

Relative Density

Chapters 3.5

Relative Density

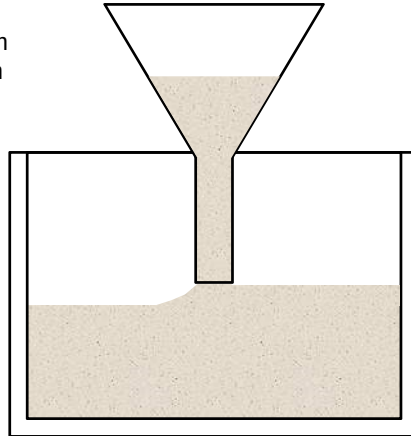
$$D_r = \frac{e_{\max} - e}{e_{\max} - e_{\min}} = \frac{\left[\frac{1}{\gamma_{d(\min)}} \right] - \left[\frac{1}{\gamma_d} \right]}{\left[\frac{1}{\gamma_{d(\min)}} \right] - \left[\frac{1}{\gamma_{d(\max)}} \right]}$$

Table 3.2 Qualitative description of granular soil deposits

Relative density (%)	Description of soil deposit
0–15	Very loose
15–50	Loose
50–70	Medium
70–85	Dense
85–100	Very dense

Minimum Density

Pluviate soil from
height of 25 mm



Maximum Density

Vibrate for 8 minutes



Relative Density Correlations

Clean sand ($0 \leq F_c \leq 5\%$)

$$e_{\max} = 0.072 + 1.53 e_{\min}$$

Sand w/ fines ($5 \leq F_c \leq 15\%$)

$$e_{\max} = 0.25 + 1.37 e_{\min}$$

Sand w/ fines and clay ($15 \leq F_c \leq 30\%$)

$$e_{\max} = 0.44 + 1.21 e_{\min}$$

$$e_{\max} - e_{\min} = 0.23 + \frac{0.06}{D_{50} \text{ (mm)}}$$

Relative Density Correlations

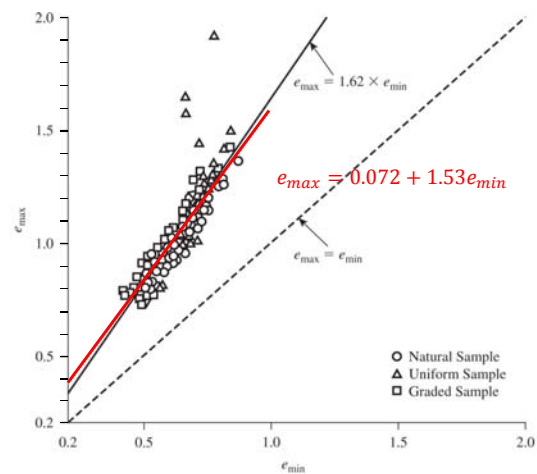
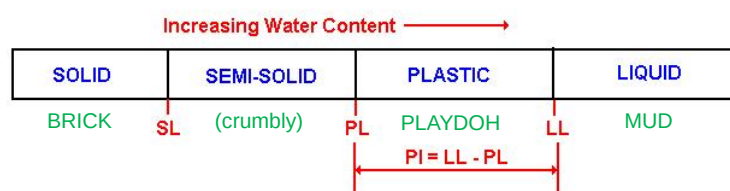


Figure 3.7 Test results of Miura et al. (1997)—plot of $e_{\max}$ vs. $e_{\min}$ for clean sand

