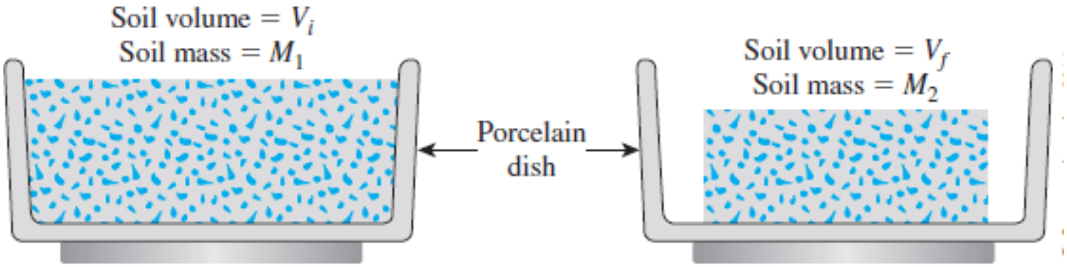
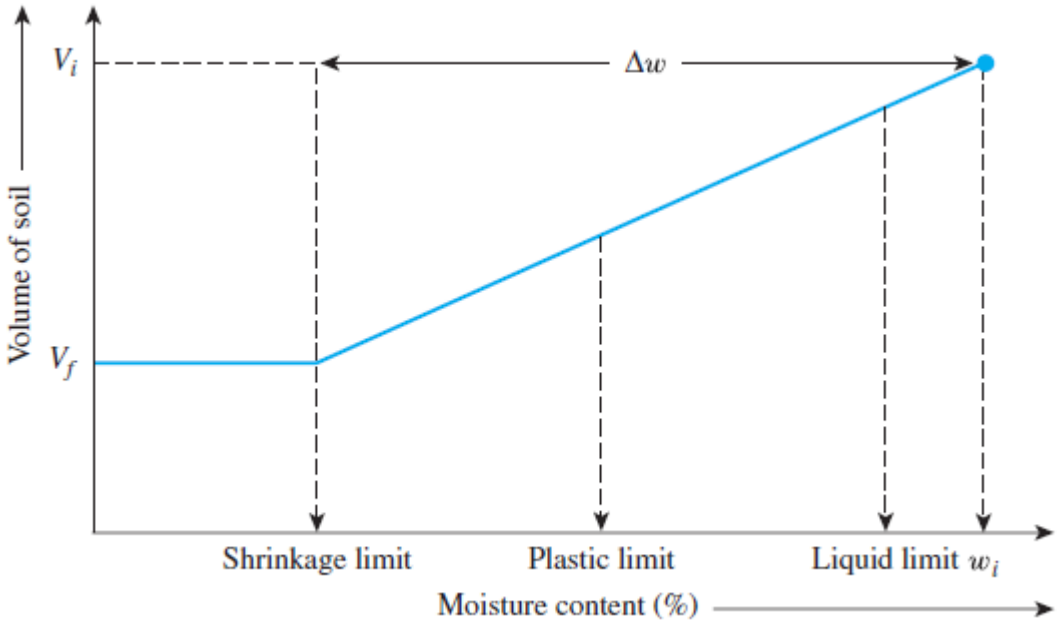
Shrinkage Limit (*SL*)

Soil shrinks as moisture is gradually lost from it. With continuing loss of moisture, a stage of equilibrium is reached at which more loss of moisture will result in no further volume change. The moisture content, in percent, at which the volume of the soil mass ceases to change is defined as the shrinkage limit.

Shrinkage limit tests [ASTM D-427] are performed in the laboratory with a porcelain dish about 44 mm in diameter and about 12.7 mm high. The inside of the dish is coated with petroleum jelly and is then filled completely with wet soil. Excess soil standing above the edge of the dish is struck off with a straightedge. The mass of the wet soil inside the dish is recorded. The soil pat in the dish is then oven-dried. The volume of the oven-dried soil pat is determined by the displacement of mercury.





the shrinkage limit can be determined as

$$SL = w_i\,(\%) - \Delta w\,(\%)$$

where w_i = initial moisture content when the soil is placed in the shrinkage limit dish
Δw = change in moisture content (that is, between the initial moisture content and the moisture content at the shrinkage limit)

However,

$$w_i\,(\%) = \frac{M_1 - M_2}{M_2} \times 100$$

where M_1 = mass of the wet soil pat in the dish at the beginning of the test (g)
M_2 = mass of the dry soil pat (g)

$$\Delta w\,(\%) = \frac{(V_1 - V_f)\rho_w}{M_2} \times 100$$

where V_i = initial volume of the wet soil pat (that is, inside volume of the dish, cm^3)
V_f = volume of the oven-dried soil pat (cm^3)
ρ_w = density of water (g/cm^3)

$$SL = \left(\frac{M_1 - M_2}{M_2}\right)(100) - \left(\frac{V_i - V_f}{M_2}\right)(\rho_w)(100)$$

Example

Following are the results of a shrinkage limit test:

- Initial volume of soil in a saturated state = 24.6 cm3
- Final volume of soil in a dry state = 15.9 cm3
- Initial mass in a saturated state = 44.0 g
- Final mass in a dry state = 30.1 g

Determine the shrinkage limit of the soil.

