

The Mechanics of Engineering Soils – Laboratory Practical Testing Methods

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1 The 'Sieve Analysis' (Textural Classification) Test

1.1 Introduction

A sieve analysis textural classification test was carried out on a soil sample to determine the particle-size distribution and assess the material's grading. This test is used in geotechnical engineering to classify soils based on particle size and distinguish between coarse-grained materials such as sand and gravel and finer materials, including clay and silt. Understanding particle size distribution is important as it influences key engineering properties such as drainage, permeability and compaction behaviour.

In the experiment, a mass of dry soil was placed into a stack of sieves arranged in order of decreasing mesh size. The sieve stack was placed in a mechanical sieve shaker, which vibrated and separated the soil particles according to their size. Larger particles were collected in the upper sieves, while smaller particles passed to the lower sieves.

After shaking, the mass of soil retained on each sieve was measured and recorded. These measurements were then used to calculate the percentage each sieve collected and the percentage passing each sieve. The results were used to produce a particle size distribution curve, which allows the soil to be classified and its engineering behaviour to be understood better (BS 1377,1990).

1.2 Methodology

1.2.1 Materials / Equipment:

- Soil sample
- Oven
- Precision balance scales (± 0.01 accuracy)
- Scale pan
- Collection tray lined with a plastic sheet
- Scoop
- Sieve stack (with different mesh sizes ranging from 2mm to 0.02mm)
- Sieve lid and base pan
- Sieve Shaker
- Brush for cleaning sieves

1.2.2 Method:

1. A soil sample was heated in the oven for 24 hours at 120 degrees.
2. The scale pan was checked and ensured it was empty before it was placed on the precision scales and tared to 0
3. The sample was scooped into the scale pan until it weighed 1400.04g (Figure 2 and Figure 1).



Figure 2: Image of the soil sample being scooped into the scale pan.

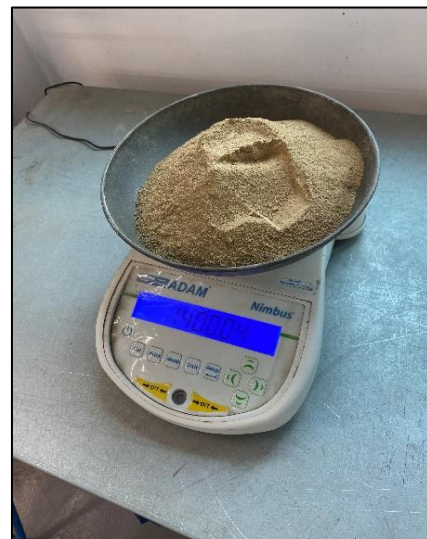


Figure 1: Image of soil sample weighing 1400.04g on precision scales.

4. 10 test sieves with sizes including 2mm, 1.18mm, 0.6mm, 0.425mm, 0.3mm, 0.063mm, 0.053mm, 0.045mm, 0.038mm, 0.02mm were stacked with the smallest size (0.02mm) on the bottom and the largest (2mm) on the top (Figure 3).



Figure 3: Image of the 10 test sieves stack with the largest sieve size on top, and the smallest on the bottom.

5. The soil was poured carefully into the top sieve to reduce the chance of a spilt sample (Figure 4).



Figure 4: Image of the soil sample being poured into the top sieve on the stack.

6. Clamping rods and tightening knobs were used to secure the sieve stack and lid before operating the sieve shaker (Figure 5).



Figure 5: Image of the tightening knobs being secured on the sieve stack lid.

7. The sieve shaker was turned on and vibrated for 2 minutes until turned off (Figure 6 and Figure 7).



Figure 6: Image of the sieve shaker on with a cloud of dust coming from it.



Figure 7: Image showing the soil granules collected by the top sieve after vibration.

8. Each sieve was separated one at a time, and the sample it contained was poured into a collection tray lined with a plastic sheet.

9. Any remaining soil trapped in the sieve was brushed using a cleaning brush into the tray (Figure 8).



Figure 8: Image of the soil remnants on the sieve being brushed into the collection tray lined with a plastic sheet.

10. The soil was then transferred into the scale pan, and any debris on the plastic sheet was once again brushed into the pan (Figure 9 and Figure 10).



Figure 9: Image of the soil granules being transferred into the scale pan via a plastic sheet.



Figure 10: Image of soil dust being brushed due to static of the plastic sheet.

11. The soil collected was placed on the scales, weighed and recorded (Figure 11 and Figure 12).



Figure 11: Image of soil collected from a sieve being weighed on a scale.



Figure 12: Image of another soil mass collected from a different sieve size.

12. The sample was discarded.

13. Steps 8-12 were repeated for each sieve size (Figure 13 and Figure 14).



Figure 13: Image of a stack reducing one by one.



Figure 14: Image of pan after all sieves removed.

The procedure was carried out in accordance with BS 1377 (1990).

1.3 Results

Test 1: Particle Size Distribution for Texture

Original Sample Size = 1400.04g

Sieve Size (mm)	Mass (g)	% on sieve	% Passing
2	10.96	0.78	99.22
1.18	19.13	1.37	97.85
0.6	131.85	9.42	88.43
0.425	309.40	22.10	66.33
0.3	303.42	21.67	44.66
0.063	558.36	39.88	4.78
0.053	55.88	3.99	0.79
0.045	5.08	0.36	0.43
0.038	0.83	0.06	0.37
0.02	0.82	0.06	0.31
PAN	0.04	0.003	0.31

Proportion %:

SAND = 774.76g SILT = 620.97g CLAY = 0.04g
 = 55.34% = 44.35% = 0.003%

Figure 15: A filled table with data including original sample size, sieve size, mass of soil on each sieve, percentage on sieve, percentage passing, and proportion percentages.

