Geotechnical Engineering–I

BSc Civil Engineering – 4th Semester

Lecture # 6

13-Feb-2015

by

Dr. Muhammad Irfan

Assistant Professor

Civil Engg. Dept. – UET Lahore

Email: mirfan1@msn.com

Lecture Handouts: https://groups.google.com/d/forum/geotec-1

SIEVE ANALYSIS – Calculations

Sieve No.	Diameter (mm)	Wt. of soil retained (gm)	Cumulative soil weight retained on each sieve (gm)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
(Col. 1)	(Col. 2)	(Col. 3)	(Col. 4)	(Col. 5)	(Col. 6)

(Col. 4) = (Col. 3) + (Col. 4) of previous line

(Col. 5) = [(Col. 4)/Total wt.] x 100

(Col. 6) = 100 – (Col. 5)

SIEVE ANALYSIS
(Practice Problem)

500 grams of dry soil was tested for grain size analysis and following observations recorded:

Grain size (mm)	Weight retained (gm)
2.00	10
1.40	18
1.00	60
500µm	135
250µm	145
125µm	56
75µm	45

Plot the gradation curve and compute the following:

(i) Percentages of gravel, coarse sand, medium sand, fine sand, and silt and clay fraction.

(ii) Coefficient of uniformity C_u

(iii) Co-efficient of curvature C_c

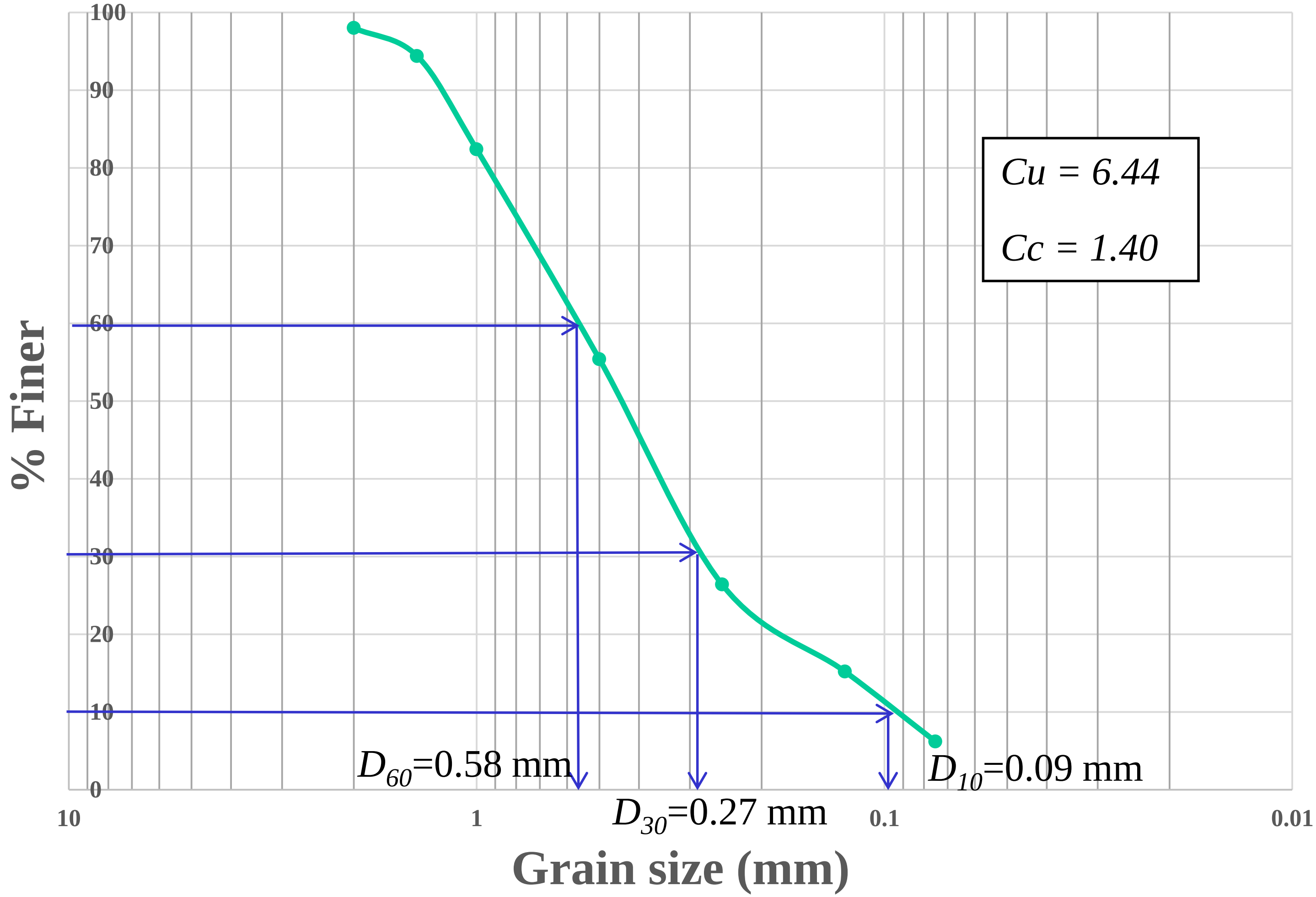
(iv) Comment on the soil type.

