EXPERIMENT 5

HYDROMETER ANALYSIS

Purpose:

The hydrometer method is used to determine the distribution of the finer particles.

The theoretical part:

Hydrometer analysis is the procedure generally adopted for determination of the particle-size distribution in a soil for the fraction that is finer than No. 200 sieve size (0.075 mm). The lower limit of the particle-size determined by this procedure is about 0.001 mm.

In hydrometer analysis, a soil specimen is dispersed in water. In a dispersed state in the water, the soil particles will settle individually. It is assumed that the soil particles are spheres, and the velocity ofthe particles can be given by Stoke's law as

$$\boxed{\upsilon = \frac{\gamma_s - \gamma_w}{18\eta} D^2}$$

where υ = velocity (cm/s)

γ_s = specific weight of soil solids (g/cm^3)

γ_w = unit weight of water (g/cm^3)

η = viscosity of water $\left(\frac{\text{g}\cdot\text{s}}{\text{cm}^2}\right)$

D = diameter of the soil particle

If a hydrometer is suspended in water in which soil is dispersed (Fig. 5-1), it will measure the specific gravity of the soil-water suspension at a depth L. The depth L is called the effective depth. So, at a time t minutes from the beginning of the test, the soil particles' that settle beyond the zone of measurement (i.e., beyond the effective .depth L) will have a diameter given by

$$\boxed{\frac{L\,(\mathrm{cm})}{t\,(\mathrm{min})\times 60}=\frac{(\gamma_s-\gamma_w)\ \mathrm{g/cm^3}}{18\eta\left(\frac{\mathrm{g\cdot s}}{\mathrm{cm^2}}\right)}\left[\frac{D\,(\mathrm{mm})}{10}\right]^2}$$

