

Geo-technics And Foundation Technology

ACBA5004

Soil Mechanics Practical

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Contents

1) Atterberg Limits Test	3
1a) Introduction	3
1b) Methodology of Liquid Limit	4
1c) Methodology of Plastic Limit	7
1d) Results and Analysis	8
1e) Conclusion	13
2) Constant Head Permeameter Test	15
2a) Introduction	15
2b) Methodology	16
2c) Results and Analysis	18
2d) Conclusion	20
3) Sieve Analysis Test	21
3a) Introduction	21
3b) Methodology	22
3c) Results and Analysis	24
3d) Conclusion	26
4) References	27
5) Appendix	27
5a) Atterberg Limit Test Images	27
5b) Constant Head Permeameter Test Images	30
5c) Sieve Analysis Test Images	31

1) Atterberg Limits Test

1a) Introduction

Atterberg limits is a testing method used within geotechnical engineering to establish the properties of fine-grained soils. The tests concentrate on how the moisture content can affect the consistency of the soil. The output from the test is essential in civil engineering for the construction of the foundation design, allowing a greater understanding of the soil transition from solid, semi-solid, plastic, and liquid states, thus allowing engineers to classify the soil and the ability to predict its expected behaviors.

The definitions and the results from the Atterberg Limit are highlighted below

(www.geoengineer.org, n.d.)

Plastic Limit (PL) is the water content at which a soil changes from a plastic state to a semisolid state.

Liquid Limit (LL) is the water content at which the soil changes from a liquid state to a plastic state.

Plasticity Index (PI) is calculated as the Plastic Limit subtracted from the Liquid Limit and is an important value when classifying soil types.

$$PI = LL - PL$$

The tests that were undertaken in the laboratory were in accordance with BS 1377-2:1990 - Classification and geotechnical properties of soils for civil engineering purposes.

The importance of Atterberg Limit test is imperative for civil engineers, it allows analysis to be undertaken on foundation design, earthwork construction, slope stabilization, road & pavement design. The ability to understand the soil properties helps the concept, construction & project lifecycle, ensuring that the loads and stresses being applied will not have any immediate or long-lasting effect on the substructure.

1b) Methodology of Liquid Limit

Albert Atterberg established a laboratory test method to determine the liquid limit of a soil sample. This method is called the 'Casagrande Cup Method' and can be done in accordance with British Standard (BS 1377-2:1990). This method can be used, and results are plotted on a graph where the Liquid limit is marked at the 25-repetition blow.

It is imperative to understand the limitations of the testing before undertaking the testing. The main limitation is the conditions the testing is undertaken, given we are undertaking the experiment in a university establishment the room temperature could not be controlled, and neither could the room humidity. These can affect the results because the testing of the liquid limit is purely based on moisture content.

Another limitation that can affect the results is the alternating personnel undertaking each sample. The timings of the drops on the Casagrande and the mixing of the water into the dry soil sample could also be affected. An individual undertaking the test would have consistency in the method and routine of each test.

Only 1 soil sample was tested, to ensure accuracy the testing would be repeated to ensure the accuracy of the results.

Once the limitations are realized the following steps can be undertaken to complete the liquid limit testing.

Equipment used for the Casagrande Cup Method test: -

- Digital Scale
- Flat Grooving Tool
- Spatula
- Casagrande Cup Apparatus
- Metal Mixing Bowl
- Metal Containers (Marked for each sample)
- Dried Soil Sample
- Water
- Oven

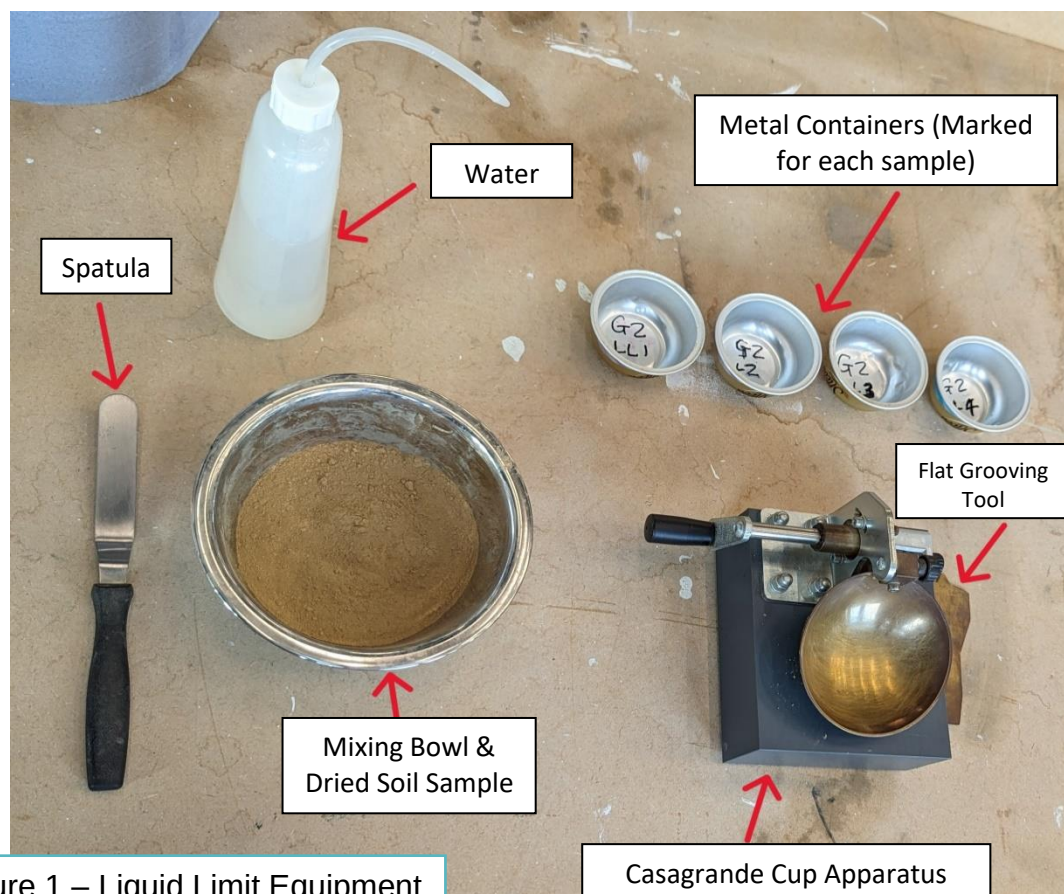
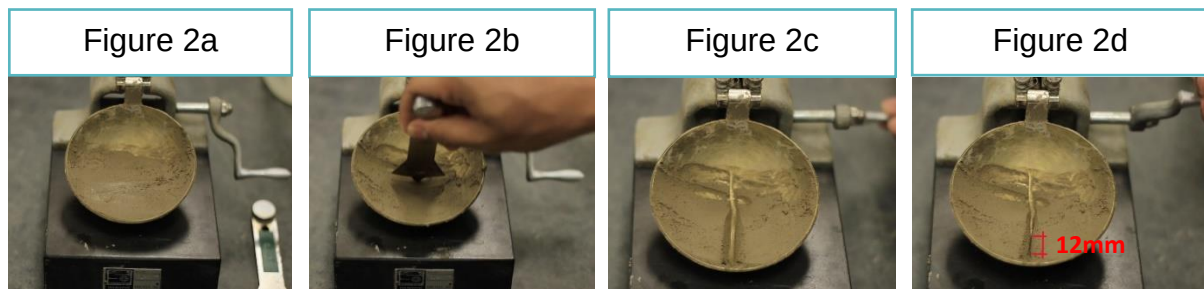