SIEVE ANALYSIS

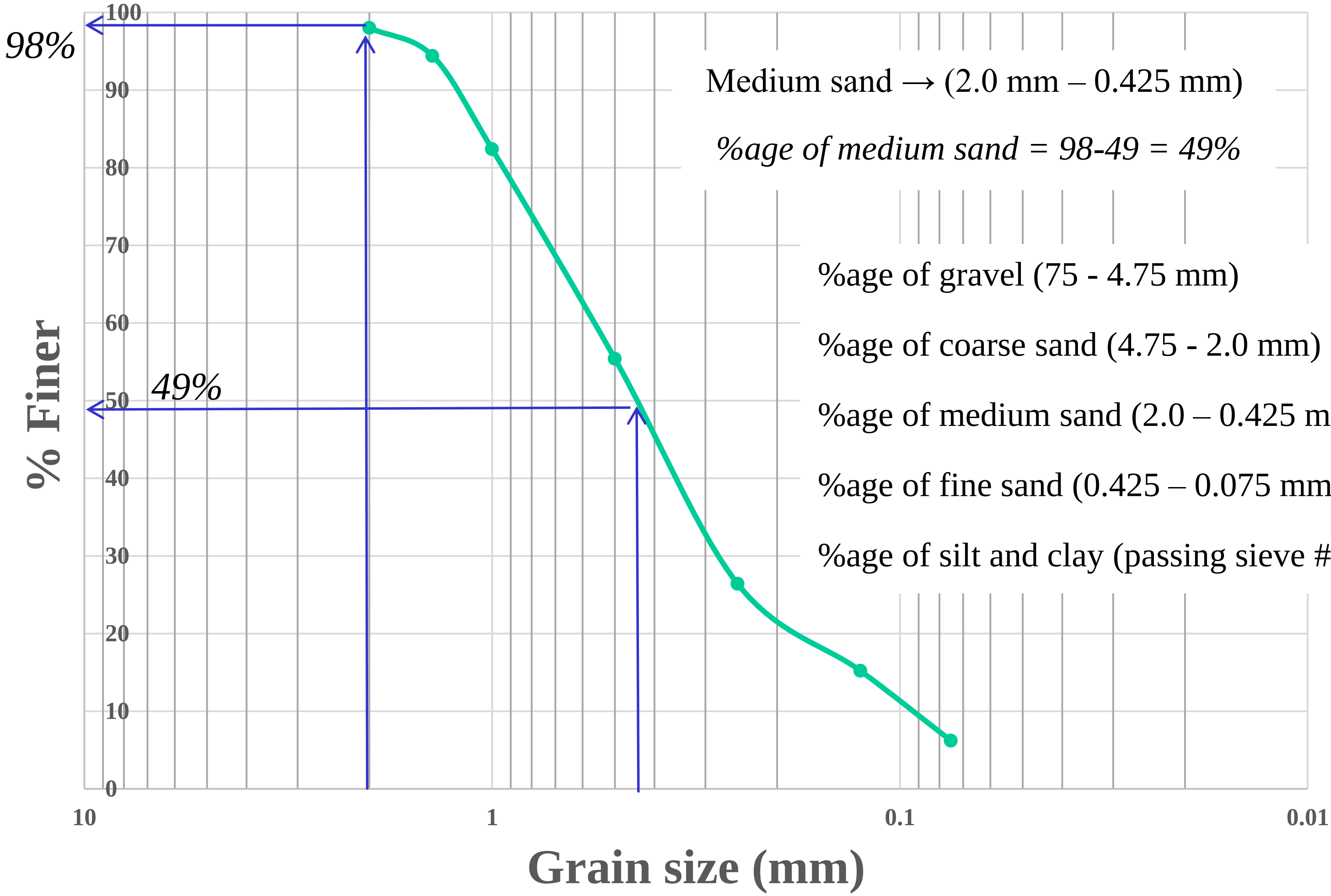
(Practice Problem)

