Hydrometer Analysis

Hydrometer Analysis

- Grain size distribution of soil which contain **significant** amount of finer particles (silt and clay)
- **Cannot be done** by sieve analysis
- Hydrometer analysis will be performed on a fine grained soil that **passes #200 sieve**



Hydrometer

- The hydrometer is made of **glass**, has a **stem**, and a **bulb**.
- When it is inserted into a liquid, it floats or submerges in an upright position with its bulb on the downside
- Usually there are readings from **0 to 60** on a hydrometer stem



- The hydrometer floats in the suspension and the reading on its stem tells how much soil is still suspended in the liquid at that moment.
- When the reading is 30, it means that there are 30 gm of soil in 1000cc soil suspension

- There are two types of ASTM soil hydrometers:

1. ASTM 151H
2. **ASTM 152H**

Determination of Particle Diameter

- **Stoke's Law:**

The terminal velocity (v) of a freely falling sphere through a medium is proportional to the square of the diameter (D) of the particle

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

Where, v = velocity (cm/s)

γ_s = Unit wt. of soil particles (gm/cc)

γ_w = Unit wt. of water (gm/cc)

η= Viscosity of water ($\frac{gm \cdot s}{cm^2}$)

D = Diameter of particle (cm)

$$D = \sqrt{\frac{18\eta}{\gamma_s - \gamma_w}} . \sqrt{v}$$

L= Distance of fall of a particle in time t

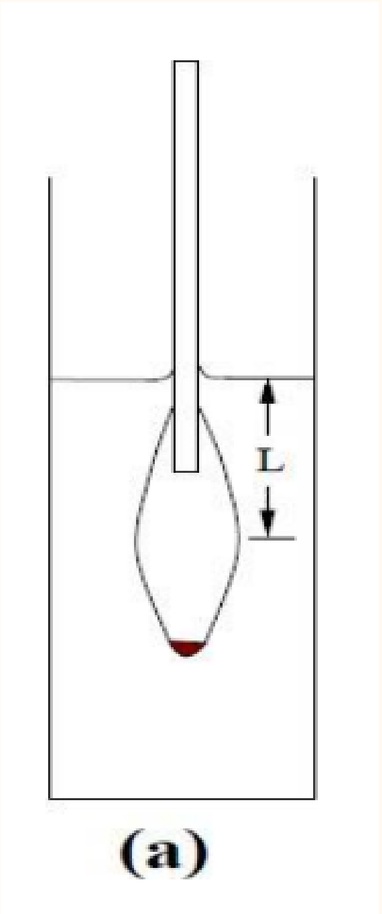
Velocity, v=L/t → $$D = \sqrt{\frac{18\eta}{\gamma_s - \gamma_w}} . \sqrt{\frac{L}{t}}$$

If we want to put t in minute, L in cm, η in poise (1 gm-sec per square cm =g poise =980.7 poise) and want to obtain D in mm then the above equation should be modified as

$$D\,(mm) = \sqrt{\frac{18\eta}{980.7 * (\gamma_s - \gamma_w)}} . \sqrt{\frac{L}{t * 60}} * 10$$