Figure 1 – Liquid Limit Equipment

Casagrande Cup Methodology Steps

- 1) Ensure all equipment is available, clean, and calibrated ready for testing (See Figure 1)
- 2) Choose 4no. containers and label each container with the sample reference (LL1, LL2, LL3, LL4). Once labeled, weigh each container individually. The weight of the container should be recorded in the table of results.
- 3) Place the initial dry soil sample in a mixing bowl, add a small amount of water (5 drops each time or up to 2ml), and mix/knead well until the soil sample has reached a clay consistency.
- 4) The estimated clay consistency is then placed into the Casagrande apparatus in accordance with British Standard 1377-2:1990 (See Figure 2a). The sample should be spread into the bowl with an even consistency of 10mm depth (Use the spatula to smooth and squeeze the clay down into the bowl).

- 5) The gauging tool should then scrape through the sample from back to front creating a groove in the sample. This should avoid any side tear of the sample. (See Figure 2b & 2c)
- 6) Zero the drop counter on the Casagrande apparatus. Begin the lift and drop of the cup by rotating the crank handle at a rate of 2 drops (revolutions) per second. Continue the revolutions until the groove between the sample is closed at a single point at a minimum length of 12mm (See Figure 2d).



(Hossain et al., 2021)

Note. For Step 3/4/5/6. This method is a trial and error method until consistency achieves the required 30-35 drops of the Casagrande apparatus for the first sample.

- 7) Once the consistency is achieving the 30-35 drops for the first sample, the number of drops should be recorded in the results table under the sample reference LL1.
- 8) Remove a sample of soil by using the spatula and add it to the empty container labeled LL1. The sample should be weighed, and results recorded under 'container & weight of wet soil.'
- 9) To continue the testing the steps above should be repeated with the number of drops of the Casagrande apparatus decreasing with the more moisture being added to the sample and results should be achieved for above and below the 25-blow mark.
- 10) Following all 'container & weight of wet soil' results are recorded. The four soil samples are placed into the oven to be dried for 24 hours removing the moisture from the sample.
- 11) The individual samples should then be weighed and recorded in the results table under 'container & weight of dry soil'.

1c) Methodology of Plastic Limit

Equipment used for the plastic limit test: -

- Digital Scales
- Rolling board (Free from scratches)
- Rod (3mm in diameter approx. 100mm long)
- Water
- Oven
- Soil Sample
- Metal Marked Containers
- Metal Mixing Bowl

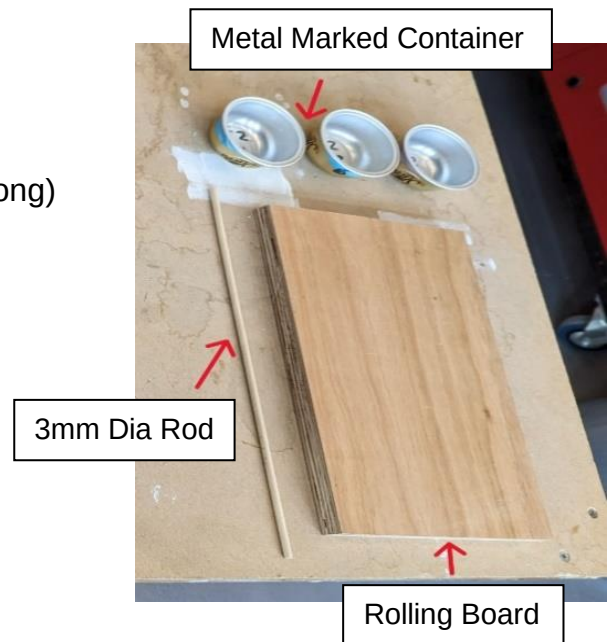


Figure 3 – Plastic Limit Equipment

Plastic Limit Methodology Steps: -

The plastic limit testing was done directly after the liquid limit testing, and the sample used for liquid limit testing was transferred over for the plastic limit testing, the methodology will represent the procedure done in the laboratory.

- 1) Choose 3no. containers and label each container with the sample reference (PL1, PL2, PL3). Once labeled, weigh each container individually. The weight of the container should be recorded in the table of results.
- 2) Take the final sample from the liquid limit test, if too wet add dry soil that was unused from the liquid limit test.
- 3) Collect a ball of clay in the palm of your hand and roll it between your palms until the ball starts to crack. By rolling the ball the warmth from your hand helps dry the sample slowly.
- 4) Separate the ball of clay into 3 individual samples (Estimated 10g each).
- 5) Roll the first sample into a thread and gently reduce the diameter into a 3mm diameter thread (Use the 3mm rod as a reference).

Note. For Step 3/4/5. This method is a trial and error method until consistency achieves the required 3mm diameter thread when the sample starts to crumble.

- 6) Once the crumbling point is achieved at the 3mm diameter point. This is classed as the plastic limit moisture content, where it is shearing longitudinally and transversally as it is rolled. It is imperative that the crumbling is caused by the rolling and not the pressure from the hand.
- 7) Gather the sample and add to the first referenced container PL1. Weigh the 'container & wet soil sample' and record in the results table.
- 8) Repeat the above for the final 2 samples and record the results accordingly.
- 9) The three soil samples are placed into the oven to be dried for 24 hours removing the moisture from the sample. giving the results for the 'container & dry soil weight' complete the results table accordingly.
- 10) The moisture content for the plastic limit test can be done by taking the average of the three results.

1d) Results and Analysis

Following the methodology above for both the Liquid & Plastic Limit, we were able to gather the results for the weight of each container, weight of the dry soil (including container) & the weight of wet soil (including container). See Table 1 & Table 2 below for the data collected from the laboratory tests.

Table 1 - Liquid Limit Laboratory Results

Container Reference Number	LL1	LL2	LL3	LL4
Weight of wet soil & container (g)	15.38	16.53	14.02	14.19
Weight of dry soil & container (g)	13.27	14.20	12.13	12.24
Weight of container (g)	4.75	4.71	4.72	4.73
Weight of moisture (g)				
Weight of dry soil (g)				
Moisture content (%)				
Number blows				

Table 2 - Plastic Limit Laboratory Results

Container Reference Number	PL1	PL2	PL3
Weight of wet soil & container (g)	7.75	8.52	7.19
Weight of dry soil & container (g)	7.30	7.94	6.81
Weight of container (g)	4.73	4.72	4.71
Weight of moisture (g)			
Weight of dry soil (g)			
Moisture content (%)			

The results generated from the laboratory test allow us to calculate the weight of moisture & weight of dry soil, enabling us to determine the moisture content.