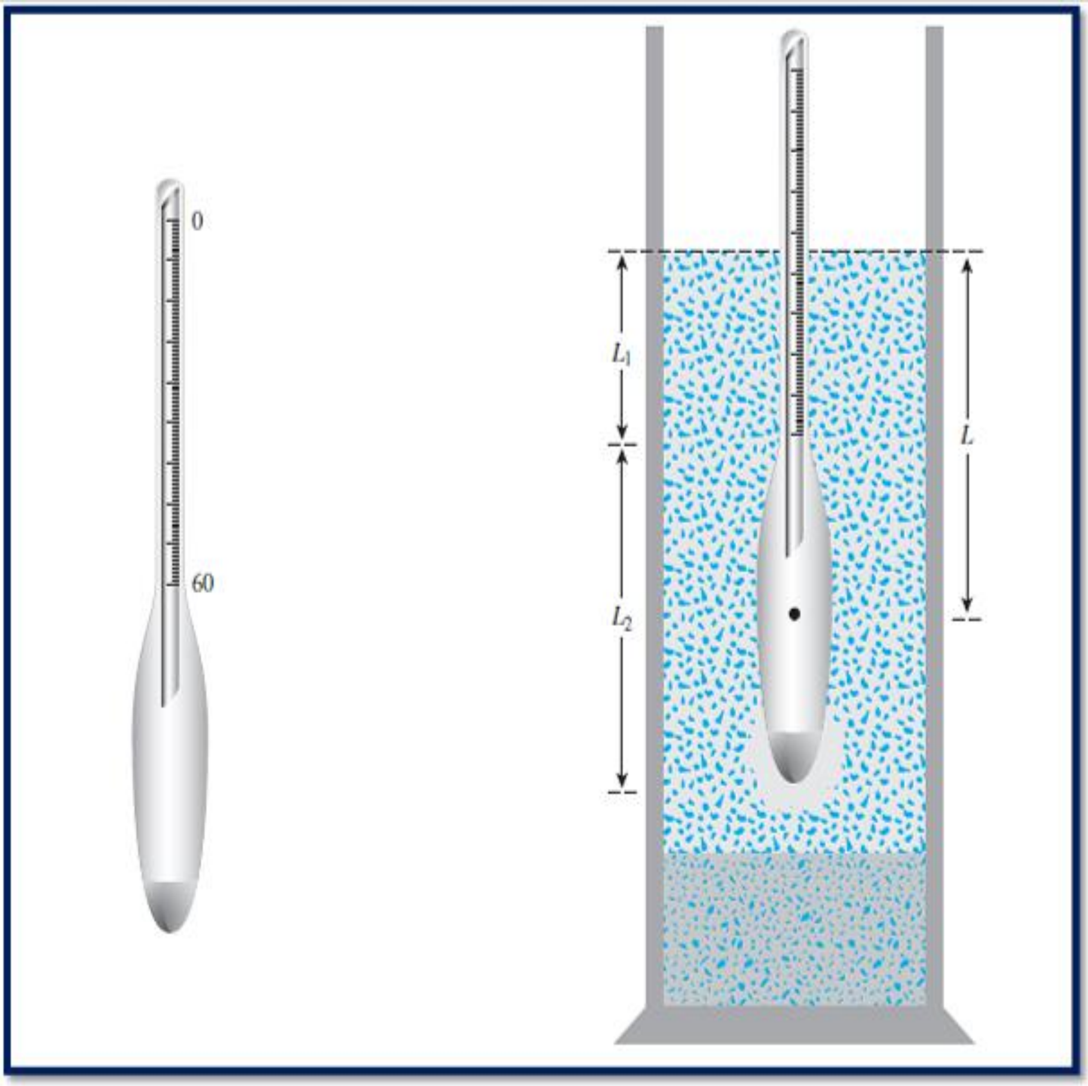


Figure 5-1. Hydrometer suspended in water in which the soil is dispersed.

$$D\,(\mathrm{mm}) = \frac{10}{\sqrt{60}}\sqrt{\frac{18\eta}{(\gamma_s - \gamma_w)}}\sqrt{\frac{L}{t}} = A\sqrt{\frac{L\,(\mathrm{cm})}{t\,(\mathrm{min})}}$$

$$\text{where } A = \sqrt{\frac{1800\eta}{60(\gamma_s - \gamma_w)}} = \sqrt{\frac{30\eta}{(\gamma_s - \gamma_w)}}$$

In the test procedure described here, the *ASTM 152-H* type of hydrometer will be used. From Fig. 5-1 it can be seen that, based on the hydrometer reading (which increases from zero to 60 in the *ASTM 152-H* type of hydrometer), the value of *L* will change. The magnitude of *L* can be given as

$$L = L_1 + \frac{1}{2}\left(L_2 - \frac{V_B}{A_C}\right)$$

where *L1* = distance between the top of hydrometer bulb to the mark for a hydrometer reading. For a hydrometer reading of zero, *LI* = 10.5 cm. Also, for a Hydrometer reading of 50 g/liter, *L1* = 2.3 cm. Thus, in general, for a given hydrometer reading

$$L_1\,(\text{cm}) = 10.5 - \left(\frac{10.5 - 2.3}{50}\right) \times (\text{hydrometer reading})$$

L2 =14cm

VB = volume of the hydrometer bulb = 67.0 cm3

Ac = cross-sectional area of the hydrometer cylinder = 27.8 cm2

Based on Eq. (5.4), the variation of *L* with hydrometer reading is shown in Table 5-1.

For actual calculation purposes we also need to know the values of *A* given by Equation (5.3). An example of this calculation is shown below.