Particle size distribution chart

Form 2.N

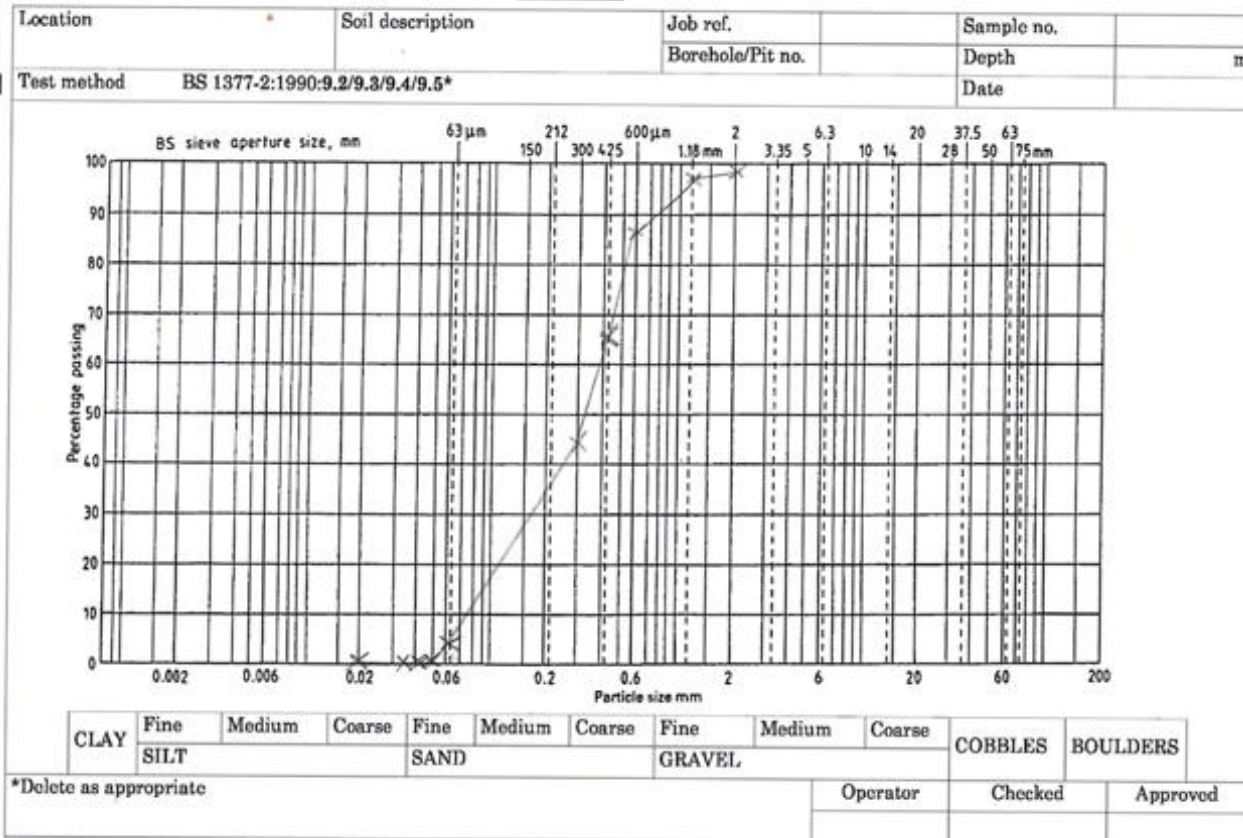


Figure 16: The particle size distribution chart (BS 1377, 1990) showing a curved graph of the percentage of soil passing through each sieve size, as seen in Figure 15.

Triangular graph of Soil Texture

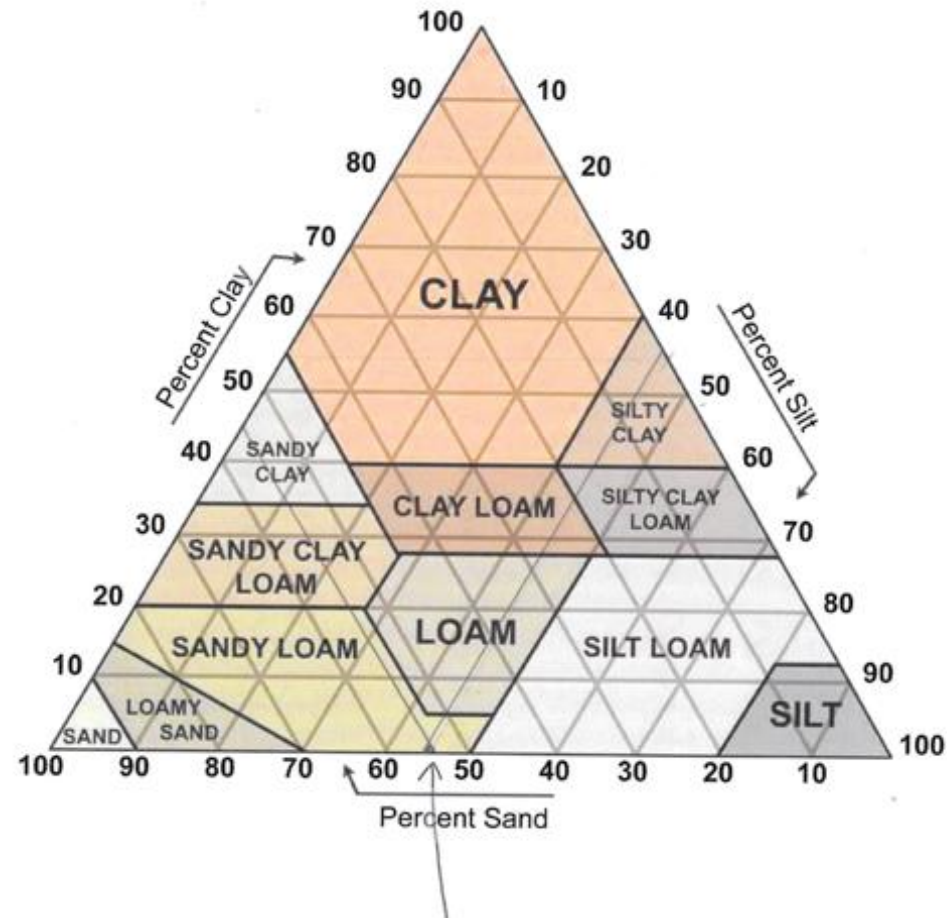


Figure 17: The triangular graph of soil texture classifying the soil texture as sandy loam based on the sand, silt and clay proportion percentages.

1.4 Analysis

The mass of soil collected on each sieve was used to calculate the percentage collected and percentage passing, which were then plotted to produce the particle size distribution curve, Figure 16. From this curve, the proportions of sand, silt and clay-sized particles were determined based on the corresponding sieve sizes. These percentages were subsequently plotted on the Soil texture triangle, Figure 17, allowing the soil to be classified according to its particle size distribution.

The results, Figure 15, show that the soil sample consisted of 55.34% sand, 44.35% silt, and a negligible clay fraction (0.003%), resulting in a classification of sandy loam (BS 5930 (1999)). This classification is typically dominated by sand with a significant proportion of silt and minimal clay content. The particle size distribution curve, Figure 16, shows a relatively steep gradient within the sand fraction, indicating that a large proportion of particles fall within a narrow particle size range. This suggests that the soil may be relatively uniformly graded rather than well graded.

