

2.GRAIN SIZE ANALYSIS.

(IS : 2720 – PART – 4)

INTRODUCTION:

Most of the methods for soil identification and classification are based on certain physical properties of the soils. The commonly used properties for the classification are the grain size distribution, liquid limit and plasticity index. These properties have also been used in empirical design methods for flexible pavements, and in deciding the suitability of sub grade soils.

Grain size analysis also known as mechanical analysis of soils is the determination of the percent of individual grain sizes present in the sample.

The mechanical analysis consists of two parts:

- (i) the determination of the amount and proportion of coarse material by the use of sieves.
- (ii) the analysis for the fine grained fraction by sedimentation method.

The sieve analysis is a simple test consisting of sieving a measured quantity of material through successively smaller sieves. The weight retained on each sieve is expressed as a percentage of the total sample. The sedimentation principle has been used for finding the grain size distribution of fine soil fraction; two methods are commonly used (i) Pipette method and (ii) Hydrometer method.

The grain size distribution of soil particles of size greater than 75 micron is determined by sieving the soil on a set of sieves of decreasing sieve opening placed one below the other and separating out the different size ranges. Two methods of sieve analysis are as follows:

- (i) wet sieving applicable to all soils and
- (ii) dry sieving applicable only to soils, which have negligible proportion of clay and silt.

The soils received from the field is divided into two parts: one, the fraction retained on 2mm sieve and the other passing 2mm sieve. The sieve analysis also may be carried out separately for these two fractions. The fraction retained on 2mm sieve may be subjected to dry sieving using bigger sieves and that passing 2mm sieve may be subjected to wet sieving; however if this fraction consists of single grained soil with negligible fines passing 0.075mm size, dry sieving may be carried out.

Apparatus:

Various apparatus include set of standard sieves of different sieve sizes, balance, rubber covered pestle and mortar, oven, riffle and sieves shaker.



Standard sieves

Procedure:

(a) For the fraction retained on 2.0mm sieve: Sufficient quantity of the dry soil retained on 2.0mm sieve is weighed out. The quantity of sample taken may be increased when the maximum size of particles is higher. The sample is separated into various fractions by sieving through the set of sieves of sizes 100, 63, 20, 6, 4.75 and 2 mm IS sieves. Additional sieve size may also be introduced if necessary. After initial sieving, the material retained on each sieve is collected, the lumps broken down using mortar and rubber covered pestle and is re-sieved thus the soil fraction retained on each sieve is carefully collected and weighed.

(b) For the fraction passing 2.0mm sieve and retained on 0.075mm sieve: Dry sieving may be done in the case of soils which are cohesion less, single grained and without lumps. Rifling or quartering method takes the required quantity of soil sample, dried in oven at 105⁰ to 110⁰C and is subjected to dry sieve analysis using a set of sieves with sieve openings 2.0, 0.6, 0.425, 0.15 and 0.075 mm, pan and lid, additional sieves may be used or any of the sieves removed, depending upon the requirement of the test. The material retained on each sieve and on the pan are separately collected and weighed.

Wet sieving may be adopted in the case of clayey or cohesive soils. Required quantity of sample taken by rifling is weighed. The sample is spread in a tray or bucket and covered with water. In case of soils having fractions that are likely to flocculate a dispersing agent like sodium hexametaphosphate (2.0g) or sodium hydroxide (1.0g) and sodium carbonate (1.0g) per liter of water may be added to the water. The mix is stirred and left for soaking. The soaked soil specimen is placed over the set of sieves of sizes with the finest sieve and pan at the bottom and washed thoroughly. Washing is continued till the water passing each sieve is substantially clean. The fraction of each sieve is emptied carefully without loss of material in separate trays, oven dried at 105⁰ to 110⁰C and each fraction weighed separately.

Calculations:

The weight of dry soil fractions retained on each sieve is calculated as a percentage of the total dry weight of the sample taken.

Results:

The results are plotted on a semi-logarithmic graph with the grain size or sieve size on the X-axis in log. scale and the percentage finer of each sieve on the Y-axis in ordinary scale. The smooth curve joining the points thus obtained is known as the particle size distribution curve or diagram.

Uniformity coefficient of soil, $C_u = D_{60} / D_{10}$

Coefficient of curvature, $C_c = (D_{30})^2 / (D_{10} \times D_{60})$

Where, D60, D30 and D10 are particle sizes corresponding to 60, 30 and 10 percent finer.



(c) For the fraction passing 0.075mm sieve: Two methods are in use based on sedimentation principle that the larger grains settle more rapidly than the smaller ones. The Stoke's law is made use of according to which the velocity of settlement of spherical particles is proportional to the square of their diameters. Thus if the depth and the duration of settlement are known, the velocity and hence the diameter of particles at that depth can be estimated. The percentage of particles finer than this diameter should be found using any one of the two methods viz; (i) Pipette method and (ii) Hydrometer method.