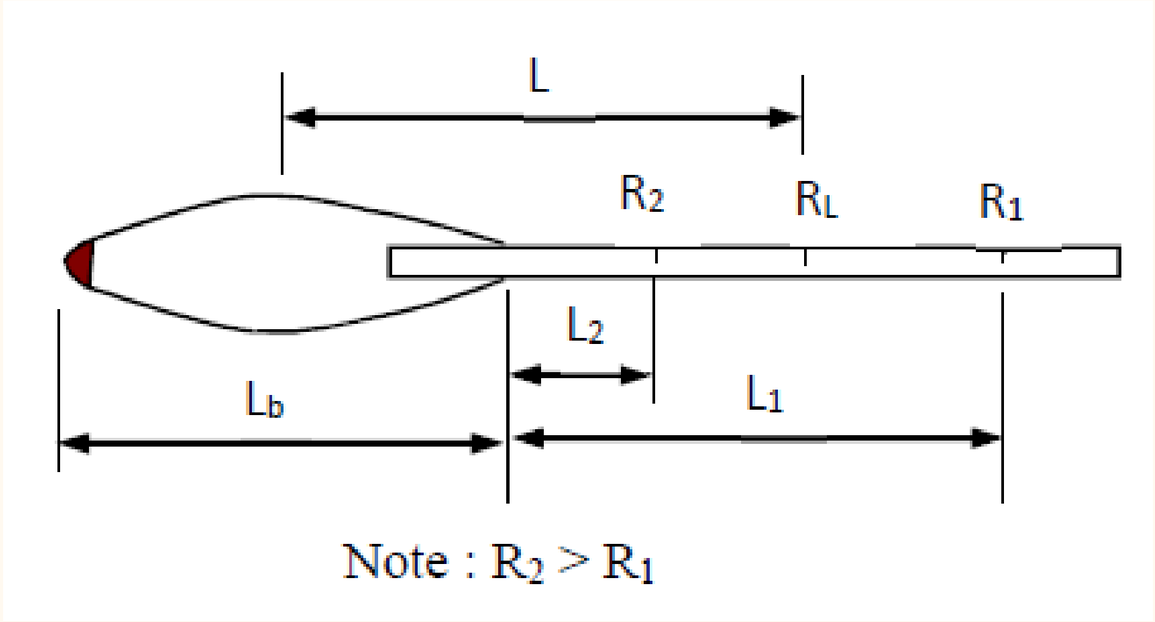
$$D\,(mm) = \sqrt{\frac{30\eta(poise)}{980.7 * [\gamma_s(\frac{gm}{cm^3}) - \gamma_w(\frac{gm}{cm^3})]}} . \sqrt{\frac{L(cm)}{t(min)}}$$

$$D = K . \sqrt{\frac{L}{t}}$$



- When we insert the hydrometer in a soil-water suspension we do not measure L directly

$$L = \frac{L_b}{2} + L_1 - \frac{L_1 - L_2}{R_2 - R_1}.(R - R_1)$$



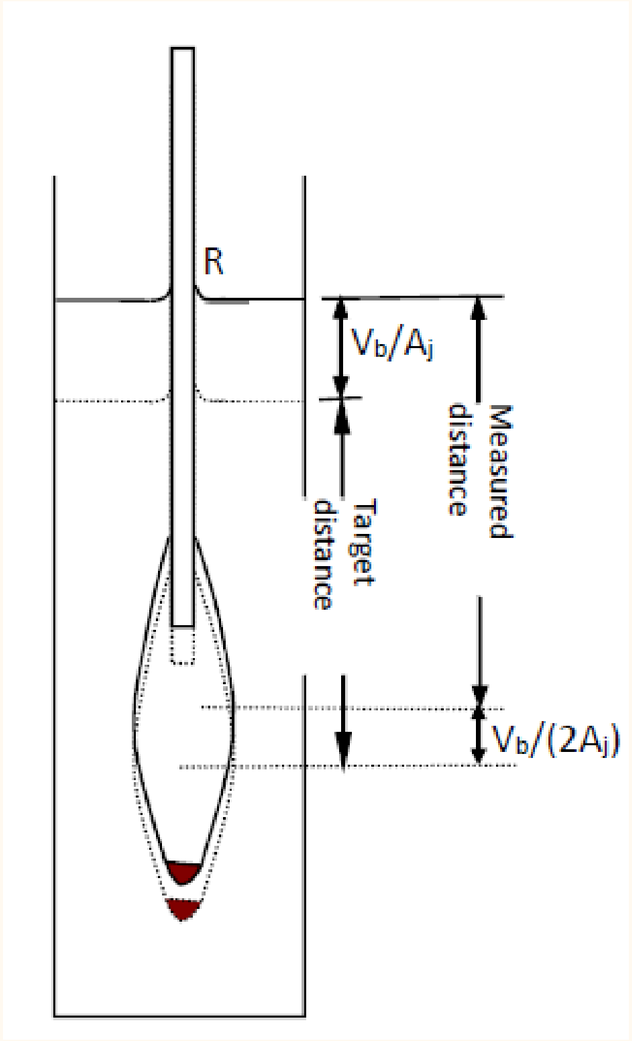
- The water level in the jar rises by $\frac{Vb}{Aj}$

