TEST 4: PARTICLE SIZE ANALYSIS

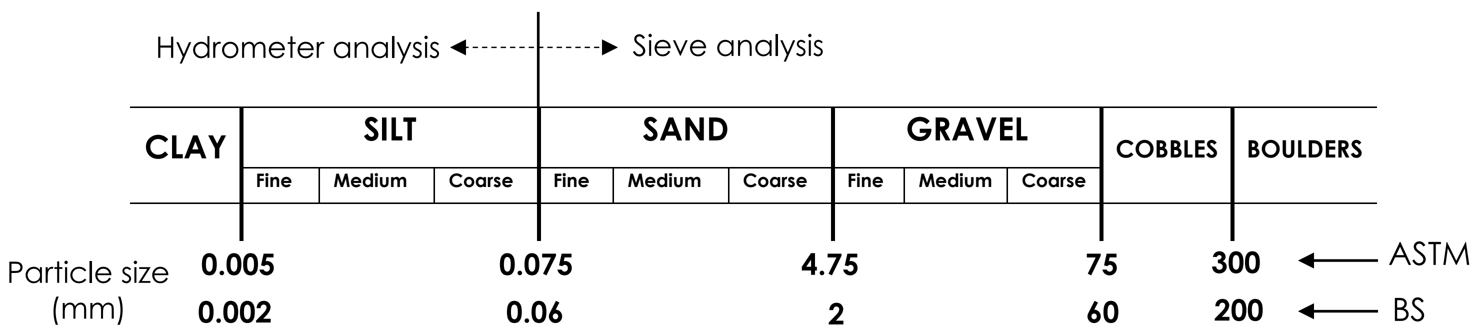
Definition:

Particle/Grain size analysis is the quantitative determination of the distribution of particle size (PSD) in soils. It is expressed as a percentage of the total dry weight. Particles sizes in soils can vary from over 200 mm to less than 0.001 mm.

Two methods are used to determine the particle size distribution of soils:

(1) Sieve analysis: for particle size larger than 75 μ (retained on Sieve No. 200).

(2) Hydrometer analysis: for particle size smaller than 75 μ (0.075 mm) using a sedimentation process.



Combined sieving and sedimentation procedures enable a continuous particle size distribution curve of a soil to be plotted from the size of the coarsest particles down to the clay size.

The particle size distribution curve, also known as a gradation curve, represents the distribution of particles of different sizes in the soil mass. Depending on it, soils are described as Well graded or Poorly graded.

Purpose and significance:

- To determine the particle size distribution (PSD) curve of soils.
- It is used to classify soils.
- The PSD of a soil is a fundamental characteristic that controls permeability, dry density/unit weight and effective angle of friction.

Standard Reference:

ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils.

BS 1377-2:1990 Methods of test for soils for civil engineering purposes: Part 2: Classification tests. Determination of particle size distribution, Dry sieving method

SIEVE ANALYSIS

Sieve analysis is the sieving operation by means of shaking a soil sample over a set of sieves that have progressively smaller openings. Two methods of sieving can be used: Wet sieving and Dry sieving.

Apparatus:

1. Set of sieves: a series of standard sieves of square mesh, including cover plate and bottom pan. Test sieves having the following aperture sizes may be used, but it will not be necessary to use every size for every test:

Sieve No.	Lid	4	10	30	50	100	200	Pan
Aperture size (mm)		4.75	2	0.6	0.3	0.15	0.075	

2. Sieve shaker.
3. Balance readability of 0. 1 g.
4. Sieve brushes (to clean the sieves).
5. A scoop.
6. Drying oven.

Specimen preparation:

Select a soil sample to be representative of the total soil. The test sample shall be obtained by riffling or quartering and shall then be oven dried at 105 °C to 110 °C to give a minimum mass complying with Table 1.