Grain size (mm)	Weight retained (gm)	% retained	Cumulative % Retained	% Finer
2.00	10	2.0	2.0	98.0
1.40	18	3.6	5.6	94.4
1.00	60	12.0	17.6	82.4
500μm	135	27.0	44.6	55.4
250μm	145	29.0	73.6	26.4
125μm	56	11.2	84.8	15.2
75μm	45	9.0	93.8	6.2

SIEVE ANALYSIS
(Practice Problem)



SIEVE ANALYSIS
(Practice Problem)



Medium sand → (2.0 mm – 0.425 mm)

%age of medium sand = 98-49 = 49%

%age of gravel (75 - 4.75 mm)	= nil
%age of coarse sand (4.75 - 2.0 mm)	= 2
%age of medium sand (2.0 – 0.425 mm)	= 49
%age of fine sand (0.425 – 0.075 mm)	= 43
%age of silt and clay (passing sieve #200)	= 6

MECHANICAL ANALYSIS OF SOIL

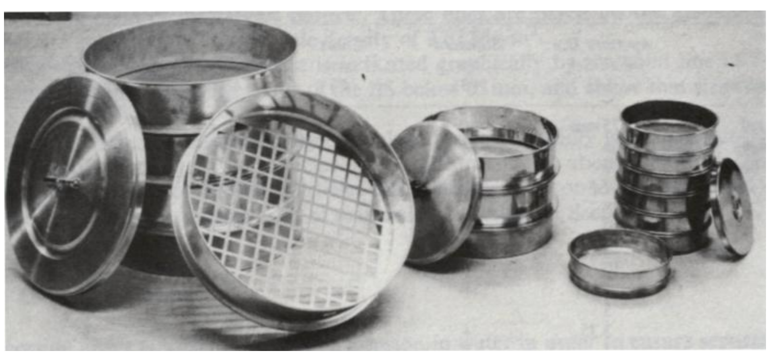
Mechanical analysis is the determination of the size range of particles present in a soil, expressed as a percentage of the total dry weight.

Coarse-grained soils: Fine-grained soils:

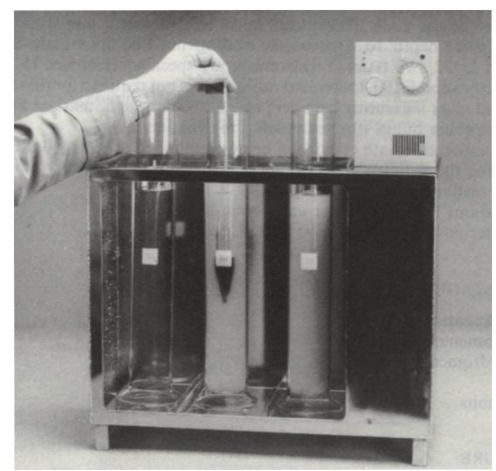
Gravel Sand Silt Clay

0.075 mm (USCS)