- Rise of the c.g. of the hydrometer bulb by half of this $\frac{Vb}{2Aj}$

$$L = \frac{Lb}{2} + L1 - \frac{L1 - L2}{R2 - R1}.(RL - R1) - \frac{Vb}{2Aj}$$

Here, Vb=Volume of the hydrometer bulb

Aj = Cross-sectional Area of the hydrometer jar

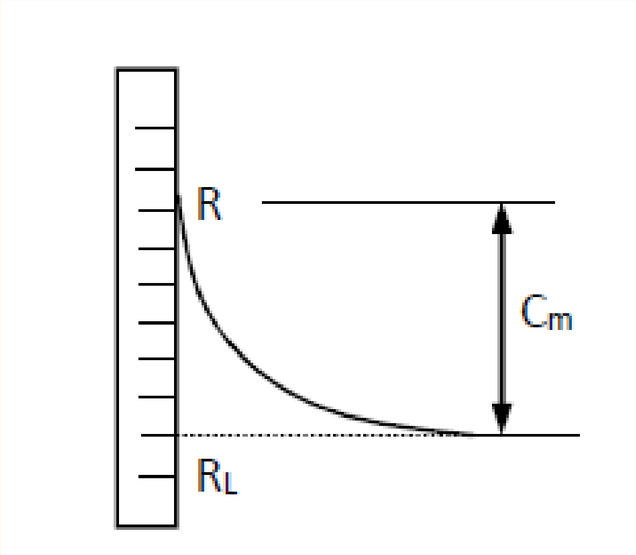


- **For ASTM 152H hydrometers:**

for R1=0 the distance L1=10.5 cm and

for R2=50, the distance L2 =2.3 cm, Lb=14 cm, Vb=67 cm3 .

The cross-sectional area of the hydrometer jar is 27.8 cm2. For these values,



$$L = 16.29 - 0.164 * R_L \text{ , (L in cm)}$$

- In the soil-water suspension we can read the upper meniscus, whereas we need the reading at the lower meniscus

$$R_L = R_0 \pm C_m$$

Table 4-2: Values of Efective depth R_L for hydrometer for which (L_1=10.5 cm, L_2=2.3 cm, R_1=-, R_2=50, L_b=14.0 cm, V_b= 67 cm^3, A_j=27.8 cm^3)

Hydrometer reading, R_L	L	Hydrometer reading, R_L	L	Hydrometer reading, R_L	L	Hydrometer reading, R_L	L
0	16.3	15	13.8	30	11.4	45	8.9
1	16.1	16	13.7	31	11.2	46	8.8
2	16.0	17	13.5	32	11.0	47	8.6
3	15.8	18	13.3	33	10.9	48	8.4
4	15.6	19	13.2	34	10.7	49	8.3
5	15.5	20	13.0	35	10.6	50	8.1
6	15.3	21	12.9	36	10.4	51	7.9
7	15.1	22	12.7	37	10.2	52	7.8
8	15.0	23	12.5	38	10.1	53	7.6
9	14.8	24	12.4	39	9.9	54	7.4
10	14.7	25	12.2	40	9.7	55	7.3
11	14.5	26	12.0	41	9.6	56	7.1
12	14.3	27	11.9	42	9.4	57	6.9
13	14.2	28	11.7	43	9.2	58	6.8
14	14.0	29	11.5	44	9.1	59	6.6

Table 4-8: Values of **k** for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature o*C*	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.0394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01269	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

Corrections

(a) Correction for meniscus (C_m): This correction is always **additive.**

(b) Zero correction (C_z): This correction is introduced because a **defloculating agent** is used in the preparation of the soil water suspension, which **increases the hydrometer reading.** This correction is always **subtractive.**

(c) Temperature correction (C_T): ASTM 152H hydrometers are calibrated at **20^0C**. So if the test **temperature is different** from soil water suspension, a correction is needed.

$$R_c = R_o + C_m - C_z \pm C_T$$

Table 4-9: Temperature Correction Factors

C_T

Temperature °C	Factor 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

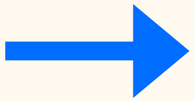
Determination of Percent Finer

$$\text{Percent finer, } N = \frac{R_c}{W_s} * 100$$

Ws=Weight (in gms) of soil used to prepare the suspension

- ASTM 152H hydrometers are calibrated such that for soil of specific gravity of **2.65**
- Because the sp.gr.of a soil may vary from 2.65 a correction factor is introduced

