

# **Coursework 1**

## **Soil Mechanics Practical**

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## 1.0 Atterberg Limit Tests

### 1.1 Introduction

The Atterberg Limits test are important for civil engineers to help determine and give indication of the properties and characteristics of soils. This test measures the water contents at which certain changes in physical behaviour occur within a given soil sample, these Atterberg limits are commonly referred to as “limits of consistency” of moisture content within that classify fine-grained soils such as clays and silts (O’Kelly, 2021). In engineering practices commonly two of the practices are used these the “plastic limit (PL)” and “liquid limit (LL)” a third limit called the “shrinkage limit (SL)” is used seldom, these limits also help us to determine the plasticity index.

The Atterberg Limit tests help to establish how the moisture contents in fine-grained soils transition between solid, semi-solid, plastic, and liquid states. Each of these states present different properties in strength, behaviour, and overall consistency and these tests help enable the classification and identification of a soil thus allowing an engineer to determine overall properties before construction (Shimobe and Spagnoli, 2019). These properties can be applied to real engineering design problems to help foundation, embankment, pavement design etc. as these values help to determine overall shear strength, settlement, permeability and expansivity. Below are some definitions for our limits and plastic index.

**Liquid Limit (LL)** – The lowest water content above which soil behaves like a liquid and begins to flow (normally below 100)

**Plastic Limit (PL)** – The lowest water content at which a soil begins to behave like a plastic material (normally below 40)

**Shrinkage Limit (SL)** – Is the water content below which soils no longer decrease their volume as they continue to dry out.

**Plastic Index (PI)** – The range between Liquid Limit (LL) and Plastic Limit (LL)

In this project we will be using the standard procedure “ASTM D 4318 – Standard Test Method for Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index of Soils (PI)” In order to determine our soil sample classifications (ASTM, 2018).

## 1.2 Methodology of Liquid Limit (Cassagrande Cup Method)

The method of determining the LL of a soil is defined by the laboratory test originally developed by Albert Atterberg in 1911 utilising the ‘Cassagrande Cup’ apparatus. This methodology is outlined below including equipment etc.

### Equipment

- Cassagrande Cup Device
- Digital Scales
- Soil Specimen
- Flat Grooving tool with gage
- Spatula
- Wash bottle filled with distilled water
- Metal Mixing Bowl
- Oven set at 105 degrees Celsius
- Metal marked containers (for each individual sample)

Figure 1 – A selection of equipment used for the Cassagrande Cup Method test



## **Methodology Steps**

**NOTE:** These steps were completed twice for the two soil samples in our test and labelled accordingly (LL1, LL2, LL3, LL4 (for first soil sample) and LL5, LL6, LL7 and LL8 (for second soil sample)).

1. Label and weigh four containers and record data in a table. We weigh the containers to determine the container weight that can be removed from the weight of our soil once added.
2. Insert our dry soil sample (soil 1) into a metal mixing bowl and subsequently mix with a small (1-2ml) of water, mixing in each time until the soil becomes a clay consistency that would require around 30-35 drops of the Cassagrande apparatus to cause a groove gap closure of 12mm conforming with the British Standard 'BS 13177-7:1990' (British Standards Institution, 1990). N.b. This is a trial and error test in order to get the correct consistency is reached

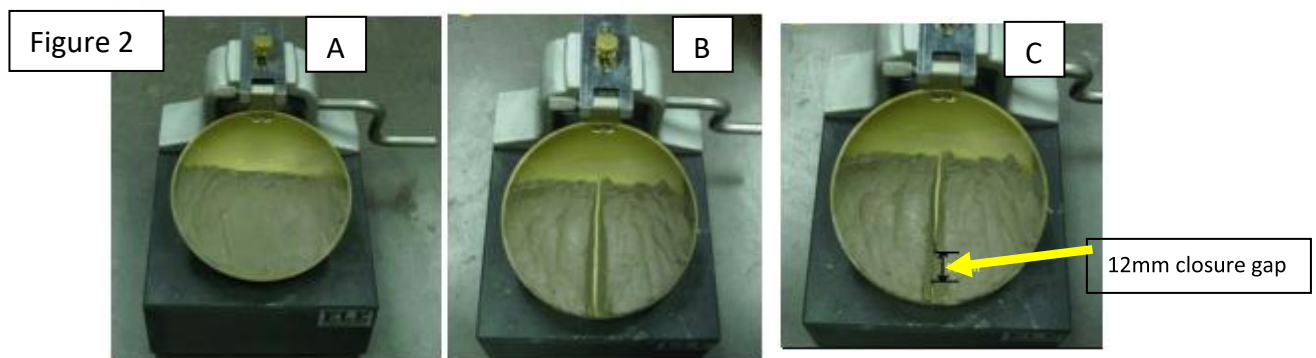


Figure 2 – Stages of Cassagrande Cup method outlined in methodology step 2 as to BS 13177:1990

3. Once we have ascertained the correct consistency, we use the spatula to place some of the mixture into the Cassagrande Cup bowl we then squeeze and spread the clay sample down with the spatula to get it as flat as possible with a base depth of 10mm and ensure to remove all air bubbles (figure 2 picture A).
4. Ensure to remove any excess soil back into the mixing bowl
5. From the back to front position in the cup use the gauging tool and cut a groove in one sweeping motion three times (continuous) while avoiding contact with the sides of the sample (figure 2 picture B).

6. Once achieved ensure that the Cassagrande Cup is zero'ed this means the sample is now ready for testing.
7. Crank the handle to lift and drop the cup at a rate of 2 revolutions per second until the soil sample close over 12mm across the gap that was made with the soil tool.
8. Ensure to record the number of drops that were needed to close the gap, as stated above the number of blows should be between 30-35 initially.
9. Next remove a slice of soil the width of the spatula from edge to edge across the sample within the Cassagrande cup, ensuring to cut through the groove.
10. Place this taken sample within one of your marked container and weight the wet soil and container together/
11. Weigh the sample using digital scales and record in a table produced earlier.
12. Repeat this four times for each soil sample but gradually increase the moisture content to reduce the number of blows. This means the consistency becomes more fluid, the object is to have samples that require above and below 25 drops with all samples falling between the 35 and 15 no. of blows range.
13. We then take all four containers with soil and place into the oven and leave for 24 hours to fully dry the samples. Once the 24 hours have passed all samples should be re-weighed and recorded within our table to determine moisture contents.