Soil Consistency

Chapter 3.6

Atterberg Limits



Liquid Limit Device



Liquid Limit Determination

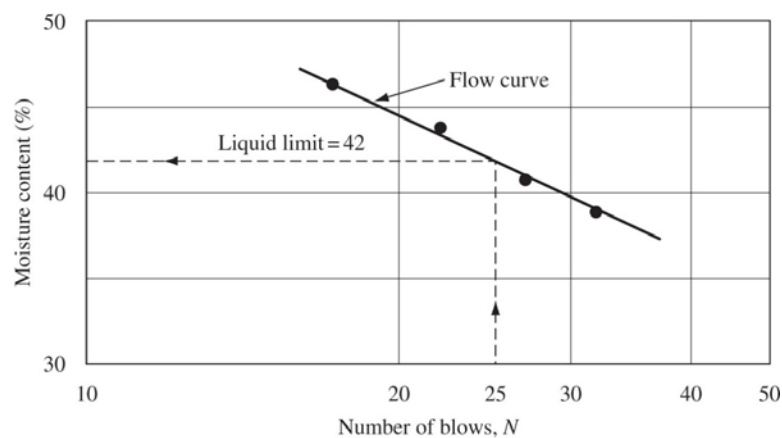


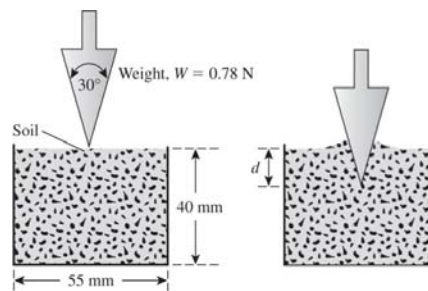
Figure 3.11 Flow curve for liquid limit determination of a silty clay

Plastic Limit Determination



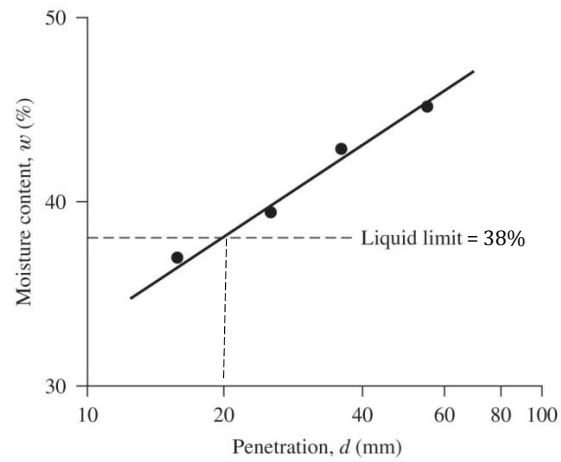
Figure 3.14 Plastic limit test (Courtesy of Braja M. Das, Henderson, Nevada)

