



ACBA 5004

Soil Mechanics Laboratory Report

The following tests were done to practically analyse the engineering properties of soils: Sieve Analysis test, Atterberg Limit test and the constant head permeability test

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Sieve Analysis: Introduction

The purpose of this experiment is to carry out textual classification of the soil sample. A soil's particle size distribution is one of the most important physical characteristics of soil. Several geotechnical and geohydrological properties of soils such as water flow potential and bearing capacity are related to the particle size distribution.

Sieve analysis is used to determine the particle size distribution of a soil sample. This is done by placing a sample of the material on a series of sieves of varying sizes, the largest openings on top and the smallest below. The sieves are then shaken for at least 2 minutes to separate particles based on their size. The particles that are too large to pass through the smaller sieve are retained and weighed, the weight of each size fraction is used to calculate the percentage of material in each size range.

Limitations in the particle size distribution lab include human error, lack of a 2 μm to properly distinguish clay and silt particles and the issue of the 63 μm sieve had a double layer, which may have affected the accuracy of the results.

After performing the sieve analysis on the soil sample, the soil texture triangle was utilized to determine the soil's texture based on the percentages of sand, silt and clay that were obtained from the analysis.

Methodology

Apparatus

1. Set of test Sieves with the following aperture size: 2 mm, 1.6 mm, 1mm, 500µm, 250 µm, 125 µm, 80 µm and 63 µm, a bottom pan and a cover lid.
2. Mechanical sieve shaker
3. Scale
4. Scale pan
5. Sieve brushes
6. Drying oven
7. A Tray
8. Scoop



Procedure

The method of this experiment was done in accordance with the BS 17892-12:2018 and the BS 1997-2:2007 requirements.

The soil sample was prepared for the experiment by oven drying it at 120 degrees Celsius for 24 hours. The dried sample was then stirred to ensure uniformity. A scale pan was placed on the scale, and its weight was zeroed. The sample was then quartered, and a sample size of 1000 g was selected for the experiment. (Photo A)

The set of sieves with the largest openings were arranged in order of opening size, starting from the top sieve with an opening size of 2 mm and ending with the bottom sieve with an opening size of 63 μm . The sample was poured onto the top sieve, and a cover was placed on top to secure the aggregate during the shaking process. (Photo B)

The stack of sieves was then placed on the mechanical shaker and locked in place. The mechanical shaker was operated for 2 minutes to shake the sample. After 2 minutes, the machine was stopped, and the lid was removed. Each sieve was removed one at a time, and the sample remaining in each sieve was poured into a tray. Any particles remaining in the sieve were brushed out and then poured into the scale pan. This process was repeated for each sieve up to 63 μm and then for the pan. (Photo C)

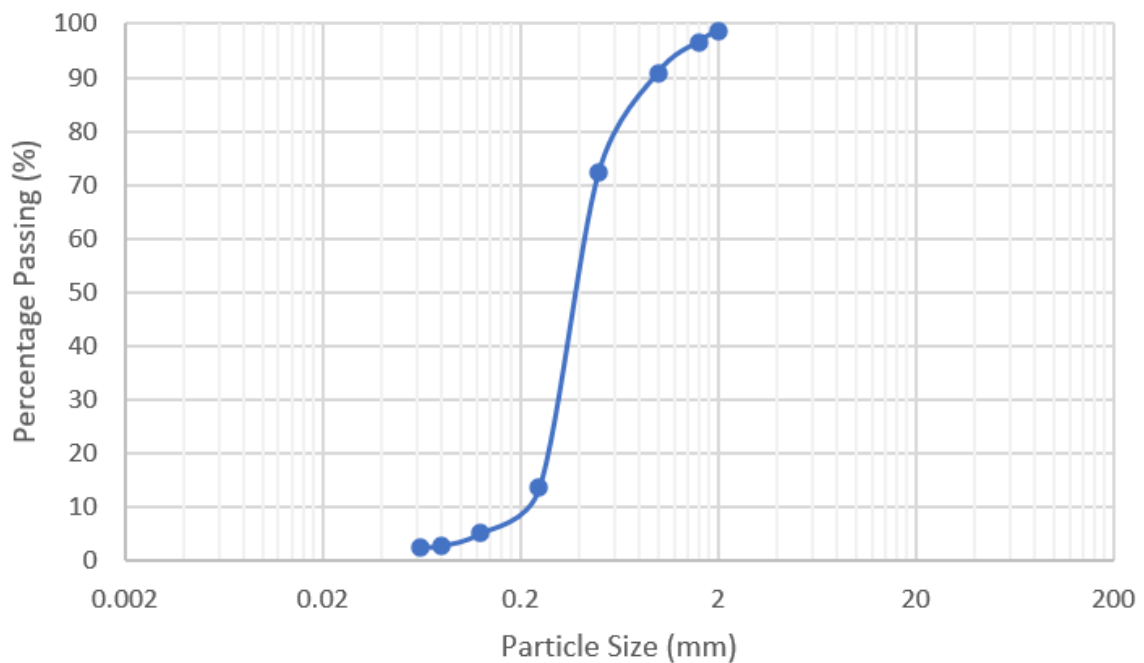
The percentages of the aggregate on the sieve and the percentage passing through the sieve were calculated to the nearest 0.1% for each size of aggregate retained on the sieve. The sieve size against the percentage passing for the sample was plotted on graph paper in accordance with the British Standards.