$$\gamma_s = G_s \gamma_w$$

where Gs = specific gravity of soil solids

Thus

$$A = \sqrt{\frac{30\eta}{(G_s - 1)\gamma_w}}$$

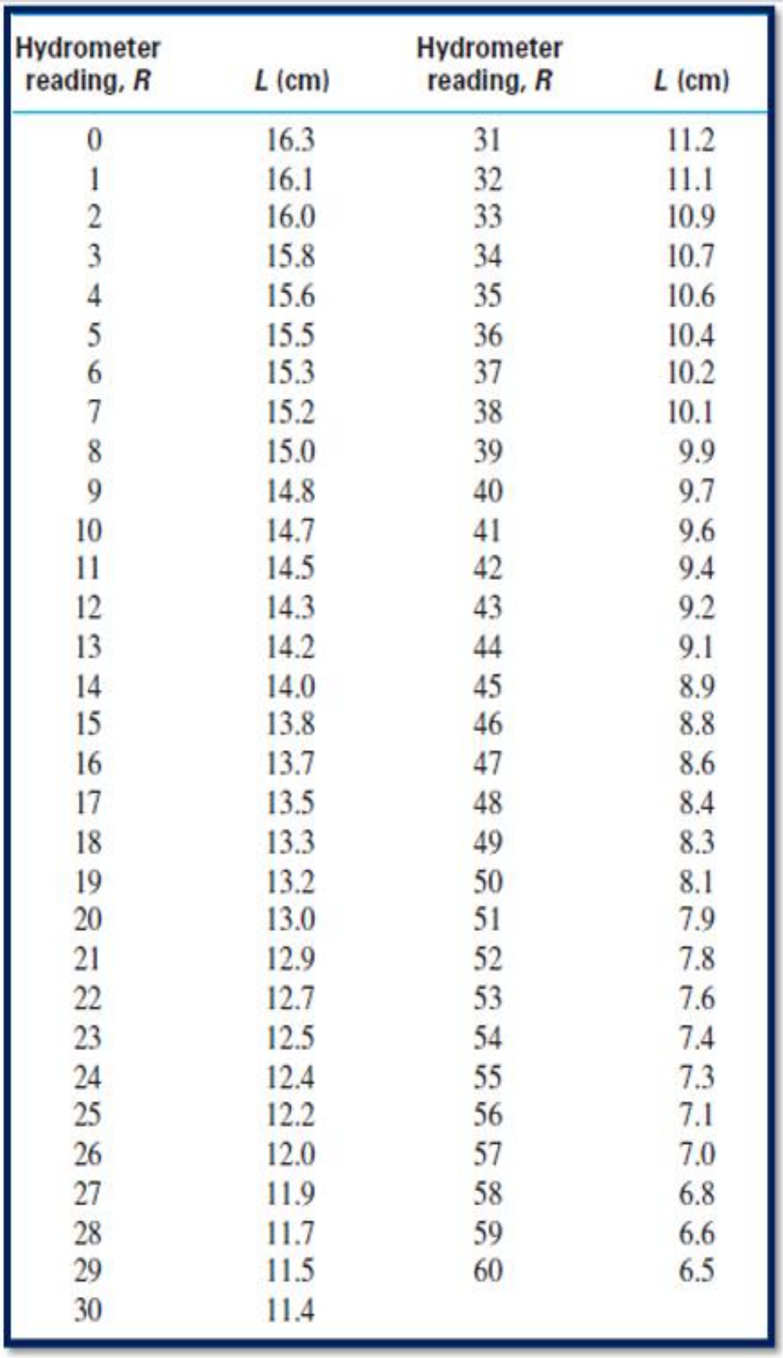
For example, if the temperature of the water is *25bC,*