Solution

$$SL = \left(\frac{M_1 - M_2}{M_2}\right)(100) - \left(\frac{V_i - V_f}{M_2}\right)(\rho_w)(100)$$

$M_1 = 44.0\text{g}$ $\quad V_i = 24.6\ cm^3$ $\quad \rho_w = 1\ g/cm^3$

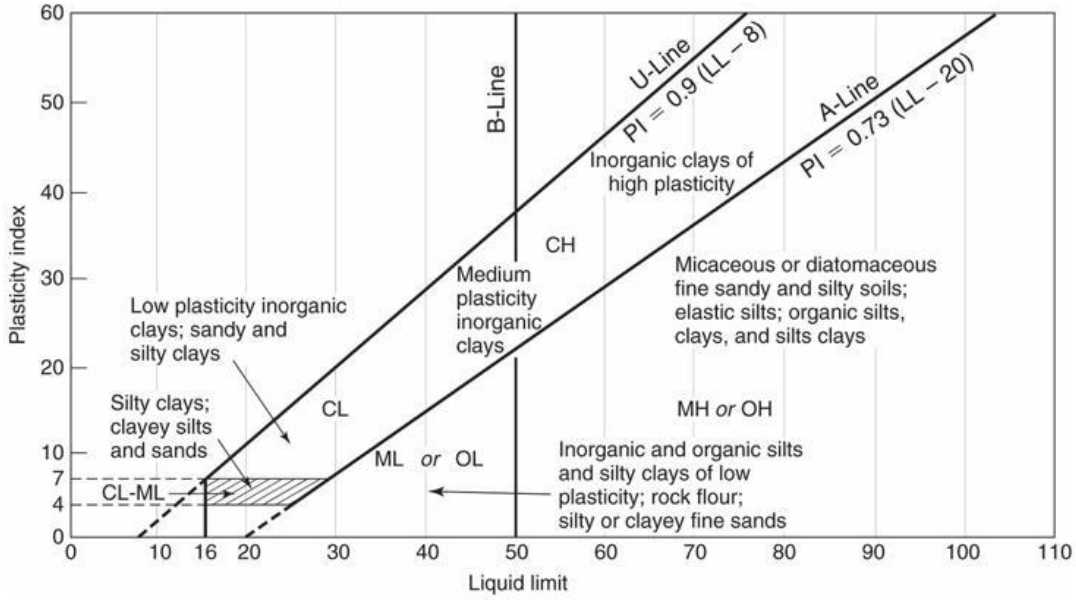
$M_2 = 30.1\text{g}$ $\quad V_f = 15.9\ cm^3$

$$SL = \left(\frac{44.0 - 30.1}{30.1}\right)(100) - \left(\frac{24.6 - 15.9}{30.1}\right)(1)(100)$$

$$= 46.18 - 28.9 = \mathbf{17.28\%}$$

Plasticity Chart

Liquid and plastic limits are determined by relatively simple laboratory tests that provide information about the nature of cohesive soils. Engineers have used the tests extensively for the correlation of several physical soil parameters as well as for soil identification



Casagrande (1932) studied the relationship of the plasticity index to the liquid limit of a wide variety of natural soils. On the basis of the test results, he proposed a plasticity chart . The important feature of this chart is the empirical *A*-line that is given by the equation $PI = 0.73(LL - 20)$. An *A*-line separates the inorganic clays from the inorganic silts. Inorganic clay values lie above the *A*-line, and values for inorganic silts lie below the *A*-line. Organic silts plot in the same region (below the *A*-line and with *LL* ranging from 30 to 50) as the inorganic silts of medium compressibility. Organic clays plot in the same region as inorganic silts of high compressibility (below the *A*-line and *LL* greater than 50). The information provided in the plasticity chart is of great value and is the basis for the classification of fine-grained soils in the Unified Soil Classification System.