Table 1:

Maximum particle size (mm)	Specimen mass (g)
10	500
Finer than Sieve No.4 (4.75)	200
Finer than Sieve No.10 (2.00)	100

Test Procedure:

1. Select a stack of sieves suitable to the soil being tested. Check that the sieves are clean. Otherwise, clean each sieve by using a brush to remove any grains stuck in the mesh openings.
2. Weigh each empty sieve and a pan.
3. Stack the sieves to be used in the correct order, largest sieve size down to the smallest, with the pan in the bottom.
4. Weigh the initial mass of the oven-dried sample (W_i)and pour it on the top sieves.
5. Place the stack of sieves in the mechanical shaker and shake for 10 min.
6. Remove the stack of sieves from the shaker, and measure the weight of each sieve and the pan with the soil retained on them.

Calculation:

1. Calculate the mass of soil retained on each sieve by subtracting the weights obtained in step 6 from those of step 2.

   Soil Retained on each sieve, $W_r = (W_{\text{sieve+soil retained}} - W_{\text{Empty sieve}})$

2. Calculate the total actual mass retained (W_t), which equals the sum of the mass of soil retained on each sieve. Compare it with the initial sample weight (W_i).

   If $W_t \neq W_i$ then Calculate the corrected mass retained for each sieve size using the following equation:

$$W_c = W_r + \left(\frac{(W_i - W_t)}{W_t} x W_r\right)$$

3. Calculate the percentage retained on each sieve and the pan using the following equation:

   % Retained on each sieve = $\frac{W_c}{W_i} \times 100$

   As a quick check, total up the percentages – they should add up to 100%.

4. Calculate the cumulative percentage passing. The cumulative percentage passing is equal to (100 – the percentage retained on that sieve and all larger sieves).

   % Passing/finer = 100 – Σ Cumulative of % Retained

5. Using a semi-logarithmic chart, plot the percentage passing (% finer) as ordinate (on linear scale) against the particle (sieve) size as abscissa (on log scale). This plot is **the particle-size distribution curve**.
6. Find gravel, sand and (silt and clay) percentage according to the ASTM.

Note:

The particle-size distribution curve can be used to determine some of the basic soil parameters such as the:

- Effective size (D_{10}); is the diameter of the particles in the particle size distribution curve corresponds to 10% passing.
- Uniformity coefficient (C_U); is a measure of the slope of the curve. It is defined as:

$$C_U = \frac{D_{60}}{D_{10}}$$

Where D_{60} = diameter corresponding to 60% finer/passing.

1. Coefficient of gradation or concavity (C_C); is defined as:

$$C_C = \frac{(D_{60})^2}{D_{10} \times D_{30}}$$

Where D_{30} = diameter at which 30% of the total soil mass is passing.

PARTICLE SIZE ANALYSIS (SIEVE ANALYSIS)
DATA SHEET

Date tested:
Tested by:
Class:

Weight of Container:
Weight of Container +Dry Soil:
The initial sample weight (W_i):

Sieve No.	Sieve size (mm)	Mass of empty sieve (g)	Mass of sieve +soil Retained (g)	Mass Retained (g)		% Retained $\frac{W_c}{W_i} \times 100$	% Passing
				Actual W_r	Corrected W_c		
4	4.75						
Total mass retained (W_t)				Σ			

From the Particle Size Distribution Curve:

% Gravel =
% Sand =
% Fines =

D_{10} = mm
D_{30} = mm
D_{60} = mm

Group names:

1-
2-
3-
4-
5-

Supervisor signature

Discussion: Answer the following questions by referring to relevant References.

1. Define each of the following terms. Include suitable ranges of values for C_U in each case and sketch the typical profile of the PSD graph.