0.06 mm (BS)



Sieve Analysis

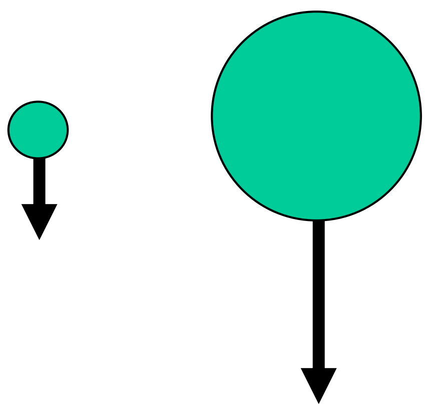


Hydrometer Analysis

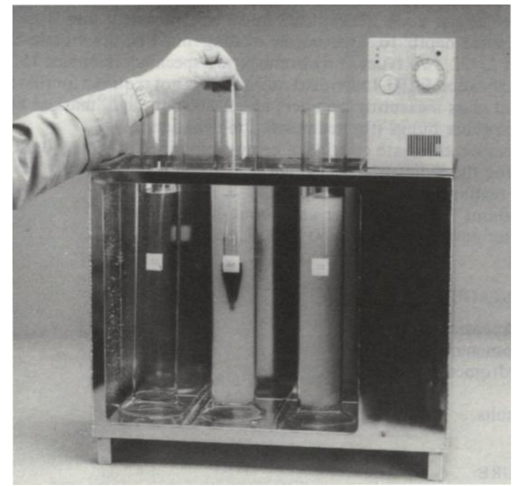
HYDROMETER ANALYSIS – *Stoke's Law*

For a sphere moving in a fluid, the drag force acting on it is a function of its diameter.

Stoke's Law



$V_1 < V_2$



→ Silt will settle *faster* compared to clay.

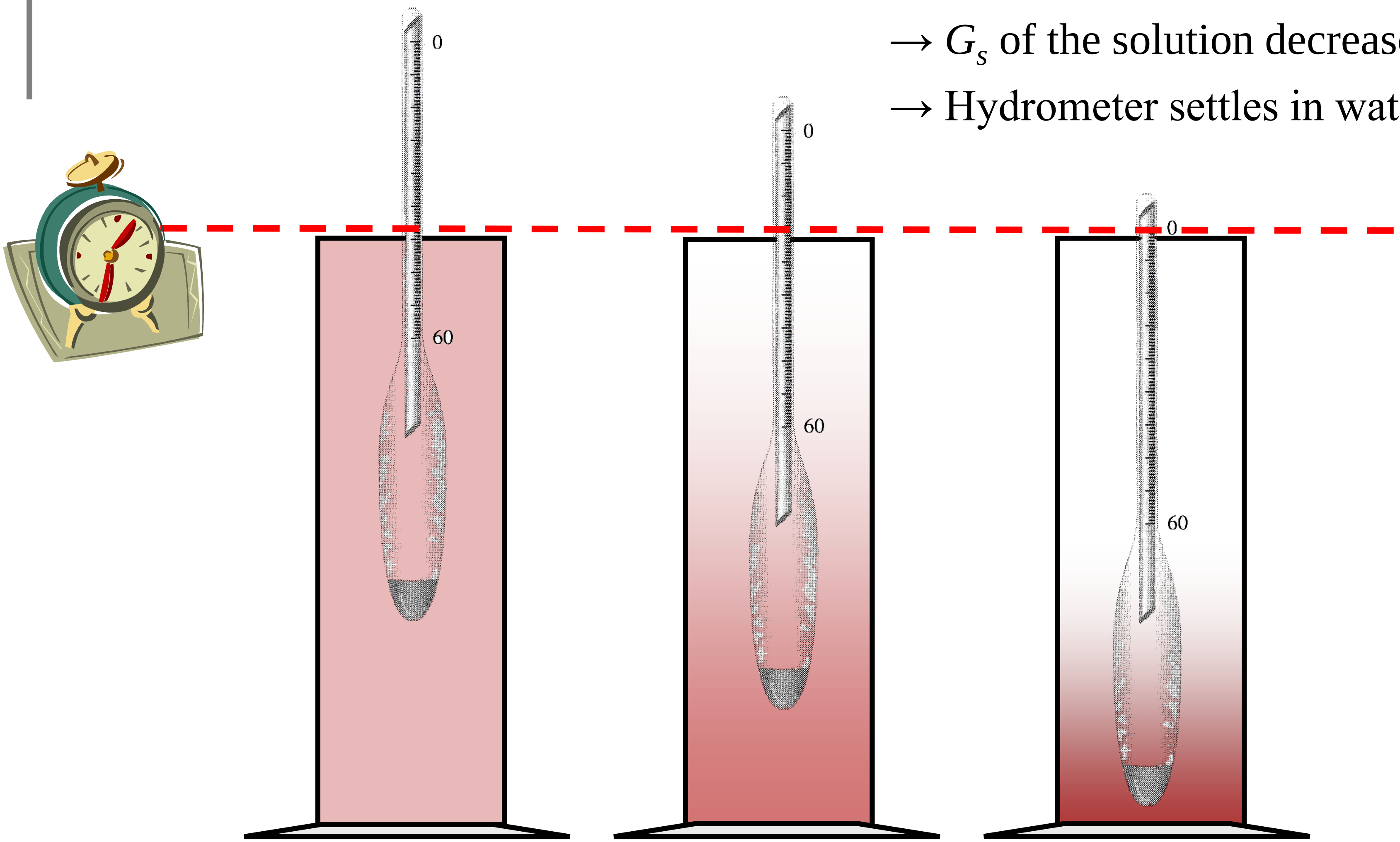
→ Why soil particles settle in water?

