GRAIN SIZE ANALYSIS BY HYDROMETER

1. Objective

Hydrometer test is carried out to quantitatively determine the Particle/Grain Size Distribution for soil particles of size smaller than 75 micron.

2. Apparatus Required

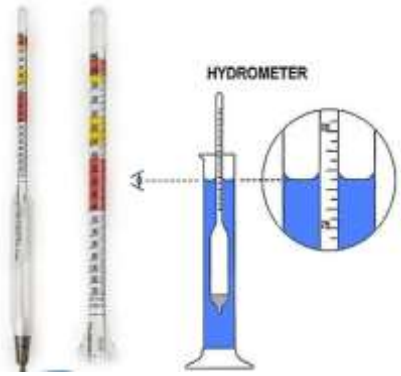	**Fig. 1: Hydrometer** Calibrated at 27°C, range of 0.995 to 1.030 g/cc, graduation lines at interval of 0.0005; in conformity with IS-3104: 1965. The maximum permissible scale error on the hydrometer is plus or minus one scale division.
	**Fig. 2: Laboratory setup for Hydrometer Test** Two 1000 ml graduated cylinders, Dispersing agent solution containing sodium hexa-metaphosphate, Mechanical stirrer, Water Bath, Balance, Sieve, Dessicator and Centimetre Scale.
	**Fig. 3: Porcelain Evaporating Dish**

Fig. 4: Thermometer
For measuring Temperature required for Temperature corrections- with accuracy of 0.5^0 C

Fig. 5: Stop Watch
For recording Time interval.

3. Reference

IS-2720 (Part 4):1985 (Reaffirmed- May 2020) "Methods of test for soils: Grain size analysis".

4. Procedure

4.1 Calibration of Hydrometer

1. Determination of volume of the hydrometer bulb (V_h): Pour about 800 ml of water in the 1000 ml measuring cylinder and note the reading at the water level. Immerse the hydrometer in water and note the water reading. The difference between the two readings is recorded as the volume of the Hydrometer bulb plus the volume of that part of the stem which is submerged. For practical purpose the error due to the inclusion of this stem volume may be neglected. Alternatively, weigh the hydrometer to the nearest 0.1g. This mass in grams is recorded as the volume of the hydrometer in ml. This includes the volume of the bulb plus the volume of the stem below the 1.000 graduation mark.
2. In order to find the area of cross-section (A) of the measuring cylinder in which the hydrometer is be used, measure the distance, in cm, between two graduations of the cylinder. The cross-sectional area (A) is then equal to the volume included between the two graduations divided by the distance between them. Record it in cm^2
3. Measure the distance (h) from the neck to the bottom of the bulb, and record it in cm as the height of the bulb.

4. With the help of an accurate scale, measure the height between the neck of the hydrometer to each of the other major calibration marks i.e.,R_h in cm (H). For convenience, the hydrometer readings (Rh) ae recorded after subtracting 1 and multiplying the remaining digits by 1000. For example, the reading of 1.015 will be recorded as (1.015-1)*1000 = 15.

5. Calculate the effective depth (H_e) corresponding to each of the calibration marks (or hydrometer readings, R_h) by the following expressions:
   $H_e = H + 0.5 (h - V_h/A)$

   NOTE : The factor V_h/A) in the above equation shall not be applied to hydrometer reading after period of sedimentation of half, one, two and four minutes.
6. The readings may be recorded as illustrated in Table 1:

Table 1

S. No.	Hydrometer Reading, R_h	H (cm)	Effective depth, H_e (cm)
1			
2			
3			

7. Draw a calibration curve between H_e and R_h which may be used for finding the effective depth (H_e) corresponding to hydrometer readings (R_h) during test.