Finally, the percentage of each type of soil (silt, sand, and clay) in the sample was calculated, and the results were represented on the triangular graph of soil texture.

Results and Analysis

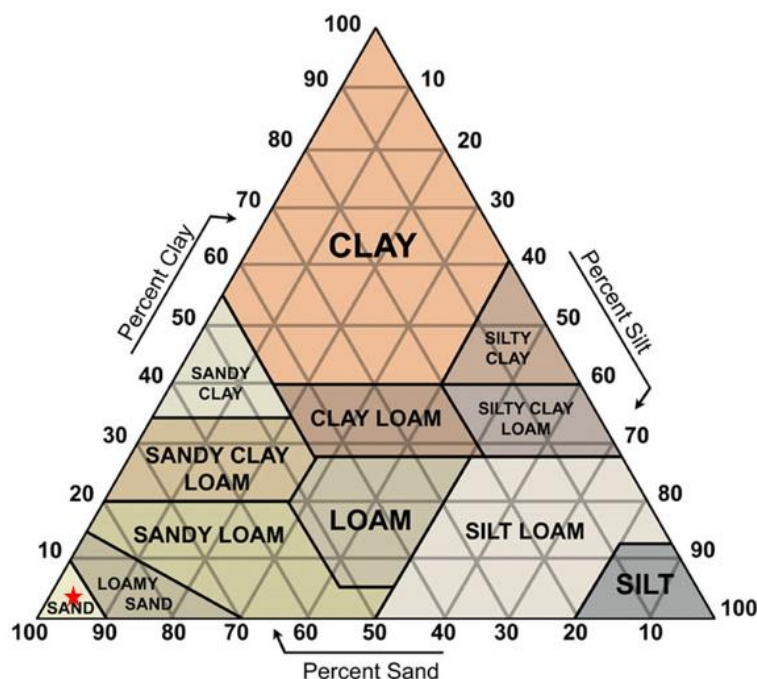
Sieve size (mm)	Mass (g)	% Retained on sieve	% Passing
2 mm	12.53	1.253	98.647
1.6 mm	20.27	2.027	96.62
1 mm	57.14	5.714	90.906
500µm	186.07	18.607	72.299
250µm	587.79	58.779	13.520
125µm	83.76	8.376	5.144
80µm	22.67	2.267	2.877
63µm	2.71	0.271	2.606
Pan	26.06	2.606	N/A

Particle Size Determination



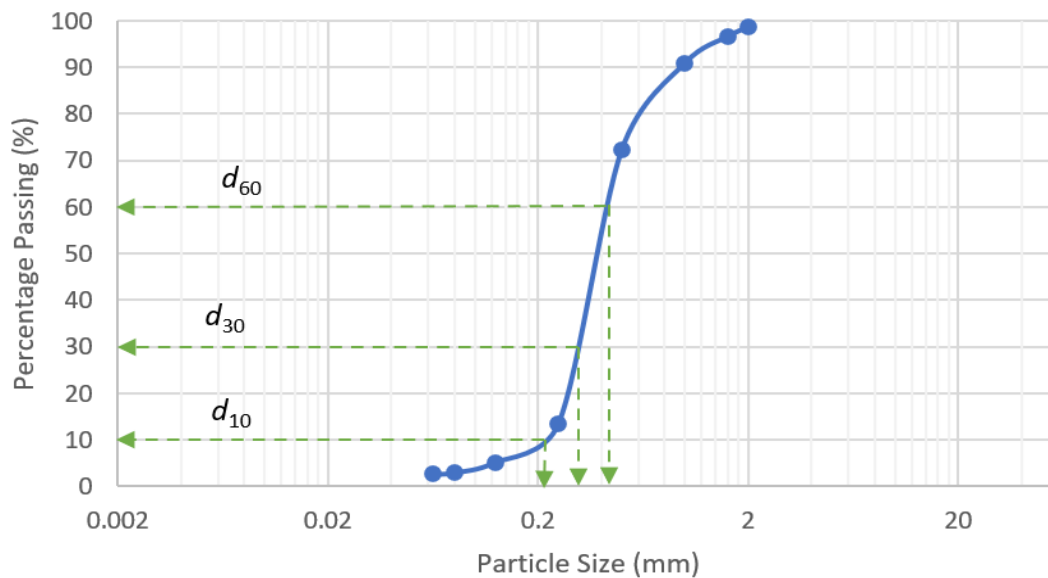
It was possible to obtain the particle size distribution curve by performing the sieve analysis and plotting the results on a semi-log graph. This was used to determine the grading of the soil as well as the percentage of coarse and fines present in the sample. The particle size distribution curve shows a sample with uniform grading. The sample can be described as well graded sample that is predominantly sand with only a small fraction of silt/ clay present. The size range of sand particles falls between 0.0063 mm and 2 mm, while silt particles range from 0.002 mm to 0.0063 mm and clay particles are smaller than 0.002 mm. Due to the unavailability of the 2 μ m sieve, we were unable to obtain accurate percentages of silt and clay. Hence, the assumption was made that all particles that passed the 63 μ m sieve and were in the pan was silt.