### 1.3 Methodology of Plastic Limit

The method of determining the PL of a soil is defined by the laboratory test by finding the minimum water content at which a soil will just begin to crumble when it is rolled into a thread of approx. 3mm in diameter. It is the moisture content that helps define where the sample will change from a semi-solid to a plastic state (Kaliakin, 2017).

#### **Equipment**

- Soil Samples
- Digital Scales
- Glass Plate (free from scratches)
- Rod (3mm in diameter approx. 100mm long)
- Spatulas
- Distilled Water
- Oven

- Metal Marked Containers
- Metal Mixing Bowl

### **Methodology Steps**

NOTE: These steps were completed twice for the two soil samples in our test and labelled accordingly (PL1, PL2, PL3 (for first soil sample) and PL4, PL5, PL6 (for second soil sample)).

1. Label and weigh three containers and record data in a table. We weigh the containers to determine the container weight that can be removed from the weight of our soil once added.
2. Take our soil sample and knead into clay sample adding small amounts of water
3. Create and mould a small ball of clay in fingers and palm so that the warmth of the hand dries it very slowly.
4. As small cracks appear on the surface of the clay ball, divide into three equal parts equating to around 10g each and ensure to keep them separate.
5. Use a glass rod to indicate size of cylinder, roll out a ball of clay to match the rod, this should be around 6mm in diameter, it must be ensured that the clay thread is intact and homogenous.
6. Using steady rolling pressure with palm we must reduce the thread to around 3mm.
7. Repeat the process until the thread starts to 'crumble' around the 3mm mark indicated above. Maintaining uniform pressure while rolling is important. The 'crumbling' is defined as shearing both longitudinally and transversally as it is rolled. The crumbling must be attained by result of the rolling directly not through pressure caused by the hand. **The crumbling point is the Plastic Limit moisture content.**
8. Once this stage has been reached, gather all crumbled and broken pieces of the clay/soil sample, and place them into a container and weigh the soil on digital scales, once again record this into the table.
9. Repeat the above steps for the two other 10g samples (also repeat whole process for soil sample 2 as stated in note).
10. Place soil samples in metal containers within the oven and leave for 24 hours. Once these 24 hours have passed re-weigh the samples and record into our table.
11. Take the average of all 3 results to obtain moisture content mean. This moisture content mean is the Plastic Limit moisture content indicator.

## 1.4 Results and Analysis

Following both tests being completed for both Plastic Limit and Liquid Limit we can now calculate from the data gathered the moisture content within each of the samples and subsequently we can also determine Plasticity index.

Table 1 & 2 below shows the data collected from our tests outlined above for two samples. It should be noted that “LL” refers to Liquid Limit and “PL” refers to Plastic Limit.

| <i>Table 1</i>                     | SOIL SAMPLE 1 |       |       |       |      |      |      |
|------------------------------------|---------------|-------|-------|-------|------|------|------|
|                                    | 1             | 2     | 3     | 4     | 5    | 6    | 7    |
| Type Of Test                       | LL            | LL    | LL    | LL    | PL   | PL   | PL   |
| Container Number                   | LL1           | LL2   | LL3   | LL4   | PL1  | PL2  | PL3  |
| Weight of Wet Soil & Container (g) | 16.43         | 16.94 | 11.92 | 15.52 | 8.19 | 9.16 | 8.07 |
| Weight of Dry soil & Container (g) | 14.08         | 14.41 | 10.43 | 13.25 | 7.54 | 8.25 | 7.45 |
| Weight of Container (g)            | 4.38          | 4.69  | 4.72  | 4.75  | 4.69 | 4.76 | 4.7  |
| Weight of Moisture (g)             |               |       |       |       |      |      |      |
| Weight of Dry soil (g)             |               |       |       |       |      |      |      |
| Moisture Content (%)               |               |       |       |       |      |      |      |
| No. of Blows                       | 37            | 22    | 20    | 15    |      |      |      |

| <i>Table 2</i>                     | SOIL SAMPLE 2 |       |       |       |       |      |      |
|------------------------------------|---------------|-------|-------|-------|-------|------|------|
|                                    | 1             | 2     | 3     | 4     | 5     | 6    | 7    |
| Type Of Test                       | LL            | LL    | LL    | LL    | PL    | PL   | PL   |
| Container Number                   | LL5           | LL6   | LL7   | LL8   | PL4   | PL5  | PL6  |
| Weight of Wet Soil & Container (g) | 14.48         | 14.06 | 15.77 | 13.05 | 10.04 | 6.95 | 8.18 |
| Weight of Dry soil & Container (g) | 12.28         | 11.89 | 13.13 | 11.01 | 9.01  | 6.55 | 7.56 |
| Weight of Container (g)            | 4.72          | 4.66  | 4.76  | 4.7   | 4.71  | 4.75 | 4.76 |
| Weight of Moisture (g)             |               |       |       |       |       |      |      |
| Weight of Dry soil (g)             |               |       |       |       |       |      |      |
| Moisture Content (%)               |               |       |       |       |       |      |      |
| No. of Blows                       | 33            | 32    | 26    | 21    |       |      |      |

Using the results generated above from our tests we can then determine the weight of moisture, weight of the dry soil and the percentage of moisture content. These can be seen once again in the tables below that have been inputted with results. The calculations for each of the missing results are highlighted below using example sample container LL1.