$$\eta = 0.0911 \times 10^{-4} \left(\frac{g \cdot s}{cm^2}\right)$$

And Gs=2.7

$$A = \sqrt{\frac{30(0.0911 \times 10^{-4})}{(2.7 - 1)(1)}} = 0.0127$$

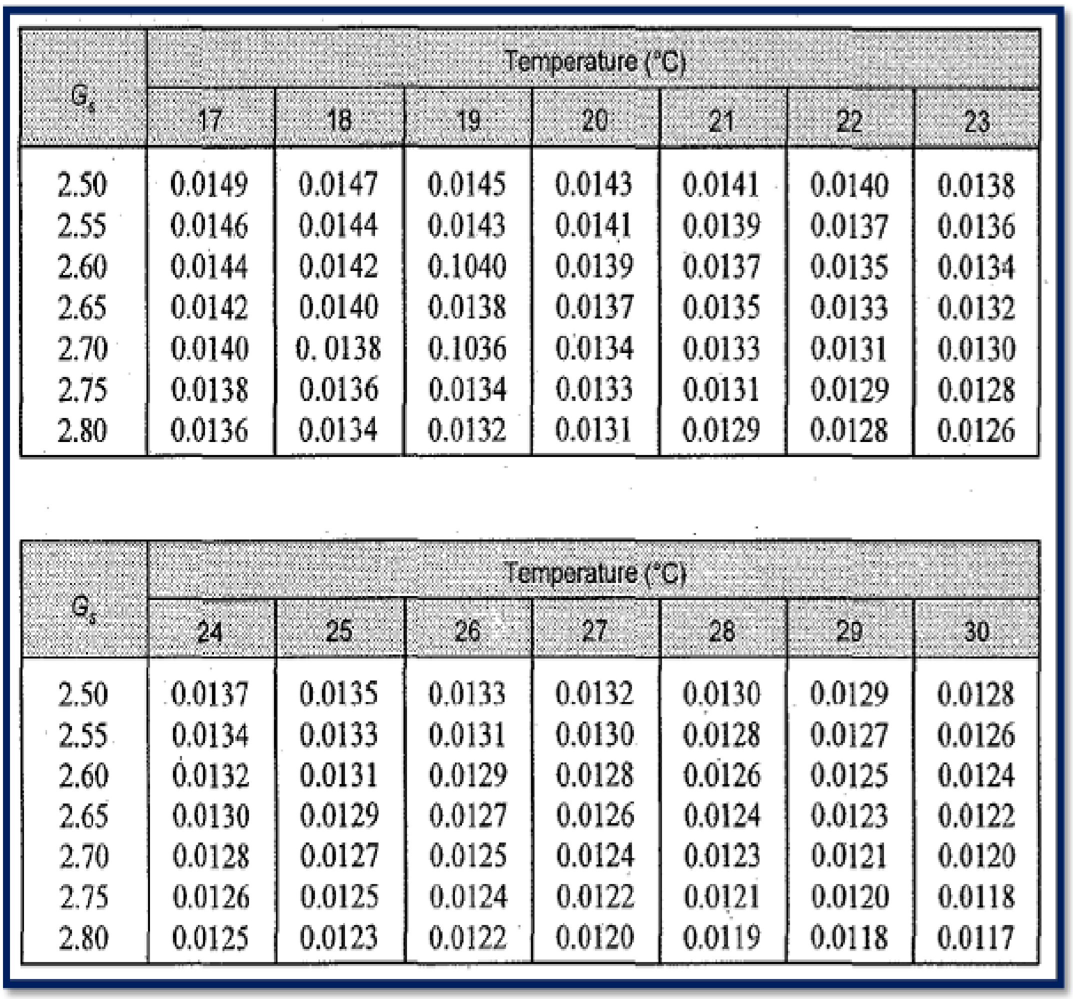
The variations of A with Gs and the water temperature are shown in Table 5-2.



Hydrometer reading, *R*	*L* (cm)	Hydrometer reading, *R*	*L* (cm)
0	16.3	31	11.2
1	16.1	32	11.1
2	16.0	33	10.9
3	15.8	34	10.7
4	15.6	35	10.6
5	15.5	36	10.4
6	15.3	37	10.2
7	15.2	38	10.1
8	15.0	39	9.9
9	14.8	40	9.7
10	14.7	41	9.6
11	14.5	42	9.4
12	14.3	43	9.2
13	14.2	44	9.1
14	14.0	45	8.9
15	13.8	46	8.8
16	13.7	47	8.6
17	13.5	48	8.4
18	13.3	49	8.3
19	13.2	50	8.1
20	13.0	51	7.9
21	12.9	52	7.8
22	12.7	53	7.6
23	12.5	54	7.4
24	12.4	55	7.3
25	12.2	56	7.1
26	12.0	57	7.0
27	11.9	58	6.8
28	11.7	59	6.6
29	11.5	60	6.5
30	11.4		

Table 5-1. Variation of L with hydrometer reading ASTM 152-H hydrometer

The *ASTM 152-H* type of hydrometer is calibrated up to a reading of 60 at a temperature of 20°C for soil particles having a $Gs = 2.65$. A hydrometer reading of, say, 30 at a given time of a test means that there are 30 g of soil solids *(Gs* = 2.65) in. suspension per 1000 cc of soil water mixture at a temperature of20oe at a depth where the specific gravity of the soil-water suspension is measured (i.e., *L).* From this measurement, we can determine the percentage of soil still in suspension at time *t* from the beginning of the test and all the soil particles will have diameters smaller than *D* calculated by Equation (5.2). However, in the actual experimental work, some corrections to the observed hydrometer readings need to be applied. They are as follows:



G_s	Temperature (°C)						
	17	18	19	20	21	22	23
2.50	0.0149	0.0147	0.0145	0.0143	0.0141	0.0140	0.0138
2.55	0.0146	0.0144	0.0143	0.0141	0.0139	0.0137	0.0136
2.60	0.0144	0.0142	0.1040	0.0139	0.0137	0.0135	0.0134
2.65	0.0142	0.0140	0.0138	0.0137	0.0135	0.0133	0.0132
2.70	0.0140	0. 0138	0.1036	0.0134	0.0133	0.0131	0.0130
2.75	0.0138	0.0136	0.0134	0.0133	0.0131	0.0129	0.0128
2.80	0.0136	0.0134	0.0132	0.0131	0.0129	0.0128	0.0126

G_s	Temperature (°C)						
	24	25	26	27	28	29	30
2.50	0.0137	0.0135	0.0133	0.0132	0.0130	0.0129	0.0128
2.55	0.0134	0.0133	0.0131	0.0130	0.0128	0.0127	0.0126
2.60	0.0132	0.0131	0.0129	0.0128	0.0126	0.0125	0.0124
2.65	0.0130	0.0129	0.0127	0.0126	0.0124	0.0123	0.0122
2.70	0.0128	0.0127	0.0125	0.0124	0.0123	0.0121	0.0120
2.75	0.0126	0.0125	0.0124	0.0122	0.0121	0.0120	0.0118
2.80	0.0125	0.0123	0.0122	0.0120	0.0119	0.0118	0.0117

Table 5-2. Variation of *A* with Gs

1. Temperature correction (FT)-The actual temperature of the test may not be 20°C. The temperature correction (F T) may be approximated as

$F_t = -4.85 + 0.25T$ (for Tbetween 15°C and 28°C)

where F_t = temperature correction to the observed reading

(can be either positive or negative)

T= temperature of test in C^o

2. Meniscus correction (Fm)-Generally, the upper level of the meniscus is taken as the reading during laboratory work (Fm is always positive).

3. Zero correction (Fz)- A deflocculating agent is added to the soil-distilled water suspension for performing experiments. This will change the zero reading (Fz can be either positive or negative).

Equipment and tools:

1. ASTM 152-Hhydrometer
2. Mixer
3. Two 1000-cc graduated cylinders
4. Thermometer
5. Constant temperature bath
6. Deflocculating agent
7. Spatula
8. Beaker
9. Balance

10. Plastic squeeze bottle

11. Distilled water

12. No. 12 rubber stopper

The equipment necessary (except the balance and the constant temperature bath) i shown in **Fig. 5-2**.