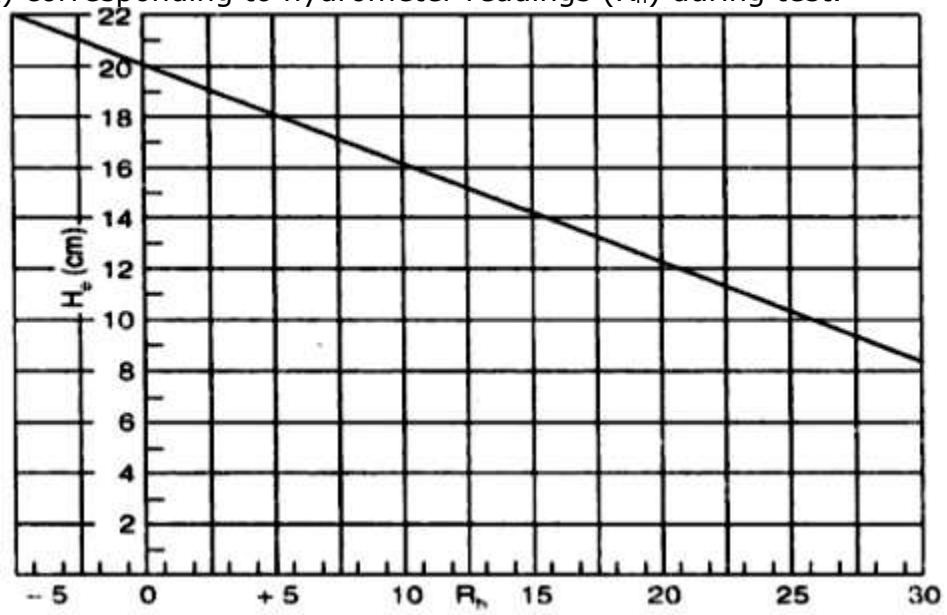

Fig. 6 : Calibration Curve for Hydrometer

8. Meniscus correction:

Insert the hydrometer in the measuring cylinder containing about 700 ml of water. Take the readings of the hydrometer at the top and bottom of the meniscus. The difference between two readings is taken as meniscus correction (C_m) which is a constant for a hydrometer. During the actual sedimentation test, the readings should be taken at the bottom of the

meniscus but since the soil suspension is opaque, readings are taken at the top of meniscus, It is clear that readings decrease in the upward direction. Thus, the observed hydrometer readings are always less than the true one. Hence the meniscus correction is always positive.

9. Pre-treatment of soil:

The percentage of soluble salts shall be determined. In case it is more than one percent, the soil shall be washed with water before further treatment.

4.2 Dispersion of Soil

1. In the case of soils containing Calcium compounds or soluble salts and having organic content more than 2 percentage, the soil shall be pre-treated as below:

   Weigh 50 to 100g of oven-dried soil sample (M_a) passing the 4.75 mm IS Sieve to nearest 0.01 g (50g for clay soil and 100g if it is a sandy soil) and place it in a wide mouthed conical flask. Add 150 ml of hydrogen peroxide to the soil sample and stir it gently for few minutes with a glass rod. Cover the flask with glass and level it to stand overnight.

   Next morning, the mixture in the conical flask is gently heated in an evaporating dish, stirring the contents periodically. Reduce the volume to 50 ml by boiling. Place the dish and its contents to the oven. Filter and wash the mixture with warm water, until the filtrate shows no acid reaction to litmus. Transfer the damp soil on filter paper and funnel to the evaporating dish using a jet of distilled water, using minimum quantity of distilled water. Dry the contents of dish in oven at 105-110^{0}C. Transfer them to desiccator and cool them. Weigh them to 0.01 g (M_b) and use for further testing.

2. Add 100 ml of sodium hexametaphosphate solution to the soil from step-1 above or otherwise (of mass M_b) from the soil passing 4.75 mm sieve and warm the mixture gently for about 10 minutes. Transfer the mixture to the cup of the mechanical mixer using a jet of distilled water and stir it well for about 15 minutes. Transfer the soil suspension to the 75 micron IS sieve placed on a receiver and wash the soil on this sieve using jet of distilled water from a wash bottle. The amount of distilled water used during this operation may be about 150 ml. Stir the suspension for about 15 minutes.

