

# SHRINKAGE LIMIT TEST

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## **Purpose:**

This lab is performed to determine the shrinkage limit of soil by Mercury Method. The shrinkage limit is the water content dividing the semisolid and solid states of a soil.

## **Standard Reference:**

D0427-04 - Test Method for Shrinkage Factors of Soils by the Mercury Method

## **Significance:**

Shrinkage limit (SL) 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. Below the shrinkage limit, 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. 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

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

where:

SR = shrinkage ratio

$\Delta V$  = soil volume change,  $\text{cm}^3$

$V_o$  = volume of oven dried soil,  $\text{cm}^3$

$\Delta m_w$  = change in water mass, g

$m_o$  = mass of oven-dried soil, g

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

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

## Equipment:

Evaporating dish, shrinkage dish, spatula, steel straightedge, shrinkage limit dish [i.e. the glass cup (2.5in. in diameter and 1.25in. in depth)], glass plate with metal prongs, balance, liquid mercury, petroleum jelly, water squeeze bottle, and paper towels.

## Test procedure:

(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 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  $v_d = m_8 / \rho_{\text{merc}}$ . Mercury has a specific gravity  $G_8$  of 13.6.

Dish#	Vc (cm <sup>3</sup> )	Dish#	Vc (cm <sup>3</sup> )
1	17.15	5	17.04
2	15.25	6	17.25
3	15.25	7	17.43
4	15.25		

Table1: Container volumes for shrinkage dishes

### Analysis:

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 following calculations are required:

a. The dry density  $\rho_d$  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.

b. The water content that saturates the soil in its dry state (SL) can be easily computed from the relation  $S_e = G_s \omega$  as  $SL = (e/G_s) 100\%$ .

c. An alternative estimate of SL is:

$$SL = \omega_i - \Delta\omega = \omega_i - [(V_i - V_d) \rho_w / m_5] 100\%$$

SHRINKAGE LIMIT DETERMINATION  
DATA SHEET

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Date Tested:

Tested By:

Project Name:

Sample Number:

Sample Description:

<u>Measurement</u>	<u>Trial 1</u>	<u>Trial 2</u>
<b>m1</b>		
<b>m2</b>		
<b>m3</b>		
<b>m4</b>		
<b>m5</b>		
<b>m6</b>		
<b>m7</b>		
<b>m8</b>		
<b><math>V_i</math></b>		
<b><math>\omega_i</math></b>		
<b><math>V_d</math></b>		
<b><math>\rho_d</math></b>		
<b>SR</b>		
<b>SL</b>		