   (a) Well Graded

   Range:

   (b) Uniformly Graded

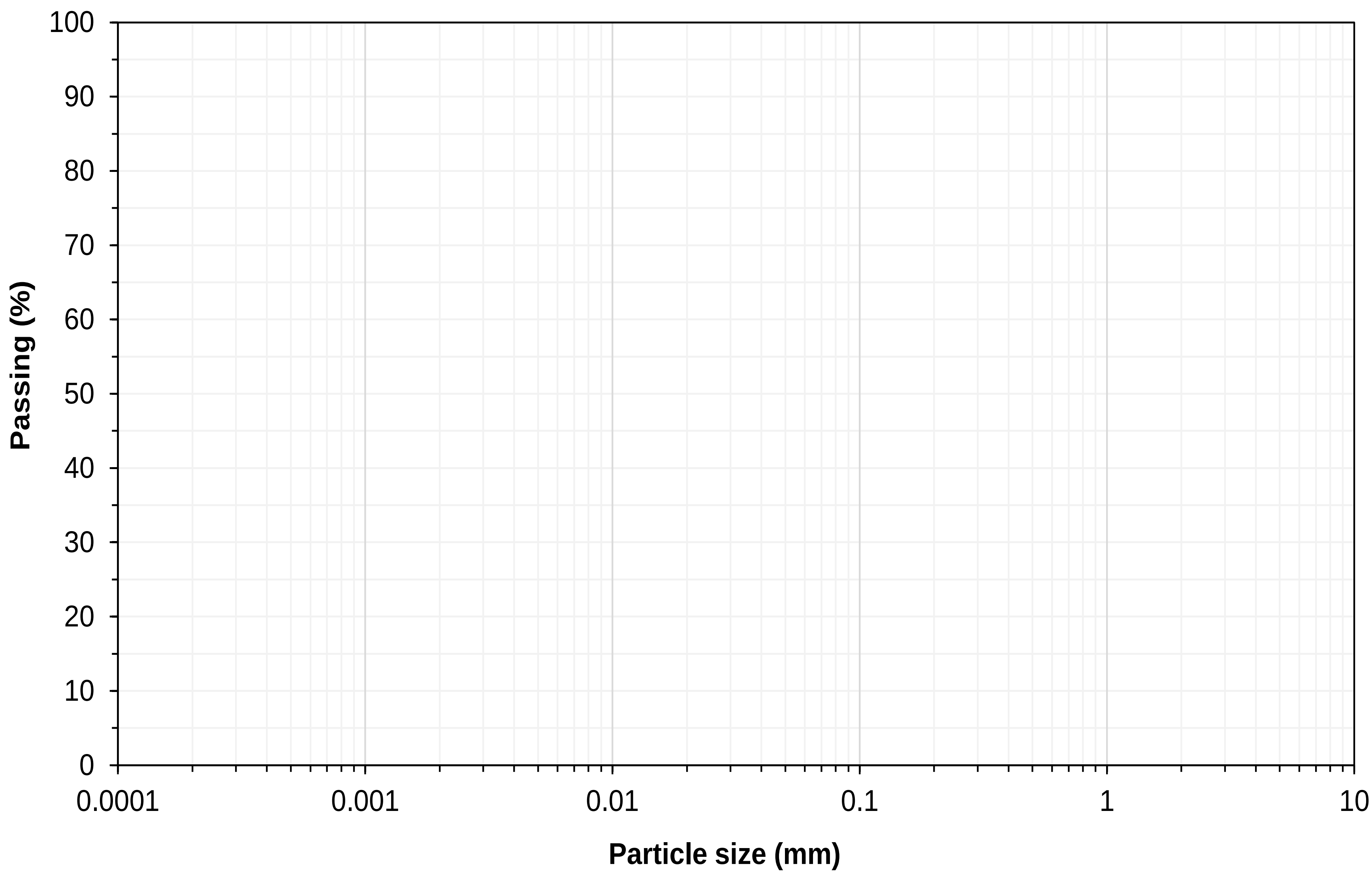
   Range:

   (c) Poorly Graded

   Range:

2. Compare, with sketches, how the soil structure, dry density, unit weight and permeability will vary between a well graded and uniformly graded soil.

