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Indian Standard

METHODS OF TEST FOR SOILS

PART 4 GRAIN SIZE ANALYSIS

(Second Revision)

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Indian Standard

METHODS OF TEST FOR SOILS

PART 4 GRAIN SIZE ANALYSIS

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part 4) (Second Revision) was adopted by the Indian Standards Institution on 25 January 1985, after the draft finalized by the Soil Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 With a view to establishing uniform procedures for determination of different characteristics of soils and also for facilitating comparative studies of the results, this standard on methods of test for soils (IS : 2720) is being issued in parts. This part which was originally published in 1965 and revised in 1975 deals with the method for the determination of grain size distribution in soils. An analysis of this kind express quantitatively the proportions by mass of the various sizes of particles present in the soil. In a soil the gravel, sand silt and clay fractions are recognized as containing particles of decreasing magnitude. The actual range of dimensions of the particles are given in IS : 1498-1970*. The results of a grain size analysis may also be represented graphically in the form of a grain size distribution curve in which the cumulative percentages finer than known equivalent grain sizes are plotted against these sizes, the latter being on a logarithmic scale. The results of grain size analysis are widely used in soil classification. The data obtained from grain size distribution curves is used in the design of filters for earth dams to determine the suitability of soils for road construction.

0.2.1 In this second revision of the standard, grain sizes have been brought in line with IS : 1498-1970*. A plummet balance method as an alternative method has been included.

0.3 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960†.

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*Classification and identification of soil for general engineering purposes (*first revision*).

†Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard (Part 4) covers the method for the quantitative determination of grain size distribution in soils.

1.1.1 Two methods are given for finding the distribution of grain sizes larger than 75-micron IS Sieve; the first method, wet sievings shall be applicable to all soils and the second, dry sieving, shall be applicable only to soils which do not have an appreciable amount of clay.

1.1.2 For the determination of distribution of grain sizes smaller than 75-microns the pipette method is given as the standard method; the hydrometer method is given as a subsidiary method. This method shall not applicable if less than 10 percent of the material passes the 75-micron IS Sieve (determined as given in **4**).

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 2809-1972* shall apply.

3. SIEVE ANALYSIS OF SOILS FRACTION RETAINED ON 4·75 mm IS SIEVE (DRY METHOD)

3.1 Apparatus

3.1.1 *Balance* — sensitive to 0·1 percent of the weight of sample to be weighed.

3.1.2 *Sieves* — 100-mm IS Sieve, 75-mm IS Sieve, 19-mm IS Sieve and 4·75-mm IS Sieve conforming to the requirement of IS : 460 (Part 1)-1978†.

3.1.3 *Rubber Pestle and Mortar*

3.2 Preparation of Sample — The soil sample received from the field shall be prepared as specified in IS : 2720 (Part 1)-1983‡. The soil fractions retained on and passing 4·75-mm IS Sieve shall be taken separately for the analysis.

3.3 Procedure — The portion of the soil sample retained on 4·75-mm IS Sieve, selected as given in **3.2**, shall be weighed and the mass recorded

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*Glossary of terms and symbols relating to soils mechanics (*first revision*).

†Specification for test sieves : Part 1 Wire cloth test sieves (*second revision*).

‡Methods of test for soils: Part 1 Preparation of dry soil samples for various tests (*second revision*).

as the mass of the sample uncorrected for hygroscopic moisture. The quantity of the soil sample taken shall depend on the maximum particle size contained in the soil (*see* Note 1). The sample shall be separated into various fractions by sieving through the Indian Standard Sieves specified in **3.1.2**. Other sieves may be introduced between the sieves mentioned in **3.1.2** depending upon the additional information that may be desired to be obtained from the analysis. While sieving through each sieve, the sieve shall be agitated so that the sample rolls in irregular motion over the sieve. Any particles may be tested to see if they will fall through but they shall not be pushed through. The material from the sieve may be rubbed, if necessary, with the rubber pestle in the mortar taking care to see that individual soil particles are not broken and re-sieved to make sure that only individual particles are retained. The quantity taken each time for sieving on each sieve shall be such that the maximum weight of material retained on each sieve at the completion of sieving does not exceed the values given in Note 2.

