84-031 SHRINKAGE FACTORS OF A DISTURBED SOIL

1. Application

1.1 The accurate measurement of the change in volume and moisture content of a disturbed soil provides the data base required to calculate the following soil constants: shrinkage limit, shrinkage ratio, volumetric shrinkage, linear shrinkage and an approximate specific gravity.

2. Apparatus

2.1 Shrinkage mould: A circular metal dish (44.4 mm diameter) having a flat bottom, an inside depth of 12.7 mm such that the top rim and bottom of the dish are parallel.

2.2 Balance (sensitivity 0.01 g).

2.3 Glass cup: Approximately 57 mm in diameter and 31 mm deep, the top rim and bottom of the cup being parallel.

2.4 Glass or acrylic plastic plate: Approximately 76 mm square x 3.0 mm thick, with 3 metal prongs 1 mm in diameter extending 3.5 mm from the plate, the prongs are equally spaced (radially) 1.37 cm from the center of the plate.

2.5 Evaporation dish (diameter 14 cm).

2.6 Glass plate (25 cm square or larger).

2.7 Spatula (metal 10-15 cm)

2.8 Desiccator.

2.9 Drying chamber.

2.10 Graduated cylinder (25 mL).

2.11 Syringe (10 mL).

2.12 Water bottle.

3. Reagents

3.1 Mercury (sufficient to fill the glass cup to overflowing).

3.2 Petroleum jelly or some other equivalent heavy grease.

3.3 Desiccant ($CaSO_4$ or P_2O_5).

4. Procedure

4.1 Weigh out 30 g of air dry sample ground to pass a 425 μm sieve.

4.2 Place the sample in an evaporation dish or on the glass plate, add distilled water and mix thoroughly; adjust the water content by adding water with the syringe until a fluid state is reached approximately 10% higher than the liquid limit value.

4.3 Coat the inside of a preweighed shrinkage mould (Wd) with a thin layer of petroleum jelly (Use a Q-tip or equivalent to spread the grease evenly). This prevents adhesion of the soil to the mould on drying.

4.4 Place a volume of soil which is approximately 1/3 of the mould volume in the center of the dish.

4.5 Tap the mould on a firm surface, this causes the sample to move to the edges of the mould and removes any trapped air bubbles. Caution: prolonged tapping will result in a migration of water to the soil surface which will result in cracking and flaking of the sample along this plane when the sample is oven dried. An upward adjustment of water content will reduce this problem.

4.6 Repeat 4.4 and 4.5 until the mould is filled.

4.7 Strike off the excess soil with the edge of a metal spatula (a sawing action rather than a straight pull of the spatula across the sample will result in a smoother surface).

4.8 Remove any excess soil from the outside of the shrinkage mould.

4.9 Weigh the mould plus soil and record the value as Ww.

4.10 Allow the sample to air dry (in the mould) until a colour change is apparent (i.e. dark to light grey), oven-dry at 105°C for 24 hours.

4.11 Remove the sample from the oven and immediately place it in a desiccator containing desiccant, cool to room temperature, weigh the sample and record the value as Ws.

4.12 Determine the volume of the dry soil by the following procedure which involves removing the sample from the shrinkage mould and immersing the sample in the glass cup which is filled with mercury.

a) Place the glass cup in an evaporation dish and fill to overflowing with mercury.

b) Remove the excess mercury by pressing the 3 prong plate over the top of the cup.

c) Carefully remove the plate (the level of mercury will appear to decrease slightly, this is due to the inverted meniscus), remove the cup (filled with mercury) from the evaporation dish and pour the excess mercury from the evaporation dish into a storage container, return the mercury filled glass cup to the evaporation dish.
d) Place the soil sample on the surface of the mercury.
e) Position the glass plate such that the prongs are in contact with the soil, tilt the sample slightly and slowly press it into the mercury (air bubbles should not be present under either the glass plate or the soil sample).
f) To accurately determine the volume of the soil sample it is critical that following the immersion of the sample "no" additional mercury is displaced from the glass dish. The most common occurance of accidental mercury overflow is when the sample is being brought back up to the surface of the mercury. To prevent this overflow the following is recommended. With the soil sample immersed, move the glass plate to one side of the glass dish and slowly lift the glass plate while tilting the inner most portion of the sample up, when the soil breaks the mercury's surface make certain the mercury does not splash over the side (Should this happen repeat steps a-f).
g) Remove the glass cup from the evaporation dish and measure the volume of mercury which was displaced by immersion of the soil sample using a graduate cylinder, observe and record the top of the meniscus as Vo (volume of the dry soil sample). An alternative method is to determine the weight of the displaced mercury and divide by the density of the mercury at the observed temperature at the time of measurement.
h) The volume of the shrinkage mould (V) which is equal to the volume of the wet sample is determined by; filling the mould with mercury, remove the excess mercury by pressing the glass plate to the top of the shrinkage mould, the mercury in the mould is poured into the graduated cylinder and the volume is recorded as V.

5. Calculations

5.1 Water Content (%) = Θ

$$\Theta = (Ww - Ws)/(Ws - Wd) \times 100$$

where: Ww = wt of mould plus soil (wet).
Ws = wt of mould plus soil (oven-dry).
Wd = wt of shrinkage mould.

5.2 Shrinkage Limit (SL)

$$SL = \Theta - [(V-Vo)/Wo] \times 100$$

where: SL = the maximum water content at which a reduction in Θ will not cause a decrease in the volume of the soil mass.
V = volume of soil (wet).
Vo = volume of soil (dry).
Wo = weigh of soil (dry) Wo = Ws - Wd

The following assumptions are made:
1) that the soil was fully saturated and it remained saturated to the shrinkage limit
2) and that the volume change was the result of water loss, and the density of the water was equal to 1 g/cm^3.

5.3 Shrinkage Ratio (R)

$$R = Wo/Vo$$

where: R = the ratio of a given volume change expressed as a percentage of dry volume, to the corresponding change in water content above the shrinkage limit, expressed as a percentage of the mass of oven-dry soil (assumes a density of water equal to 1 g/cm^3).

5.4 Volumetric shrinkage (Vs)

$$Vs = (\Theta_1 - SL)\,R$$

where: Vs = the decrease in volume expressed as a percentage of the soil mass when dried, of a soil mass when the water content is reduced from a given percentage to the shrinkage limit.

Θ_1 = given percentage of water content.

5.5 Linear Shrinkage (Ls)

$$Ls = 100\,[1-[100/(Vs + 100)]^{1/3}]$$

where: Ls = the decrease in one dimension of a soil mass expressed as a percentage of the original dimension when the water content is reduced from a given value to the shrinkage limit.

5.6 Specific Gravity (Gs) approximate

$$Gs = 1/\,[(1/R)-(SL/100)]$$

The assumption is made that half of the water loss is from shrinkage and half is from the extraction of water from the soil pores.

6. References

6.1 ASTM D427-61, 1967.

6.2 Bowles, J.E. 1970. Engineering Properties of Soils and their Measurement, McGraw-Hill Book Co. pp. 25-31.

6.3 Lambe, T.W. 1957. Soil Testing for Engineers, John Wiley and Sons Inc., pp. 22-28.

6.4 McKeague, J.A. ed. 1978. Manual on soil sampling and methods of analysis. Can. Soc. of Soil Sci. Suite 907, 151 Slater St., Ottawa, Ont.