3. Under what conditions wet sieving should be used instead of dry sieving?

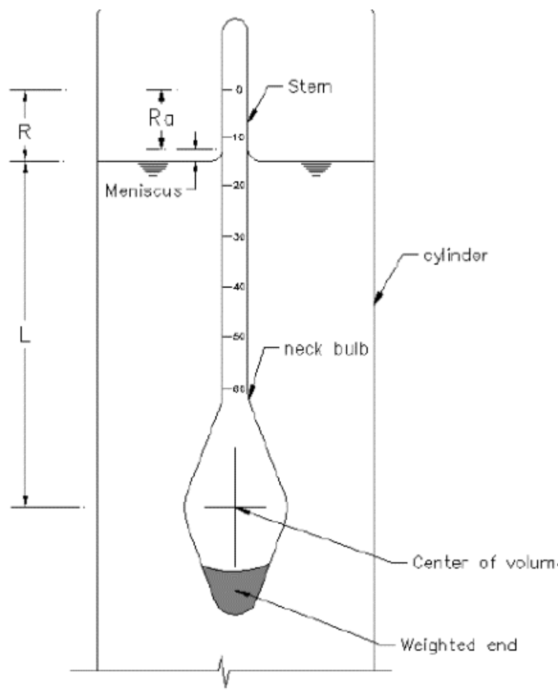

100
90
80
70
60
50
40
30
20
10
0
Passing (%)
0.0001
0.001
0.01
0.1
1
10
Particle size (mm)

HYDROMETER ANALYSIS

Hydrometer analysis is the sedimentation process by means the particles are allowed to settle under gravity. It is based on the fact that large particles in a suspension in water settle more quickly than small particles, assuming that all particles have similar densities and shapes (Stokes, 1891). From certain measurements made at known intervals of time, particle size distribution can be assessed. 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.

Apparatus:

1. 152H Hydrometer,
2. Mixer (dispersion apparatus),
3. Beaker.
4. Sedimentation cylinder,
5. Control cylinder,
6. Glass stirring rod,
7. Thermometer,
8. Wash bottle and distilled water,
9. Stopwatch.



Specimen preparation:

Take 50 g of the fine soil (passed sieve No. 200) that remained on the pan of the sieve set for the hydrometer test. The soil must be treated with dispersant and thoroughly agitated to ensure that discrete particles are separated. The dispersion agent contains 4% NaPO3 and can be prepared by mixing 40 g of sodium hexametaphosphate (NaPO3) known commercially as (Calgon) with 1L of distilled water.

Test Procedure:

1. Take the 50 g soil specimen and place it into a beaker. Add 125 mL of the dispersing agent (sodium hexametaphosphate (40 g/L)) solution. Stir the mixture until the soil is thoroughly wet. Let the soil soak for at least ten minutes.
2. Transfer the soil slurry into a mixer by adding more distilled water (≥ half mixer cup). Then mix the solution for a period of 5 minutes.
3. Immediately transfer the soil slurry into the empty sedimentation cylinder. Add distilled water up to the mark (1000 ml).
4. Cover the open end of the sedimentation cylinder with a stopper and secure it with the palm of your hand and carefully agitate for about 1 min by turning the cylinder upside down and back upright (The cylinder should be inverted approximately 30 times during the minute).
5. At the end of 1 min, set the cylinder down, immediately insert the hydrometer, and Take hydrometer readings at the upper rim of the meniscus after periods of 0.5, 1, 2, 4 min from the beginnings of the sedimentation also take temperature reading of sedimentation cylinder.
6. Remove the hydrometer slowly, rinse in distilled water and place it in the control cylinder (containing 125mL of dispersing agent and filled with distilled water to the mark). Take meniscus correction, zero correction and temperature from the control cylinder.
7. Reinsert the hydrometer in the soil suspension (sedimentation cylinder) and take additional hydrometer and temperature readings at elapsed time of 8, 15, 30, min followed by 1, 2, 4, 8, 16, 24, 48, 96 hr.

Note: when it desired to take the hydrometer readings, insert the hydrometer slowly about 20-25 s before a reading is due to minimize any disturbance, and the release of the hydrometer should be made as close to the reading depth as possible to avoid excessive bobbing.

Correction of Hydrometer Readings:

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 - 1.0** g/L for most 152 H hydrometer. The correction hydrometer reading for meniscus is:

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 Table 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/cylinder 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**". It is the reading at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero is recorded as a negative (-) correction and a reading between zero and sixty is recorded as a positive (+) correction.