HYDROMETER ANALYSIS – *Conceptual Basis*

→ Soil settles down

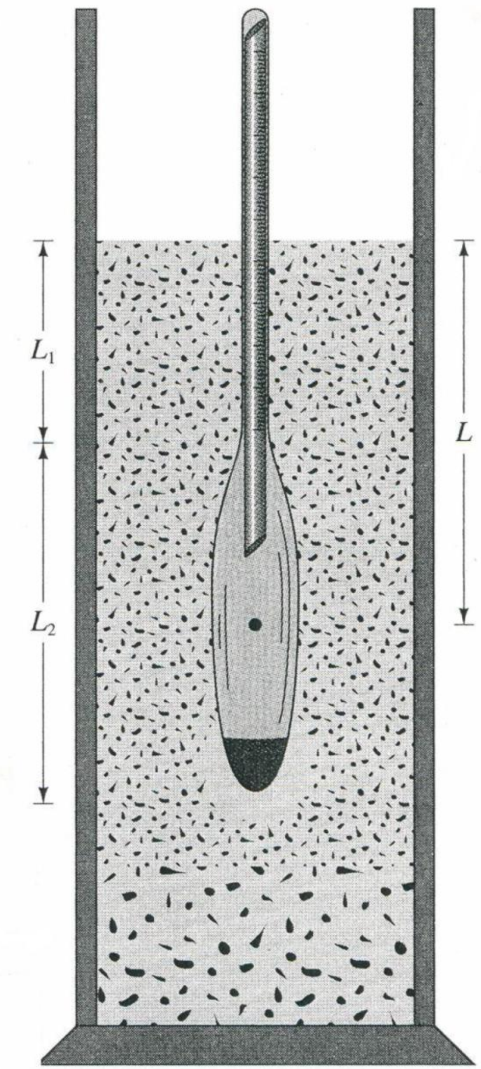
→ G_s of the solution decreases

→ Hydrometer settles in water



HYDROMETER ANALYSIS

- At any time t, hydrometer measures the specific gravity of the suspension near the vicinity of its bulb (depth L).
  - For *pure water* hydrometer reading will be *1*.
- It indirectly gives the amount of soil that is still in suspension.
- By knowing the amount of soil in suspension, L, and t, we can calculate the %age of soil by weight finer than a given diameter.



