The University of Iowa
Department of Civil & Environmental Engineering
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53:030 Soil Mechanics
Lab Experiment No. 4:
Shrinkage Limit Measurement

Equipment: Evaporating dish, shrinkage dish, spatula, steel straightedge, shrinkage limit dish [*i.e.* the glass cup ($2\frac{1}{2}$ in. in diameter and $1\frac{1}{4}$ in. in depth)], glass plate with metal prongs, balance, liquid mercury, petroleum jelly, water squeeze bottle, and paper towels.

A. Background

The *shrinkage limit* is the water content dividing the semisolid and solid states of a soil. It is quantified for a given soil as the water content that is just sufficient to fill the voids when the soil is at the minimum volume it will attain on drying. Restated, the smallest water content at which a soil can be completely saturated at this dry volume is called the *shrinkage limit.* Below the *shrinkage limit* (SL), any water content change **will not** result in a volume change of the soil. Above the shrinkage limit, any water content change **will** result in accompanying volume change.

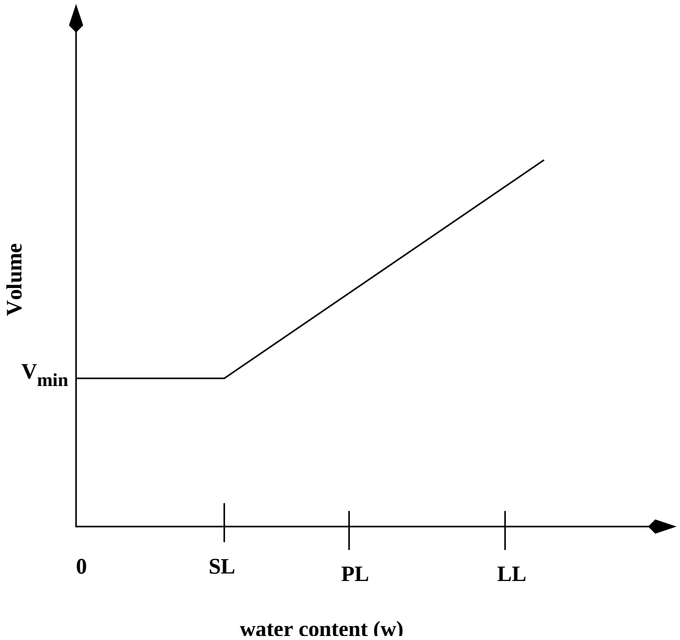

Figure 1: Schematic of volume change versus water content for fine-grained soils.

Another soil parameter that is often determined in conjunction with the SL is the *shrinkage ratio*, which is an indicator of how much volume change is possible as changes in water content above the SL occur. The *shrinkage ratio* (SR) is defined as the ratio of a given volume change, expressed as a percentage of the dry volume, to the corresponding change in water content above the SL, expressed as a percentage of the mass of oven-dried soil. Expressing the shrinkage ratio SR in equation form,

$$\text{SR} = \frac{\Delta V/V_o}{\Delta m_w/m_o} \tag{1}$$

where:

SR = shrinkage ratio
ΔV = soil volume change, cm^3
V_o = volume of oven − dried soil, cm^3
Δm_w = change in water mass, g
m_o = mass of oven − dried soil, g

Since $\Delta m_w = (\Delta V)\rho_w$, where ρ_w is the mass density of water in g/cm^3, (1) may be rewritten as

$$\text{SR} = \frac{\Delta V/V_o}{(\Delta V)\rho_w/m_o} = \frac{m_o}{(V_o)(\rho_w)} = \frac{\rho_d}{\rho_w}. \tag{2}$$

Thus, the higher the dry density of a fine-grained soil, the more expansion it can see when exposed to water. The SL and SR are particularly useful in assessing the expansiveness of fine-grained soils with changes in water content. The shrinkage ratio gives an indication of how much volume change may occur as changes in water content above the shrinkage limit occur. Large changes in soil volume are important considerations for soils to be used as fill material for highways and railroads, or for soils that are to support structural foundations. Uneven settlement or lifting resulting from volume changes can result in cracks in structures or uneven roadbeds.

B. Experimental Procedure for the Shrinkage Limit Test

> **WARNING:** In this experiment you will be working with liquid mercury. If mishandled, mercury can be very harmful to your health. Avoid skin contact and do not breathe the vapors. Protective gloves are provided for handling mercury in this experiment. Avoid spilling mercury, and consult with the lab instructor on how to dispose of the mercury you use. After completing this lab experiment, thoroughly wash your hands to remove any traces of mercury droplets.