Below are the calculations for the container reference number (LL1), these calculations can be repeated for all the samples, for both liquid limit and plastic limit tests. (Refer to Table 3 & Table 4).

Calculations

Weight of Moisture (g) =

$$\text{Moisture Weight (g)} = \text{Weight of Wet Soil \& Container (g)} - \text{Weight of Dry Soil \& Container (g)}$$

$$15.38\text{g} - 13.27\text{g} = 2.11\text{g}$$

Weight of Dry Soil (g) =

$$\text{Dry Soil Weight (g)} = \text{Weight of Dry Soil \& Container (g)} - \text{Container Weight (g)}$$

$$13.27\text{g} - 4.75\text{g} = 8.52\text{g}$$

Moisture Content (%) =

$$\text{Moisture Content (\%)} = \frac{\text{Weight of Moisture}}{\text{Weight of Dry Soil}} \times 100$$

$$\frac{2.11\text{g}}{8.52\text{g}} \times 100 = 24.77\%$$

Table 3 - Liquid Limit Determination

Container Reference Number	LL1	LL2	LL3	LL4
Weight of wet soil & container (g)	15.38	16.53	14.02	14.19
Weight of dry soil & container (g)	13.27	14.20	12.13	12.24
Weight of container (g)	4.75	4.71	4.72	4.73
Weight of moisture (g)	2.11	2.33	1.89	1.95
Weight of dry soil (g)	8.52	9.49	7.41	7.51
Moisture content (%)	24.77%	24.55%	25.51%	25.97%
Number blows	37	35	27	20

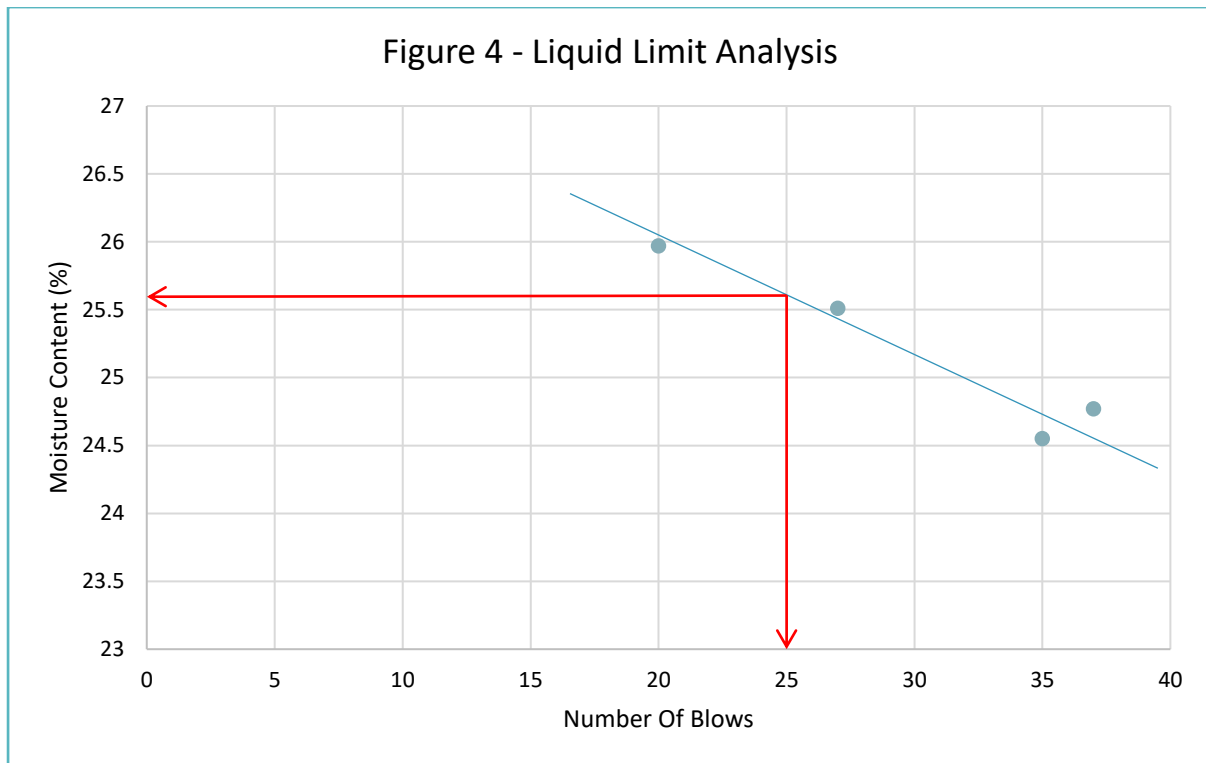
Table 4 - Plastic Limit Determination

Container Reference Number	PL1	PL2	PL3
Weight of wet soil & container (g)	7.75	8.52	7.19
Weight of dry soil & container (g)	7.30	7.94	6.81
Weight of container (g)	4.73	4.72	4.71
Weight of moisture (g)	0.45	0.58	0.38
Weight of dry soil (g)	2.57	3.22	2.1
Moisture content (%)	17.51%	18.01%	18.10%

Liquid Limit

Now that the data set is complete for all samples, the liquid limit percentage can be determined by plotting a graph. The graph is made up of the 'number of blows' on the X-axis and the 'moisture content' on the Y-axis.

By plotting the four results from Table 3 above, we can establish a trend line. By reading the Moisture content at the 25th blow this is the Liquid Limit Percentage for this particular soil sample.



The Liquid Limit Result for the soil sample is 25.6%

Plastic Limit

The plastic limit result is calculating the average of the moisture content from the plastic limit determination table (Table 4). See equation below.

Equation

$$Average = \frac{PL1 \text{ Moisture Content} + PL3 \text{ Moisture Content} + PL3 \text{ Moisture Content}}{\text{Number of Results}}$$

Plastic Limit Result

$$Average = \frac{17.51\% + 18.01\% + 18.10\%}{3}$$

Plastic Limit = 17.87%

Plasticity Index (PI)

Havin the result of both the Liquid Limit (LL) & Plastic Limit (PL). We can now calculate the Plasticity Index (PI). The Plasticity Index allows the soil to be classified into the plasticity chart as shown in Figure 5.

Equation

$$PI = LL - PL$$

Calculation

$$25.6\%(LL) - 17.87\%(PL) = 7.73\%$$

The Plasticity Index can now be plotted onto the plasticity chart for the classification of fine soils and finer part of coarse soils, which conforms with British Standard BS 5930-1999.