The results of the sieve analysis showed the soil sample had a 96.041% Sand, 1.253 % Gravel and 2.606% of Silt. The percentages were plotted on the triangular graph of soil texture which indicated the sample is predominantly sand as indicated by the red star on the graph.



Further analysis of the grading curve was carried out by using geometric values. First the following three points were located on the grading curve to give the following characteristic sizes:

Particle Size Determination



- d_{10} which is the maximum size of the smallest 10 per cent of the sample = **0.2**.
- d_{30} which is the maximum size of the smallest 30 per cent of the sample = **0.3**.
- d_{60} which is the maximum size of the smallest 60 per cent of the sample = **0.43**.

From this it was possible to determine the uniformity coefficient and the coefficient of gradation using the equations:

1. $C_u = d_{60} / d_{10}$
2. $C_g = (d_{30})^2 / d_{60} \times d_{10}$

When the Uniformity Coefficient (C_u) is less than 3 this indicates uniform grading while if its more than 3, it indicates a well-graded soil. A coefficient of Gradation (C_g) between 0.5 and 2.0 indicates well graded soils.

1. $C_u = d_{60} / d_{10}$
 $= 0.43 / 0.2$
 $= 2.15.$

➤ This is less than 3 which indicates uniform grading.

2. $C_g = (d_{30})^2 / d_{60} \times d_{10}$
 $= (0.3)^2 / (0.43 \times 0.2)$
 $= 1.04.$

➤ This is between the range of 0.5 and 2.0 which indicates a well- graded soil.

Conclusion

This experiment aimed to classify the soil sample based on its particle size distribution, which is a crucial physical characteristic of soil as several engineering properties are related to a soil's particle size, e.g., compressibility and permeability. To determine particle size, we did a sieve analysis which involved using a series of sieves with varying sizes to separate particles based on their size. It is important to note we encountered an issue with the 63 μm sieve, which had a double layer that may have affected the accuracy of the results. Despite these limitations, we were able to use the percentages of sand, silt, and clay obtained from the sieve analysis to determine the soil's texture using the soil texture triangle. We were also able to further analyse the sample's grading characteristics in which the sample can be classified as a uniformly graded sand soil with little fines.

Atterberg Limit: Introduction

The Atterberg limit test is a method used to classify fine-grained soils by determining the moisture content and the ability of the soil to deform without cracking or crumbling (Plasticity).

The tests were developed by Albert Atterberg in 1911 to classify soils based on plastic and liquid properties. Arthur Casagrande later developed a device as a more precise and standardized method for determining the Atterberg limit tests of soils.

The device consists of a metal cup, a grooving tool and a crank-operated mechanism that allows the cup to be dropped from a standardized height.

This experiment was done to determine the liquid limit and plastic limit of the soil sample using the Casagrande method as outlined in the British Standards: BS EN ISO 17892-12:2018+A2:2022.

The results were then used to plot on the plasticity index chart to examine the degree of plasticity. In the discussion section of this report, we examine how these findings may impact the applications in engineering and construction.

This information is critical in geotechnical engineering as it provides insight into the soil's strength, physical properties, and behaviour as you can observe how the sample will react to changes in water content. It is necessary to know this information when building foundations, in road construction and other civil engineering applications.

Before continuing through the report, it is important to understand the subsequent terminologies.

Plastic Limit (W_P) this is the point which the water content present in the soil causes a change from plastic state to a semi-plastic solid state.

Liquid limit (W_L) is the point which the water content in the soil causes a change from liquid state to plastic state.