## Calculations

### **Moisture Content Calc -**

*Weight of Wet Soil & Container – Weight of Dry Soil & Container = Moisture Content*

$$16.43g - 14.08g = 2.35g$$

### **Weight of Dry Soil –**

*Weight of dry Soil & Container – Weight of container = Weight of dry soil*

$$14.08g - 4.38g = 9.7g$$

### **Moisture Content –**

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

$$\frac{2.35g}{9.7g} \times 100 = 24.23\%$$

These calcs should be repeated for each of the samples.

| <u>Table 1</u>                     | SOIL SAMPLE 1 |       |       |       |       |       |       |
|------------------------------------|---------------|-------|-------|-------|-------|-------|-------|
|                                    | 1             | 2     | 3     | 4     | 5     | 6     | 7     |
| Type Of Test                       | LL            | LL    | LL    | LL    | PL    | PL    | PL    |
| Container Number                   | LL1           | LL2   | LL3   | LL4   | PL1   | PL2   | PL3   |
| Weight of Wet Soil & Container (g) | 16.43         | 16.94 | 11.92 | 15.52 | 8.19  | 9.16  | 8.07  |
| Weight of Dry soil & Container (g) | 14.08         | 14.41 | 10.43 | 13.25 | 7.54  | 8.25  | 7.45  |
| Weight of Container (g)            | 4.38          | 4.69  | 4.72  | 4.75  | 4.69  | 4.76  | 4.7   |
| Weight of Moisture (g)             | 2.35          | 2.53  | 1.49  | 2.27  | 0.65  | 0.91  | 0.62  |
| Weight of Dry soil (g)             | 9.7           | 9.72  | 5.71  | 8.5   | 2.85  | 3.49  | 2.75  |
| Moisture Content (%)               | 24.23         | 26.03 | 26.09 | 26.71 | 22.81 | 26.07 | 22.55 |
| No. of Blows                       | 37            | 22    | 20    | 15    |       |       |       |
|                                    |               |       |       |       |       |       |       |
| <u>Table 2</u>                     | SOIL SAMPLE 2 |       |       |       |       |       |       |
|                                    | 1             | 2     | 3     | 4     | 5     | 6     | 7     |
| Type Of Test                       | LL            | LL    | LL    | LL    | PL    | PL    | PL    |
| Container Number                   | LL5           | LL6   | LL7   | LL8   | PL4   | PL5   | PL6   |
| Weight of Wet Soil & Container (g) | 14.48         | 14.06 | 15.77 | 13.05 | 10.04 | 6.95  | 8.18  |
| Weight of Dry soil & Container (g) | 12.28         | 11.89 | 13.13 | 11.01 | 9.01  | 6.55  | 7.56  |
| Weight of Container (g)            | 4.72          | 4.66  | 4.76  | 4.7   | 4.71  | 4.75  | 4.76  |
| Weight of Moisture (g)             | 2.2           | 2.17  | 2.64  | 2.04  | 1.03  | 0.4   | 0.62  |
| Weight of Dry soil (g)             | 7.56          | 7.23  | 8.37  | 6.31  | 4.3   | 1.8   | 2.8   |
| Moisture Content (%)               | 29.10         | 30.01 | 31.54 | 32.33 | 23.95 | 22.22 | 22.14 |
| No. of Blows                       | 33            | 32    | 26    | 21    |       |       |       |
|                                    |               |       |       |       |       |       |       |

Once we have calculated the percentage value for all the moisture contents for every sample, we now need to create a graph to plot the liquid limit (%) on the y-axis against the number of blows on the x-axis. This can be seen in figure 3 & 4 below.