HYDROMETER ANALYSIS

Corrected hydrometer reading;

$R_c = R_{actual}$ – Zero Correction + Temp. Correction

$$Percent\ \ finer = \frac{R_c \times a}{W_s} \times 100$$

a = correction factor for specific gravity

W_s = Total weight of soil specimen

For ASTM 152H hydrometer

$$L\,(\text{cm}) = 16.29 - 0.164R\,(\text{cm})$$

where, R = hydrometer reading corrected for meniscus

How to correlate L with particle size?

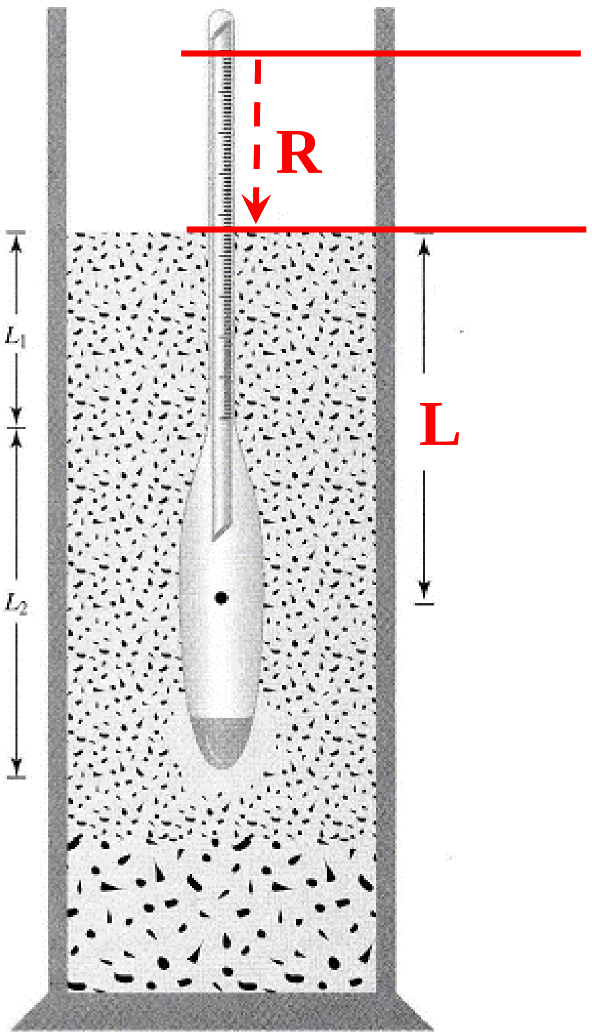
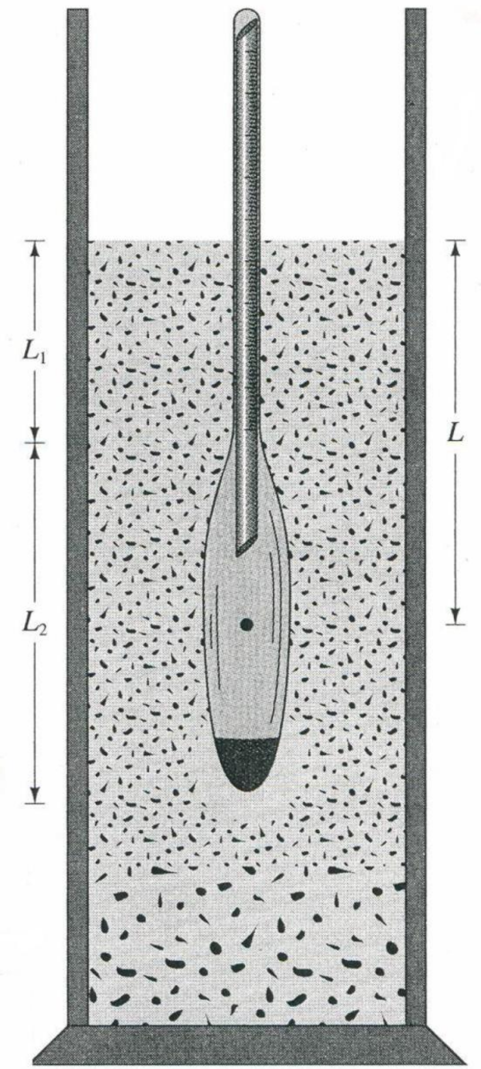


Figure 2.17 Definition of L in hydrometer test

HYDROMETER ANALYSIS

- Principle → sedimentation of soil grains in water
- *Velocity of particle settlement* depend on their shape, size, weight, and viscosity of water.