Plastic Index (I_P) this represents the range the soil can exhibit plastic behaviour. It is calculated by subtracting the plastic limit from the liquid limit. $I_P = W_L - W_P$

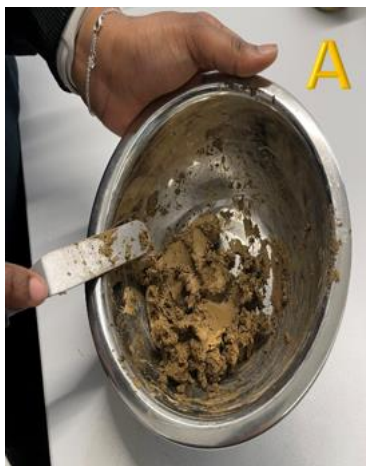
Shrinkage Limit (W_S) this is the point at which the water content in a soil ceases to cause volume change when drying out.

Methodology

Apparatus

1. Spatula
2. Glass plate
3. Soil specimen
4. Moisture cans
5. Grooving tool
6. Casagrande apparatus
7. Drying oven
8. Scale sensitive to 0.01g.
9. Plastic squeeze bottle of water

Procedure



Liquid Limit Test

The liquid limit test using the Casagrande method was conducted by following the standard procedures. Four containers were chosen, marked and weighed, and the weight of each container was recorded. A soil sample of around 250g was taken and placed in a metal mixing bowl.

Small amounts (1-2ml) of water were added to the soil sample while stirring, kneading, and chopping it with a spatula. The aim was to obtain a soil consistency that would require 30-35 drops of the Casagrande apparatus to cause a groove gap closure of 12mm. The consistency of the soil was adjusted by trial and error until the required

consistency was reached. (Photo A)

Once the right consistency was achieved, a portion of the soil mixture was taken and placed in the cup bowl. The soil was pressed down using a spatula and spread as flat as possible across the base to a depth of about 10mm. The gauging groove tool was then used to cut a groove in the soil sample from back to front. Three gentle swipes were made to avoid side tearing, and the soil sample was cut through to the base of the cup. (Photo B)

The drop counter on the Casagrande apparatus was zeroed, and the crank handle was turned at a rate of 2 revolutions per second while lifting and dropping the cup until the two halves of the soil closed over a distance of 12mm across the slot made with the gauge tool. The number of drops required to close the 12mm gap was recorded.

A slice of soil the width of a spatula was removed from edge to edge across the sample, cutting through the groove. The slice of soil was placed in a marked container, and the wet soil and container were weighed together. The process was repeated for four samples, gradually increasing the moisture content slowly to obtain samples that required above and below 25 drops to close the gap. The number of drops ranged between 15 and 35.

The four samples were dried in an oven, and the dry sample and container were weighed together to determine the moisture content. Overall, the liquid limit test using the Casagrande method was successfully conducted, and the results were recorded for further analysis.

Plastic Limit Test

The Plastic Limit Test was conducted by following the below procedures. Three containers were chosen, marked, and weighed, and the weight of each container was recorded. A clay sample was taken and kneaded thoroughly, it was mixed with water to adjust the moisture content to the required limits.

A small ball of clay was molded between the fingers and rolled between the palms of the hands so that it dries slowly. Once slight cracks appeared on the surface, the ball was divided into three equal parts of about 10kg each and kept separate.

Using the glass rod provided, each ball was rolled into a thread on the glass plate,

measuring it against the rod. The thread was about 6mm in diameter and was intact and homogeneous. With steady rolling pressure with the palm of the hand, the diameter of the thread was reduced to around 3mm, repeating the rolling process until the thread started to "crumble" at around the 3mm diameter mark. Uniform rolling pressure was maintained throughout, and the crumbling was due to the reduction of moisture as a result of rolling directly, and not by mechanical breakdown due to undue pressure from the hand.

The point at which the thread started to crumble was noted as the Plastic Limit moisture content. The crumbs were gathered as the crumbling stage was reached, placed in a container, and weighed along with the wet soil and container.