NOTE 1 — Depending on the maximum size of material present in substantial quantities in the soil, the mass of soil sample taken for analysis may be as follows:

Maximum Size of Material Present in Substantial Quantities mm	*Mass to be taken for Test* kg
75	60
40	25
25	13
19	6·5
12·5	3·5
10	1·5
6·5	0·75
4·75	0·4

NOTE 2 — Maximum weight of material to be retained on each sieve at the completion of sieving shall be as follows:

IS Sieve Designation	*450-mm Dia Sieves* kg	*300-mm Dia Sieves* kg
80-mm	15	6
20-mm	4	2
4·75 mm	1·0	0·5

The mass of the material retained on each sieve shall be recorded. If the sample appears to contain over 5 percent moisture, the water content of the material shall be determined in accordance with

IS : 2720 (Part 2)-1973* and the masses corrected accordingly. When the sample contains less than 5 percent moisture it is not necessary to determine the water content for dry weight computations and all the determinations may be made on the basis of wet weight only. If the soil contains more than about 20 percent gravel particles and the fines are very cohesive with considerable amounts adhering to the gravel after separation, the gravel shall be washed on 4·75-mm IS Sieve using sodium hexametaphosphate solution, if necessary. For further analysis a fresh portion of the fraction passing 4·75-mm IS Sieve shall be taken.

3.4 Calculations — The percentage of soil retained on each sieve shall be calculated on the basis of the total mass of soil sample taken and from these results the percentage passing through each of the sieves shall be calculated.

4. SIEVE ANALYSIS OF SOIL PASSING 4·75 mm IS SIEVE AND RETAINED ON 75-MICRON IS SIEVE

4.1 Apparatus

4.1.1 *Balance* — Sensitive to 0·1 percent of the mass of sample to be weighed.

4.1.2 *Sieves* — The following Indian Standard Sieves conforming to IS : 460 (Part 1)-1978†:

2-mm IS Sieve, 425-micron IS Sieve, and 75-micron IS Sieve.

The sieves should be periodically checked up for aperture sizes.

4.1.3 *Oven* — Thermostatically controlled to maintain the temperature between 105 and 110°C, with interior of non-corroding material.

4.1.4 *Trays or Bucket* — two or more large metal or plastic watertight trays or a bucket about 30 cm in diameter and 30 cm deep (convenient sizes of the trays are in the range of 45 to 90 cm^2 and 8 to 15 cm deep).

4.1.5 *Brushes* — sieve brushes and a wire brush or similar stiff brush.

4.1.6 *Mortar with a Rubber Covered Pestle*

4.1.7 *Mechanical Sieve Shaker* (*Optional*)

4.1.8 *Riffler*

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*Methods of test for soils: Part 2 Determination of water content (*second revision*).

†Specification for test sieves : Part 1 Wire cloth test sieves (*second revision*).

4.2 Reagents — sodium hexametaphosphate (chemically pure) or a mixture of sodium hydroxide (conforming to IS : 376-1976*) and sodium carbonate (analytical grade conforming to IS : 296-1974†) or any other dispersing agent which has been found suitable.

4.3 Procedure

4.3.1 *Analysis by Wet Sieving* — The portion of the soil passing 4·75-mm IS Sieve obtained as given in **3.2** shall be oven-dried at 105 to 110°C. The oven-dried material shall then be riffled so that a fraction of convenient mass is obtained. This shall be about 200 g if a substantial proportion of the material only, just passes the 4·75-mm IS Sieve or less if the largest size is smaller. The fraction shall be weighed to 0·1 percent of its total mass and the mass recorded. The riffled and weighed fraction shall be spread out in the large tray or bucket and covered with water.