Calculation:

1. Apply meniscus correction (C_m) only to the hydrometer reading from sedimentation cylinder.

$$R_a = R + C_m$$

   Where R_a = actual hydrometer reading.
2. From Table 1, obtain the effective depth (L) in cm using R_a.
3. For known Gs of the soil (if not known, assume 2.65 for this lab purpose), obtain the value of K from Table 2.
4. Calculate the equivalent particle diameter by using the following formula:

$$D = K\sqrt{\frac{L}{T}}$$

   Where: T is in minutes, and D is given in mm.

5. Determine correction factor "a" from Table 4 using Gs.

6. Calculate corrected hydrometer reading as follows:

$$R_c = R_a - zero\ correction + \mathrm{C_T}$$

7. Calculate percent finer as follows:

$$P = \frac{R_c \times a}{w_s} \times 100$$

   Where: w_s is the weight of the soil sample in grams.
8. Adjusted percent finer as follows:

$$P_A = \frac{P \times F_{200}}{100}$$

   Where: F_{200} = % finer of #200 sieve as a percent
9. Plot the grain size curve D versus the adjusted percent finer P_A on the semilogarithmic sheet.

Table 1. Values of Effective Depth Based on Hydrometer and sedimentation Cylinder of Specific Sizes.

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L (cm)	Actual Hydrometer Reading	Effective Depth, L (cm)	Actual Hydrometer Reading	Effective Depth, L (cm)
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5	36	10.4
1.006	14.7	6	15.3	37	10.2
1.007	14.4	7	15.2	38	10.1
1.008	14.2	8	15.0	39	9.9
1.009	13.9	9	14.8	40	9.7
1.010	13.7	10	14.7	41	9.6
1.011	13.4	11	14.5	42	9.4
1.012	13.1	12	14.3	43	9.2
1.013	12.9	13	14.2	44	9.1
1.014	12.6	14	14.0	45	8.9
1.015	12.3	15	13.8	46	8.8
1.016	12.1	16	13.7	47	8.6
1.017	11.8	17	13.5	48	8.4
1.018	11.5	18	13.3	49	8.3
1.019	11.3	19	13.2	50	8.1
1.020	11.0	20	13.0	51	7.9
1.021	10.7	21	12.9	52	7.8
1.022	10.5	22	12.7	53	7.6
1.023	10.2	23	12.5	54	7.4
1.024	10.0	24	12.4	55	7.3
1.025	9.7	25	12.2	56	7.1
1.026	9.4	26	12.0	57	7.0
1.027	9.2	27	11.9	58	6.8
1.028	8.9	28	11.7	59	6.6
1.029	8.6	29	11.5	60	6.5
1.030	8.4	30	11.4		
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				
1.039	5.9				

Table 2. Values of k for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis.

Temperature °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

Table 3. Temperature Correction Factors C_T

Table 4. Correction Factors a for Unit Weight of Solids.

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

Unit Weight of Soil Solids, g/cm^3	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

PARTICLE SIZE ANALYSIS (HYDROMETER ANALYSIS)
DATA SHEET

Date tested: ……………………….. Tested by: ……………………………

Class: ……………………………….. Wt. of dry soil, Ws = ...

Gs of solids = ……………………… a from Table 4= ....

Meniscus correction, Cm = ………….. Zero correction = ………………

Time	Elapsed time (min.)	Temp. (°C)	Hydr. Rdg. (R)	Actual Hydr. Rdg. (R_a)	L from Table 1	K from Table 2	D mm	C_T from Table 3	Corr. Hydr. Rdg. (R_c)	% Finer P	% Adjusted Finer P_A

Group names:

