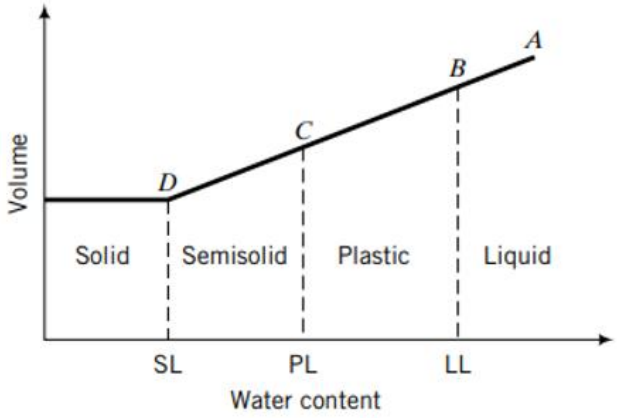
SMG-04: ATTERBERG LIMIT TEST

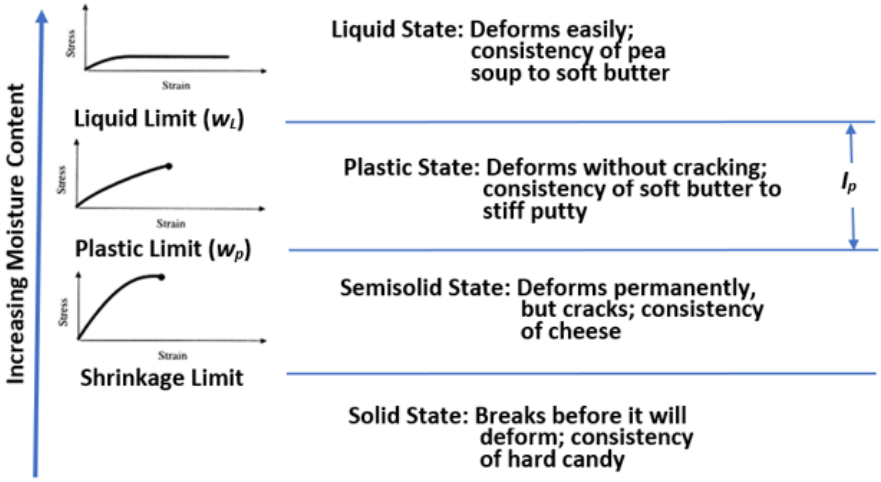
(Determination of Liquid Limit, Plastic Limit and Plasticity Index)

Reference Standard: BS EN ISO 17892-12; BS1377: Part 2:1990 and BS1377: Part2:1990:5.3; ASTM D4318 and BS 1377: Part 2: 1990:4.3; ASTM D427

Fine-grained soil can exist in four distinct states or consistency: solid, semi-solid, plastic and liquid in order of increasing moisture content. The moisture content, in percent at which the transition from solid, to semi-solid, to plastic and to liquid is defined as shrinkage limit (SL or w_S), plastic limit (PL or w_P) and liquid limit (LL or w_L) respectively (Figure 1).



Changes in soil states as a unction of soil volume and water content
(source: Budhu M. 2011)



Consistency and stress-strain relationship of fine-grained soil at different mlisture content
(adapted from Coduto, 1998)

Figure 1: The four states of fine-grained soil and the Atterberg limits

Clay soil will exhibit plasticity between certain limit of water content due to its high clay mineral content, whereas silt exhibit only slightly plastic. When water is added to fine-grained soil containing clay minerals, each clay particles is covered with a film of water called the adsorbed water. This film of water gives the cohesive nature of the soil making the soil soft and pliable. To determine the plasticity characteristic of a fine-grained soil, PL and LL must be obtained. The range of moisture content when the soil behaves as plastic; that is between PL and LL is termed as Plasticity Index (PI or I_P). Hence, PI is the difference between PL and LL.

$$PI = LL - PL$$

The plasticity index PI and liquid limit LL will then be used to identify whether the fine-grained soil is clay or silt using any engineering classification of soil.