4.3.1.1 Two grams of sodium hexametaphosphate or one gram of sodium hydroxide and one gram of sodium carbonate per litre of water used should then be added to the soil (*see* Note 1). The mix should be thoroughly stirred and left for soaking. The soil soaked specimen should be washed thoroughly over the nest of sieves specified in **4.1.2** (*see* Note 2) nested in order of their fineness with the finest sieve (75-micron IS Sieve) at the bottom. Washing shall be continued until the water passing each sieve is substantially clean. Care shall be taken to see that the sieves are not overloaded in the process (*see* Note 3). The fraction retained on each sieve should be emptied carefully without any loss of material in separate trays. Oven dried at 105 to 110°C and each fraction weighed separately and the masses recorded.

Alternatively, the soaked soil specimen may be washed on the 75-micron IS Sieve until the water passing the sieve is substantially clean. The fraction retained on the sieve should be tipped without loss of material in a try, dried in the oven and sieved through the nest of sieves specified in **4.1.2** (*see* Note 2) either by hand or by using mechanical sieve shaker. The fraction retained on each sieve should be weighed separately and the masses recorded.

NOTE 1 — The amount of dispersing agent may be varied depending on the type of soil. A dispersing agent may not be required in the case of all soils; in such cases the wet sieving may be carried out without the addition of dispersing agent.

NOTE 2 — The sieves listed in **4.1.2** correspond to the limits of coarse, medium and fine sand specified in IS : 1498-1970‡. Other sieves may be introduced depending on the additional information that may be desired to be obtained from the analysis.

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*Specification for sodium hydroxide, analytical reagent (*second revision*).

†Specification for sodium carbonate, anhydrous (*second revision*).

‡Classification and identification of soils for general engineering purposes (*first revision*).

NOTE 3 — The permissible maximum mass of sample on the 200-mm diameter sieves shall be as follows:

IS Sieve Designation	*Maximum Mass of Sample* g
2-mm	200
425-micron	50
75-micron	25

4.3.2 *Analysis by Dry Sieving*

4.3.2.0 In the case of clayey soils this method shall not be used; wet sieving shall be used.

4.3.2.1 The portion of the soil passing 4·75-mm IS Sieve obtained as in **3.2** shall be oven-dried at 105 to 110°C and weighed to 0·1 percent of its total mass.

The sieve or sieves shall be agitated so that the sample rolls in irregular motion over the sieve. No particle shall be pushed through the sieve. The material retained on the sieve shall be rubbed with the rubber pestle in mortar in re-sieved to make sure that only individual particles are retained on the sieve. The amount retained on the sieve shall be weighed. The material retained in the receiver shall be transferred to a steel tray and the receiver fitted to the nest largest sized sieve. The contents of the steel tray shall then be placed on this sieve and the operations indicated above repeated. These operations shall be repeated through all the sieves specified in **4.1.3** (*see* Note 2 of **4.3.1.1**). If a mechanical shaker is available these tests may be performed in one operation. Care shall be taken to ensure that sieving is complete. A minimum of 10 minutes shaking shall be used. The soil fraction retained on each sieve shall be carefully collected in containers and the mass of each fraction determined and recorded.

4.4 Calculation — The cumulative mass of soil fraction retained on each sieve shall be calculated. The percentage of soil fraction retained on each sieve shall be calculated on the basis of the mass of the sample passing 4·75-mm IS Sieve taken for the initial analysis. The combined gradation on the basis of the total soil sample taken for analysis shall then be calculated.

5. GRAIN SIZE ANALYSIS OF THE FRACTION PASSING 75-MICRON IS SIEVE OUT OF THE PORTION PASSING 4·75-mm IS SIEVE

5.1 Pipette Method (Standard Method)

5.1.0 This method is not applicable if less than 10 percent of the material passes 75-micron IS Sieve as obtained in **4.3.1.**

5.1.1 *Apparatus*

5.1.1.1 *Sampling pipette* — of the type illustrated in Fig. 1 fitted with a pressure and suction inlet and having a capacity of approximately 10 ml. The pipette shall be so arranged that it can be inserted to a fixed depth into a sedimentation tube when the latter is immersed in a constant temperature bath (*see also* Fig. 4).