In terms of engineering behaviour, loam soils typically have moderate permeability as the sand fraction allows water to pass through the soil, while the presence of silt contributes to moderate water retention. Due to the very low clay content, the soil is likely to be of low plasticity, which aligns with the particle size distribution.

1.5 Conclusions

The sieve analysis showed that the soil sample consisted primarily of sand and silt, with a negligible clay fraction, resulting in a sandy loam classification. This indicates a soil likely to have moderate permeability and low plasticity.

However, several limitations may have influenced the accuracy of the results. Environmental conditions such as room temperature and humidity may have significantly influenced the results of the sieve analysis by altering the moisture content. High humidity can cause particles to absorb moisture and clump together, preventing them from passing through smaller sieve sizes. This can lead to an increased sand proportion.

Loss of particles during handling and transfer may have caused inaccuracies in mass. The total mass of soil taken from the sieves is 1395.77g – a loss of 4.27g during the experiment. A factor in this issue is the spilling of soil during the initial pour into the sieve shaker, Figure 4. Future tests could reduce this error by pouring the sample more slowly and carefully, using a funnel or scoop to guide the soil into the top sieve.

Dust clouds were visible during the sieve vibration, Figure 6, the transportation of soil and brushing. This indicates the fine particles may have become airborne and lost from the sample. Dust particles were also static on the plastic sheet of the collection tray and were brushed aggressively to remove them. These issues could be reduced by ensuring the sieve stack cover is extra secure, minimising excessive brushing, and removing the plastic sheet from the tray and pouring directly from the metal tray.

2 The 'Atterberg Limits' Test

2.1 Introduction

The Atterberg limits test was performed on a soil sample to establish how the fine-grained soils behave with changes in moisture content. The test is widely used in geotechnical engineering to enable soil classification and to inform design decisions and risk assessment in construction projects, helping engineers understand how the ground is likely to perform under varying conditions.

The test establishes the liquid limit (LL), which represents the transition from plastic to liquid behaviour, and the plastic limit (PL), which defines the transition from semi-solid to plastic behaviour. The difference between these values is the plasticity index (PI), which represents the range of moisture contents at which the soil exhibits plastic behaviour. Together, these parameters indicate the soil's plasticity, compressibility, and sensitivity to moisture changes (BS 1377, 1990).

2.2 Methodology

2.2.1 Materials / Equipment:

- Soil sample
- Oven
- Precision balance scales (± 0.01 accuracy)
- Scale pan
- 7 containers (labelled with LL1, LL2, LL3, LL4, PL1, PL2 and PL3)
- Mixing bowl
- Scoop
- Distilled water
- Casagrande apparatus device
- Gauging groove tool
- Spatula or palette knife
- Paper towels
- Glass plate (rolling surface)
- Rolling rod/wooden dowel (3mm diameter)



Figure 18: Image showing distilled water, mixing bowl containing the dry soil sample, spatulas, Casagrande apparatus device and groove tool.



Figure 19: Image of labelled containers.

2.2.2 Method:

2.2.2.1 Liquid Limit Procedure

1. The soil sample was dried in an oven for 24 hours at 120 degrees (Figure 20).



Figure 20: Image of the dry soil sample in the mixing bowl and scoop.

2. The mass of each empty labelled container was measured on the precision scales and recorded (Figure 21).



Figure 21: Image of empty containers being weighed on the precision scales.

3. The dry sample, weighing approximately 250g, was placed into a mixing bowl, and distilled water was added (Figure 22).



Figure 22: Image showing some distilled water mixed into the soil sample.

4. The mixture was combined thoroughly using a spatula until a uniform paste was formed (Figure 23).

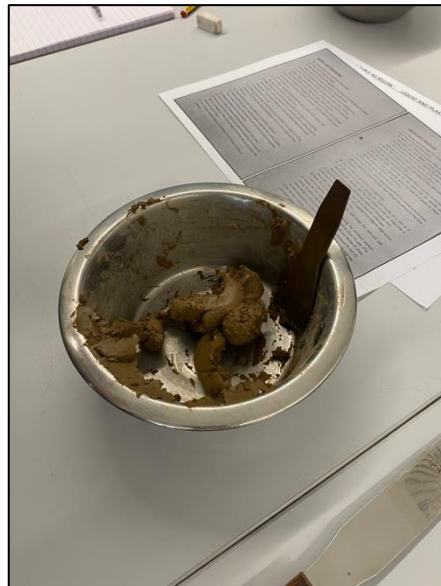


Figure 23: Image of the paste formed, ready to be spread in the device.

5. The soil paste was evenly spread to a depth of approximately 10mm on the bottom half of the apparatus cup (Figure 24).

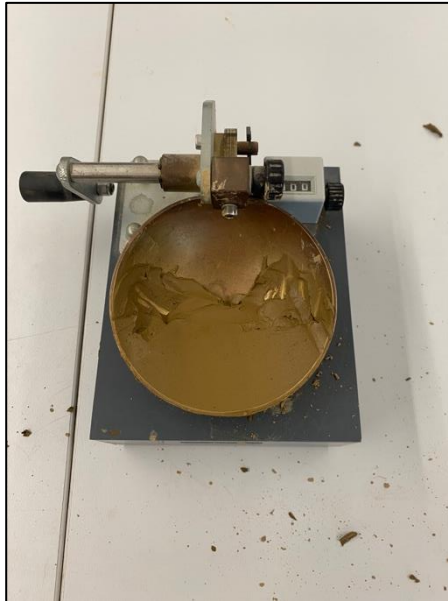


Figure 24: Image showing the paste spread in the Casagrande apparatus device cup.

6. A groove tool was used to cut a 12mm wide gap in the centre of the clay (Figure 25).

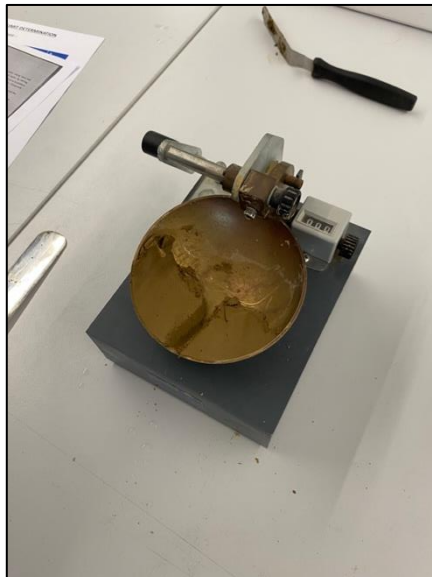


Figure 25: Image showing the cut made into the paste using the groove tool.