Figure 3

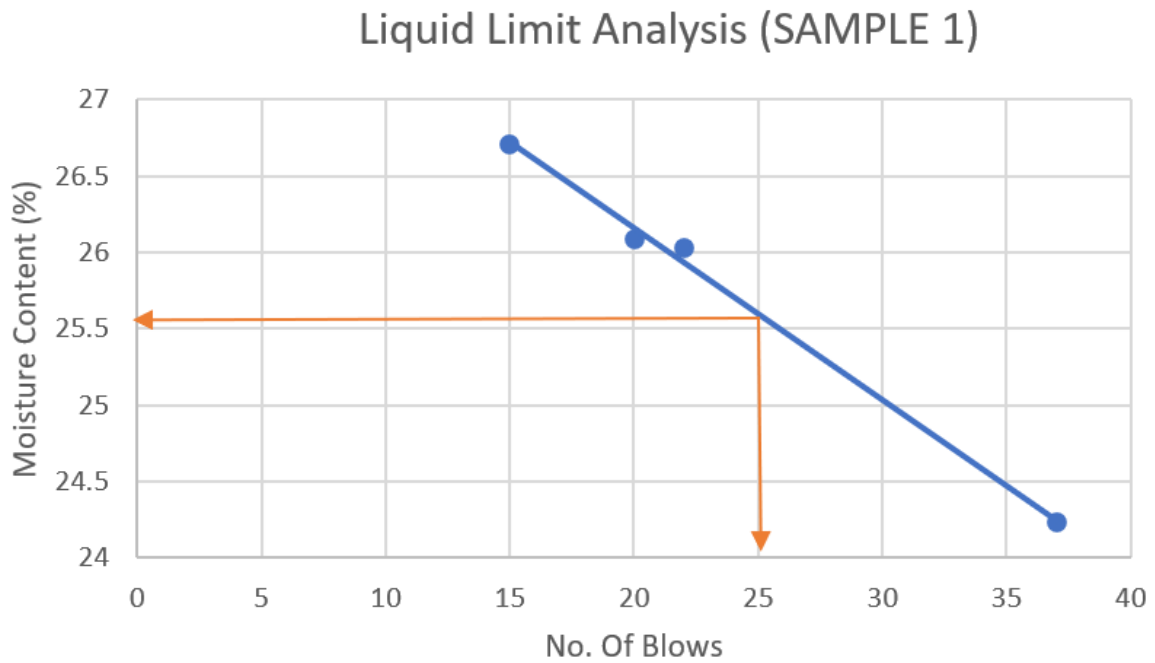
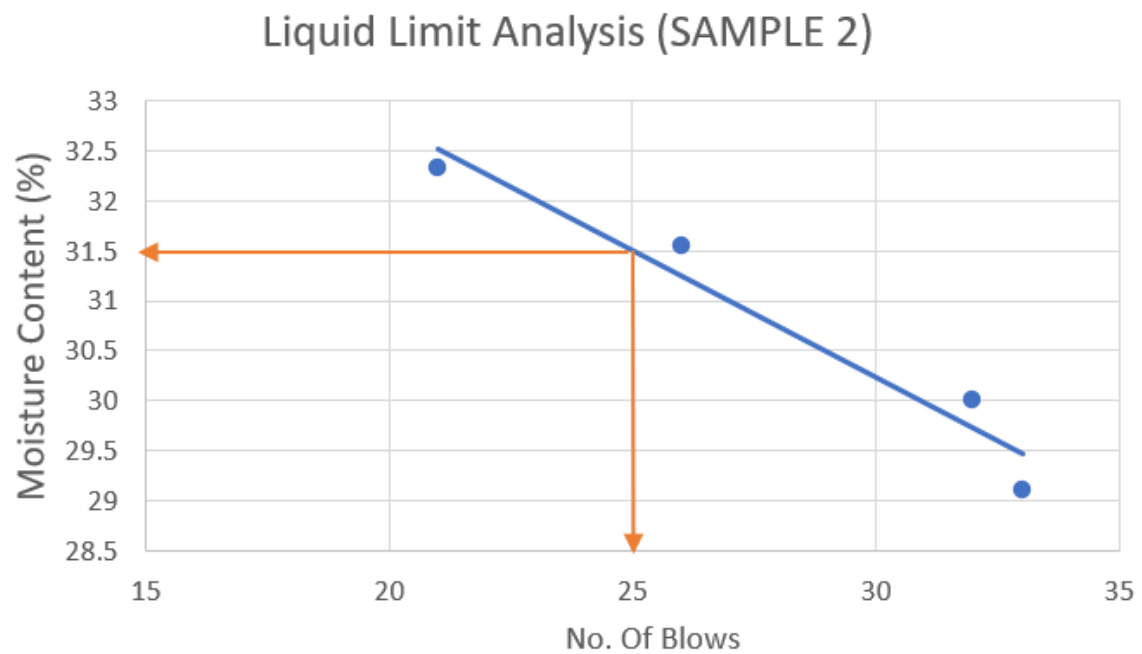


Figure 4



From both examples above we can see a trend whereas the number of blows decrease the moisture content increases. For both our samples we can now calculate the Liquid Limit (LL)

of the sample 1 and 2. The moisture content and number of blows allows us to plot a general trend line for the samples. We then take a moisture content line for the sample at 25 'blow mark' and follow it up where it intersects with our trend line we then read across to moisture content (%) which we can then derive our Liquid Limit for the sample.

For **Sample 1 the Liquid Limit is 25.6%** and for **Sample 2 the Liquid Limit is 31.5%**.

### **Plastic Limit**

To calculate our Plastic Limits, we simply get an average percentage of moisture content of our samples as indicated below.

*Sample 1 =*

$$Average = \frac{22.80 + 26.07 + 22.54}{3}$$

**Plastic Limit = 23.8**

*Sample 2 =*

$$Average = \frac{23.95 + 22.22 + 22.14}{3}$$

**Plastic Limit = 22.77**

### **Plasticity Index (PI)**

Plasticity Index can now be calculated for both samples as we have both Liquid Limits and Plastic Limits. We simply subtract the PL from the LL and it gives us our PI (%)

