Section Two / Sedimentation Analysis

Definition

Sedimentation analysis defines the grain size distribution curve of soils that are too fine to be tested with sieves. Sedimentation analysis sorts soil particles by size using the physical process that is described by (Stokes, 1891) when the particles are allowed to settle under gravity.

Introduction

- The theory of sedimentation is based on the fact that large particles in suspension in a liquid settle more quickly than small particles, assuming that all particles have similar densities and shapes.
- Sedimentation test can be described by **hydrometer analysis** or **pipette analysis**.
- A dispersing (also deflocculating) agent is used with a soil suspension in water in order to ensure separation of discrete particles of soil. Two materials are often used as dispersal agent to neutralize the soil particle charges:
  1- Sodium hexa-metaphosphate ($NaPO_3$) known commercially as (**Calgon**) and for most purposes it has found that Calgon is one of the most suitable and convenient dispersants.
  2- Sodium silicate or **water glass** (Na_2SiO_3).

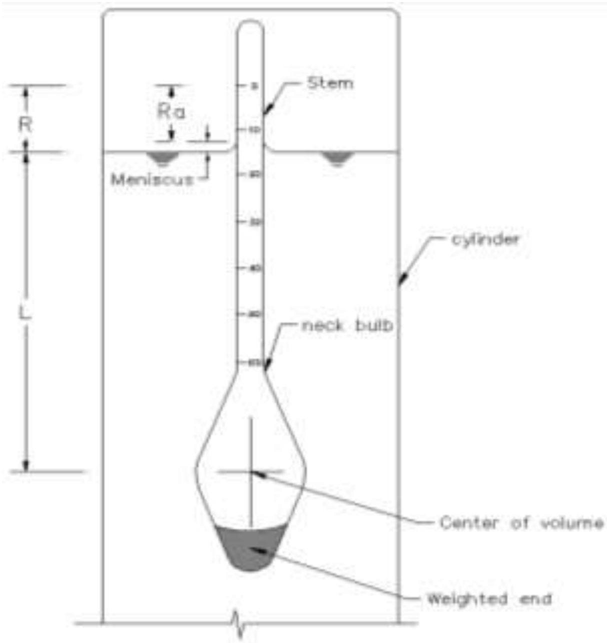
Hydrometer Analysis

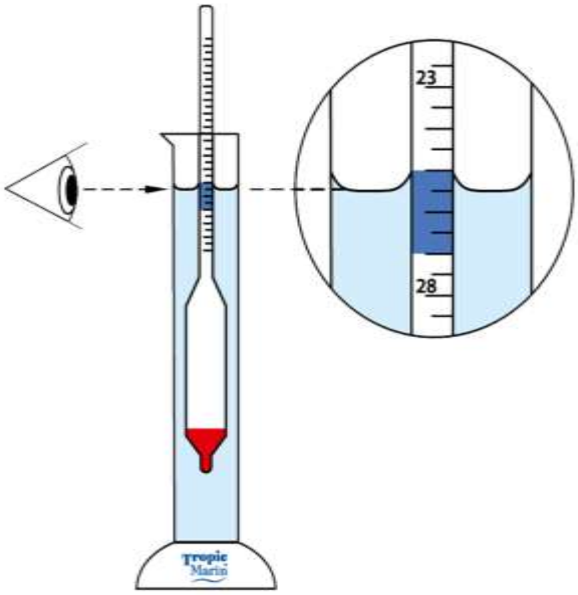
Definition

Hydrometer test is used to determine the grain size distribution of fine grained soils having particle size smaller than 0.075mm and if more than 10% of the soil passes the No.200 sieve. For soil samples have particle sizes ranging from sand to silt or clay, sieving and sedimentation analysis are combined.

Introduction

- The hydrometer is usually a type **152H** (refer to below Fig.) and is calibrated to read grams of soil that still in suspension of a value of G_s=2.65 in1000 cm^3. For soils of other specific gravity a correction must be made. It gives the weight of particles located around the bulb centroid but not of those located above or below.





- Stokes law does not applied for colloids that are particles smaller than **0.0002** mm, because the motion of the colloids is random and is referred to as **Brownian movement.**
- Note that ***L*** is the depth measured from the surface of the water to the center of gravity of the hydrometer bulb at which the density of the suspension is measured.
- The specific gravity (or density) decreases as the temperature rises. This will cause the hydrometer to sink deeper into the suspension.
- It is intended that the specific gravity test be made on that portion of soil which passes the **No.10 (2.00mm) sieve**, when it is to be used in calculation in hydrometer analysis.