7. The handle of the apparatus device was rotated, causing the cup to rise and drop repeatedly on the surface. The number of drops required for the groove to close was recorded (Figure 26 and Figure 27).



Figure 26: Image of the device handle being rotated while the cup is rising and dropping.



Figure 27: Image showing the groove has closed.

8. A sample of the paste in the cup was taken and placed in its corresponding labelled container (Figure 28).



Figure 28: Image of the paste sample being weighed on the precision scales.

9. The mass of the container and wet soil was weighed and recorded.

10. The test was repeated several times, with additional distilled water added each time to increase the moisture content and receive a range of blow counts.
11. The containers were placed in an oven for 24 hours before being reweighed to obtain the dry mass of the soil (Figure 29 and Figure 30).



Figure 29: Image showing all containers containing wet samples before being dried in the oven.

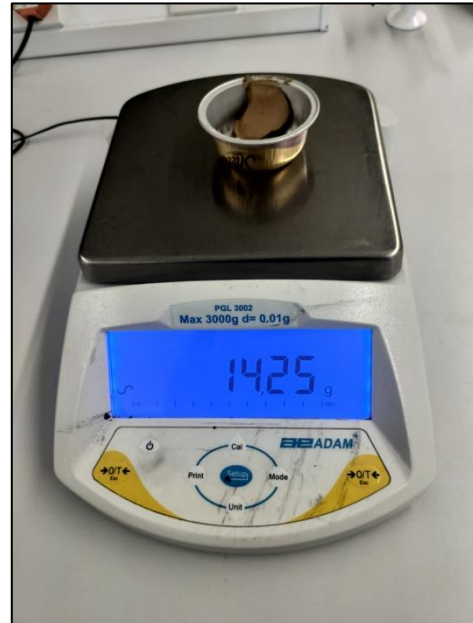


Figure 30: Image of an LL sample and container being weighed after drying in the oven.

2.2.2.2 Plastic Limit Procedure

1. Soil from the prepared sample from the liquid limit procedure was mixed with dry soil until a stiff, mouldable consistency was achieved.
2. A small portion of soil was separated and rolled between the palm and a glass plate to form a thread.

3. The soil was rolled until it reached 3mm in diameter, at which point it began to crack or crumble. The wooden rolling rod was used as a guide (Figure 31).



Figure 31: Image of the crumbled soil thread against the wooden rod.

4. The crumbed soil was placed into a PL container and weighed and recorded (Figure 32).

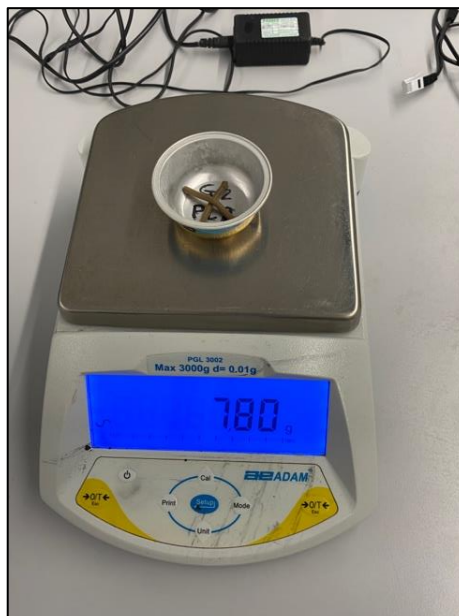


Figure 32: Image showing the soil thread being weighed in the container on the precision scales.

5. The procedure was repeated for the other 2 PL samples.
6. The containers were oven-dried for 24 hours and reweighed to determine the dry mass of the soil (Figure 33 and Figure 34).



Figure 33: Image of all soil samples in containers after being dried in the oven.



Figure 34: Image of a dry PL soil sample and container being weighed on precision scales.

The test was conducted in accordance with BS 1377 (1990).

2.3 Results

DRAW UP A TABLE AS BELOW - LIQUID AND PLASTIC LIMIT DETERMINATION							
Student Name - Emma Mackay				Date - 2/3/26			
	1	2	3	4	5	6	7
Type of Test	LL	LL	LL	LL	PL	PL	PL
Container Number	LL 1	LL 2	LL 3	LL 4	PL 1	PL 2	PL 3
Wt of wet soil + cont.	13.05	17.98	18.86	15.56	7.70	7.80	7.68
Wt of dry soil + cont.	10.73	14.25	14.75	12.36	7.05	7.15	7.09
Wt of Container	4.71	4.68	4.59	4.80	4.76	4.72	4.71
Wt of moisture	2.32	3.73	4.11	3.20	0.65	0.65	0.59
Wt of dry soil	6.02	9.57	10.16	7.56	2.29	2.43	2.38
Moisture Content	38.54	38.98	40.45	42.33	28.38	26.75	24.79
Number of Blows	39	31	26	14	N/A	N/A	N/A
Liquid Limit = 40.6%				Remarks: Weight of moisture = Weight wet soil – weight dry soil Weight dry soil = (Dry soil+container) – container			
Plastic Limit = 26.64%							
Plasticity Index = 13.96%							
Soil Classification = silt intermediate plasticity							

Figure 35: A filled table containing masses of containers, dry soil, wet soil, number of blows, moisture content, the percentage of liquid limit, plastic limit, plasticity index, and soil classification.

Figure 35: A filled table containing masses of containers, dry soil, wet soil, number of blows, moisture content, the percentage of liquid limit, plastic limit, plasticity index, and soil classification.