   Transfer the soil suspension to 75 micron IS Sieve and wash on this sieve using a jet of distilled water from wash bottle. The amount of distilled water used may be about 500 ml. Transfer the suspension passing through the sieve to 1000 ml measuring cylinder and make up to exactly 1000 ml using distilled water. This suspension shall be used for sedimentation analysis..

   Collect the material retained 75 micron sieve and put it in the Oven for drying. Determine the dry mass of soil retained on 75 micron sieve.

4.3 Sedimentation Test with Hydrometer

1. Insert a rubber ball or any other suitable cover on the top of the 1000 ml measuring cylinder containing the soil suspension and shake it vigorously end over end. Stop shaking and allow it to stand. Immediately, start the stop watch, and remove the top cover from the cylinder.
2. Immerse the hydrometer gently to a depth slightly below its floating position and then allow it to float freely. Take the hydrometer readings after periods of 1/2, 1, 2 and 4 minutes. Take out the hydrometer, rinse it with distilled water and allow it to stand in a jar containing distilled water at the same temperature as that of the test cylinder.

3. The hydrometer is re-inserted in the suspension and readings are taken after periods of 8, 15 and 30 minutes; 1, 2 and 4 hours after shaking. The hydrometer should be removed, rinsed and placed in the distilled water after each reading. After end of 4 hours, readings should be taken once or twice within 24 hours, the exact periods of sedimentation being noted. Finally take a reading at 24 hours.

4. Composite correction:

In order to determine the composite correction, make up a 1000 ml cylinder full of distilled water containing the same proportion of dispersing agent. The cylinder should be maintained at the same temperature as that of the test cylinder containing soil specimen. Insert the hydrometer in this comparison cylinder containing distilled water and the dispersing agent and take the reading corresponding to the top of the meniscus. The negative of the hydrometer reading so obtained gives the composite correction (C). The composite correction is found before the start of the test, and also at every time intervals of 30 minutes, 1 hour, 2 hours and 4 hours after the beginning of the test, and afterwards, just after each hydrometer reading is taken in test cylinder.

5. The temperature of the suspension should be observed and recorded once during the first 15 minutes and then after every subsequent reading.

5. Diameter of Particles (in millimeters)

$D = \sqrt{((30\,\mu)/(980(G-G1))} * \sqrt{((He/t))}$

Where, μ = Coefficient of viscosity of water at the temperature of suspension, at the time of taking hydrometer reading (in poise) as below :

Temp, (^{0}C)	μ (in poise)	Temp, (^{0}C)	μ (in poise)	Temp, (^{0}C)	μ (in poise)
15	0.01145	25	0.00896	35	0.00721
16	0.01116	26	0.00875	36	0.00706
17	0.01088	27	0.00855	37	0.00692
18	0.01060	28	0.00836	38	0.00679
19	0.01034	29	0.00818	39	0.00666
20	0.01009	30	0.00800	40	0.00654
21	0.00984	31	0.00783		
22	0.00961	32	0.00767		
23	0.00938	33	0.00751		
24	0.00916	34	0.00736		

G = Specific Gravity of soil used
G_1= Specific Gravity of water (=1)
H_e = Effective depth corresponding to R_h (in cm)
t = Time elapsed between the beginning of sedimentation and hydrometer reading (in Minutes)
The hydrometer reading corrected for meniscus (Rh) shall be calculated from the following formula :
$R_h = R_{h'} + C_m$
Where, Rh' = Hydrometer reading at the upper ring of meniscus
Cm = Meniscus Correction

6. Observation and Recording

Sample No. :
Mass of oven dried sample passing 4.75 mm Sieve (M_a) = g
Mass of soil sample, out of Ma, used for sedimentation (M_b) = g