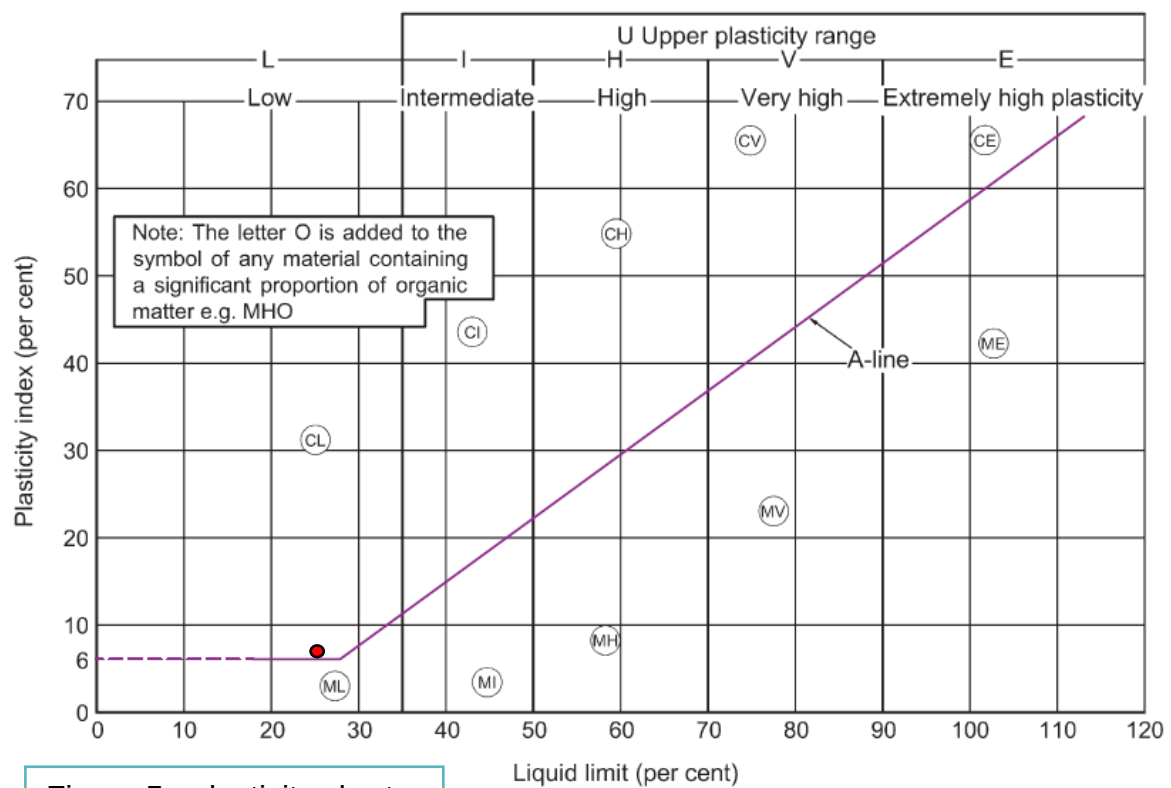


Figure 5 - plasticity chart for the classification of fine soils and finer part of coarse soils. (Smith.2014)

Key	
M	Silt (M-Soil) – Below A-Line
C	Clay – Above A-Line
●	Sample Result

Plasticity Index (%)	Soil Type	Degree of Plasticity	Degree of Cohesiveness
0	Sand	Non-Plastic	Non-Cohesive
< 7	Silt	Low Plastic	Partly Cohesive
7 – 17	Silt Clay	Medium Plastic	Cohesive
> 17	Clay	High Plastic	Cohesive

Table 5 – Plasticity Index table range

As shown in Figure 5 & Table 5 the Plasticity Index of 7.73% & Liquid Limit of 25.6% has been marked to determine the soil classification.

1e) Conclusion

The Atterberg Limit provides valuable information for civil engineers, allowing them to classify soils, assess their properties, and make informed decisions during the design, construction, lifecycle of a project. It is imperative to understand the water content and its effects on the state of the soil properties, the overall effect of increased water content, the strength of the soil decreases.

The results of the Atterberg Limits tests conducted show the characteristics of the soil under investigation. The classification of the soil type is silty clay, with the low plasticity range, it suggests that under stress it has a potential for deformation, the sample is classed as partly cohesive which shows the soil has some degree of to maintain some structural integrity.

In Industry this soil type would be classified as weak and unstable soil, methods to help improve the soil for this area would be a compaction method such as vibro-compaction or dynamic compaction. For foundation methods, deep pile foundations would be most suitable to reach more stable ground or for a shallower foundation would be a raft foundation to spread the load over a greater area.

During the Atterberg limits testing of the soil sample, recognizing the inherent limitation in the testing process. Foremost among these limitations is the constraint

on sample testing, due the time constraints, only one sample could be tested. To increase the accuracy and a more establish result, conducting tests on multiple samples from the same specimen is imperative.

Additionally, another limitation stems from potential inconsistencies arising from not having a single person conduct the test. Alternating personnel during testing procedures can introduce variations in the method, potentially impacting the reliability and consistency of the results.

The Atterberg limit test has help establish the plastic and liquid limit of the soil sample examined, allowing civil engineers a greater understanding of the soil expected behavior, and the limits of it consistency.

2) Constant Head Permeameter Test

2a) Introduction

Soil permeability is a critical property for civil engineers to understand the rate of flow that a fluid can travel through a soil sample. Constant head permeameter test is a laboratory test done to provide an accurate means to examine a soil sample's permeability, the test mainly focuses on granular soils such as sand & gravels that contain minimal or no silt. Civil engineers can use the output from the constant head permeameter test to predict the soil's stability, predict potential slope failure & allow the engineers to design retaining walls & foundations. The constant head permeameter test has a direct link with Darcy's law by determining the hydraulic conductivity of a soil sample.

The experiment undertaken was done following 'BS 1377-3:2018 - Methods of test for soils for civil engineering purposes.'

Some of the limitations that were found for the laboratory testing, during the testing of the second sampling the hydraulic head difference was minimal and the readings from the first testing showed a worse permeability than sample 1. Based on the contents in both samples the anticipation would be that the sample 2 would have a higher permeability because of the granular size being much larger. The Equipment was altered to give a more realistic result but still the result seemed closer than originally anticipated.

Other limitations include human factors, timings between opening and closing of the isolation valve and the starting and stopping of the stopwatch could affect the overall outcome, an automated technique would be a lot more accurate.

Lastly, given the limited time to undertake the tests only 2no. samples were undertaken. If more time was allocated, more samples should have been tested to allow for greater understanding of the variance of soil types.

2b) Methodology

Equipment for the constant head permeameter test:

test: -

- Water Supply
- Water Tank Reservoir
- Rubber hoses
- Constant Head Permeameter Cylinder (CHPC)
- Soil Sample
- Vernier gauge
- Manometer Tubes with measurement board.
- Measuring Cylinder/Container
- Stopwatch



Figure 6 – Constand Head Permeameter Test - Laboratory Setup

Constant head permeameter test methodology steps: -

1. Ensure all equipment is available clean and in working condition.
2. Using the vernier gauge measure the internal diameter of the CHPC.
3. Place the soil ample within the CHPC, ensuring filters are installed at the top & bottom of the cylinder. (*Do Not Compact to keep the results as per site expectation*)
4. Set up the equipment as shown in the Figure 7.
 - Water Supply to the Water Tank Reservoir.
 - Rubber hose from the underside of Water Tank Reservoir to the CHPC.