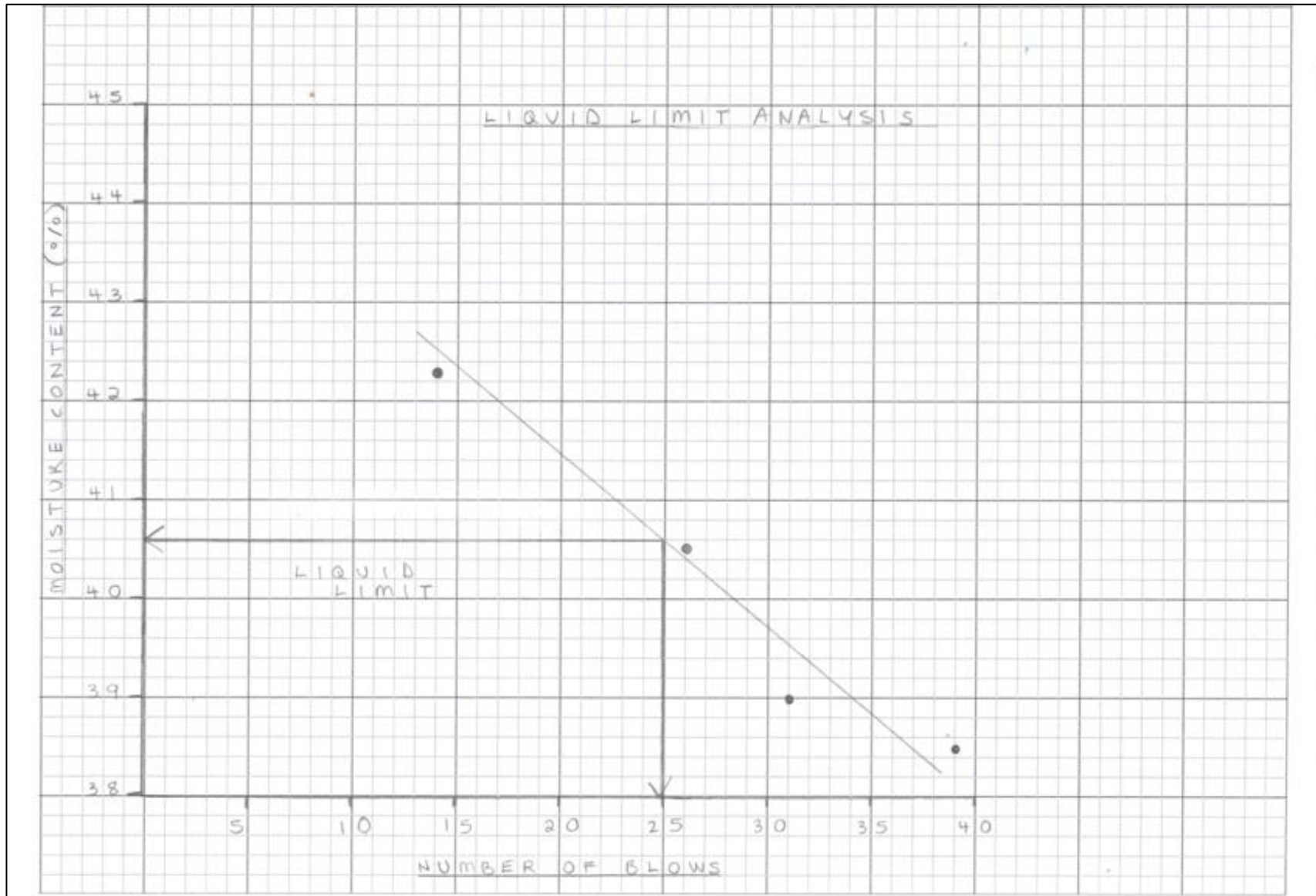
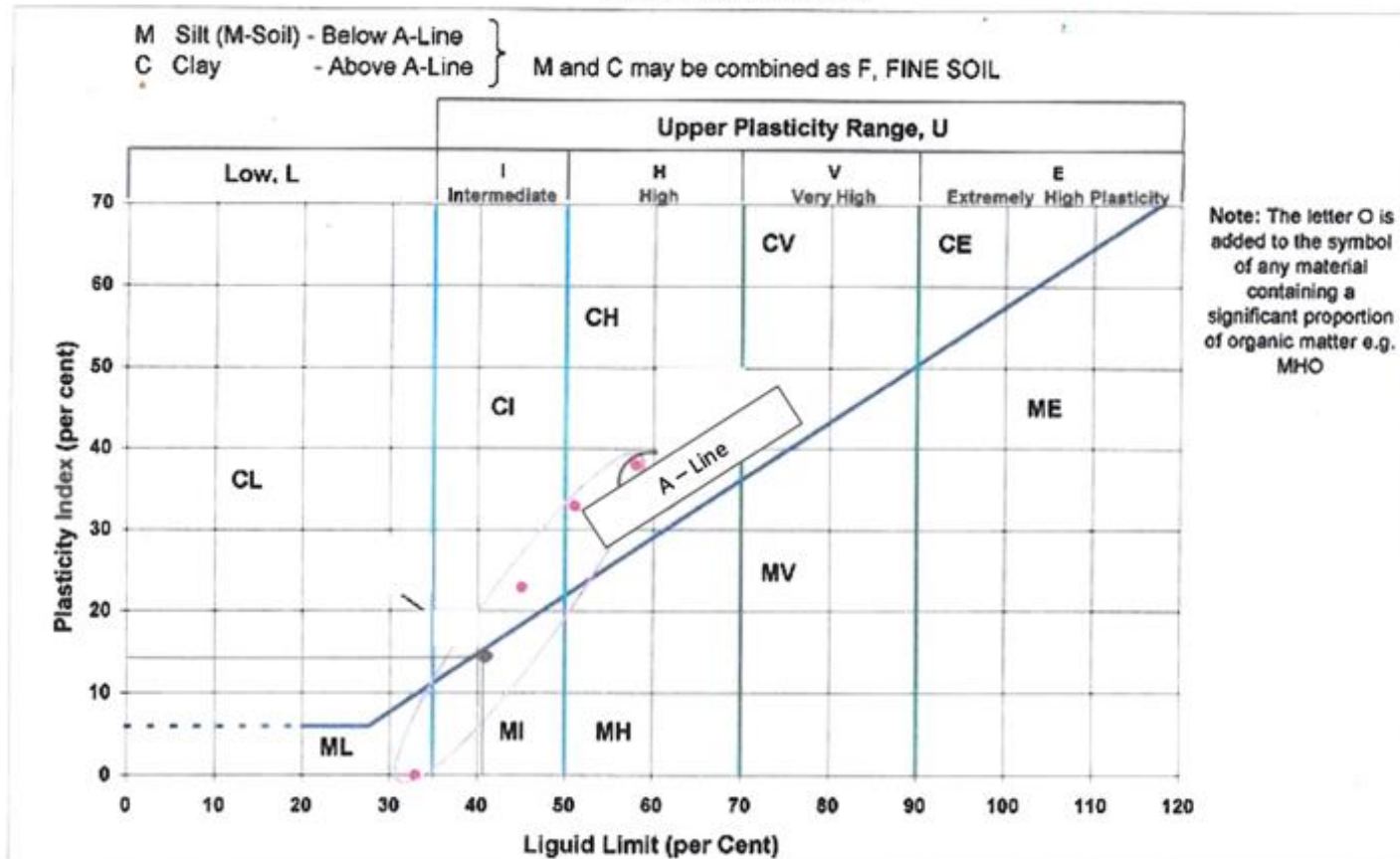


Figure 36: Liquid limit analysis graph, evaluated by plotting moisture content against the number of blows.