*Sample 1 –*

PL = 23.8%

LL = 25.6%

**PI = 25.6% - 23.8% = 1.8%**

*Sample 2 –*

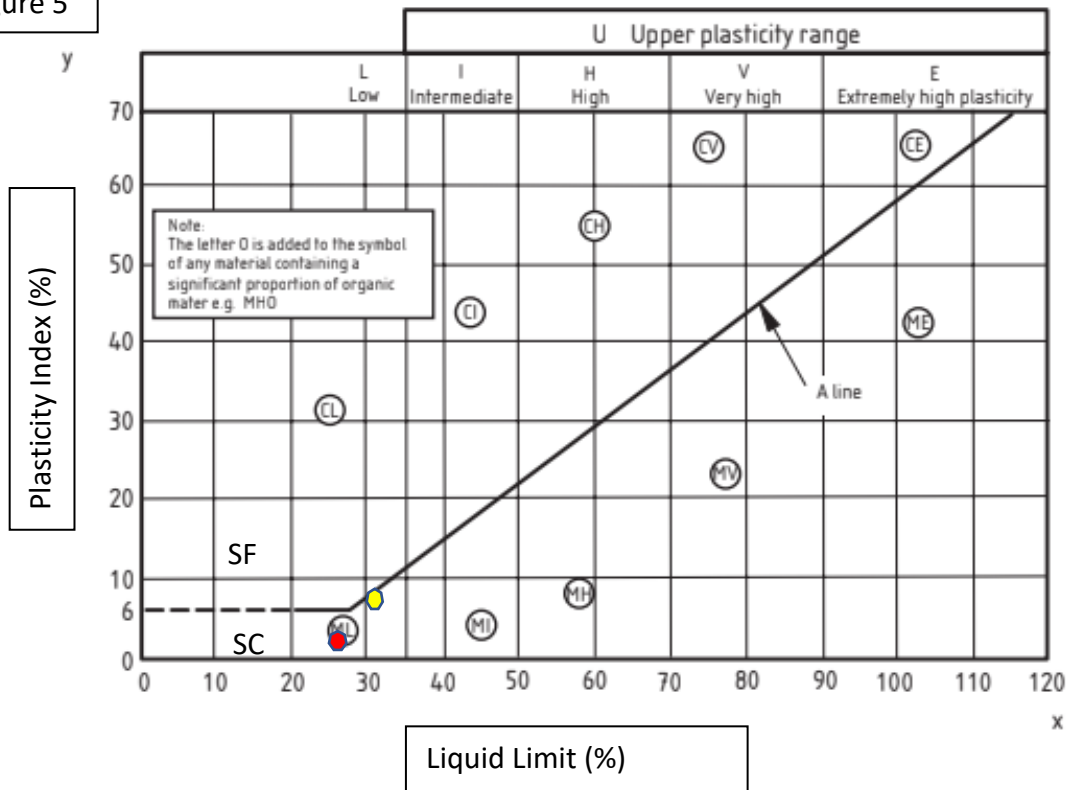
PL = 22.77%

LL = 31.5%

**PI = 31.5% - 22.77% = 8.73%**

This PI can now be plotted onto a Plasticity chart to allow us to classify our soil samples, this can be seen in figure 5 (Sample 1 & 2) below. The Plasticity chart for the classification of fine soils and finer part of coarse soils conforms with BS 5930-1999 (British Standards Institution, 1999).

Figure 5



#### KEY

M = SILT (M-SOIL) – BELOW A-LINE

C = CLAY – ABOVE A- LINE

SC = SANDS WITH CLAY

SF = SANDS WITH FINES

SAMPLE 1 = ●

SAMPLE 2 = ●

Figure 5 – Plasticity Chart with Samples 1 & 2 plotted for the classification of fine soils as per BS 5930:1999

Using Figure 5 and Figure 6 below we can now determine our soil sample classification.

Figure 6

| 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               |

Figure 6 – Plasticity Index Table Roy, (Surendra & Bhalla, Sanjeev. 2017).

Our Sample 1 falls within a Sandy Clay with low plasticity, Sample on the other hand is classed as a siltier Clay with a more intermediate plasticity.

### 1.5 Conclusion

Using the Atterberg Tests it has enabled us to determine the Plastic Limit, Liquid Limit and classification of soils through the Plasticity Index, thus allowing us as civil engineers to determine how the different soil specimens will behave under certain conditions. These methods will subsequently allow us to determine the best civil engineering foundations to use from these samples. These methods are an inexpensive way to help us distinguish the classification of soils between silts and clays.

The significance of water content within soils affects the properties of soils it means that the strength decreases as the water content increases. Fine-grained soils possess similar properties to liquids as water content increases, on the other hand as water content reduces the volume of soil decreases and the soils become more plastic. The plasticity index allows us to determine that a clay soil with high plasticity is likely to have poorer properties from an engineering standpoint due to high-water content. Strength and shear strength decreases as water content increases and clays ultimately swell. The PL and LL have a massive impact on the effective stresses on soil samples.

From our sample 1 we can determine that the soil is within the silt/low plastic/partly cohesive range meaning it has a very low shear strength with low plastic properties it is a Sand with Clay. Sample 2 on the other hand is within the ML/MI range indicating that it has a more intermediate plasticity with a higher degree of cohesiveness with more shear strength and medium plasticity. This meaning it has a higher value with regards to stability of soil slopes and less engineering construction is required. Overall sample 2 is better for stability. This test has helped determine the LL and PL enabling us to better understand the behaviour soils in limits of consistency.

## 2.0 Constant Head Permeameter Test

### 2.1 Introduction

The Constant Head Permeameter Test is to help determine the overall permeability of a given soil sample. Permeability is the ease of which a fluid (water) can flow through a soil. There are two tests to determine permeability of soils by laboratory methods the first being ‘Constant head permeability test’ for soils ( $k > 10^{-4}$  cm/s) and the second being the ‘fallen head permeability test’ for soils ( $k < 10^{-4}$  cm/s). In this investigation we will use the Constant head permeameter test for a more granular soil. The purpose of this test is significant to civil engineers to help determine the soil mechanics for the quantity of underground seepage under various hydraulic condition, it will help us determine filtration, drainage, settlement and also stability calculations (Projectsxta, 2022). Therefore, the engineer can determine from this what requirements are required for stability of said construction such as yield of water bearing strata, stability of earthen dams, embankments, seepage in dams, settlement issues. We do this test for two samples of soil.

In this experiment we will use ‘ASTM D 2434 – Standard Test Method for Permeability of Granular Soils (Constant Head).

### 2.2 Methodology

#### **Equipment**

- Constant Head Permeameter
- Tamper
- Water
- Soil Sample

- Digital Scales
- Measuring Cylinder
- Ruler/Tape Measure
- Container
- Rubber hoses
- Balancing Tank
- Water Tank Reservoir
- Stopwatch
- Push weight
- Manometer Tanks