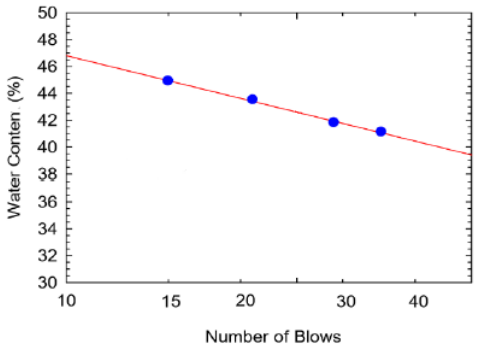
Note that a line called the *U*-line lies above the *A*-line. The *U*-line is approximately the upper limit of the relationship of the plasticity index to the liquid limit for any currently known soil. The equation for the *U*-line can be given as

$$PI = 0.9(LL - 8)$$

Soil Mechanics

Chapter Three – Soil Consistency

Example1: The Figure below represents the data that was obtained from a liquid-limit test on a silty clay soil. The soil is consisting of 55% of clay and 45% of silt and has a water content equals to 35%. Three plastic-limit determinations had water contents of 24.2%, 24% and 23.8%. Determine:



1- Liquid Limit (LL).

2- Plastic Limit (PL).

3- Plasticity Index (PI)

4- Soil Activity (A).

5- Liquidity Index (LI).

6- Consistency Index (CI).

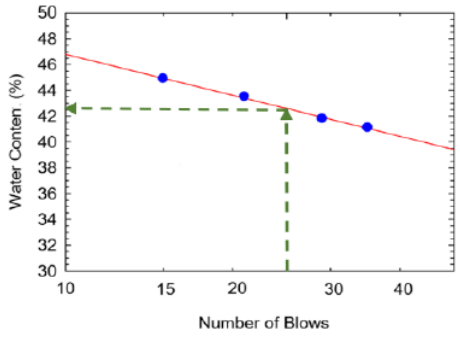
7- The degree of plasticity using Burmister (1949).

8- Classify the soil using Casagrande plasticity chart.

Solution:

1- لايجاد حد السيولة (LL) نستخدم الرسم المعطى في السؤال والذي هو نتيجة للفحص مختبري الذي تم التحدث عنه بالمحاضرة. من تعريف حد السيولة مختبريا (هو المحتوى المائي المقابل لعدد ضربات 25) اذا نسقط 25 من محور X ونقرأ المحتوى المائي من محور Y هو يمثل حد السيولة اذا يساوي تقريبا:

Liquid Limit (LL) = 42.8%



2- لايجاد حد اللدونه (PL) في السؤال معطى ثلاث قيم للمحتوى المائي لكل محاولة في تجربة حد اللدونة.
اذا ناخذ المعدل للمحاولات الثلاثة فقط هو يساوي حد اللدونة :

(24.2% + 24% + 23.8%) / 3 = 24% ……. PL = 24%

3- لحساب مؤشر اللدونة plasticity Index (PI) هو الفرق بين LL و PL

Plasticity Index (PI) = LL – PL = 42.8% - 24% = 18.8%

4-لحساب فعالية التربة (Soil Activity, A) نستخدم المعادلة المذكورة في المحاضرة by Skempton (1953):

$$A = \frac{PI}{\%\ of\ Clay}$$

$$A = \frac{18.8\%}{55\%} = 0.34$$

5- لحساب مؤشر السيولة Liquidity Index (LI) نستخدم المعادلة التالية:

$$LI = \frac{w - PL}{LL - PL} = \frac{35\% - 24\%}{42.8\% - 24\%} = 0.585$$

6- لحساب مؤشر القوام Consistency Index (CI) نستخدم المعادلة التالية:

$$CI = \frac{LL - w}{LL - PI} = \frac{42.8\% - 35\%}{42.8\% - 18.8\%} = 0.325$$

7- لايجاد درجة اللدونة Degree of Plasticity نستخدم الجدول المعطى بالمحاضرة Burmister (1949) والذي نحتاج فيه الى Plasticity Index والذي سبق وتم حسابه = 18.8% ومن النظر الى الجدول نجد ان مؤشر اللدونة يقع ضمن 10 to 20 كما تم تاشيره ادناه. اذا التربة ذات لدونة متوسطة Medium plasticity

Plasticity Characteristics According to the Plasticity Index Burmister (1949)

Plasticity index	*Plasticity*
0	Non-plastic
1 to 5	Slight
5 to 10	Low
10 to 20	Medium
20 to 40	High
> 40	Very high

8-لايجاد تصنيف التربة باستخدام Casagande plasticity chart والذي نستخدمه دائما لتصنيف الترب الناعمة فقط والتي تكون فيها نسبة المواد العابرة من منخل رقم 200 اكبر من 50%. نحتاج ال LL و PI لاستخدام المخطط كما موضح بالصورة ادناه حيث ان نقطة تقاطع الخطين تقع ضمن منطقة ال CL المؤشرة بالدائرة أي بمعنى Clay Low plasticity اذا التربة CL