$$a = \frac{G_s * 1.65}{(G_s - 1) * 2.65}$$



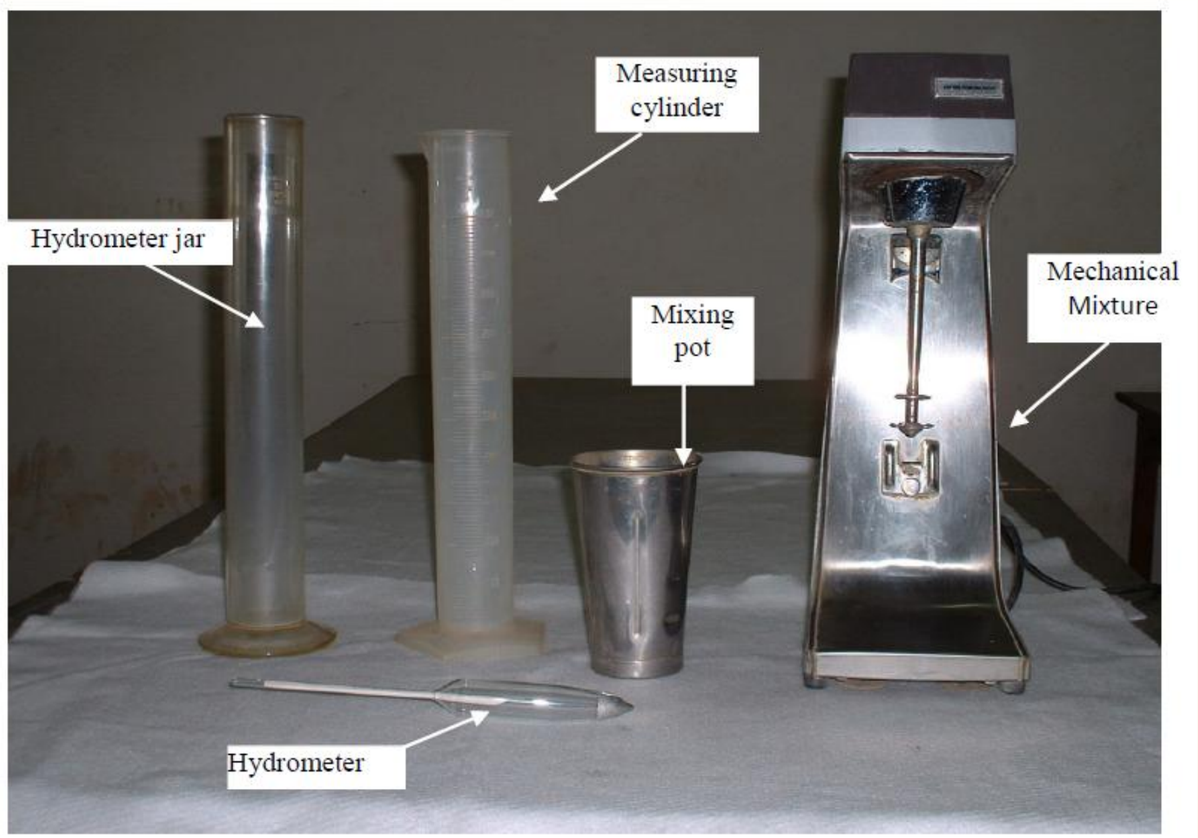
$$\text{Percent finer, } N = a * \frac{R_c}{W_s} * 100$$

Table 4-5: Correction factor for Different Specific Gravity of Soil Particles

Specific gravity	Correction factor
2.95	0.94
2.90	0.95
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	1.03
2.45	1.04

Equipment

- Hydrometer- **ASTM 152H**
- Hydrometer jar
- Balance
- Measuring cylinder / graduated jar
- Thermometer
- Mechanical mixture & mixing pot
- Can
- Water bath
- Wash bottle
- Stop watch