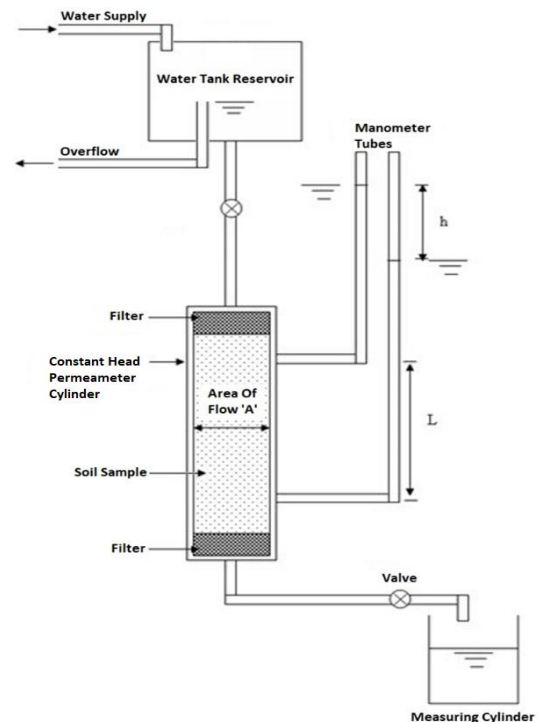


Figure 7 – Constant Head Permeameter Equipment Setup (Ranjan and Rao, 2007)

- Connect Manometer Tubes to the Constant Head Permeameter Cylinder.
 - Connect a hose with an Isolation Valve onto the lowest outlet of the Constant Head Permeameter Cylinder.
5. Once the apparatus is set up & all valves are closed. The water supply can be turned on to fill up the Water Tank Reservoir to make the system at a constant. This is established when the water is flowing consistently out of the overflow into the sink.
 6. Once the system is at a constant the valves for the Manometer can be opened to establish the hydraulic head difference (h). Hydraulic head is the cause of water being pushed up through the tubes in the monometer by the pressure cause from the constant water flow. The different in pressure is cause by the difference in height (L) between the outlets in the Constant Head Permeameter Cylinder.
 7. At this point the soil sample is fully saturated, and the test can begin.
 8. Using a stopwatch, measure the flow of water passing through the lowest outlet of the CHPC at various intervals (Flow Over Time = q). The measuring is done by opening the valve allowing the flow of water into the measuring cylinder and starting the stopwatch at the same time. Finishing by closing the valve at the end of the interval period. For our testing the times used were 20s / 40s / 60s.
 9. The quantity acquired in the measuring cylinder is recorded in the results table as shown in '2c) Results & Analysis – Sample 1 results.'

Following the methodology above allows for the analysis to be undertaken to find the resulting coefficient of permeability of the soil sample.

2c) Results and Analysis

In line with BS 1377-3:2018, by using Darcy's law (flow of fluid through a porous medium) we can establish the coefficient of permeability of the 2no. soil samples examined.

Equation for Coefficient of Permeability

$$K = \frac{QL}{Aht}$$

K = Coefficient of permeability

Q = Flow overtime 't' in m³/s

L = Length of flow line

A = Area of flow

h = Hydraulic head difference

t = Time in seconds

Sample 1 Results –

Q = After 20s = 85ml (0.000085m³)

After 40s = 170ml (0.000170m³)

After 60s = 250ml (0.000250m³)

L = 70mm (0.07m)

A = 78.52mm (0.07852m)

h = Top Reading = 63.3cm – Lower Reading = 10.6cm = 52.7cm (0.0527m)

t = 20s / 40s / 60s

20 seconds test results:

$$K = \frac{QL}{(A=\pi r^2)ht} \quad K = \frac{0.000085 \times 0.07}{(\pi 0.039^2) \times 0.527 \times 20} \quad K = \frac{0.000085 \times 0.07}{0.00478 \times 0.527 \times 20}$$

$$K = \frac{0.00000595}{0.0504} \quad K = \underline{1.180 \times 10^{-4}}$$

40 seconds test results:

$$K = \frac{QL}{(A=\pi r^2)ht} \quad K = \frac{0.000170 \times 0.07}{(\pi 0.039^2) \times 0.527 \times 40} \quad K = \frac{0.000170 \times 0.07}{0.00478 \times 0.527 \times 40}$$

$$K = \frac{0.0000119}{0.101} \quad K = \underline{1.178 \times 10^{-4}}$$

60 seconds test results:

$$K = \frac{QL}{(A=\pi r^2)ht} \quad K = \frac{0.000250 \times 0.07}{(\pi 0.039^2) \times 0.527 \times 60} \quad K = \frac{0.000250 \times 0.07}{0.00478 \times 0.527 \times 60}$$

$$K = \frac{0.0000175}{0.151} \quad \underline{K = 1.159 \times 10^{-4}}$$

Coefficient of Permeability for Sample 1

$$K = \frac{\text{Result at 20s} + \text{Result at 40s} + \text{Result at 60s}}{\text{Number of Results}} \quad K = \frac{1.180 \times 10^{-4} + 1.178 \times 10^{-4} + 1.159 \times 10^{-4}}{3}$$

$$\underline{K = 1.17 \times 10^{-4}}$$

Sample 2 Results –

Q = After 20s = 138ml (0.000138m³)

After 40s = 280ml (0.000280m³)

After 60s = 420ml (0.000420m³)

L = 70mm (0.07m)

A = 78.52mm (0.07852m)

h = Top Reading = 52cm – Lower Reading = 41.6cm = 10.4cm (0.104m)

t = 20s / 40s / 60s

20 seconds test results:

$$K = \frac{QL}{(A=\pi r^2)ht} \quad K = \frac{0.000138 \times 0.07}{(\pi 0.039^2) \times 0.104 \times 20} \quad K = \frac{0.000138 \times 0.07}{0.00478 \times 0.104 \times 20}$$

$$K = \frac{0.00000966}{0.00994} \quad \underline{K = 9.719 \times 10^{-4}}$$

40 seconds test results:

$$K = \frac{QL}{(A=\pi r^2)ht} \quad K = \frac{0.000280 \times 0.07}{(\pi 0.039^2) \times 0.104 \times 40} \quad K = \frac{0.000280 \times 0.07}{0.00478 \times 0.104 \times 40}$$

$$K = \frac{0.0000196}{0.0199} \quad \underline{K = 9.849 \times 10^{-4}}$$

60 seconds test results:

$$K = \frac{QL}{(A=\pi r^2)ht} \quad K = \frac{0.000420 \times 0.07}{(\pi 0.039^2) \times 0.104 \times 60} \quad K = \frac{0.000420 \times 0.07}{0.00478 \times 0.104 \times 60}$$

$$K = \frac{0.0000294}{0.0298} \quad \underline{K = 9.866 \times 10^{-4}}$$

Coefficient of Permeability for Sample 2

$$K = \frac{\text{Result at 20s} + \text{Result at 40s} + \text{Result at 60s}}{\text{Number of Results}}$$

$$K = \frac{9.719 \times 10^{-4} + 9.178 \times 10^{-4} + 1.159 \times 10^{-4}}{3}$$

$$K = 1.17 \times 10^{-4}$$

The coefficient of permeability for both samples can now be applied to the permeability table (See Table 6). For classifying the soil and determining the suitability of the soil for the required application For Soil Sample 1 & Soil Sample 2, the results based off the permeability table show the soil type as the same classification of gravel sand mixtures, thus giving the soil sample a good permeability classification.