### **Methodology Steps**

1. Set up Constant head permeameter test (as seen in figure 7)

Figure 7

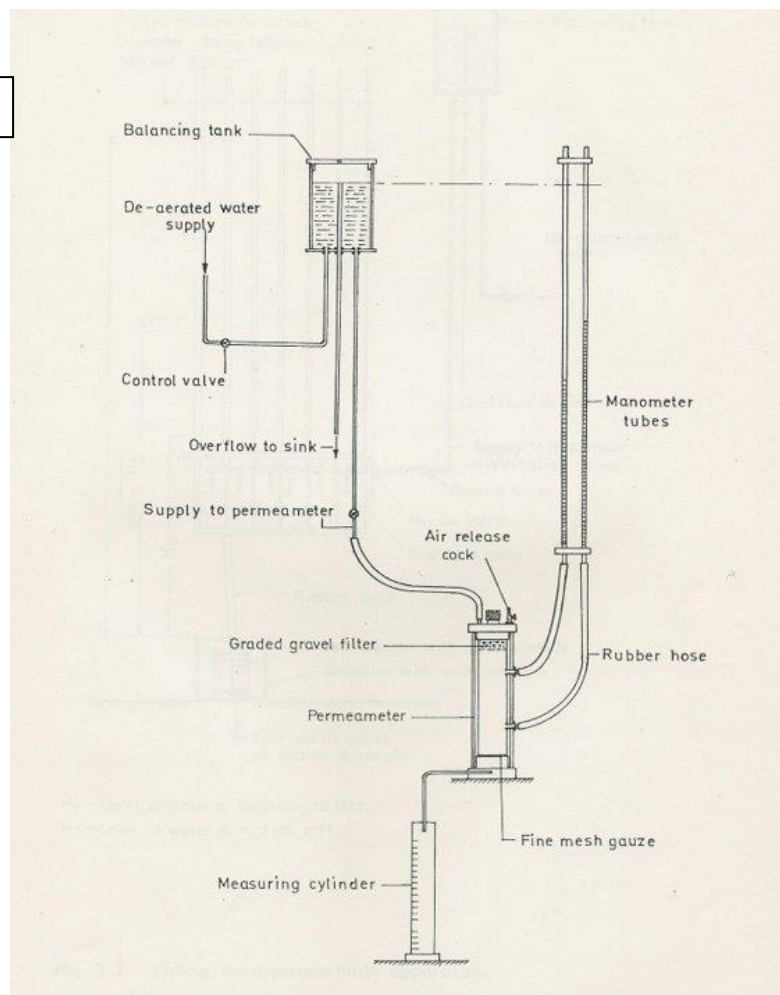


Figure 7 – Constant head permeability apparatus set up

2. Pour water into the permeameter, subsequently insert a mesh gauze into the permeameter to prevent soil sample escaping, next insert soil sample into the permeameter through the water.
3. Keep inserting soil at steady intervals ensure to compress and compact the soil and repeat this until the permeameter is full.
4. Next insert a graded gravel filter onto the soil sample and then secure with a lid and screws (Figure 8)



Figure 8 – Soil inserted with graded gravel filter on top of permeameter (Reddy, n.d.)

5. Next connect all the rubber hoses to both the line from the reservoir to the top of the cylinder and connect tubes to the monometer tubes on the permeameter.
6. Also connect the tubes to the reservoir balancing tank and water supply.
7. Turn on the water tap and ensure water is flowing correctly.
8. Once the water has filled the reservoir and flowing into the sink through the overflow pipe then the reservoir is now at a 'constant'
9. Next open the valve to establish the constant head difference as ' $h$ ' (Hydraulic Head difference). It is the head used up in pushing water through the permeameter a length ' $L$ ' of the test samples.
10. Once we are satisfied that our soil sample has been fully saturated, and water is flowing with no air within our soil sample we can now begin the test.
11. Use a stopwatch to record the time for the water to flow into our beaker over various intervals first beginning at 20second then 40 then 1 minute these are our ' $q$ ' values (Flow over time)
12. Record results of how much liquid (ml) is contained within our measuring cylinder.

13. Ensure to record the 'h' height difference of manometers after each test.

### 2.3 Results and Analysis

To ascertain our permeability co-efficient of soil sample we need to follow Darcy's Law as the British Standard (BS1377-6). Darcy's Law is outlined below.

The Equation for the Coefficient of Permeability is:

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

Where:

K = Coefficient of permeability

Q = Flow over time "t" in m<sup>3</sup>/s

A = Area of Flow

L = Length of Flow Line

h = Hydraulic head difference

t = time in seconds

*NOTE:* We must repeat this calculation for each of the three times.

There are also several constants for the calculation that can be used in all 3 calculations for each of the times recorded that are noted below for the two samples of soil.

#### **Soil Sample 1**

L = 0.066m

h = 0.592

A = 0.00478m<sup>2</sup>

Below is a table for the volume of water collected against the times specified.

|                              |       |       |      |
|------------------------------|-------|-------|------|
| Vol. of Water Collected (ml) | 157   | 318   | 440  |
| Time Aimed (s)               | 20    | 40    | 60   |
| Actual Time (s)              | 20.09 | 40.09 | 59.9 |

In the first test of sample one 157ml of water was collected over 20.09 seconds. This can be calculated for our Q value so  $157 \times 10^{-6} = 0.000157\text{m}^3$ .

We can now calculate our equation of permeability for sample 1 test 1.

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

$$K = \frac{0.000157 \times 0.066}{0.00478 \times 0.592 \times 20.09}$$

$$K = 1.822 \times 10^{-4}$$

We can then repeat this for sample 1 test 2 with Q value 0.00318

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

$$K = \frac{0.000318 \times 0.066}{0.00478 \times 0.592 \times 40.09}$$

$$K = 1.852 \times 10^{-4}$$

We can then repeat this for sample 1 test 3 with Q value 0.00040

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

$$K = \frac{0.00040 \times 0.066}{0.00478 \times 0.592 \times 59.90}$$

$$K = 1.713 \times 10^{-4}$$

Now we have our three results we need to average the values to find the coefficient for the sample under the test carried out for soil sample 1.

$$K = 1.745 \times 10^{-4}$$

The value above for this soil sample can now be assigned into the Permeability table for Darcy's Law to classify and identify the soil. Figure 9 shows the coefficient table.

Range of values for k (m/s)

|                  |                                           |
|------------------|-------------------------------------------|
| 10 <sup>2</sup>  | Clean gravels                             |
| 10               |                                           |
| 1                |                                           |
| 10 <sup>-1</sup> |                                           |
| 10 <sup>-2</sup> | Clean sands<br>Gravel-sand mixtures       |
| 10 <sup>-3</sup> |                                           |
| 10 <sup>-4</sup> |                                           |
| 10 <sup>-5</sup> | Very fine sands<br>Silt and silty clays   |
| 10 <sup>-6</sup> |                                           |
| 10 <sup>-7</sup> |                                           |
| 10 <sup>-8</sup> | Clay silts (>20% clay)<br>unfissured clay |
| 10 <sup>-9</sup> |                                           |

Figure 9 – Permeability table for Darcy's law to classify and identify soil.