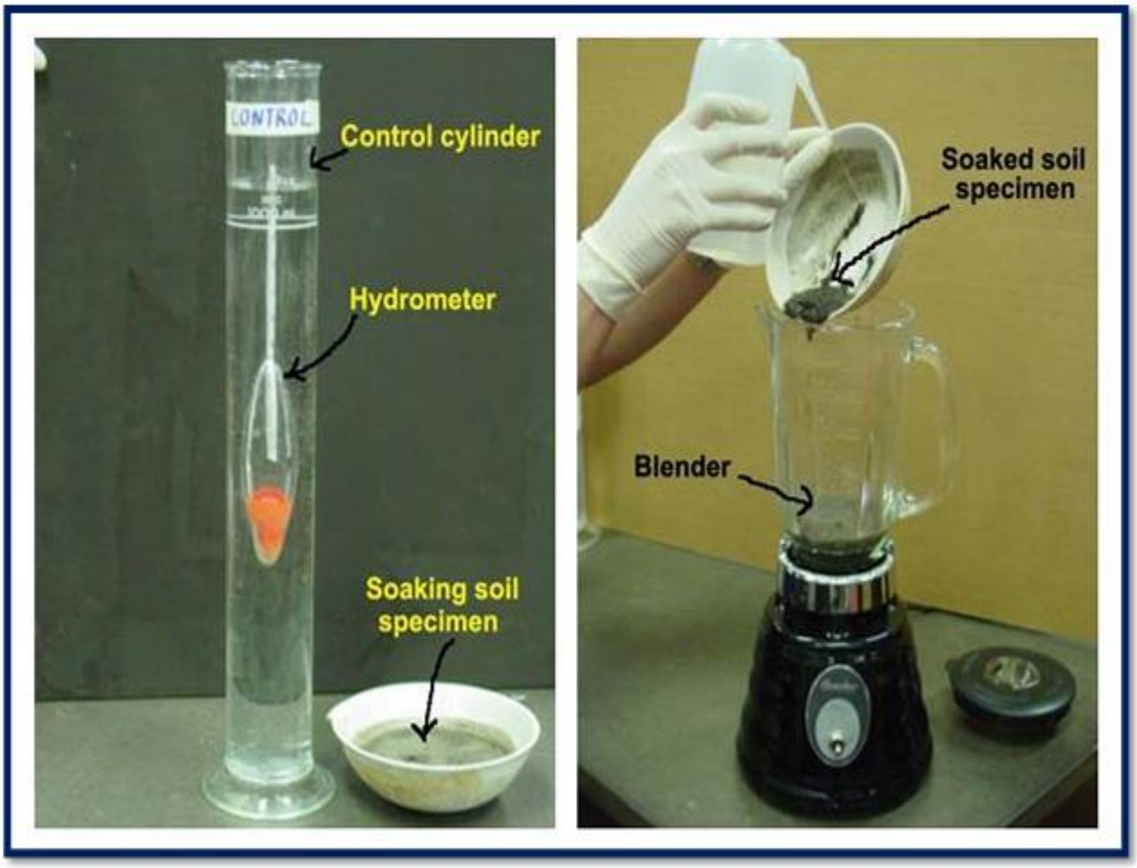


Figure 5-2. Equipment for hydrometer test.

Procedure:

Note: This procedure is used when more than 90 per cent of the soil is finer than No. 200 sieve.

1. Take 50 g of oven-dry, well-pulverized soil in a beaker.

2. Prepare a deflocculating agent. Usually a 4% solution of sodium hexametaphosphate (Calgon) is used. This can be prepared by adding 40 g of Calgon in 1000 cc of distilled water and mixing it thoroughly. ,

3. Take 125 cc of the mixture prepared in Step 2 and add it to the soil taken in Step 1.

This should be allowed to soak for about 8 to 12 hours.

4. Take a IOOO-cc graduated cylinder and add 875 cc of distilled water plus 125 cc of deflocculating agent in it. Mix the solution well.

5. Put the cylinder (from Step 4) in a constant temperature bath. Record the temperature of the bath, T (in c^{o}).

6. Put the hydrometer in the cylinder (Step 5). Record the reading. (Note: The top a/the meniscus should be read.) This is the zero correction (Fz), which can be +ve or -ve. Also observe the meniscus correction (F m).

7. Using a spatula, thoroughly mix the soil prepared in Step 3. pour it into the mixer cup.

Note: During this process, some soil may stick to the side of the beaker. Using the plastic squeeze bottle filled with distilled water, wash all the remaining soil in the beaker into the mixer cup.

8. Add distilled water to the cup to make it about two-thirds full. Mix it for about two minutes using the mixer.

9. Pour the mix into the second graduated 1000-cc cylinder. Make sure that all of the soil solids are washed out of the mixer cup. Fill the graduated cylinder with distilled water to bring the water level up to the 1000-cc mark.

10. Secure a No. 12 rubber stopper on the top of the cylinder (Step 9). Mix the soil-water

well by turning the soil cylinder upside down several ,times.

11. Put the cylinder into the constant temperature bath next to the cylinder described in Step 5. Record the time immediately. This is· cumulative time t= O. Insert the hydrometer into the cylinder containing the soil-water suspension.

12. Take hydrometer readings at cumulative times t = 0.25 min., 0.5 min., 1 min., and 2 min. Always read the upper level of the meniscus.

13. Take the hydrometer out after two minutes an<l put it into the cylinder next to it (Step5).

14. Hydrometer readings are to be taken at time t = 4 min., 8 min., 15 min., 30 min., 1 hr., 2 hr., 4 hr., 8 hr., 24 hr. and 48 hr. For each reading, insert the hydrometer into the cylinder containing the soil-water suspension about 30 seconds before the reading is due. After the reading is taken, remove the hydrometer and put it back into the cylinder next to it (Step 5).