Assuming particles to be spheres, their velocities can be expressed by Stokes law.

$$v = \frac{\rho_s - \rho_w}{18\eta} D^2$$

where v = velocity (cm/s)

ρ_s = density of soil particles (g/cm^3)

ρ_w = density of water (g/cm^3)

η = viscosity of water (g-sec/cm^2)

D = diameter of soil particles (cm)

STOKE'S LAW

$$v = \frac{\rho_s - \rho_w}{18\eta} D^2$$

where, v = velocity (cm/s)

ρ_s = density of soil particles (g/cm^3)

ρ_w = density of water (g/cm^3)

η = viscosity of water (g-sec/cm^2)

D = diameter of soil particles (cm)

$$D = \sqrt{\frac{18\eta v}{\rho_s - \rho_w}} = \sqrt{\frac{18\eta}{\rho_s - \rho_w}}\sqrt{\frac{L}{t}}$$

where $v = \dfrac{\text{Distance}}{\text{Time}} = \dfrac{L}{t}$

$$\rho_s = G_s \rho_w \quad \Rightarrow \quad D = \sqrt{\frac{18\eta}{(G_s - 1)\rho_w}}\sqrt{\frac{L}{t}}$$

STOKE'S LAW

$$D = \sqrt{\frac{18\eta}{(G_s - 1)\rho_w}}\sqrt{\frac{L}{t}}$$

If L is in cm, t is in min, ρ_w in g/cm^3, η in g-sec/cm^2, and D in mm, then above equation can be written as

$$\frac{D(\mathrm{mm})}{10} = \sqrt{\frac{18\eta}{(G_s - 1)\rho_w}}\sqrt{\frac{L}{t \times 60}} \quad \Rightarrow \quad D = \sqrt{\frac{30\eta}{(G_s - 1)\rho_w}}\sqrt{\frac{L}{t}}$$

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

$$\boxed{\text{where, } K = \sqrt{\frac{30\eta}{(G_s - 1)}}}$$

Assuming $\rho_w = 1$ g/cm^3

STOKE'S LAW

Values of K for several specific gravity of solids and temperature combinations

	G_s of Soil Solids							
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	0.0139	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

HYDROMETER ANALYSIS

(Practice Problem #1)

A 50 gram soil sample is dispersed in 1000 ml of water. How long after the start of sedimentation should the hydrometer reading be taken in order to estimate the percentage of particles less than 0.003 mm effective diameter, if the center of the hydrometer is 150 mm below the water-soil suspension? $G_s = 2.65$, $\mu = 0.001$ SI units

From Stokes law:

$$v = KD^2 = \frac{\gamma_w (G_s - 1)}{18\mu} D^2$$

$$= \frac{1000(2.65 - 1)9.81}{18 \times 0.001} (\frac{0.003}{1000})^2 \text{ m/sec} = 0.0081 \text{ mm/sec}$$

but

$$v = L/t, \qquad \therefore\ t = \frac{L}{v} = \frac{150}{0.0081 \times 60 \times 60} = 5.15 \text{ hr.}$$

HYDROMETER ANALYSIS

(Practice Problem #2)

A soil sample consisting of particles of size 0.5 mm to 0.01 mm is put on the surface of still water tank 5m deep. Calculate the time of settlement of the coarsest and finest particles of the sample to the bottom of the tank. Assume average specific gravity of soil particles as 2.66 and viscosity of water as 0.01 poise.

CONCLUDED