DATA PROCESSING

From data recorded in Form 2.C, perform the following tasks to determine Plastic Liit (PL), Liquid Limit (LL) and Plasticity Index (PI)

LIQUID LIMIT

1) Calculate the moisture content of each test sample.
2) Plot the relationship between moisture content and cone penetration with the percentage moisture contents as abscissa and the cone penetrations as ordinates, both on linear scale.
3) Plot the best straight line fitting the points and read off the moisture content corresponding to a cone penetration of 20 mm. Report this reading to the nearest whole number as the liquid limit (LL or w_L) of the soil sample.

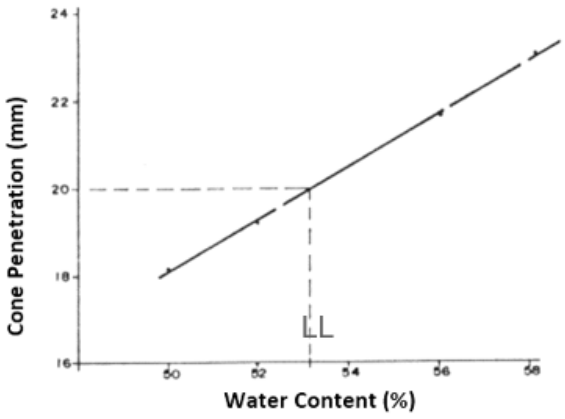


Figure 5: Determination of LL from cone penetrometer graph

PLASTIC LIMIT

1) Calculate the average of moisture content and record this value to the nearest whole number as plastic limit (PL or w_P). If the difference between the two results is more than 0.5% repeat the whole test

PLASTICITY INDEX

1) Calculate the plasticity index as PI=LL-PL.

OBJECTIVE

To determine the plasticity characteristic of a soil sample passing 425 µm test sieve by obtaining the liquid limit (LL) using the Cone Penetrometer test and plastic limit (PL) using the Plastic Limit test for soil classification purposes.

LIQUID LIMIT TEST (CONE PENETROMETER METHOD)

(Use form 2.C (extract from BS1377: Part 2: 1990))

APPARATUS

List out equipment and apparatus use in the experiment complete with figures.

PROCEDURE

1) Take and place 200g soil sample that pass 425μm sieve onto the glass plate. Mix thoroughly with distilled water using the palette knife to a consistency for at least 10 minutes so that the first cone penetration reading is about 15 mm.
2) Push a portion of the mixed soil into the cup in several layers with a palette knife taking care not to trap air. Strike off excess soil with the straightedge to give a smooth level surface.
3) Lower the cone assembly so that the tip of the cone just touches the centre of the soil surface. Adjust / zero the dial gauge and record the initial reading to the nearest 0.1 mm.
4) Release the cone for the period of 5 ± 1 second. Record this final reading and record the difference between the final and the initial reading as the cone penetration.
5) Lift out the cone and clean it carefully.
6) Add a little more wet soil and level off. Repeat procedure (3) to (5). If the difference between the first and second reading < 0.5 mm, record the cone penetration as average of the two and proceed. If the difference between the first and second reading is 0.5 mm – 1.0 mm, carry out third test and if the overall range is less than 1 mm, record the cone penetration as average of the three readings. If overall range is more than 1 mm, remove the soil, remix and repeat (2) to (5).
7) Take about minimum mass of 15 g of the sample from the cup with the smaller palette knife for determination of moisture content.
8) Return the sample from the cup to the glass plate and add more distilled water. Mix thoroughly and repeat procedure (2) to (7) for at least four points with different water content. Proceed from drier to the wetter condition of the soil so that a range of penetration values approximately 15 – 25 mm is covered by 4 or more evenly spaced test points.
9) Each time when the cup is emptied, the cup must be cleaned and dried.
10) After 24 hours, determine the moisture content for all test runs. Record all data using Form 2.C (extract from BS1377: Part 2: 1990)

PLASTIC LIMIT TEST

(Use Form 2.C (extract from BS1377: Part 2: 1990))

APPARATUS

List out equipment and apparatus use in the experiment complete with figures.