Our soil sample 1 falls within the clean sands/gravel-sands mixtures category.

## **Soil Sample 2**

We then repeated the test again for soil sample 2 this time for 15, 30 and 45 seconds and seeing how much water was collected we then inserted the values into the equations again.

The table below shows the values collected.

|                              |       |     |       |
|------------------------------|-------|-----|-------|
| Vol. of Water Collected (ml) | 380   | 725 | 1830  |
| Time Aimed (s)               | 15    | 30  | 45    |
| Actual Time (s)              | 15.05 | 30  | 45.21 |

We then need to remeasure our 'H' & 'L' values for the equation

$$H = 0.001$$

$$L = 0.072$$

We can now calculate our K value for each sample starting with Sample 2 test 1 our Q value for this test is  $380 \times 10^{-6} = 0.000380$

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

$$K = \frac{0.000380 \times 0.072}{0.00478 \times 0.001 \times 15.05}$$

$$K = 0.380$$

We can then repeat this for sample 2 test 2 with Q value 0.000725

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

$$K = \frac{0.000725 \times 0.072}{0.00478 \times 0.001 \times 30}$$

$$K = 0.364$$

We also repeated this test for Sample 2 test 3 and produced a final K value of 0.0609, however we are to disregard this value due to equipment/human error where there was air within the system.

We therefore only average the first two results

K1 + K2 and divide by 2 for the average giving a K value of 0.372m/s.

We then once again input this into our permeability table (figure 9) giving a value around the clean sands/gravel sands mixtures sample result.

## 2.4 Conclusion

Overall, from using the constant head permeameter test we have been able to classify both samples within our permeability table and able to classify them as clean sands and gravel-sand mixtures.

These tests allow us to gain knowledge in solving real engineering problems that involve an amount of water and its effect on bearing strata's, seepage through earthen dams and also the stability of embankments and dams alike. As water enters the water table and soil the rate at which water permeates through the surface will greatly affect how stable the soil is, where the ground is fully saturated there is no shear resistance on the soils and therefore can fail under pressure and cause a structure to collapse. These calculations can help an engineer effectively design a foundation/structure to mitigate any potential risks that may be induced. The higher the permeability the faster the water will drain and vice versa.

There were some limitations that should be considered namely human error in timing of the results while aiming on the stopwatch for a given time it is inevitable that some additional water will get into the cylinder. There was also an error on sample 2 test 3 where air got into the permeameter.

### 3.0 Particle Size Distribution Test

#### 3.1 Introduction

The purpose of a Particle Size Distribution Test is to help determine the percentage of each size of grain that is contained within any given soil sample. The size of a soil particle ultimately affects the overall characteristic of a soil. Once the test has been completed, we can then use the data to plot a size distribution curve. There are two tests that are typically used for finding grain size distribution, the first being sieve analysis which is used for particle sizes that are greater than 0.075mm in diameter and the second being Hydrometer analysis for particles less than 0.075mm in diameter. To this test, we will be using the Particle Sieve analysis test this will be performed to the British standard procedure 'BS 812-103.1: 1989' (British Standards Institution, 1989).

The particle sieve analysis test will allow us to determine the particle size distribution (usually for sand and gravels) but shouldn't be used as the sole method for determining grain size of finer samples. We will then be able to comment on the sample and its suitability for use.

Soils are usually categorised as the below:

- Clay = less than 0.002mm
- Silt = 0.002mm – 0.063mm
- Sand = 0.063 – 2mm
- Gravel = 2mm to 20mm (medium)

Once we have our results, we can then determine the gradation, this is defined as the textural distribution of a particular soil sample. A larger gradation will mean a wider particle size distribution, thus a more 'well graded' sample will indicate a wider range of sizes (e.g. glacial tills) and 'poorly graded' indicates a narrow range (e.g. beach sand).

#### 3.2 Methodology

##### **Equipment**

- Stack of sieves with a cover from 4.75mm sieve size to <0.0038mm (range of sizes seen in results table).
- Digital Scales
- Oven

- Various Brushes
- Mechanical sieve shaker
- Metal Pans
- Soil Sample (737.88g)

### **Methodology Steps**

1. Weigh our scale pan and record results in table.
2. Collect a sample of our soil (737.88g) Weigh this using our digital scales and accurately measure the sample to the nearest 0.1g and record the weight.
3. Place the set of sieves with the largest opening on top to the smallest opening on the bottom on the mechanical sieve shaker and pour the aggregate onto the top sieve (figure 10)



Figure 10 – Pouring our sample soil into the sieve (Hossain, Islam, Badhon and Imtiaz, 2022)

4. Secure the stack into the machine and turn on the shaker to vibrate the sample for 2 minutes, after this stop the machine and remove the top lid (figure 11).



Figure 12 – securing sieves into vibration machine (Hossain, Islam, Badhon and Imtiaz, 2022)

5. Weigh an empty metal pan and record the weight of this into our table (do this for each measurement of sample as we move through sieve sizes).
6. Take the top sieve off and brush all the soil within this sieve into our empty weighed metal pan.
7. Weigh the metal pan with soil sample to the nearest 0.1g and record this within our table.
8. Empty the metal container with soil sample contained and ensure to brush off any excess residue.
9. Repeat above steps for each sieve size (steps 5-8).
10. Repeat this process until the weight of the material on each sieve has been recorded
11. Record all the percentages to the nearest 0.1% for each size of aggregate retained on each sieve
12. Ensure to prevent as best as possible the loss of material during the sieving operation. There should be a minimum loss of less than 0.2% for the original dry weight and sum of the weights measured at the various sizes. If the discrepancy is greater ensure to repeat the test with a new sample to correct the error.
13. Finally plot the sieve size against the percentage passing for the sample measured on a particle size distribution chart.