Soil Type	Description	Permeability (k)	Suitability
Cobbles and Boulders	Permeability may be greater as flow may be turbulent	1 m/s	Excellent
Gravels	Uniformly graded coarse aggregate with zero fines and minimal sand	10^{-1} to 10^{-2} m/s	Very Good
Gravel Sand Mixtures	Clean, well graded, with minimal fines.	10^{-3} to 10^{-4} m/s	Good
Clean Sands	Sands with low silt or clay content	10^{-4} to 10^{-6} m/s	Good to Moderate
Silt Mixtures	Mixtures of Sand, Silt & Clay	10^{-6} to 10^{-10} m/s	Moderate to Poor
Clays	Pure Clay	10^{-10} to 10^{-12} m/s	Practically Impermeable
Artificial	Bituminous mixtures, cement stabilized soil, geosynthetic liners	$<10^{-12}$ m/s	

Table 6 – Permeability Table for Soil Classification (ABG Geosynthetics, n.d.)

2d) Conclusion

The permeability classification is an integral part of understanding the flow of liquid through the soil samples, allowing engineers to be well informed in everyday engineering problems and use the correct course of action required for individual specific site location.

There is a direct link between the particle size & the sample compaction with the permeability of the soil. The greater the particle size the more permeable. The more compact the soil sample the less permeable the soil.

The results of the two samples show the samples have good permeability with the soil type classification as gravel sand mixtures. An engineer's recommendation would be ground compaction to limit any potential foundation movement or bank destabilization.

It must be made aware that the limitations should be reduced in future examinations, ensuring all the equipment is working accurately, more time should be allowed to undertake several examinations of different soil samples to gain a greater understanding of the accuracy of the samples examined.

3) Sieve Analysis Test

3a) Introduction

The Sieve analysis is a method used to classify the soil based on particle size, it allows for the understanding of the textural properties and the engineering behaviors of the soil.

The Sieve Analysis test is essential in textural classification, as it provides valuable insights into the soil's composition, helping engineers and geologists understand its drainage characteristics, strength, compaction potential, and suitability for various construction purposes.

The results obtained from sieve analysis form the basis for categorizing soils into different classes based on particle size, these are clay, silts, sands & gravels.

The key to a well graded soil sample is a wider distribution of the particle size, allowing the smaller particles to fill the voids between the larger particle sizes.

Soil Type	Particle Size
Clay	< 0.002mm
Silt	0.002mm – 0.063mm
Sand	0.063mm – 2mm
Gravel	2mm – 20mm

Table 7

During the sieve analysis laboratory tests, some limitations may have an impact on the overall results. During a sieve analysis test the pans should range between 4.75mm to $<0.0038\text{mm}$. Due to the availability of equipment, only 2mm to 0.045mm sieve pans. Other limitations include suitable equipment to transfer the soil sample from the sieve pan to the metal pans. This has an effect because some of the sample may have been lost during the transfer from sieve to metal pan.

3b) Methodology

Equipment used for the sieve analysis test: -

- Digital Scales
- Metal Container (Figure 8a)
- Metal Tray for sample transfer - Plastic bag for ease of transfer (Figure 8b)
- Mechanical Sieve Shaker (Figure 8c)
- Sieve trays with a range between 2mm sieve size to $<0.045\text{mm}$ (Figure 8c)
- Brush
- Soil Sample



Figure 8a



Figure 8b



Figure 8c

Sieve analysis test methodology steps:

- 1) Ensure all equipment is available clean and in working condition.
- 2) Weigh the metal pan (Figure 8a) using a digital scale.
Record the weight of the empty metal pan.
- 3) Quarter the dry soil sample & select 1 at random. (See Figure 9) Transfer the selected quarter to the metal pan and weigh the pan with the sample. Adjust the sample quantity to achieve as close to 1kg in sample weight.



Figure 9

Note. All Weights are to be measured to the nearest 0.01g

- 4) Set the sieve pans in place on the mechanical sieve shaker Using an enclosed sieve pan at the bottom followed by the smallest size of 0.045mm and increasing in sieve size to the top. (Figure 8c).
- 5) With all sieves securely in place, pour the sample into the top sieve pan (2mm). Place the lid on top and secure it by locking onto the rods. (Figure 8c).
- 6) Run the mechanical sieve shaker for a 2-minute duration. Upon the vibration completion, carefully remove the lid.

Note. Be mindful of any dust from the sample caused by the vibration.

- 7) Remove the first sample from the sieve stack and pour the 2mm sieve pan onto the tray (Figure 8b) using a brush ensuring all the content is removed from the sieve pan. This sample can then be transferred to the pan used for weighing, again use the brush to ensure all sample is collected.
- 8) Weigh the sample and record it in the results table, under 'Mass Including Container (g)'
- 9) Repeat the process from step 7 for all the sieve pans, to determine the individual aggregate weights retained in each sieve.
- 10) Upon completion of the weighs for all the sieve pans, complete the examination by transferring the final pan into the weighing bowl and recording the weight.

3c) Results and Analysis

The results below follow the methodology stated in 3b.

Initial sample weight including pan = 1276.64g

Empty pan weight = 276.62g

Initial Sample Weight Equation

Initial Sample Weight (g) = Initial Sample Weight Including Container(g) – Container Weight(g)

Initial Sample Weight (g) = 1276.64g – 276.62g

Initial Sample Weight (g) = 1000.02g

Table 8 - Particle Size Distribution Test Results

Sieve Size (mm)	Mass Including Container (g)	Mass Excluding Container (g)	Aggregate On Sieve (%)	Aggregate Passing (%)
2.000	308.17	31.55	3.15	96.85
1.180	338.48	61.86	6.19	90.60
0.600	406.26	129.64	12.96	77.70
0.425	546.16	269.54	26.95	50.75
0.300	516.71	240.09	24.01	26.74
0.150	445.33	168.71	16.87	9.87
0.075	348.83	72.20	7.22	2.65
0.063	282.85	6.23	0.63	2.02
0.053	287.56	10.94	1.09	0.93
0.045	277.79	1.17	0.12	0.81
Pan	281.78	5.16	0.52	
Total		997.09		

From the laboratory testing, only the 'sieve size' & 'Mass including container' columns would be completed. To complete the entire table the following equations are used.