Fall Cone

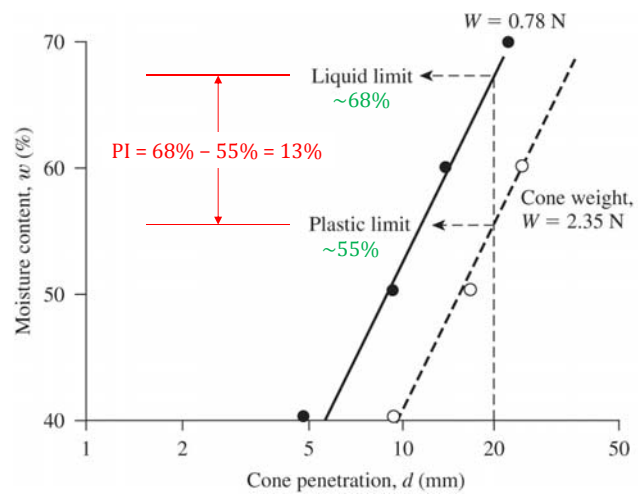


20 mm penetration in 5 seconds @ LL

Fall Cone



Fall Cone



Shrinkage Limit

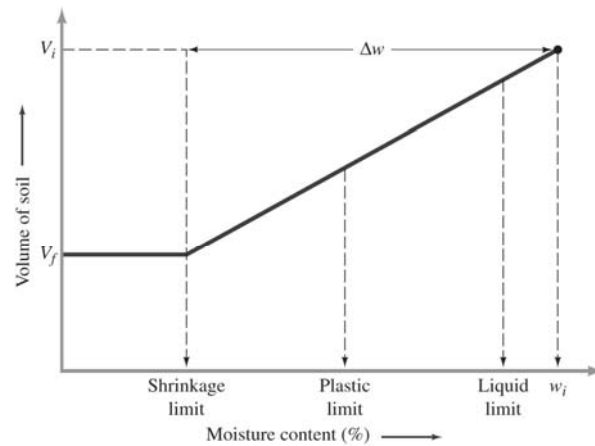


Figure 3.16 Definition of shrinkage limit

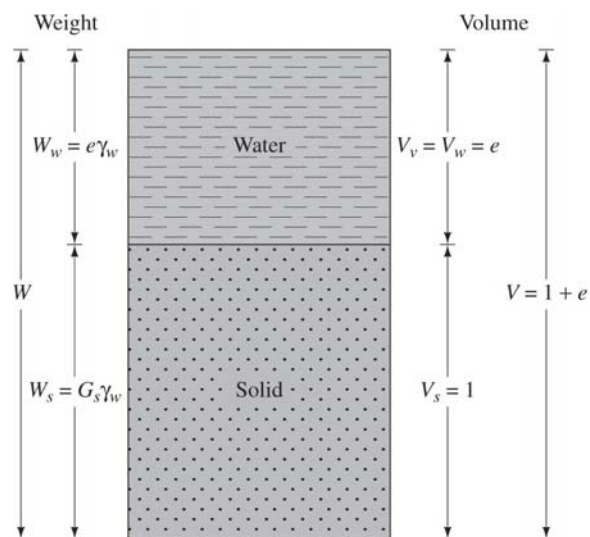


Figure 3.3 Saturated soil element with volume of soil solids equal to 1

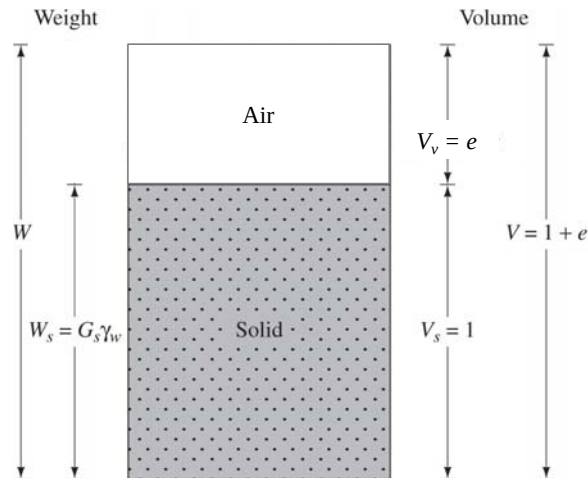


Figure 3.3 Saturated soil element with volume of soil solids equal to 1

Shrinkage Limit

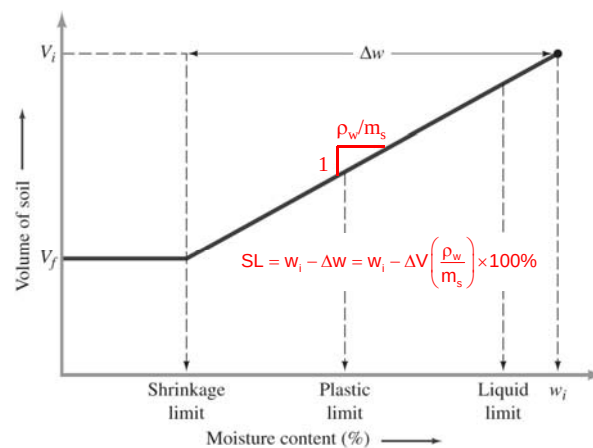


Figure 3.16 Definition of shrinkage limit

Shrinkage Limit

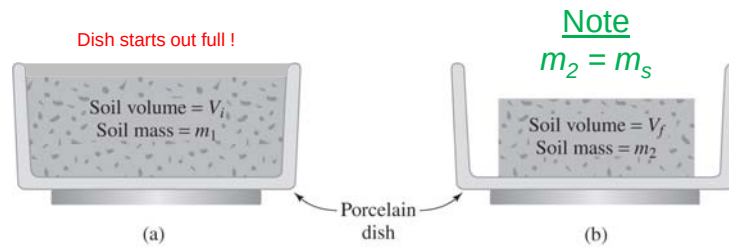


Figure 3.17 Shrinkage limit test: (a) soil pat before drying; (b) soil pat after drying

$$SL = \left(\frac{m_1 - m_2}{m_2} \right) (100) - \left[\frac{(V_i - V_f) \rho_w}{m_2} \right] (100)$$

Activity

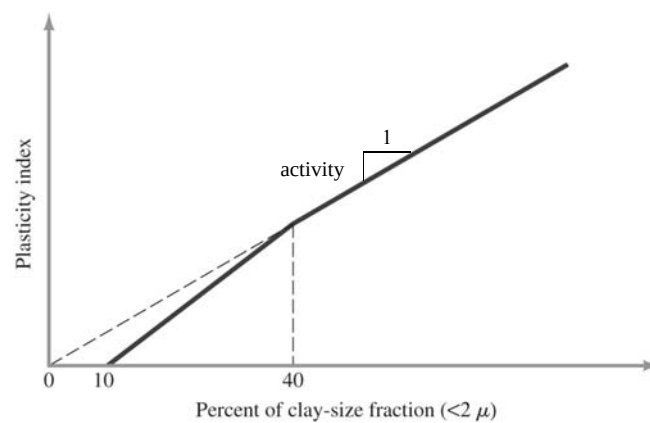


Figure 3.18 Simplified relationship between plasticity index and percent of clay-size fraction by weight