PROCEDURE

1) Take 20g of mixed soil sample from liquid limit test (drier one) and mold the ball of soil between palms until the heat of the hands has dried the soil sufficiently for slight cracks to appear on its surface.
2) Divide the sample into 2 (10 g each); put one portion aside in air-tight container. Carry out test for each 10 g separately.
3) Divide the first 10 g into 4 (2.5 g each).
4) Take one sample (keeping the other three of 2.5g in another air-tight container), knead lightly and mold into 6 mm diameter thread using first finger and thumb. Transfer onto the glass plate.
5) Roll the thread between the fingers, from fingertip to the second joint, of one hand and the surface of the glass rolling plate. Use enough pressure to reduce the diameter of the thread to about 3 mm in five to 10 complete forward and backward movements of the hand. Stop when thread shears both longitudinally and transversely. The first crumbling point is the plastic limit.
6) Gather the portions of the crumbled soil thread, put them in air-tight container.
7) Repeat (4) to (6) placing all the three portions in the same container as in the first one. Test for moisture content.
8) Repeat procedure (4) to (7) for the next 10g.
9) After 24 hours, determine the moisture content. Record all data using Form 2.C (extract from BS1377: Part 2: 1990)

Note: It is important to maintain a uniform rolling pressure throughout; do not reduce pressure as the thread approaches 3 mm diameter. Crumbling must be the result of the decreasing moisture content only and not due to mechanical breakdown caused by excessive pressure, or oblique rolling or detachment of an excessive length beyond the width of the hand).

Figure 4: Determination of plastic limit

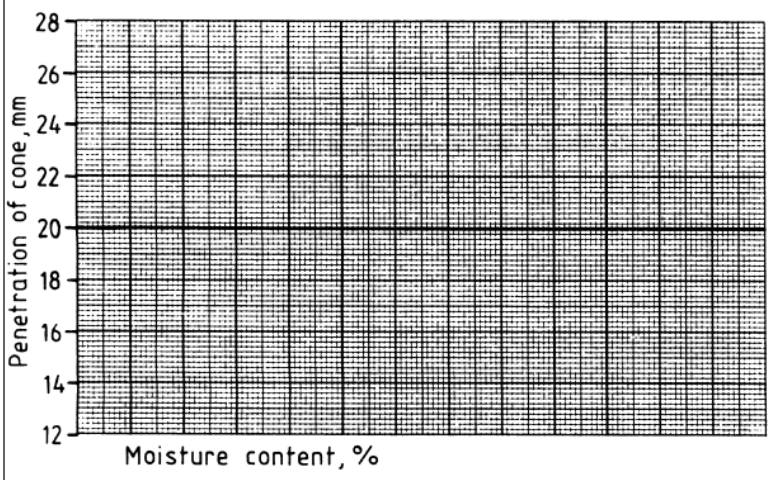
DATA SHEET

Liquid limit (cone penetrometer) and plastic limit | Form 2.C

Location		Job ref.	
		Borehole/Pit no.	
Soil description		Sample no.	
		Depth	m
Test method	BS 1377-2:1990:**4.3/4.4***	Date	

PLASTIC LIMIT	Test no.	1	2	Average
Container no.				
Mass of wet soil + container	g			
Mass of dry soil + container	g			
Mass of container	g			
Mass of moisture	g			
Mass of dry soil	g			
Moisture content	%			

LIQUID LIMIT	Test no.	1	2	3	4
Initial dial gauge reading	mm				
Final dial gauge reading	mm				
Average penetration	mm				
Container no.					
Mass of wet soil + container	g				
Mass of dry soil + container	g				
Mass of container	g				
Mass of moisture	g				
Mass of dry soil	g				
Moisture content	%				



Sample preparation*

as received
washed on 425 µm sieve
air dried at .....°C
oven dried at .....°C
not known
Proportion retained
on 425 µm sieve .....%