Hydrometer method.

Apparatus:

- a) Density hydrometer conforming to IS: 3104-1965 –(Range 0.995 – 1.030).
- b) Two glass-measuring cylinders of 1000ml capacity with ground glass or rubber stoppers about 7cm diameter and 33cm high marked at 1000ml volume.
- c) Thermometer to cover the range 0 to 50⁰C, accurate to 0.50⁰C.
- d) Water bath or constant temperature room
- e) Stirring apparatus
- f) 75 micron sieve.
- g) Balance accurate to 0.01g
- h) Stop watch
- i) Wash bottles containing distilled water
- j) Glass rod, about 15 to 20 cm long and 4 to 5 mm in diameter
- k) Reagents: Hydrogen peroxide, Hydrochloric acid N solution and Sodium hexametaphosphate.
- l) Conical flask of 1000ml capacity
- m) Funnel, filter paper, measuring cylinder of 100ml capacity and blue litmus papers.

Procedure:

(A) Calibration of Hydrometer:

1. Determination of volume of the hydrometer bulb (V_h): Pour about 800ml of distilled water in the 1000ml-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 purposes, the error due to the inclusion of this stem volume may be neglected. Alternatively, weigh the hydrometer to the nearest 0.2g. This weight 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. For practical purposes the error due to the inclusion of the stem may be neglected.

2. In order to find the area of cross-section (A) of the measuring cylinder in which the hydrometer is to be used, measure the distance, in cm, between two graduations of the

cylinder. The cross-section area (A) is then equal to the volume included between the two graduations divided by the distance between them.

3. Measure the distance (h) from the neck to the bottom of the bulb, and record it as the height of the bulb.

4. With the help of an accurate scale, measure the height (H) between the necks of the hydrometer to each of the other major calibration marks (R_h).

5. Calculate the effective depth (H_e) corresponding to each of the major calibration marks (or hydrometer readings, R_h) by the following expression:

$$H_e = H + \frac{1}{2} \left(h - \frac{V_h}{A} \right)$$

6. 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) obtained during the test.

7. Meniscus correction (C_m) : Insert the hydrometer in the measuring cylinder containing about 700ml of water. Take the readings of the hydrometer at the top and bottom of the meniscus. The difference between two readings is taken as the meniscus correction (C_m), which is a constant for 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. The meniscus correction is always positive.

(B) Pre- treatment of soil:

1. Weigh accurately (to 0.01g) 50 to 100 g of oven dried soil sample (W_d) passing the 0.075mm IS sieve. If the percentage of soluble salts is more than one percent, the soil should be washed with water before further treatment, taking care to see that the soil particles are not lost.

2. Add 150ml of hydrogen peroxide to the soil sample placed in a wide mouth conical flask and stir it gently for few minutes with a glass rod. Cover the flask with glass and leave it to stand overnight.

3. Next morning, the mixture in the conical flask is gently heated in an evaporating dish, stirring the contents periodically. Reduce the volume to about 50ml by boiling. With very organic soils additional peroxide may be required to complete the oxidation.

4. If the soil contains insoluble calcium compounds, add about 50ml of hydrochloric acid to the cooled mixture of soil obtained in step 3. The solution is stirred with a glass rod for a few minutes and allowed to stand for one hour or for longer periods, if necessary. The solution will have an acid reaction to litmus.

5. Filter the mixture and wash it with warm water until the filtrate shows no acid reaction to litmus. Transfer the damp soil on the filter paper and funnel to the evaporating dish using a jet of distilled water. Place the dish and its contents to the oven. Take the weight (W_b) of the oven-dried soil remaining after pre-treatment and find the loss of weight due to pre-treatment.

(C) Dispersion of soil:

1. To the oven-dried soil, add 100ml of sodium hexametaphosphate solution 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. The sodium hexametaphosphate solution is prepared by dissolving 33 g of sodium hexametaphosphate and 7 grams of sodium carbonate in distilled water to make one liter of solution. This solution is unsuitable and should be freshly prepared approximately once in a month.
2. Transfer the soil suspension to the 75 micron IS sieve placed on a receiver and washes 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 500ml.
3. Transfer the soil suspension passing the 75-micron IS sieve to the 1000ml-measuring cylinder, and adds more water to make the volume to exactly 1000ml in the cylinder.
4. Collect the material retained on 75-micron sieve and put it in the oven for drying. Determination the dry weight of soil retained on 75-micron sieve.