Equations: -

Mass Excluding Container

$$\text{Mass Excluding Container (g)} = \text{Mass Including Container(g)} - \text{Container Weight(g)}$$

Aggregate on sieve (%)

$$\text{Aggregate on sieve (\%)} = \frac{\text{Mass Excluding Container Weight (g)}}{\text{Initial Sample Weight (g)}} \times 100$$

Aggregate Passing (%)

For the first sample, the percentage used for 'Previous Result of Aggregate Passing' is 100%.

$$\text{Aggregate Passing (\%)} = \text{Previous Result of Aggregate Passing (\%)} - \text{Aggregate On Sieve (\%)}$$

Before classifying the aggregate types of the soil sample, a check to the amount of aggregate lost during the testing should be undertaken, if greater than a 0.2% loss then the testing procedure should be rerun until the loss is less than 0.2%.

$$\frac{\text{Total Mass Excluding Container (g)}}{\text{Total Initial Soil Sample Weight (g)}} \times 100$$

$$\frac{997.09g}{1000.02g} \times 100$$

$$\text{Result} = 99.71\%$$

The result shows that there is a 0.29% difference between the 'total initial soil sample weight' and the 'total mass excluding container weight', the testing should be rerun and re-recorded. For assignment purposes, I will continue to complete the soil sample results.

From the results table (Table 8) and Table 7, the soil sample examined showed the following results:-

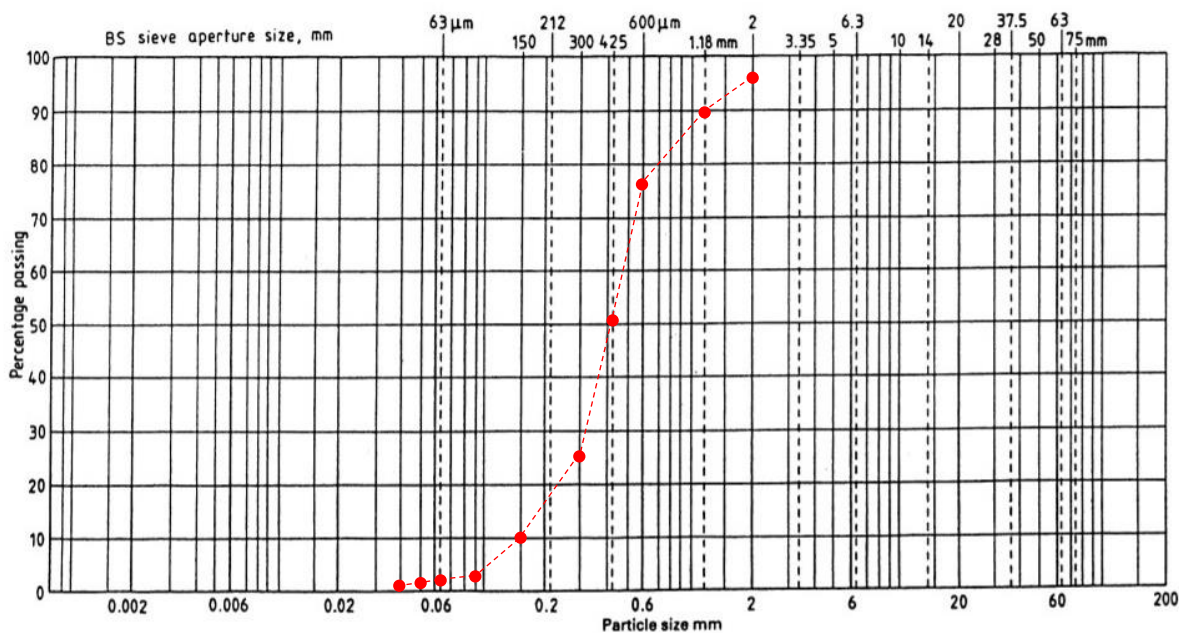
Sands (Aggregate Size Range = 2mm to 0.063mm) = Total Weight of 979.82g which is 97.98% of the total soil sample.

Silt (Based on equipment used only sieve sizes 0.053mm & 0.048mm applicable) = Total Weight of 12.11g which is 1.21% of the total soil sample.

Due to the lack of sieve pans below the size of 0.048mm, the remaining aggregates cannot be classified. The total weight remaining in the pan is 5.16g which is 0.52% of the total weight.

The results of the percentage passed through each sieve can now be plotted on the particle size distribution chart. This is done in accordance with British Standard BS1377-2:2019. This document was recently replaced by BS1377-2:2022.

Figure 10 – Particle Size Distribution Chart



3d) Conclusion

The sieve analysis test provides key information for civil engineers to use in engineering projects. By understanding the particle sizes, civil engineers can make decisions for construction material selection, foundation design, and soil stabilization techniques, thus improving its mechanical properties.

From the results, it shows the soil sample is mainly built up of sands (97.98%) which has a coarse and granular texture. A minor proportion of the aggregates are silt sized particles (1.21%). This soil sample would be classed to have good permeability due to its coarse build up, This could be a disadvantage if in an area with heavy rainfall where soil erosion could be an issue. Improvements can be made to the soil that can benefit its mechanical properties for engineering projects. This can include compaction; this will increase its load bearing capacity. Vegetation coverage in

heavy rainfall area to reduce the soil erosion. Lime, cement or fly ash can be added for embankment stabilization.

The limitations are a key factor effecting the overall results, but a lot of benefits can come from the sieve analysis test. With the limited time allocated for the experiment, a lot of information that can help engineering problems can come from it.