Liquid limit %

Plastic limit %

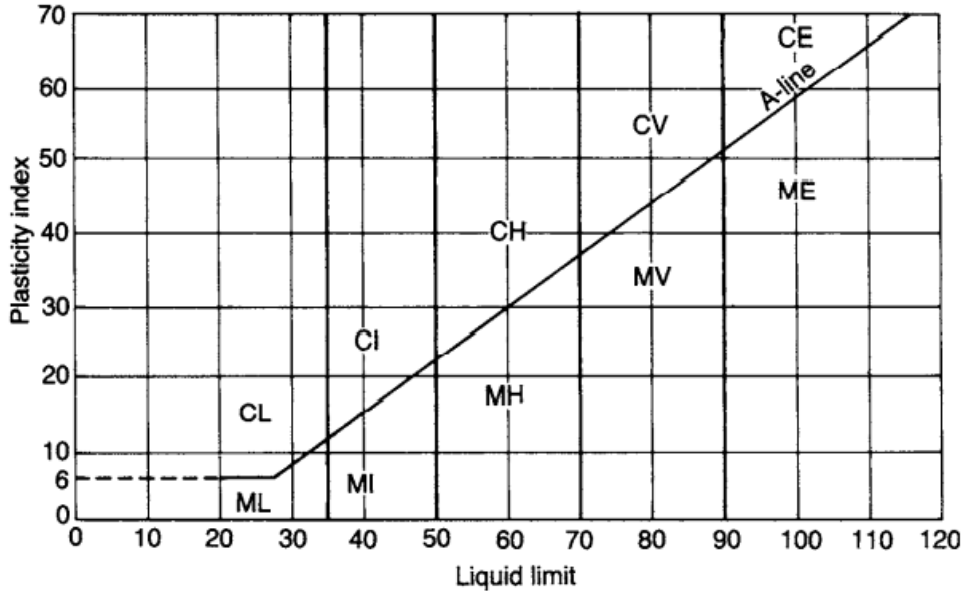
Plasticity index

* Delete as appropriate

Operator	Checked	Approved

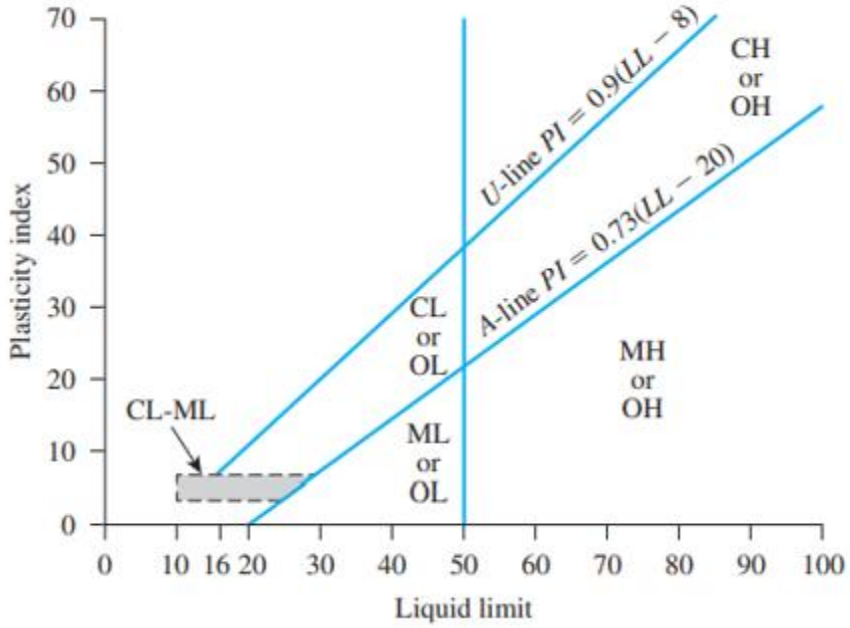
(Source: extracted and adapted fromBS1377: Part 2: 1990)

PLASTICITY CHART



The British Soil Classification System (BSS) Plasticity Chart

(Source: Knappett J. and Craig R. F. (2012))



The Unified Soil Classificatiion System (USCS)Plasticity Chart

(Source: Das B. M. (2006))

Figure 6: Plasticity Charts