SN	Elapsed Time t (min.)	Temp. (^{0} C)	Hydrometer Reading $R_{h'}$	$R_h = R_{h'} + C_m$	Eff. Height H_e (cm)	μ (Poise)	Dia. of Particle D (mm)	Composite Correction (C)	% finer than size D (W) (%)	Combined % finer than size D of total sample weight (N) (%)
1	0.5									
2	1									
3	2									
4	4									
5	8									
6	15									
7	30									
8	60									
9	120									
10	240									
11	480									
12	960									
13	1440									

Table 2: Determination of Grain Size by Hydrometer

The results of the Table 2 are plotted to get a particle size distribution curve with "percentage finer" (N) as the ordinate and the "particle diameter" (D) on logarithmic scale as abscissa as shown in Fig.7.

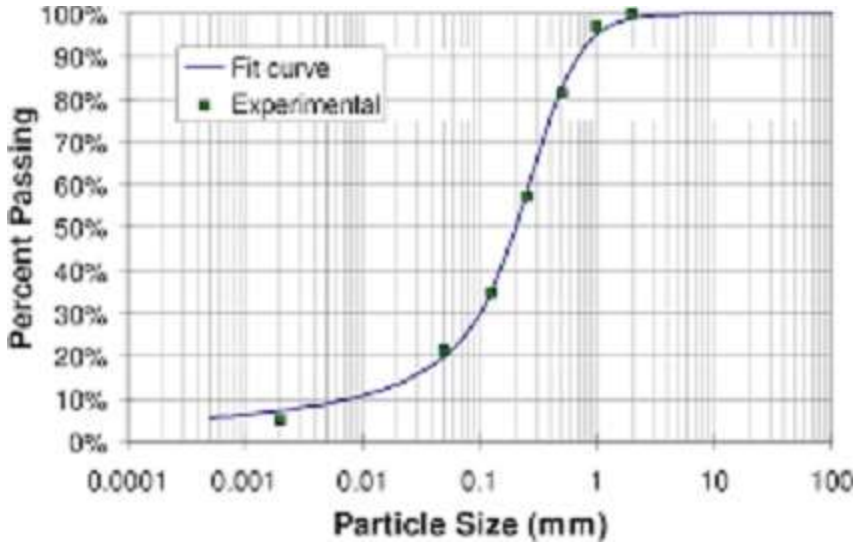

Fig. 7: Particle Size Distribution Curve

7. Percentage Finer Than D

The percentage by Mass (W) of particles smaller than corresponding equivalent particle diameters shall be calculated from the formula :

$W = \{(100^* G) / (Mb(G-1))\} (R_h - C)$

Where, G = Specific gravity of soil
M_b = Weight of soil after pre-treatment, used for
R_h = Hydrometer reading corrected from meniscus
C = Composite correction
The values of W shall be calculated for all the values of D obtained and shall be expressed as percentage of particles finer than the corresponding value of D.

These percentages shall then be expressed as combined percentage of the total soil sample taken for analysis (including sieve analysis):
$N = W * (Ma/Mb)$

Where, Ma = Total dry mass of the soil sample, passing 4.75 mm Sieve
Mb = Mass of soil sample, out of Ma, taken for hydrometer analysis.

8. General Remarks

1. Sodium hexametaphosphate has been found to ineffective when dealing with certain highly flocculated soils. In such cases dispersion may be carried out by adding N-sodium hydroxide solution at the rate of 4 ml per 10 g of soil.
2. The suspension should be kept out of direct sunlight and away from any local source of heat. Evaporation should be retarded by keeping a cover on the measuring cylinder between the readings.
3. The specific gravity should he determined for the fraction of the sample passing 75 micron sieve.
4. This method shall not applicable if less than 10% of the material passes the 75 micron IS Sieve.

9. Video

Grain Size Analysis by Hydrometer

10. Download

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