1-
2-
3-
4-
5-

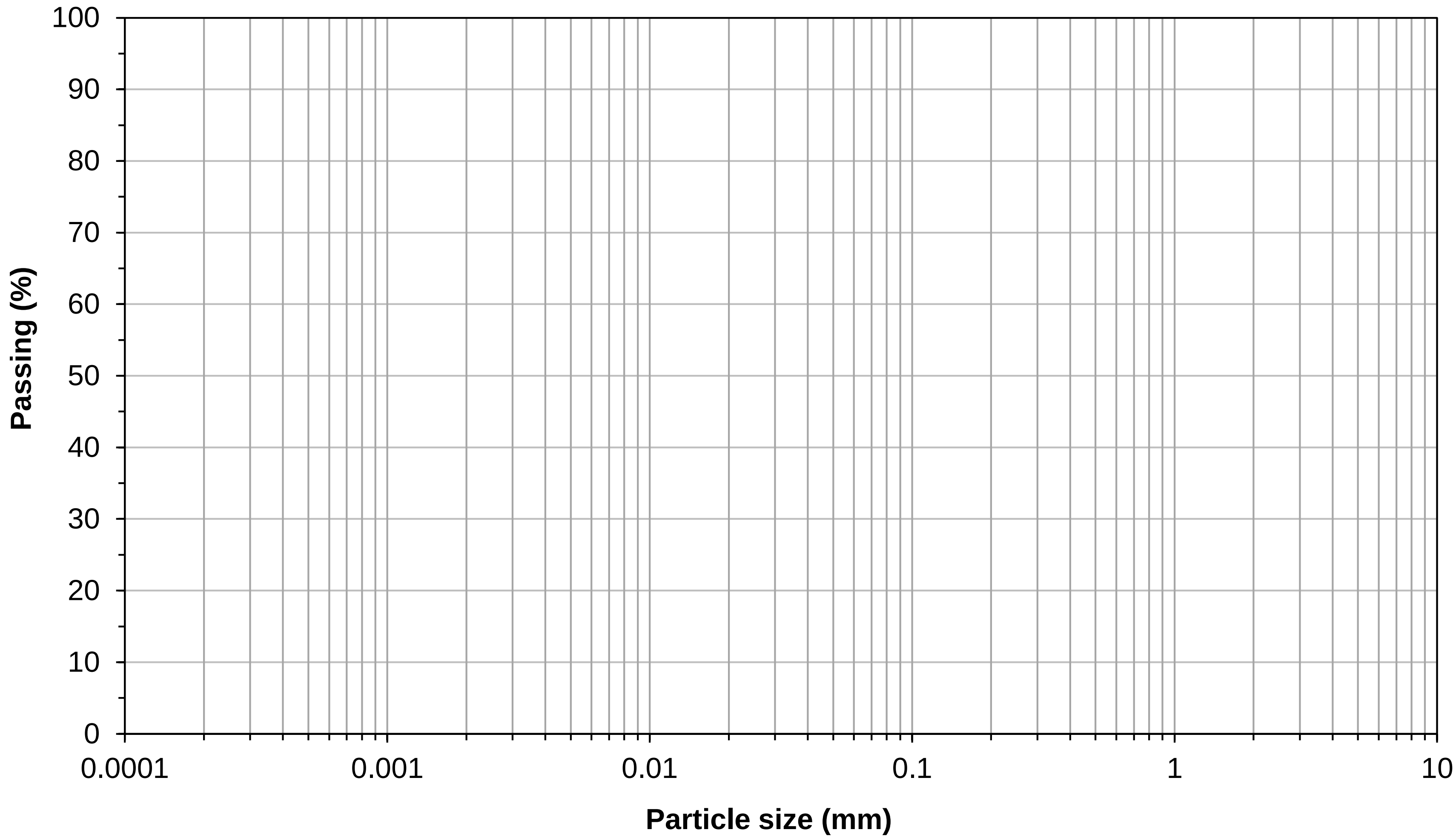
Supervisor signature

Discussion: Answer the following questions by referring to relevant References.

1. Hydrometer test is conducted on only 50 g of the fine soil passing sieve No. 200?

2. Correction for meniscus only is used to find the value of (L)?

3. What is the effect of the specific gravity (or density) decreases on the hydrometer reading?


Passing (%)
100
90
80
70
60
50
40
30
20
10
0
0.0001
0.001
0.01
0.1
1
10
Particle size (mm)