Plasticity Chart for the Classification of Fine Soils and Finer Part of Coarse Soils

According to BS 5930:1999



The degree of plasticity is plotted on the Cassagrande chart above. The chart separates fine grain soils into two basic groups by means of an empirical line known as the A line. The soils are then further divided into zones of plasticity according to their liquid limit values.

Figure 37: The plasticity chart for the classification of fine soils (adapted from BS 5930 (1999)) and the finer part of coarse soils, assigning a final soil classification for the sample.

2.4 Analysis

In accordance with the dry and wet masses of the soil sample containers, the moisture contents were calculated and recorded, Figure 35. By plotting moisture content against the number of blows, Figure 36, the liquid limit was determined as 40.6%, while the plastic limit was calculated as 26.64% based on the average of the plastic limit samples. This resulted in a plasticity index of 13.96%.

The plasticity index represents the range of moisture contents over which the soil exhibits plastic behaviour. A value of 13.96% indicates a soil with moderate plasticity characteristics, meaning it can undergo deformation without cracking but is still sensitive to moisture changes. When the liquid limit and plasticity index are plotted on the Casagrande plasticity chart, Figure 37, the point lies slightly below the A-line within the intermediate plasticity region. According to BS 5930 (1999), this classifies the soil as MI (Silt of intermediate plasticity).

This classification indicates a fine-grained soil with moderate compressibility and plasticity. These soils can be moulded without immediate failure but may undergo volume changes with variations in moisture content. In engineering terms, this suggests the soil may exhibit moderate settlement under load and has limited drainage capacity compared to coarse-grained soils, although it will perform better than high-plasticity clays. These characteristics are important when considering the soil's suitability for construction, particularly in relation to foundation stability and moisture sensitivity.

2.5 Conclusions

The Atterberg limits test showed that the soil is classified as silt of intermediate plasticity, meaning it has moderate plasticity and compressibility, and has sensitivity to moisture content changes.

However, there are possible limitations of the experimental method that may have significantly affected the results. A potential source of error was not noting the temperature of the room when the test was carried out. A warmer room temperature is an environmental condition that may have caused reductions in the liquid limit, plastic limit and plasticity index percentages. Despite this, the amount of effect on the results likely depends on the type of clay, as some types are more sensitive to temperature changes than others. Therefore, it's difficult to estimate how big the impact on the results could be, if any. To ensure the results are consistent in the future, the test should be performed within the standard room temperature range of 20-25 degrees Celsius.

A limitation of the test is that the plastic limit was determined by averaging the moisture contents of multiple samples. If each sample crumbled into approximately 3mm in diameter, the results are considered consistent and support the validity of the average value. However, the identification of the crumbling point is subjective and may introduce minor variation in the results.

3 The 'Constant Head Permeameter' Test

3.1 Introduction

The constant head permeameter test is used to determine the permeability of coarse-grained soils with relatively high permeability, typically down to values of approximately 10^{-4} m/s. The test was performed to determine the coefficient of permeability for two soil samples (Soil sample 1 and Soil sample 2), so that a comparison could be made, and a classification given to each sample based on its permeability.

In this test, a constant water head is maintained across the soil sample, allowing water to flow steadily through it. Once the equilibrium flow is achieved, the discharge is measured over a set period, and the coefficient of permeability (K) is calculated using Darcy's Law (BS 1377, 1990)

The permeability of a soil sample is essential in geotechnical engineering because it controls water movement through soil. It directly influences drainage and groundwater flow, which are vital for designing safe and stable foundations. Soils with high permeability allow water to pass easily, reducing the risk of pore water pressure buildup, while low-permeability soils can hold water, increasing pore pressure and decreasing shear strength. This can cause problems such as excessive settlement, slope instability, or reduced bearing capacity. Therefore, understanding permeability is crucial for designing effective drainage systems and maintaining long-term structural stability.

3.2 Methodology

3.2.1 Materials / Equipment (Figure 38):

- Two soil samples (Sample 1 and Sample 2)
- Two constant head permeameters
- Water reservoirs
- Inlet and outlet tubes
- Piezometer tubes (monometer board)
- Graduated cylinder
- Stopwatch/timer
- Measuring scale (ruler / digital vernier calliper)
- Filter paper



Figure 38: Image of equipment set up for both soil sample tests.

3.2.2 Method:

1. The distance between the two pressure points of the constant head permeameter was measured using a ruler and given as the value L (Figure 39).

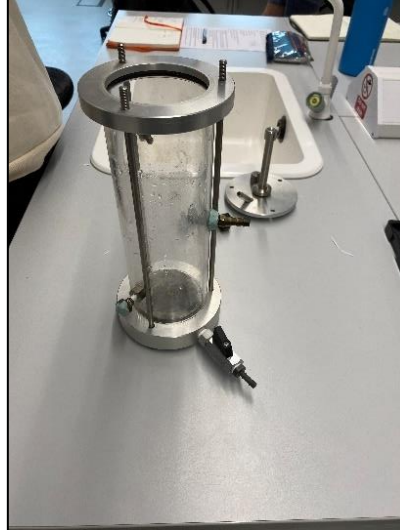


Figure 39: Image of empty constant head permeameter used to take measurements.

2. The average internal diameter (d) of the constant head permeameter was measured using the digital vernier calliper, so that the area of flow (A) could be calculated (Figure 40).



Figure 40: Image of digital vernier calliper after taking measurement of internal diameter of constant head permeameter.

3. The sample of soil was placed in the permeameter with a filter paper at the top and bottom (Figure 42 and Figure 41).



Figure 42: Image of Soil sample 1 set up.



Figure 41: Image of Soil sample 2 set up.

4. The permeameter was connected to the de-aired water reservoir to saturate the sample and allow a constant and stable flow (Figure 44 and Figure 43).