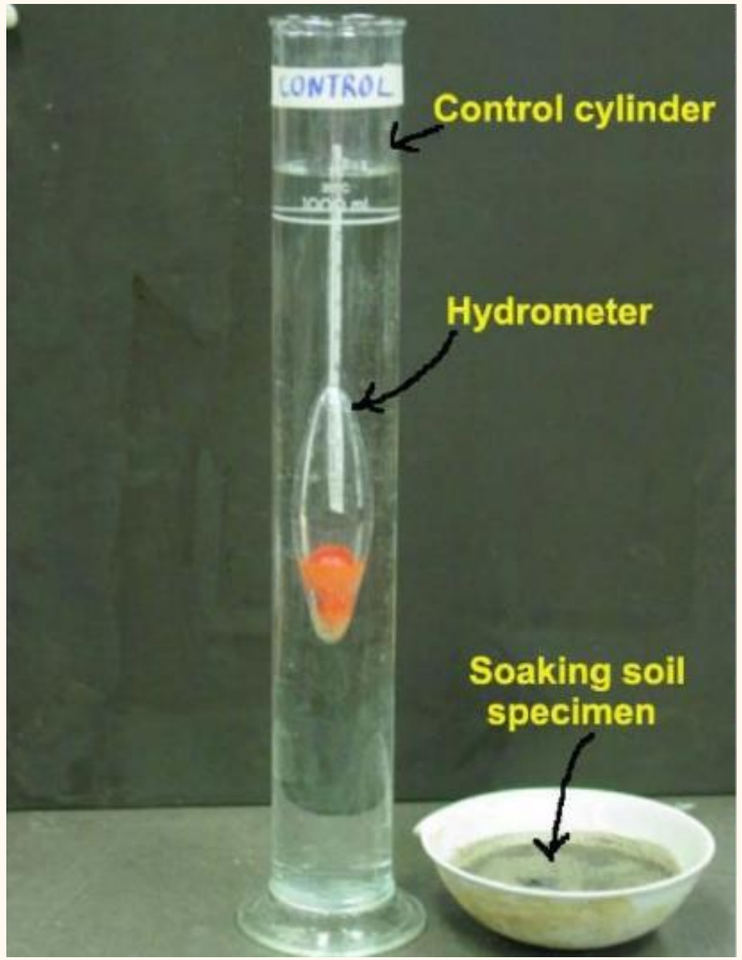


Procedure

- **50 gm** of fine soil from the bottom pan of the sieve set should be taken and placed into a beaker, and **125 mL of the dispersing agent** (sodium hexametaphosphate, 40 gm/liter) solution should be added.
- **125 mL of dispersing agent** should be added to the **control cylinder,** and it should be filled with distilled water to the mark
- The **hydrometer** and **thermometer** should be inserted into the control cylinder and the **meniscus correction, zero correction** and **temperature** should be noted respectively



- The **soil slurry** should be **transferred** into a **mixer** by adding more distilled water. The solution has to be mixed for a **two** minutes
- The soil slurry should be transferred into the **empty sedimentation cylinder** Distilled water has to added up to the mark
- The open end of the cylinder should be covered up with a stopper
- The cylinder should be inverted approximately **30 times** during a minute
- The hydrometer has to be inserted in the soil water suspension



Datasheet

Date	Time	Elapsed time,t (min)	Room temp (°C)	Actual Hydrometer reading, Ra	Reading after Meniscus Correction, R= Ra-Cm	Effective depth, L(cm)	Value of K	D in mm, $D=K\sqrt{L/t}$	C_T	a	Corrected Hydrometer reading, Rc	Percent finer,P= Rc*a*100/Ws	Adjusted % finer, $P_A = P*F_{200}/100$

Sample Calculations

Elapsed time, t = 25s

Room temperature = 22^0 C

Meniscus correction, $C_m = 1$

Zero correction, $C_z = +6$

Actual hydrometer reading, $R_a = 52.5$

Reading after Meniscus Correction $R = R_a - C_m = 52.5 - (-1) = 53.5$

Effective Depth, L (from Table 4-2) = 7.5 cm (using interpolation)

Value of K (from Table 4-8) = 0.01332 (for room temperature 22^0C and soil specific gravity 2.65)

D in mm = $K\sqrt{\frac{L}{t}}$ = 0 .01332 x $\sqrt{\frac{7.5}{2.5}}$= 0.071861

Temperature correction, C_T (from Table 4-9) = +0.40

Correction factor for unit weight of soil, a (from Table 4-5) = 0.99

Corrected Hydrometer Reading, $R_c = R_a - C_z + C_T = \{52.5 - (+6) + 0.4\}$

$= 46.9$

Percent Finer = $(R_c \times a \times 100) / W_s$

$= (46.9 \times 0.99 \times 100) / 50$

$= 92.862$

Grain Size Distribution Plot by Hydrometer