Calculation:

Refer to **Table 5-4** .

Column 2- These are observed hydrometer readings (R) corresponding to times given in Column 1.

Column 3- R = corrected hydrometer reading for calculation of percent finer

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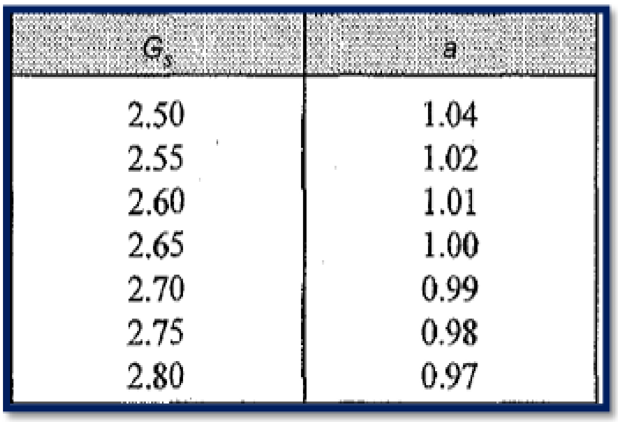
$$= R + F_T - F_Z$$

Column 4-Percent finer = $\frac{a\,Rcp}{Ws}$ (100)

where Ws = dry weight of soil used for the hydrometer analysis

a = correction for specific gravity (since the hydrometer is calibrated for Gs = 2.65)

$$\boxed{= \frac{G_s\,(1.65)}{(G_s - 1)2.65} \quad \text{(See Table 5-3)}}$$



G_s	a
2.50	1.04
2.55	1.02
2.60	1.01
2.65	1.00
2.70	0.99
2.75	0.98
2.80	0.97

Table 5-3. Variation of a with Gs

Column 5-ReL = corrected reading for determination of effective length = $R + Fm$ *(5.9)*

Column 6--Determine L (effective length) corresponding to the values of $Re\,L$ (Col. 5) given in Table 5-1.

Column 7-Determine A from Table 5-2.

Column 8- Determine D (mm)

$$= A\sqrt{\frac{L\ (\text{cm})}{t\ (\text{min})}}$$

Graph

Plot a grain-size distribution graph on semi-log graph paper with percent finer (Col.4, Table (5-4) on the natural scale and *D* (Col. 8, Table 5-4) on the log scale. A sample calculation and the corresponding graph are shown in Table 5-4 and Fig. 5-3,

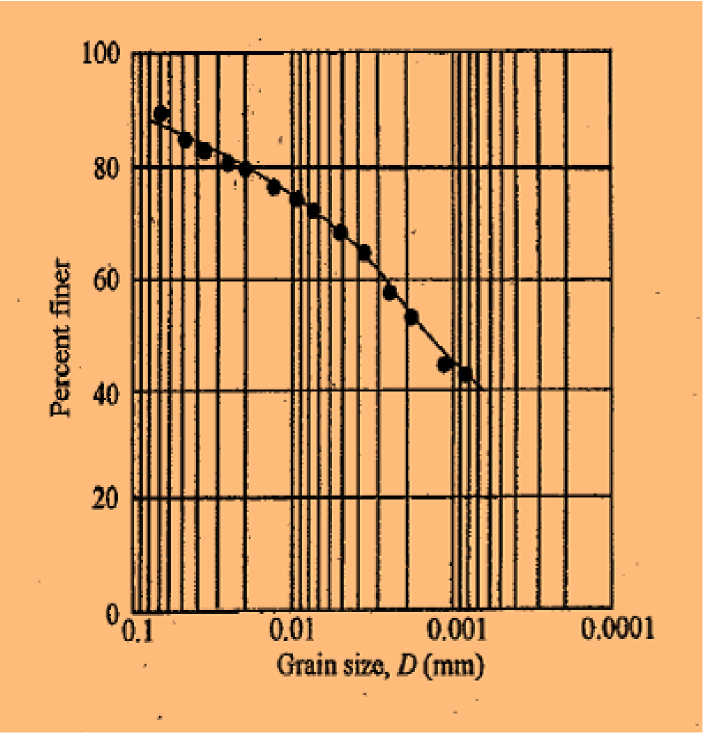


Figure 5-3. Plot of percent finer vs. grain size from the results given in **Table 5-4**.