(D) Sedimentation test with hydrometer:

1. Insert a rubber bung or any other suitable cover on the top of the 1000ml-measuring cylinder containing the soil suspension and shake it vigorously end over end. Stop shaking and allow it to stand. Immediately, start the stopwatch, 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 0.5, 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 the end of 4 hours, readings should be taken once or twice within 24 hours.
4. Composite correction (C): In order to determine the composite correction, put 100ml of dispersing agent solution in another 1000ml measuring cylinder and make it to 1000ml

by adding distilled water. 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.

Calculations:

(1) The loss in weight in pre-treatment of the soil in percentage is calculated from the following expression:

$$P = \left(1 - \frac{W_b}{W_d} \right) 100$$

Where, P = loss in weight in percentage
 W_d = weight of dry soil sample taken from the soil passing 2mm Sieve
 W_b = weight of the soil after pre-treatment

(2) The diameter of the particle in suspension at any sampling time t is calculated from:

$$D = 10^{-5} M (H_e / t)^{0.5}$$

Where, M = poise constant factor
 H_e = effective depth of the hydrometer
t = elapsed time, minutes

(3) The percentage finer N' based on the weight W_d is calculated from:

$$N' = \frac{100 G}{W_d (G - 1)} R$$

Where, N' = percentage finer, based on the weight of dry soil sample W_d
 W_d = weight of dry soil sample taken from the soil sample passing 2mm sieve.
G = specific gravity of the soil passing 75 micron sieve.
R = corrected hydrometer reading
 $R = R_h' + C$

$$R_h = R_h' + C_m$$

Where, R_h' = observed hydrometer reading

R_h = hydrometer reading, corrected for meniscus correction

(4) The percentage finer (N) based on the total weight of dry soil sample (W) is obtained from the relation:

$$N = N' \times (W' / W)$$

Where, W' = cumulative weight passing 2mm sieve.

Values of Factor 'M'

Temp. °C	• (poise)	Factor 'M'					
		G = 2.50	G = 2.60	G = 2.65	G = 2.70	G = 2.75	G = 2.80
15	0.01145	1528	1479	1458	1435	1414	1305
16	0.01116	1508	1460	1438	1417	1396	1377
17	0.01088	1490	1442	1420	1399	1379	1360
18	0.01060	1470	1423	1402	1381	1361	1342
19	0.01034	1452	1406	1384	1364	1344	1325
20	0.01009	1434	1389	1367	1347	1328	1309
21	0.00984	1417	1372	1351	1331	1311	1294
22	0.00961	1400	1355	1335	1315	1296	1278
23	0.00938	1383	1339	1318	1291	1280	1262
24	0.00916	1367	1323	1305	1284	1265	1248
25	0.00896	1351	1308	1288	1269	1251	1233
26	0.00875	1335	1293	1273	1254	1236	1219
27	0.00855	1321	1279	1259	1241	1224	1206
28	0.00836	1305	1264	1244	1226	1208	1191
29	0.00818	1291	1250	1231	1213	1195	1178
30	0.00800	1277	1236	1217	1199	1182	1165
31	0.00783	1264	1224	1205	1187	1170	1154
32	0.00767	1251	1211	1193	1175	1158	1142
33	0.00751	1238	1199	1180	1163	1146	1130
34	0.00736	1225	1186	1168	1151	1134	1118
35	0.00721	1212	1174	1156	1139	1120	1107
36	0.00706	1199	1161	1144	1127	1110	1095
37	0.00692	1188	1150	1133	1116	1100	1084
38	0.00679	1176	1139	1122	1105	1089	1074
39	0.00666	1165	1128	1110	1094	1079	1064
40	0.00654	1155	1118	1101	1084	1069	1055



Format for recording Test results is as below on next page

FORM D3

Punjab State Road Sector Project
PWD B&R Branch, Govt. of Punjab
 Punjab Roads & Bridges Development Board

GRAIN SIZE ANALYSIS

Sample No. : _____ Date Sampled : _____
 Source : _____ Date Tested : _____
 Proposed Use : _____ Original Wt., g = _____
 Oven Dry Wt., g = _____
 Wash Oven Dry Wt., g = _____

IS Sieve (mm)	Wt. Retained (g)	% Retained	Cumulative			Remarks
			Wt. Passing (g)	% Passing	% Retained	
100.0						
53.0						
25.0						
19.0						
12.5						
10.0						
6.5						
4.75						
2.36						
0.425						
0.075						
Pan						
Wash Loss						
Total						

GRAVEL, %	
SAND, %	
SILT & CLAY, %	

ACCEPTANCE CRITERIA SPECIFIED :

Remarks : _____

Approved/Not Approved:

Contractor's Representative

Materials Engineer
Consultant

Resident Engineer
Consultant