matter of soil with leachate

Table 32: Observation table for Organic matter determination of soil with leachate

Determination no.	1	2
Wt. of empty dish (gm) (M_p)	50	53
Wt. of dish+dry soil (gm)(M_{pd})	83	91
Wt. of dish+burned soil (gm)(M_{pb})	82	90
Mass of dry soil (M_D = Mpd - M_p)	33	38
Mass of burned soil ($M_B = M_{pb} - M_p$)	32	37
Mass of organic matter($M_O = M_D - M_B$)	1	1
Organic matter	3.03	3.03

Calculation:

$$\text{Organic matter} = \frac{Mo \times 100}{M_D}$$

$$= \frac{1 \times 100}{33}$$

$$= 3.03$$

$$\text{Organic matter} = \frac{Mo \times 100}{M_D}$$

$$= \frac{1 \times 100}{38}$$

$$= 3.03$$

Appendix XVIII

Atterberg Limit test soil + 3% bentonite clay with leachate

Table 33: Observation table for Liquid Limit of soil + 3% bentonite clay with leachate

Determination no.	1	2	3	4	5
No. of blows	10	14	20	23	29
Wt. of empty dish (gm)	9	6	7	11	5
Wt. of dish+wet soil (gm)	24	20	18.1	22	16
Wt. of dish+dry soil (gm)	19.5	16	15	19	13.1
Water Content (%)	42.86	40	38.75	37.5	35.8

Table 34: Observation table for Plastic Limit of Soil+3% bentonite clay with Leachate

Determination no.	1
Wt. of empty dish (gm)	14.8
Wt. of dish+wet soil (gm)	21.7
Wt. of dish+dry soil (gm)	20.5
Water Content (%)	21.05

From graph,

Liquid limit = 36.9%, plastic limit = 21.05%

Appendix XIX

Atterberg Limit test soil + 5% bentonite clay with leachate

Table 35: Observation table for Liquid Limit of soil + 5% clay with leachate

Determination no.	1	2	3	4
No. of blows	10	17	23	26
Wt. of empty dish (gm)	7.1	8	8	9
Wt. of dish+wet soil (gm)	17	26.4	19.1	20
Wt. of dish+dry soil (gm)	14	21	16	17
Water Content (%)	43.48	41.54	38.75	37.5

Table 36: Observation table for Plastic Limit of Soil+5% clay with Leachate

Determination no.	1
Wt. of empty dish (gm)	8.2
Wt. of dish+wet soil (gm)	11
Wt. of dish+dry soil (gm)	10.5
Water Content (%)	21.74

From graph,

Liquid limit = 38%, plastic limit = 21.74%

Appendix XX

Hydraulic conductivity test of soil with leachate

A. Soil + 3% bentonite clay

Table 37: Observation table for hydraulic conductivity of soil+ 3% bentonite clay with Leachate

Determination no.	1
Initial reading (cm)	10
Final reading (cm)	5
Time(min)	30×24×60×60
Permeability k(cm/s)	2.67×10^{-6}

B. Soil +5% bentonite clay

Table 38: Observation table for hydraulic conductivity of soil+ 3% bentonite clay with Leachate

Determination no.	1
Initial reading (cm)	10
Final reading (cm)	6
Time(min)	30×24×60×60
Permeability k(cm/s)	1.97×10^{-6}

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