4) References

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5) Appendix

5a) Atterberg Limit Test Images



Figure 21 – Liquid Limits Labelled Containers



Figure 12 – Plastic Limits Labelled Containers

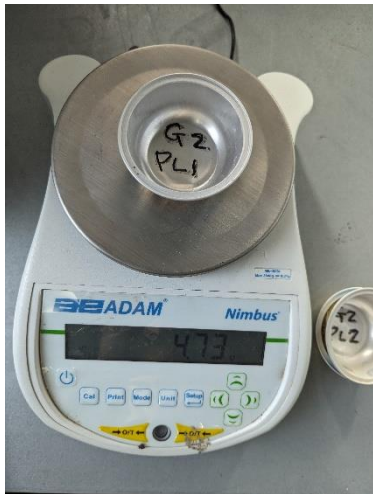


Figure 93 – Plastic Limits
Container 1 Weight



Figure 94 – Plastic Limits
Container 2 Weight



Figure 95 – Plastic Limits
Container 3 Weight

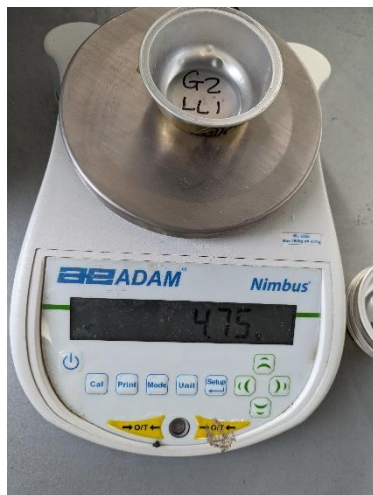


Figure 96 – Liquid Limits
Container 1 Weight

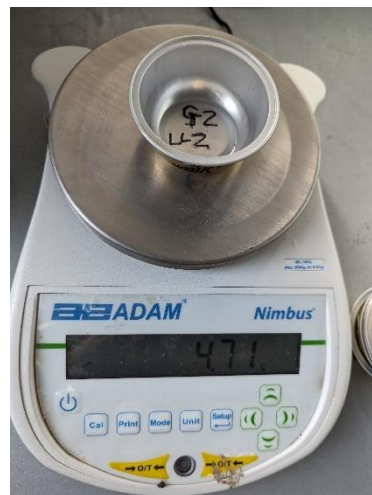


Figure 97 – Liquid Limits
Container 2 Weight



Figure 98 – Liquid Limits
Container 3 Weight



Figure 39 – Liquid Limits
Container 1 Weight

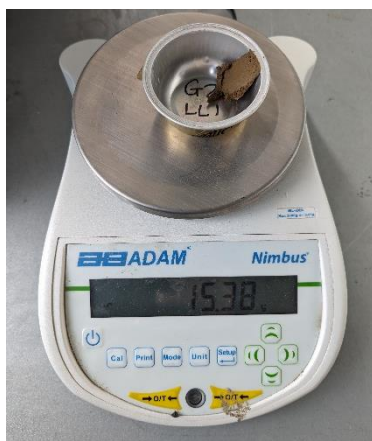


Figure 20 – Liquid Limits
Sample 1 Weight



Figure 21 – Liquid Limits
Sample 2 Weight



Figure 22 – Liquid Limits
Sample 4 Weight



Figure 23 – Soil Sample LL1 in
Casagrande Cup Apparatus



Figure 24 – Soil Sample LL1

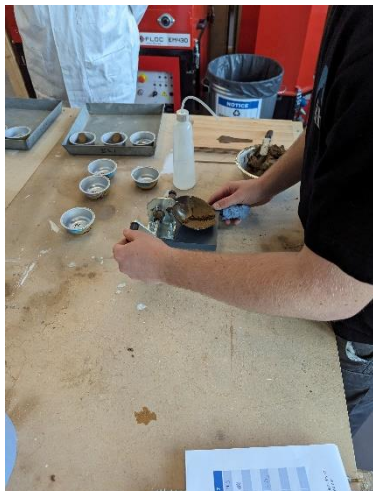


Figure 25 – LL1 Casagrande
Cup Drop Test



Figure 26 – Plastic Limits
Sample 1 Weight



Figure 27 – Plastic Limits
Sample 2 Weight



Figure 28 – Plastic Limits
Sample 3 Weight



Figure 29 – Samples Oven
dried – For Dry Soil Weight

5b) Constant Head Permeameter Test Images



Figure 30 – Measuring Cylinder/Container



Figure 31 – Sample 1 in Constant Head Permeameter Cylinder

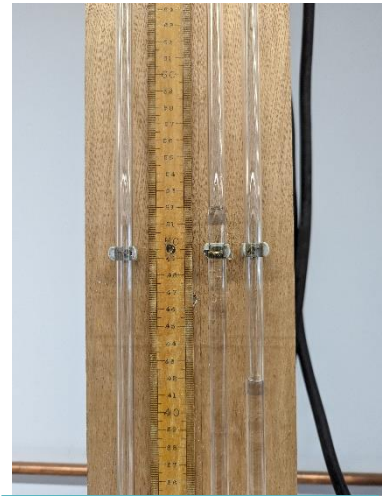


Figure 32 – Sample 1 Manometer Readings



Figure 33 – Sample 1 - Measuring flow over time.



Figure 34 – Sample 2 in Constant Head Permeameter Cylinder



Figure 35 – Sample 2 Manometer Readings



Figure 36 – Sample 2 Manometer Faulty Reading

5c) Sieve Analysis Test Images

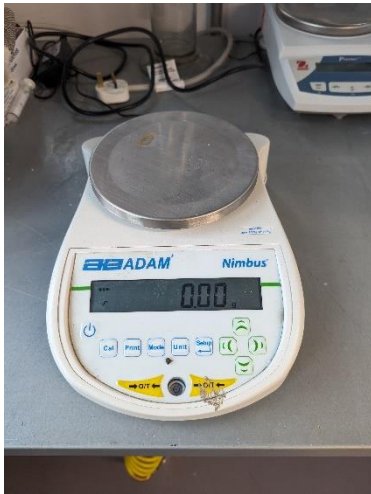


Figure 37 – Digital Scales



Figure 38 – Weight of Metal Pan

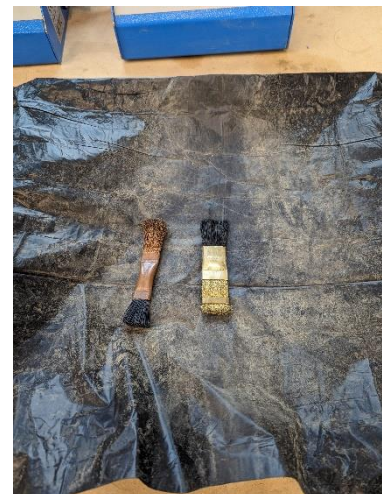


Figure 39 – Selection of brushes



Figure 40 – Initial Soil Sample Selection



Figure 41 – Weight of Initial Soil Sample.



Figure 42 – Pouring of soil sample into Mechanical Shaker



Figure 43 – Removal of sample from sieve pan



Figure 44 – Pouring of sample post-vibration into metal Pan.



Figure 45 – Weight of Sieve size 2.000mm



Figure 46 – Weight of Sieve size 1.180mm



Figure 47 – Weight of Sieve size 0.600mm



Figure 48 – Weight of Sieve size 0.425mm

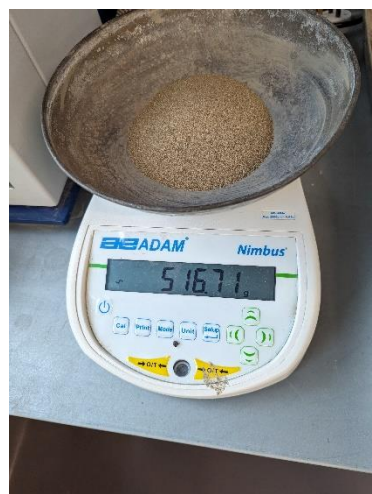


Figure 49 – Weight of Sieve size 0.300mm



Figure 50 – Weight of Sieve size 0.150mm



Figure 51 – Weight of Sieve size 0.075mm



Figure 52 – Weight of Sieve size 0.063mm



Figure 53 – Weight of Sieve size 0.053mm



Figure 54 – Weight of Sieve size 0.045mm

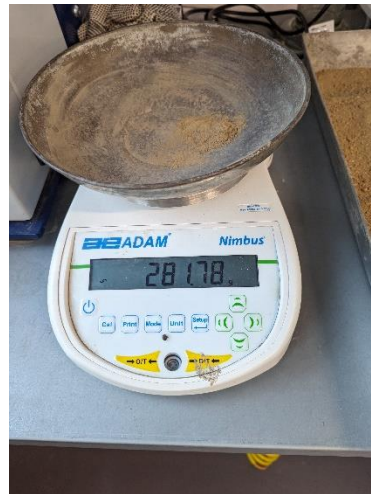


Figure 55 – Weight of Final Pan 0.045mm>