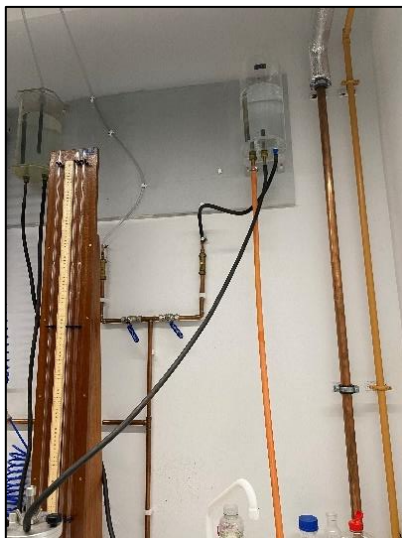


Figure 44: Image of inlet tubes connection to water reservoirs.



Figure 43: Image of water flowing out of constant head permeameter via outlet tube.

5. The hydraulic head difference (h) was measured from the piezometer tube mounted on a manometer board by measuring the difference in meniscus levels (Figure 46 and Figure 45).

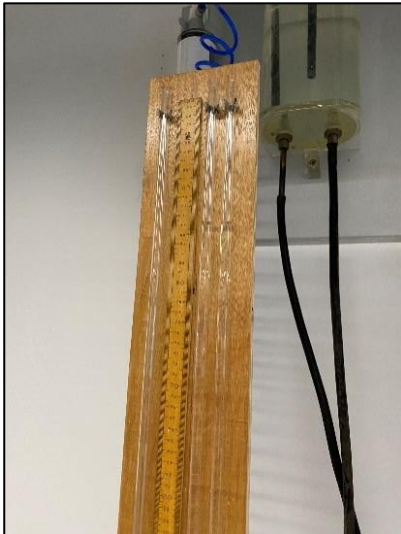


Figure 46: Image of meniscus levels in the piezometer tube of Soil sample 1.

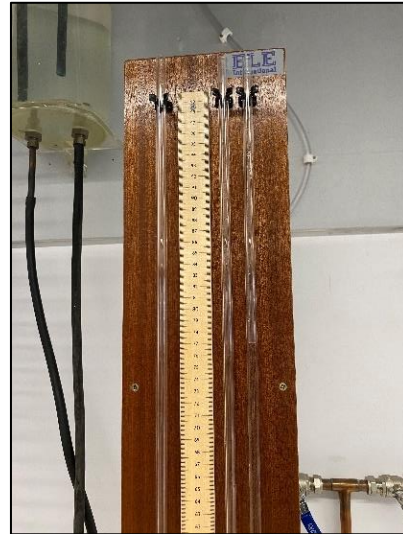


Figure 45: Image of meniscus levels in the piezometer tube of Soil sample 2.

6. The outlet tube with the flowing water was pinched and placed into the graduated cylinder. Simultaneously with the release of the tube, the timer for a set amount of time was started (Figure 47).



Figure 47: Image of water flowing out of outlet tube into a graduated cylinder whilst being timed.

7. The pipe was pinched again synchronously with the timer alarm and removed.

8. The time (t) and flow over time (Q) were recorded.
9. This was repeated twice with different time intervals to obtain consistent readings (Figure 48).



Figure 48: Image of water in graduated cylinder after set time.

10. Using Darcy's Law, the value of the coefficients of permeability (K) was calculated for each time and flow.
11. The average value of K was calculated and compared with standard permeability ranges to classify the soil.
12. The procedure was repeated for a second soil sample (Soil sample 2) to obtain a separate soil classification.

The procedure followed the guidelines of BS 1377 (1990).

3.3 Results

3.3.1 Constants

Length, $L = 0.072 \text{ m}$

Area, $A = 4.87 \times 10^{-3} \text{ m}^2$

3.3.2 Soil Sample 1 Results

Raw data:

Trial	Time, t (s)	Volume, Q (m^3)
1	20	1.86×10^{-4}
2	40	3.98×10^{-4}
3	60	5.95×10^{-4}

Head difference:

$h = 0.001 \text{ m}$

Calculated k values:

Trial	k (m/s)
1	0.137
2	0.147
3	0.147

Average:

$k = 1.44 \times 10^{-1} \text{ m/s}$

3.3.3 Soil Sample 2 Results

Raw data:

Trial	Time, t (s)	Volume, Q (m^3)
1	40	3.6×10^{-4}
2	80	7.0×10^{-4}
3	100	9.05×10^{-4}

Head difference:

$$h = 0.669 \text{ m}$$

Calculated k values:

Trial	k (m/s)
1	1.99×10^{-4}
2	1.93×10^{-4}
3	2.0×10^{-4}

Average:

$$k = 1.97 \times 10^{-4} \text{ m/s}$$

3.3.4 Sample Calculation

A sample calculation is shown below. Full calculations are provided in Appendix A: Sample Calculations.

Using Darcy's Law (BS 1377, 1990):

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

$$k = \frac{(1.86 \times 10^{-4}) \times 0.072}{(4.87 \times 10^{-3}) \times 0.001 \times 20}$$

$$k = 0.137 \text{ m/s}$$

3.4 Analysis

3.4.1 Soil sample 1

The coefficient of permeability was calculated as 1.44×10^{-1} m/s, where it was compared with standard permeability ranges to determine the soil classification of clean gravel (BS 5930 (1999)). Gravel is a highly permeable, coarse-grained soil with large pore spaces and minimal fine-grained content. During the experiment, it was noticeable that the drainage was at a very high flow rate; the classification is consistent with the experiment. This means water can pass through easily, minimising soil settlement. However, this may present challenges for foundation design as increased water flow can cause soil erosion and gradually compromise structural stability. While high permeability reduces the risk of water build-up it may also require erosion control measures in engineering applications.

3.4.2 Soil sample 2

This coefficient of permeability for this sample was calculated as 1.97×10^{-4} m/s, which is situated at the lower boundary of clean sands and gravel-sand mixtures (BS 5930, 1999). Due to its position near this boundary, the sample may include very fine sand and some silty material. This suggests the soil exhibits low to moderate permeability, likely caused by the presence of fine-grained particles that reduce the overall drainage capacity. This is consistent with the flow rate that was observed during testing, which indicated relatively restricted drainage. This permeability requires careful drainage design as the soil does not transmit water rapidly enough to prevent pore water pressure buildup, which can reduce shear strength and affect foundation stability. As this value lies close to the lower limit of suitability for the constant head test, the method remains valid; however, a falling head test may provide more accurate results for soils with lower permeability.