Discussion and Conclusions:

When a smaller amount (less than about 90%) of soil is finer than No. 200 sieve size, the following modification to the above procedure needs to be applied.

1. Take an oven-dry sample of soil. Determine its weight *(WI)'*
2. Pulverize the soil using a mortar and rubber-tipped pestle, as described in Chapter 4.
3. Run a sieve analysis on the soil (Step 2), as described in Chapter 4.
4. Collect in the bottom pan the soil passing through No. 200 sieve.
5. Wash the soil retained on No. 200 sieve, as described in Chapter 4. Collect all the wash water and dry it in an oven.
6. Mix together the minus No. 200 portion from Step'4 and the dried minus No. 200 portion from Step 5.
7. Calculate the percent finer for the soil retained on No. 200 sieve and above (as shown 'in Table 4-1).
8. Take 50 g of the minus 200 soil (Step 6) and run a hydrometer analysis. (Follow Steps 1 through 14 as described previously.)
9. Report the calculations for the hydrometer analysis similar to that shown in Table 5-4. Note, however, that the percent finer now calculated (as in Col. 8 of Table 5-4) is *not the percent finer based on the total sample.* Calculate the percent finer based on the total sample as

$$\boxed{P_T = (\text{Col. 8 of Table 5-4})\left(\frac{\text{percent passing No. 200 sieve}}{100}\right)}$$

Percent passing No. 200 sieve can be obtained from Step 7 above.

10. Plot a combined graph for percent finer versus grain-size distribution obtained from *both the sieve analysis and the hydrometer analysis.* An example of this is shown in

Fig. 5-4. From this plot, note that there is an overlapping zone. The percent finer calculated

from the sieve analysis for a given grain size does not match that calculated

from the hydrometer analysis. The grain sizes obtained from a sieve analysis are the least sizes of soil grains, and the grain sizes obtained from the hydrometer are the diameters of equivalent spheres of soil grains.

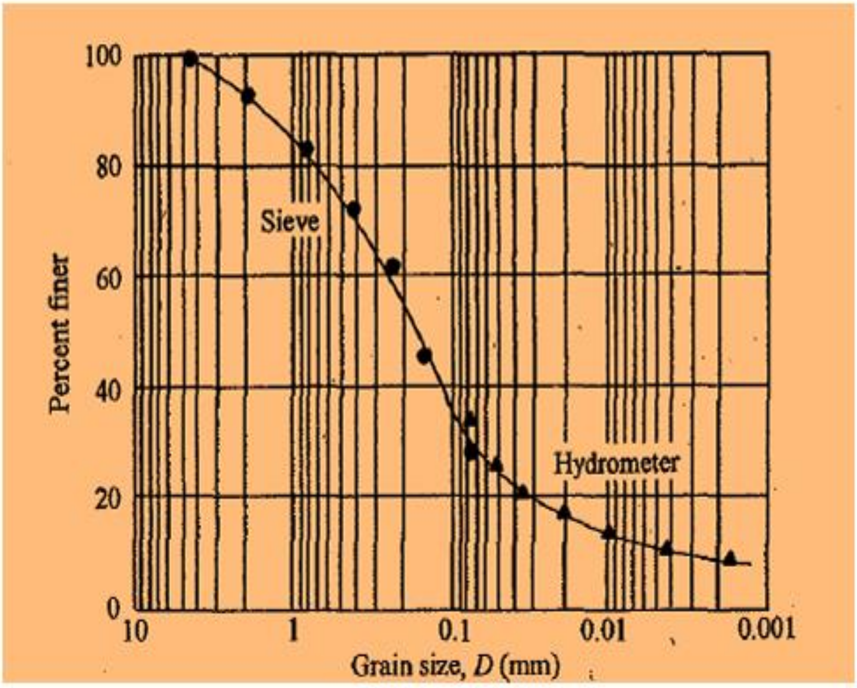


Figure 5-4. A grain-size distribution plot-combined results from sieve analysis and hydrometer analysis.