Correction of Hydrometer Reading

The hydrometer readings are corrected as under:

1. **Meniscus correction –** Since the suspension is opaque, the observations are taken at the top of meniscus. The meniscus correction is equal to the reading between the top of the meniscus and the level of the liquid. As the marking on the stem increases downward, the correction is positive and is a constant for a given hydrometer. The meniscus correction is about **0.5 to 1.0 g/L** for most 152 H hydrometer. The correction hydrometer reading for meniscus is:

   $R = R_a +$ meniscus correction   Where: R_a = the actual reading above meniscus.

2. **Temperature correction –** The hydrometer is calibrated at 20°C. If the temperature of the suspension is different from 20°C, a temperature correction (C_T) is required for hydrometer reading. The temperature correction is obtained from the table (6-3).

3. **Dispersion agent correction –** Addition of the dispersing agent to the soil specimen causes increasing in the specific gravity of the suspension. The effect of water impurities and the dispersing agent on hydrometer readings can be obtained by using a control jar from the same source and with the same quantity of dispersing agent (125 cm^3) as used in the soil-water suspension to obtain "zero correction".

Purposes

To find the grain size distribution of that fraction of soil, which has diameter smaller than 0.075 mm (Silt and Clay).

Apparatus and Materials

1. Hydrometer (152 H model preferably).
2. Two sedimentation cylinders of glass or hydrometer jar marked for a volume of (1000 ml).
3. Dispersion agent with concentration of 4% of (sodium hexa – metaphosphate), as described in below table.

Chemical	Quantity	Unit
Sodium hexameta-phosphate (Calgon)	40	g
Water	1	L

4. Malt mixer (dispersion apparatus).
5. Thermometer, ranging from 0 to 50°C, accurate to 0.5°C
6. Stopwatch.
7. 50 g of oven-dry soil passing No. 200 sieve
8. Balance accurate to 0.01g.

Procedure

1. Take exactly 50 g of oven dry (well pulverized soil), and mix with 125 ml quantity of 4% solution of sodium metaphosphate.
2. Allow the mixture to stand about 1 hr. (ASTM suggest 16 hr for clayey soils). Transfer the mixture to the malt mixer cup and add tap water until the cup is two thirds full, mix for 5 min.
3. Transfers all the contents of the cup to the sedimentation cylinder (being careful not to lose any material). The volume of dispersed soil suspension is increased to 1000 ml by adding tap water.
4. Use the palm of your hand over the open end of the sedimentation cylinder and carefully agitate for about 1 min. (be sure no soil is stuck to the base of the cylinder). Set the cylinder down, immediately insert the hydrometer, and take hydrometer reading at elapsed time 0.5, 1, 2, 4 min also take temperature reading of sedimentation cylinder and control jar, then take meniscus correction and zero correction from the control jar.
5. Repeat step 4 take another series of hydrometer readings at 0.5, 1, 2, 4min. of elapsed times. Repeat as necessary until two sets of the four reading agree within 1 unit of each other at all four reading time (take average between a pair of readings).
6. Collect additional hydrometer and temperature readings at elapsed time of 8, 15, 30, min followed by 1, 2, 4, 8, 16, 24, 48, 96 hr.

Calculation

1. Determine temperature correction (C_T) from Table (6-3).
2. Calculate corrected hydrometer reading (Rc) from following equation:

$$R_c = Ra - \text{Zero correction} + C_T$$

3. Determine (a) from Table (6-2) or from equation: a = $\frac{G_s x 1.65}{(G_s - 1) x 2.65}$
4. Calculate %Finer of soil particles from following equation:

$$\%\ \text{Finer} = \left(\frac{R_C x(a)}{Ws}\right) \text{x } 100$$

5. Calculate hydrometer reading (R)corrected for meniscus only by:
   $R = Ra$ + meniscus correction
   Ra = actual hydrometer reading from sedimentation cylinder.
6. Determine effective depth (L) from Table (6-5) by using **R**.
7. Determine K from Table (6-4) by using G_s and T.
8. Calculate diameter (D in mm) of particles suspended in the cylinder at time t in minute by:

$$D = K\sqrt{\frac{L}{t}}$$ Where: L in (cm) and; t in (min)

9. Repeat all above steps for each hydrometer readings.
10. Use the data from steps 4 & 8 above and **plot the % Finer versus D in (mm).**
11. **Find percent of silt and clay according to BS.**
12. **Find coarse, medium and fine silt according to BS.**

Discussion

1. **Why the hydrometer is slowly inserted in the cylinder, about 10 sec being taken for this.**