The significant difference in permeability between Sample 1 (1.44×10^{-1} m/s) and Sample 2 (1.97×10^{-4} m/s) highlights the influence of particle size distribution, with coarse-grained gravel allowing rapid drainage, while finer material in Sample 2 restricts flow. This demonstrates how larger pore spaces in coarse-grained soils increase permeability, whereas finer particles reduce flow paths. These results are consistent with Darcy's Law, where permeability is influenced by pore size and soil

structure, and have important implications for drainage behaviour and foundation performance.

3.5 Conclusions

The Constant head permeability test results demonstrated a clear relationship between particle size and permeability, with coarse-grained soils exhibiting significantly higher flow rates than finer material.

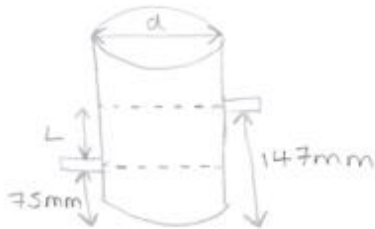
The accuracy of the results may have been influenced by timing and measurement inaccuracies. Human reaction time when using the timer and small errors in measuring water volume could affect the calculated flow rate, and consequently, the permeability. However, each measurement was repeated three times, and three corresponding Coefficients of permeability were calculated for each sample. With very similar values and the average used for analysis, it suggested that the likelihood of significant timing or measurement errors was low.

Non-uniform distribution of particle sizes within the sample is another factor that may have affected the results. If the soil was not representative, with an uneven mix of coarse and fine particles, this could create inconsistent pore spaces and flow paths. As a result, the measured permeability may not accurately reflect the overall behaviour of the soil. This limitation can be reduced by thoroughly mixing the soil prior to testing and placing it carefully in layers to ensure a uniform and representative distribution of particle sizes.

A potential source of error in the experiment was soil compaction. If the soil is not packed uniformly, the void ratio may vary throughout the sample, affecting flow paths and altering the measured permeability. However, more accurate results may be obtained by thoroughly mixing the soil before testing and placing it carefully in layers to ensure a uniform and representative distribution of particle sizes.

3.6 Appendices

3.6.1 Appendix A: Sample Calculations



$$L = 147 - 75$$

$$L = 72 \text{ mm}$$

$$L = 0.072 \text{ m}$$

$$d_1 = 78.72 \text{ mm}$$

$$d_2 = 78.86 \text{ mm}$$

$$d_3 = 78.74 \text{ mm}$$

Average internal d:

$$78.77 \text{ mm} = 0.07877 \text{ m}$$

$$A = \pi r^2$$

$$A = \pi \times 0.039385^2$$

$$A = 4.87 \times 10^{-3} \text{ m}^2$$

Soil sample ①

$$h = 861 \text{ mm} - 860 \text{ mm}$$

$$h = 10 \text{ mm}$$

$$h = 0.001 \text{ m}$$

Time / ml

$$t_1 = 20 \text{ sec}$$

$$t_2 = 40 \text{ sec}$$

$$t_3 = 60 \text{ sec}$$

$$Q_1 = 186 \text{ ml} \Rightarrow 1.86 \times 10^{-4} \text{ m}^3$$

$$Q_2 = 398 \text{ ml} \Rightarrow 3.98 \times 10^{-4} \text{ m}^3$$

$$Q_3 = 595 \text{ ml} \Rightarrow 5.95 \times 10^{-4} \text{ m}^3$$

K_1

$$Q_1 = 1.86 \times 10^{-4}$$

$$A = 4.87 \times 10^{-3}$$

$$K_1 = ?$$

$$L = 0.072$$

$$h = 0.001$$

$$t_1 = 20$$

$$K_1 = \frac{(1.86 \times 10^{-4}) \times 0.072}{(4.87 \times 10^{-3}) \times 0.001 \times 20}$$

$$K_1 = 0.137$$

κ_2

$$Q_2 = 3.98 \times 10^{-4}$$

$$A = 4.87 \times 10^{-3}$$

$$\kappa_2 = ?$$

$$L = 0.072$$

$$h = 0.001$$

$$t_2 = 40$$

$$\kappa_2 = \frac{(3.98 \times 10^{-4}) \times 0.072}{(4.87 \times 10^{-3}) \times 0.001 \times 40}$$

$$\kappa_2 = 0.147$$

κ_3

$$Q_3 = 5.95 \times 10^{-4}$$

$$A = 4.87 \times 10^{-3}$$

$$\kappa_3 = ?$$

$$L = 0.072$$

$$h = 0.001$$

$$t_3 = 60$$

$$\kappa_3 = \frac{(5.95 \times 10^{-4}) \times 0.072}{(4.87 \times 10^{-3}) \times 0.001 \times 60}$$

$$\kappa_3 = 0.147$$

κ = average of $\kappa_1, \kappa_2, \kappa_3$

$$\kappa = 0.144$$

$$\kappa = 1.44 \times 10^{-1}$$

Soil sample ②

$$h = 839 - 170$$

$$h = 669 \text{ mm}$$

$$h = 0.669 \text{ m}$$

Time/ml

$$t_1 = 40 \text{ sec} \quad Q_1 = 360 \text{ ml} \Rightarrow 3.6 \times 10^{-4} \text{ m}^3$$

$$t_2 = 80 \text{ sec} \quad Q_2 = 700 \text{ ml} \Rightarrow 7 \times 10^{-4} \text{ m}^3$$

$$t_3 = 100 \text{ sec} \quad Q_3 = 905 \text{ ml} \Rightarrow 9.05 \times 10^{-4} \text{ m}^3$$

k_1

$$Q_1 = 3.6 \times 10^{-4}$$

$$A = 4.87 \times 10^{-3}$$

$$k_1 = ?$$

$$L = 0.072$$

$$h = 0.669$$

$$t_1 = 40$$

$$k_1 = \frac{(3.6 \times 10^{-4}) \times 0.072}{(4.87 \times 10^{-3}) \times 0.669 \times 40}$$

$$k_1 = 1.99 \times 10^{-4}$$

k_2

$$Q_2 = 7 \times 10^{-4}$$

$$A = 4.87 \times 10^{-3}$$

$$k_2 = ?$$

$$L = 0.072$$

$$h = 0.669$$

$$t_2 = 80$$

$$k_2 = \frac{(7 \times 10^{-4}) \times 0.072}{(4.87 \times 10^{-3}) \times 0.669 \times 80}$$

$$k_2 = 1.93 \times 10^{-4}$$

4 References

British Standards Institution, 1990. *BS 1377: Methods of test for soils for civil engineering purposes*, London: BSI.

British Standards Institution, 1999. *BS 5930: Code of practice for ground investigations*, London: BSI.