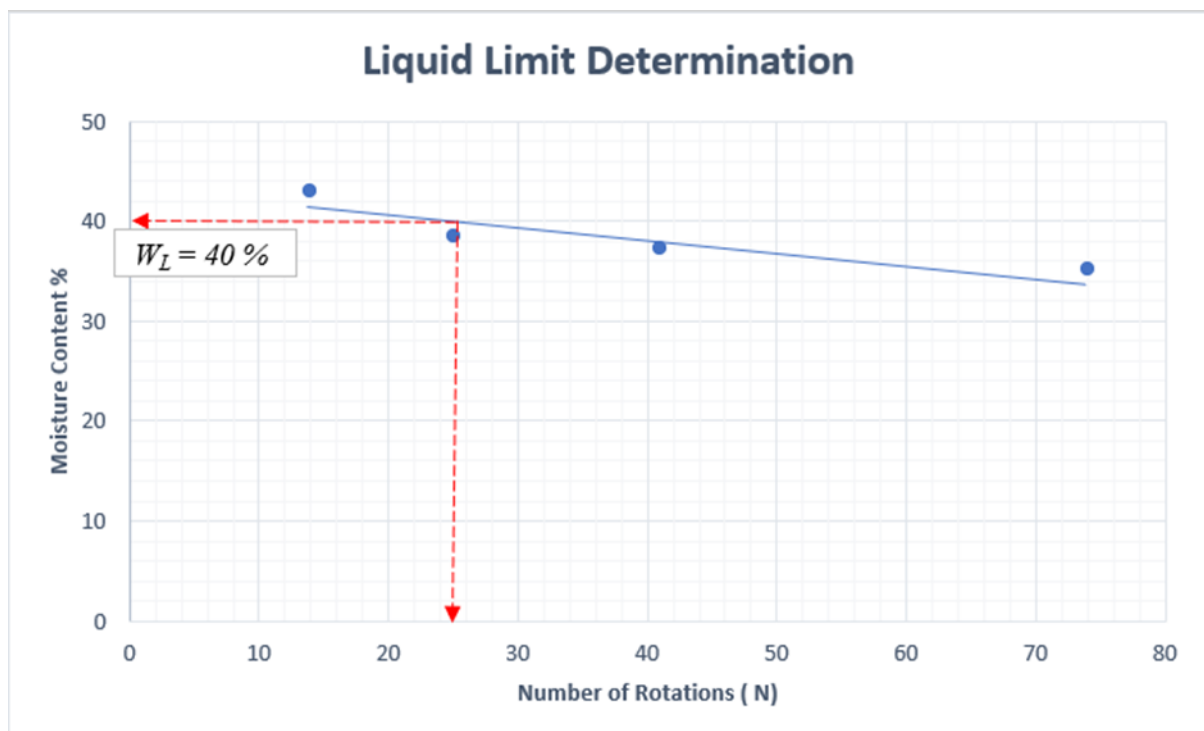
The above procedures were repeated for three samples, and the three containers with the sample inside were dried in the oven at a temperature of 120 °C for 24 hours until completely dry. After drying, the container and the dry soil were weighed together and recorded.

The moisture content was calculated by subtracting the weight of the container from the weight of the container and the dry soil combined. Finally, the average of the three results obtained in step 16 was taken to obtain the plastic limit moisture content indicator.

Results and Analysis

Liquid Limit Determination

Sample No.	1	2	3	4
Container Number	LL1	LL2	LL3	LL4
Weight of Container (g)	4.76	4.76	4.69	4.69
Weight of wet soil + Container (g)	16.23	12.78	13.00	11.04
Weight of dry soil + Container (g)	13.24	10.60	10.69	9.13
Weight of moisture (g)	2.99	2.18	2.31	1.91
Weight of dry soil (g)	8.48	5.84	6.00	4.44
Moisture Content (%)	35.26	37.3	38.5	43.02
Number of Blows	74	41	25	14



$W_L = 40\%$

Plastic Limit Determination

Sample No.	1	2	3
Container Number	PL1	PL2	PL3
Weight of Container (g)	4.74	4.74	4.70
Weight of wet soil + Container (g)	7.14	6.71	6.73
Weight of dry soil + Container (g)	6.66	6.29	6.30
Weight of moisture (g)	0.48	0.42	0.43
Weight of dry soil (g)	1.92	1.55	1.6
Moisture Content (%)	25	27.1	26.9