Table 6-1 Properties of Distilled Water

Temp (°C)	Unit weight of water (g/cm³)	Viscosity of water (poises)¹
4	1.00000	0.01567
16	0.99897	0.01111
17	0.99880	0.01083
18	0.99862	0.01056
19	0.99844	0.01030
20	0.99823	0.01005
21	0.99802	0.00981
22	0.99780	0.00958
23	0.99757	0.00936
24	0.99733	0.00914
25	0.99708	0.00894
26	0.99682	0.00874
27	0.99655	0.00855
28	0.99627	0.00836
29	0.99598	0.00818
30	0.99568	0.00801

Table 6-2 Correction Factors *a* for Unit Weight of Solids

Unit weight of soil solids (g/cm³)	Correction factor *a*
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.04

Table 6-3 Temperature Correction Factors C_T

Temp. (°C)	C_T
15	−1.10
16	−0.90
17	−0.70
18	−0.50
19	−0.30
20	0.00
21	+0.20
22	+0.40
23	+0.70
24	+1.00
25	+1.30
26	+1.65
27	+2.00
28	+2.50
29	+3.05
30	+3.80

Table 6-4 Values of K for Use in Eq. (6-8a) for Several Unit Weights of Soil Solids and Temperature Combinations

	UNIT WEIGHT OF SOIL SOLIDS (g/cm³)							
Temp. (°C)	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.0151	0.0148	0.0146	0.0144	0.0141	0.0139	0.0137	0.0136
17	0.0149	0.0146	0.0144	0.0142	0.0140	0.0138	0.0136	0.0134
18	0.0148	0.0144	0.0142	0.0140	0.0138	0.0136	0.0134	0.0132
19	0.0145	0.0143	0.0140	0.0138	0.0136	0.0134	0.0132	0.0131
20	0.0143	0.0141	0.0139	0.0137	0.0134	0.0133	0.0131	0.0129
21	0.0141	0.0139	0.0137	0.0135	0.0133	0.0131	0.0129	0.0127
22	0.0140	0.0137	0.0135	0.0133	0.0131	0.0129	0.0128	0.0126
23	0.0138	0.0136	0.0134	0.0132	0.0130	0.0128	0.0126	0.0124
24	0.0137	0.0134	0.0132	0.0130	0.0128	0.0126	0.0125	0.0123
25	0.0135	0.0133	0.0131	0.0129	0.0127	0.0125	0.0123	0.0122
26	0.0133	0.0131	0.0129	0.0127	0.0125	0.0124	0.0122	0.0120
27	0.0132	0.0130	0.0128	0.0126	0.0124	0.0122	0.0120	0.0119
28	0.0130	0.0128	0.0126	0.0124	0.0123	0.0121	0.0119	0.0117
29	0.0129	0.0127	0.0125	0.0123	0.0121	0.0120	0.0118	0.0116
30	0.0128	0.0126	0.0124	0.0122	0.0120	0.0118	0.0117	0.0115

Table 6-5 Values of L (Effective Depth) for Use in Stokes' Formula for Diameters of Particles for ASTM Soil Hydrometer 152H

Original hydrometer reading (corrected for meniscus only)	Effective depth L (cm)	Original hydrometer reading (corrected for meniscus only)	Effective depth L (cm)	Original hydrometer reading (corrected for meniscus only)	Effective depth L (cm)
0	16.3	21	12.9	42	9.4
1	16.1	22	12.7	43	9.2
2	16.0	23	12.5	44	9.1
3	15.8	24	12.4	45	8.9
4	15.6	25	12.2	46	8.8
5	15.5	26	12.0	47	8.6
6	15.3	27	11.9	48	8.4
7	15.2	28	11.7	49	8.3
8	15.0	29	11.5	50	8.1
9	14.8	30	11.4	51	7.9
10	14.7	31	11.2	52	7.8
11	14.5	32	11.1	53	7.6
12	14.3	33	10.9	54	7.4
13	14.2	34	10.7	55	7.3
14	14.0	35	10.5	56	7.1
15	13.8	36	10.4	57	7.0
16	13.7	37	10.2	58	6.8
17	13.5	38	10.1	59	6.6
18	13.3	39	9.9	60	6.5
19	13.2	40	9.7		
20	13.0	41	9.6		

Hydrometer Analysis Data Sheet

Student Name: .... Group Name : ....
Test date: / / Signature:

G_s of Solids = ...
Weight.of dry soil: W_s = ... a = ...
Meniscus correction = ... Zero correction = ...

Time (min)	Temp. °C	R_a	R_c	% Finer	R	L	$\frac{L}{t}$	K	D (mm)
0.5									
1									
2									
4									
8									
16									
24									
48