### 3.3 Results and Analysis

The results of the test are highlighted in the table below from the test above:

#### Particle Size Distribution Test

Original Pan Weight =  
276.76g

#### Results Table

|             |         |
|-------------|---------|
| Sample Size | 737.88g |
|-------------|---------|

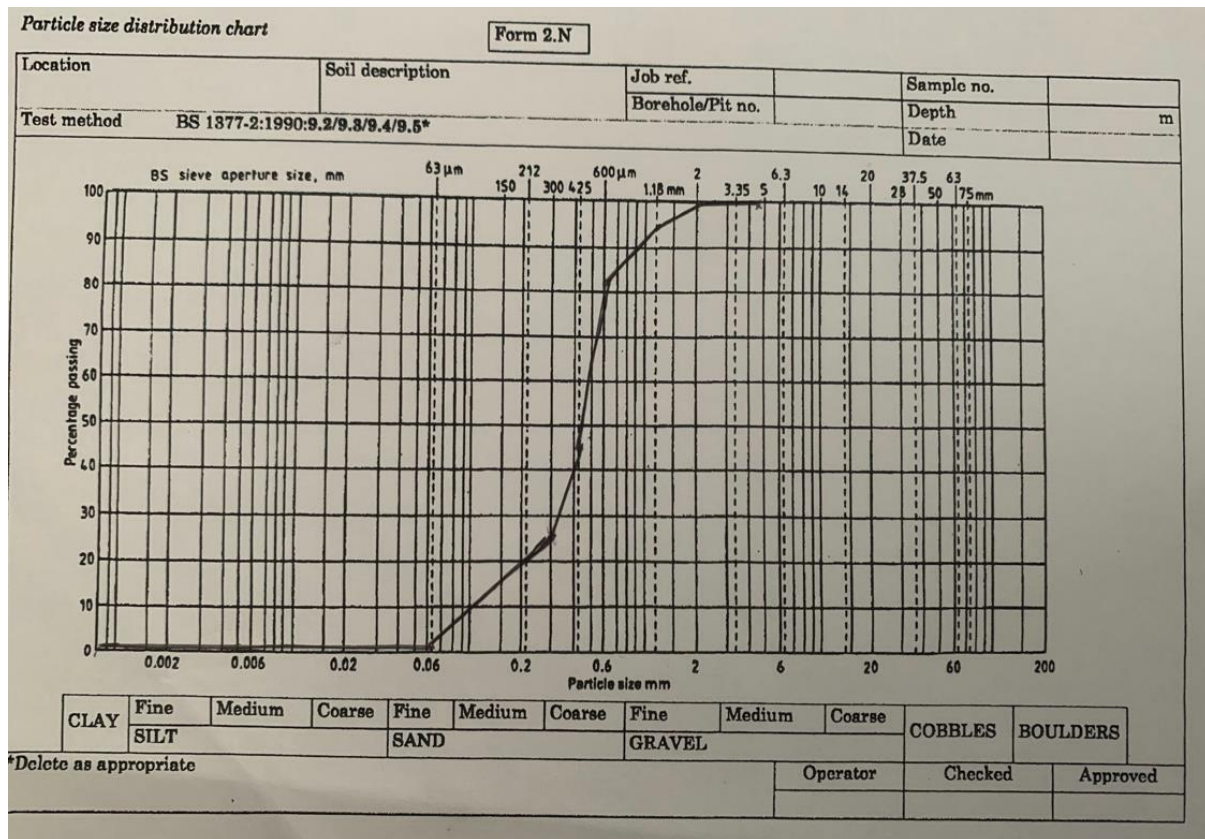
| Sieve Size (mm) | Mass (g) | % on Sieve | % Passing | Weight of Pan & Sample (g) |
|-----------------|----------|------------|-----------|----------------------------|
| 4.75            | 0.67     | 0.09       | 99.91     | 277.43                     |
| 2               | 5.86     | 0.79       | 99.12     | 282.62                     |
| 1.18            | 33.79    | 4.58       | 99.54     | 310.55                     |
| 0.6             | 90.08    | 12.2       | 82.34     | 366.84                     |
| 0.425           | 273.13   | 37.01      | 45.33     | 549.89                     |
| 0.3             | 141.2    | 19.13      | 26.2      | 417.96                     |
| 0.063           | 185.1    | 25.08      | 1.12      | 461.86                     |
| 0.045           | 3.15     | 0.42       | 0.7       | 279.91                     |
| 0.038           | 1.36     | 0.18       | 0.52      | 278.12                     |
| <0.038          | 1.75     | 0.23       | 0.29      | 278.51                     |

|       |        |       |
|-------|--------|-------|
| Total | 736.09 | 99.75 |
|-------|--------|-------|

- The sand percentage from 4.75mm to 0.063mm totals to 729.16g and a percentage of 98.81% by mass
- The silt passing at 0.045mm sieve totals to 3.15g and 0.42% by mass
- Clay from 0.038mm and <0.038mm sieve sizes to 3.11g and 0.41% by mass

It should be noted that on a typical test due to the total retained weight at the end of the experiment is greater than 0.2% at 0.25% and therefore should be repeated this is down to human error (in this case due to time constraints we continued and outlined this potential for anomaly in results.

We next plotted a grain-size distribution chart as seen below.



From the above it can be seen that the sample is uniform where it is a relatively narrow range of sand to gravel and therefore likely is a sand due to a large portion falling within the coarse-grained sand section.

### 3.4 Conclusion

To conclude our sample is a coarsely grained sand that is uniform in nature with some small amounts of fines and gravels. This test is often used as it is simplistic and easy to interpret however it only gives a general classification of the sample and further results must be inferred from the data.

This method is useful for bulk materials, however there are some disadvantages with human error through loss of soil sample as seen in our experiment where normally we would have to repeat the test due to greater loss than 0.2% of our sample, this was likely due to some of the sample getting retained within the sieves and sometimes difficult for some of the grains to pass.

This test however does provide an engineer to determine compliance for design and control, and in addition with other analysis tests such as the constant head permeameter test and liquid and plastic limit tests allow a good understanding overall of the samples.

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