Plastic Limit (W_P) = Average moisture content %

$$W_P = 25 + 27.1 + 26.9 / 3$$

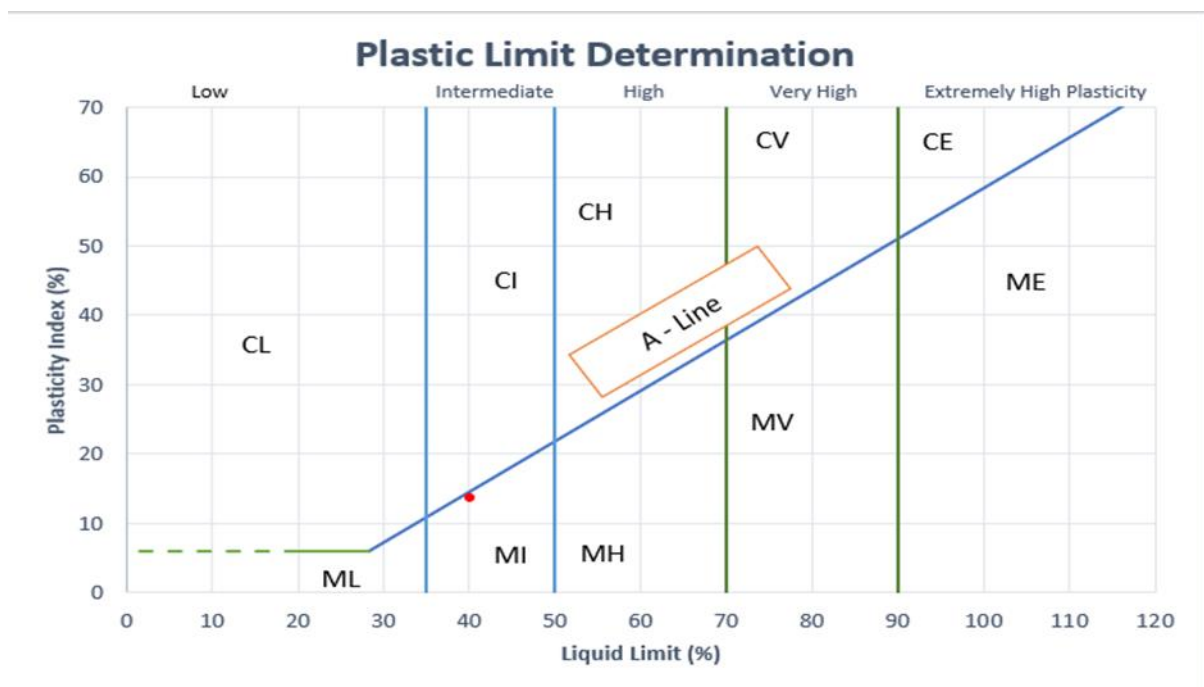
$$= 26.3\%$$

The Plasticity Index (I_P) =

$$I_P = W_L - W_P$$

$$= 40\% - 26.3\%$$

$$= 13.7 \%$$



The sample can be classified as a silty clay with medium plasticity. A liquid limit of 40% suggests that the soil is relatively prone to liquefaction and instability when subjected to loading or a disturbance. A plastic limit of 26.3% suggests that the soil is relatively less cohesive and may have a lower shear strength, making it more susceptible to erosion and instability. The soil has a Plastic index of 13.7% which is a silt soil with medium plasticity and may exhibit moderate deformation under loading.

Some common factors which can contribute to slope instability in these soils are saturation, when these soils become saturated with water, their strength and stiffness decrease which causes landslides, steep slopes, slopes with steep gradients increase the stress on the soil and can cause it to fall erosion, natural disasters such as earthquake can cause soils to deform, this type of behaviour can also be caused by heavy machinery or traffic, changes in water content due to changes in the seasons can cause shrinkage and swelling.

This is seen in 2022, where a major portion of the mountainside in Gwynedd crumbled, spilling debris onto the A498 road below due to heavy rainfall and wind.

The slope failure was a complex failure involving numerous types of failure, including soil, rock falls and debris slides.

The area's geology, which comprises of gravelly clay and silt of a soft consistency, makes the slope prone to failure, particularly during periods of significant rainfall.

The incident emphasises the necessity of analysing the stability of slopes in sensitive locations and adopting proactive actions to prevent slope failures, such as improved drainage and slope stabilisation.

While the Atterberg limit test provide geotechnical engineers with important parameters, to further evaluate susceptibility to slope instability in this type of soil it is essential to consider factors such as slope gradient, triggers such as earthquakes, etc. Drainage systems, retaining walls or slope reinforcement techniques should be employed to insure the stability and safety of slopes.

Conclusion

The Atterberg limit test results provided useful information on the plasticity of the soil. Through the tests and analyses we were able to determine liquid limit, plastic limit, and the plasticity index of the soil sample, with the data obtained we were able to classify the sample on the plasticity index chart as a silt with medium plasticity. This classification is important in determining the suitability of the soil for various applications in construction and geotechnical engineering but should be used alongside data from other tests to better understand suitability.

Permeability test: Introduction

Permeability in soils can be defined as the ability of the soil to allow water or other liquids to flow through it.

Henry Darcy, in 1856, studied the flow of water through sand and determined that the velocity of the fluid through a porous medium is directly proportional to the hydraulic gradient and cross-sectional area of the medium, this is known as Darcy's law. He also observed that the flow rate was affected by a coefficient (k), which is now referred to as hydraulic conductivity or coefficient of permeability.

There are two types of hydraulic conductivity tests such as the constant head permeability test and the falling head permeability test, but the constant head method is most used in the United Kingdom. The coefficient of permeability can also be computed from the particle size and from a consolidation test. In this lab report, a permeability test was done using the constant head method on a soil sample to determine the permeability coefficient denoted as (k), of the soil and its hydraulic conductivity. This test is used for soil samples that are coarse-grained soils such as gravels and sands that have (k) values above 10^{-4} m/s. The method involves placing a soil sample inside a permeameter with a known cross-sectional area and allowing water to flow through the soil at a constant head. By measuring the flow of water at different intervals, the soil's permeability was calculated using Darcy's law. This makes it possible to evaluate the drainage characteristics of the soil and its suitability for various applications such as the design of dams and landfills. This report will include a detailed procedure of the test, equipment used, data collected and their interpretation.