1. Place about 50 of a representative air dry soil passing a No. 40 sieve into an evaporating dish.
2. Add water to the soil from the plastic squeeze bottle and mix it thoroughly until the soil has the consistency of a creamy paste. The consistency of the soil should be leaner than the consistency at the liquid limit (that is, the water content should be higher than the LL).
3. Coat the shrinkage dish very lightly with petroleum jelly and then determine the mass of the coated dish (m_1). The container volume V_c of the shrinkage dishes varies depending upon which dish you use. Consult Table 1 below to obtain the volume V_c of your shrinkage dish.
4. Fill the dish about one-third full with the soil paste. Tap the dish on a firm surface so that the soil flows into the corners of the dish with no trapped air bubbles remaining.
5. Repeat step #4 until the dish is full.
6. Strike the dish off with a steel straight edge. Clean off the exterior of the dish with paper towels. The volume of the saturated soil V_i will be the container volume V_c of your shrinkage dish.
7. Determine the mass of the dish plus the wet soil (m_2). The mass m_3 of the saturated soil is $m_2 - m_1$.
8. Allow the dish to air dry (about 6 hours) until the color the soil pat becomes lighter. Then put the dish with soil into the oven to dry.
9. After the soil has completely dried (about 12 hours), determine the mass of the dish and the oven-dry soil pat (m_4). The mass m_5 of the dried soil is then $m_4 - m_1$.
10. Gently, remove the soil pat from the shrinkage dish. It is important the the soil pat not be broken.
11. In order to find the volume of the oven-dried soil pat, the following procedure is followed:
    a. Place a clean, dry shrinkage limit dish into a clean dry evaporating dish.
    b. Fill the shrinkage limit dish with liquid mercury until it is full and slightly overflowing. The excess mercury will be caught by the evaporating dish.

c. Press the three-pronged glass plate onto the evaporating dish to level its surface, causing additional flow of mercury into the evaporating dish.

d. Carefully remove the shrinkage limit dish and the three-pronged plate from the evaporating dish. Wipe off any excess mercury clinging to the outside of the shrinkage limit dish into the evaporating dish. Take the combined mass m_6 of the evaporating dish and the overflow mercury.

e. Now put the shrinkage limit dish back into the evaporating dish. Carefully place the dried soil pat onto the surface of the mercury in the shrinkage limit dish. Push the soil down into the mercury using the three-pronged glass plate. This will cause additional mercury displaced by the soil pat to overflow into the evaporating dish.

f. Carefully remove the shrinkage limit dish and the three-pronged plate from the evaporating dish. Wipe off any excess mercury clinging to the outside of the shrinkage limit dish into the evaporating dish. Take the combined mass m_7 of the evaporating dish and the overflow mercury.

g. The mass of mercury m_8 displaced by the soil pat can be computed as $m_8 = m_7 - m_6$. The volume of the oven-dried soil pat V_d is then $V_d = m_8/\rho_{merc.}$. Mercury has a specific gravity G_s of 13.6.

Dish #	V_c(cm^3)	Dish #	V_c(cm^3)
1	17.15	5	17.04
2	15.25	6	17.25
3	15.25	7	17.43
4	15.25	–	—–

Table 1: Container volumes for shrinkage dishes.

C. Shrinkage Limit Computations

1. The water content of the soil in its initial saturated state is $w_i = [(m_3 - m_5)/m_5] * 100\%$. The corresponding volume of the soil V_i is the container volume V_c of your shrinkage dish.
2. The shrinkage limit (SL) is the water content that saturates the oven-dry soil. Water contents below this do not cause expansion of the soil, while water contents above this limit do cause expansion of the soil. To compute the shrinkage limit, the follow calculations are required:
   a. The dry density ρ_d of the soil is computed as m_5/V_d. Noting that $\rho_d = G_s\rho_w/(1 + e)$, the void ratio of the soil can be easily computed. (If G_s for the soil was computed in Lab #1, use that value. Otherwise, ask the lab instructor for an appropriate value of G_s for the soil.)
   b. The water content that saturates the soil in its dry state (SL) can be easily computed from the relation $Se = G_s w$ as $SL = (e/G_s) * 100\%$.
   c. An alternative estimate of SL is:

$$\text{SL} = w_i - \Delta w = w_i - [\frac{(V_i - V_d)\rho_w}{m_5}] * 100\% \tag{3}$$

4. Plot the volume of the soil versus water content as was done in the class notes (Period #5, page 5). [You will have 3 data points to form the plot.]
5. Compute the shrinkage ratio for the soil using Eq. (2).

D. Data Collection

Measurement	Trial 1	Trial 2
m_1		
m_2		
m_3		
m_4		
m_5		
m_6		
m_7		
m_8		
V_i		
w_i		
V_d		
ρ_d		
SR		
SL		