Activity

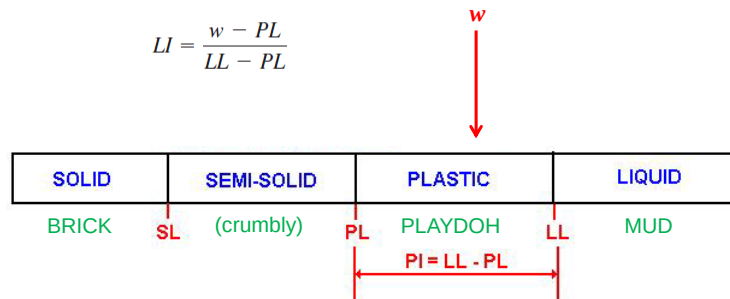
$$A = \frac{PI}{\text{percent of clay-size fraction, by weight}}$$

Table 3.3 Activity of clay minerals

Mineral	Activity, <i>A</i>
Smectites	1–7
Illite	0.5–1
Kaolinite	0.5
Halloysite (2H ₂ O) (unhydrated)	0.5
Holloysite (4H ₂ O) (hydrated)	0.1
Attapulgite	0.5–1.2
Allophane	0.5–1.2

Liquidity Index

$$LI = \frac{w - PL}{LL - PL}$$



Plasticity Chart

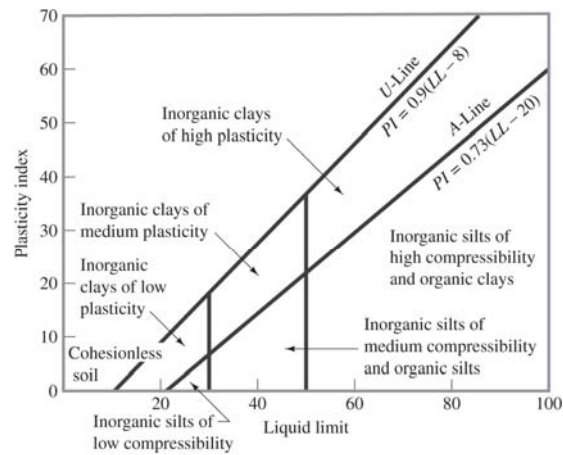
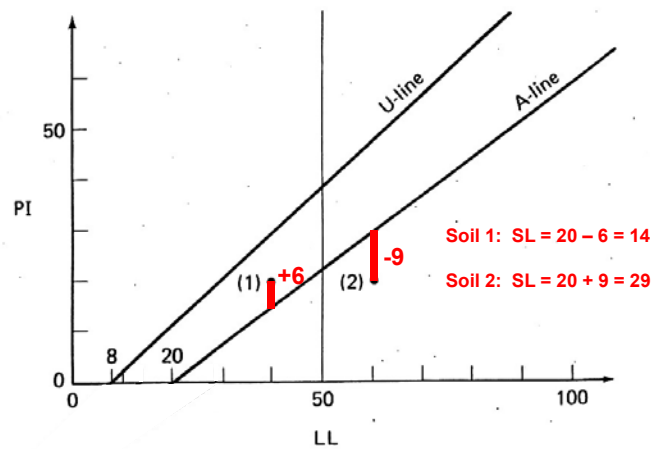


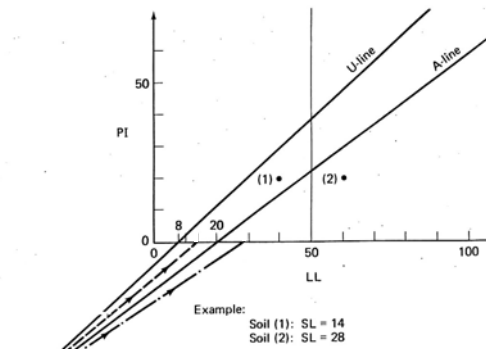
Figure 3.19 Plasticity chart

Shrinkage Limit



(Holtz & Kovacs, An Introduction to Geotechnical Engineering, 1981)

Shrinkage Limit



Casagrande's procedure for estimating the shrinkage limit.

(Holtz & Kovacs, *An Introduction to Geotechnical Engineering*, 1981)