Methodology

Equipment

1. Constant Head test apparatus
2. Timer
3. Graduated cylinder.
4. Ruler

Procedure



Photo of The Constant Head Apparatus set up.

The constant head apparatus consisted of a cylindrical soil permeameter, with a wire mesh and gravel filters above and below. The soil sample is compacted and placed inside the permeameter, which is then sealed to prevent any water leakage. The cylinder has manometer connections to enable pairs of pressure head readings to be

taken. Water flows through a reservoir and the permeameter is positioned below the de-aired water, maintaining a constant head of water above the soil sample.

The dimensions of the soil sample were measured, and its dry weight was recorded, the soil sample was installed in the permeameter and firmly compacted in three layers. Then, the permeameter was filled with water until the water level reached a certain height above the soil sample, creating a constant hydraulic gradient. Water was allowed to flow through the soil sample for a set period, while the flow rate was measured at specified time intervals. The test was repeated two other times and the values recorded. The permeability coefficient of the soil sample was calculated using Darcy's law, which involved determining the hydraulic gradient and the flow rate of water through the soil sample and the results were analysed.

Results and Analysis

Test Number	Time to accumulate water (s)	Mass of water (ml)
1	30	145
2	30	145
3	30	145

From the data collected we can calculate using Darcy's law, the:

$$\text{Coefficient of Permeability (K)} = Q \times L / A \times h \times t$$

Where:

Q = quantity of water collected or flow over time (m³/s)

A = Cross sectional Area of sample (mm²)

L = difference in manometer tapping points (mm)

h = Hydraulic head difference (mm)

t = time (seconds)

Diameter of vessel = 79.3 mm

Cross sectional area of sample = $79.3^2 \times \frac{\pi}{4} = 4936.46 \text{ mm}^2$

Total head at the top of monometer = 70 mm

Total head at the bottom of monometer = 29 mm

Vertical distance between the monometer outlets = 144 mm – 74 mm = 70 mm

- The values were converted to meters to and substituted into the equation to get:

$$k = \frac{0.000145 \text{ m}^3 \times 0.07 \text{ m}}{30 \text{ s} \times 0.00493646 \text{ m}^2 \times 0.041 \text{ m}}$$

$$k = \frac{1.015 \times 10^{-5}}{6.0718458 \times 10^{-3}}$$

Therefore, the coefficient of permeability is $1.67 \times 10^{-3} \text{ m/s}$.

The calculation is usually calculated for each test number and then the average of the coefficient of permeability is calculated. Since the flow over time remained 145ml there was no need for this.

Based on (k) being $1.67 \times 10^{-3} \text{ m/s}$, and the range of permeability coefficients for different materials we can classify the sample as a moderately permeable, clean sand or a gravel-sand mixture with good drainage.

It is important to note that other factors can influence the hydraulic conductivity of a soil sample such as obtaining a good representative sample for laboratory tests the samples are usually small and may not be a satisfactory representative sample of the soil's macrostructure, however this can be overcome by carefully selecting the sample group. Other factors to consider in the determination of (k) by a laboratory test is the presence of air bubbles in the water, the porosity of the soil and even variations in the temperature of the water. Hence laboratory tests should be supplemented with field tests and further testing may be necessary to accurately classify the sample.

Conclusion

The coefficient of permeability for the soil specimen was calculated to be 1.67×10^{-3} m/s based on the results of the constant head permeability test. This number is within the normal range for similar soils, suggesting that the soil is moderately permeable.

Although all equipment was correctly calibrated, and the test conducted carefully, it is crucial to note that the coefficient of permeability is impacted by several parameters, including soil type, compaction, and temperature of water, and may vary depending on the test circumstances.

The constant head permeability does give significant information for engineering applications such as constructing drainage systems and assessing seepage possibilities in embankments or retaining walls, but it is recommended further testing should be done to completely classify the soil's behaviour.

References

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Copies of results recorded in the lab.

24 hrs in oven
temp in oven 120°C.

Particle Size Distribution Test

Result Table 1000g

Sample Size = 1000g

Sieve Size (mm)	Mass (g)	% on sieve	% Passing
2mm	12.53	1.253	98.647
1.6mm	20.27	2.027	96.62
1mm	57.14	5.714	90.906
500 μ m	186.07	18.607	72.299
250 μ m	587.7	58.779	13.520
125 μ m	83.76	8.376	5.144
80 μ m	22.67	2.267	2.877
63 μ m	2.71	0.271	2.606
pan	26.06	2.606	N/A
Total		99.9%	

↑ gravel

— sand

%? 96.041%

— silt

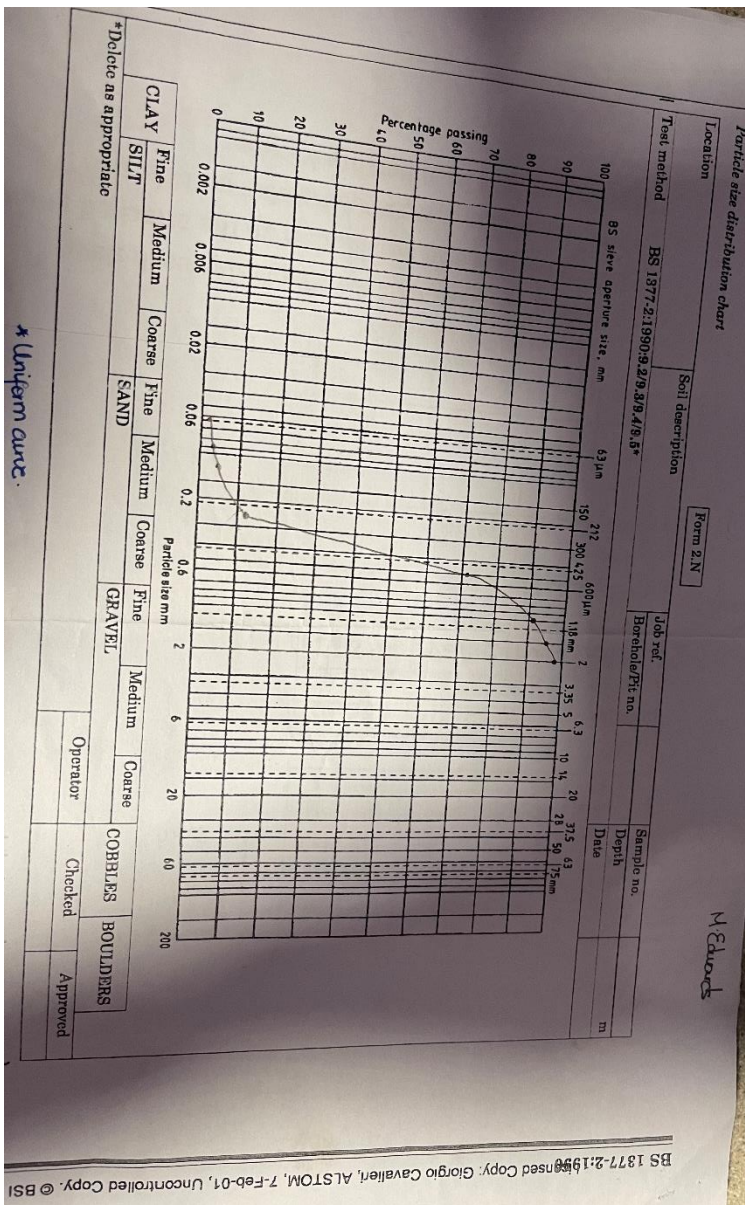
↓ clay %?

0.101

double asterisk

587.7

1. Complete the table to obtain % passing each sieve.
2. Plot the particle size distribution on the attached graph.
3. Comment on the sample aggregates particle size distribution and its suitability for use.



LIQUID AND PLASTIC LIMIT DETERMINATION

Group number -

Student Name - M. Edwards

Date - 20/02/23

	1	2	3	4	5	6	7
Type of Test	LL	LL	LL	LL	PL	PL	PL
Container Number							
Wt of wet soil + cont.	16.23g	12.78g	13.00g	11.04g	7.14g	6.71g	6.73g
Wt of dry soil + cont.	13.24g	10.60g	10.69g	9.13g	6.66g	6.29g	6.30g
Wt of Container	4.76	4.76	4.69g	4.69g	4.74	4.74	4.70
Wt of moisture	2.99g	2.18g	2.31g	1.91g	0.48g	0.42g	0.43g
Wt of dry soil	8.48g	5.84g	6.00g	4.44g	1.92g	1.55g	1.6g
Moisture Content	35.25%	37.32%	38.5%	43.01%	25% + 21.04% + 26.87%		
Number of Blows	74	41	25	14			

Remarks:

Liquid Limit = 40%

Plastic Limit = 26.323%

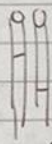
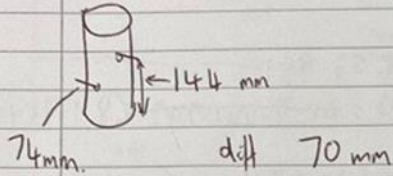
Plasticity Index = 13.677%

Soil Classification =

Test 1

$$K = \frac{Q \times L}{A \times h \times t}$$

diameter of vessel. 79.3 mm *
79.2
79.4



Head difference 0.041 m.

29 mm 70 mm

let the pressure normalise
each time

128
~~124.5~~ ml 30 Secs
145 ml
145 ml
150 ml - anom. dis. corrected.
145 ml. 147 ~~average~~
145