5.1.1.2 *Glass sedimentation tubes* — a minimum of two of 50 mm diameter and approximately 350 mm long marked at 500 ml volume with rubber bungs to fit.

5.1.1.3 *Weighing bottles* — required number, fitted with round stoppers or crucibles with suitable lids approximately 25 mm in diameter and 50 mm high. The bottles or crucibles shall be weighed to the nearest 0·001 gram.

5.1.1.4 *Constant temperature bath* — capable of being maintained at 27 ± 0·1°C, into which the sedimentation tube can be immersed up to 500 ml mark. The bath shall not vibrate the sample (optional).

5.1.1.5 *Stirring apparatus* — a mechanical stirring device in which a suitable mounted electric motor turns a vertical shaft at a speed of 8 000 to 10 000 rev/min when loaded. The shaft shall be equipped with a replaceable stirring paddle of either of the types shown in Fig. 2 and, made of metal, plastic or hard rubber. The shaft shall be of such length that the stirring paddle will operate neither less than 20 mm nor more than 35 mm above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 3 shall be provided to hold the sample while it is being dispersed.

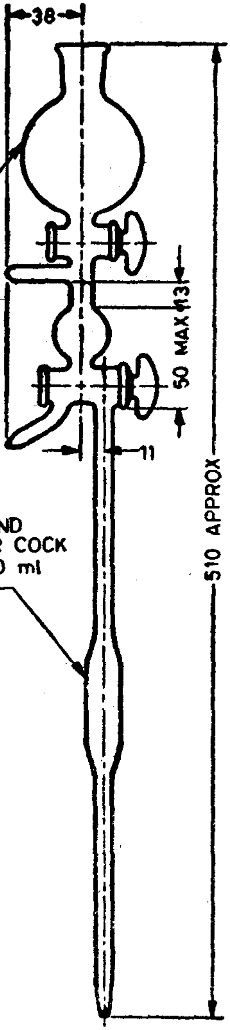
The container and baffles shall be of such material as will not be attacked by the reagents placed in the container. The motion of the soil suspension shall be sufficient to mix the contents thoroughly but it shall not be so vigorous that the particles will be crushed or lost through splashing; neither shall it be so sluggish as to leave unmixed material in the bottom of the container.

NOTE — Any other suitable dispersing device, such as mechanical bottle shaker and air-jet dispersing device which produce comparable dispersion of the soil may also be used.

5.1.1.6 *Sieves* — 2-mm, 425-micron, 75-micron IS Sieves and receiver.

5.1.1.7 *Balance* — to weigh up to 0·001 g.

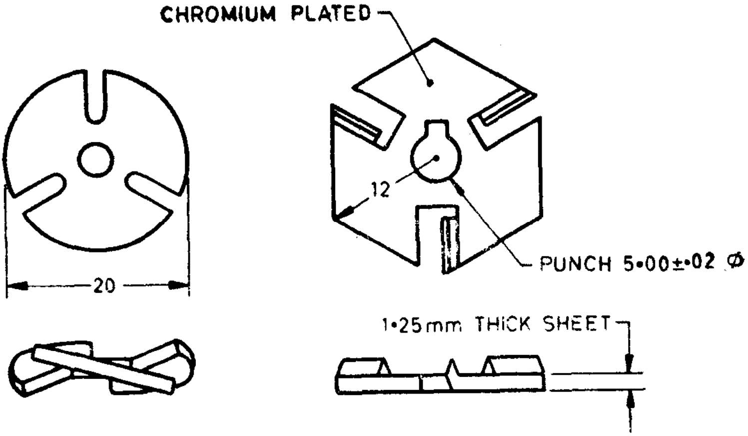
5.1.1.8 *Oven* — thermostatically controlled to maintain temperature of 105 to 110°C, will interior of non-corroding material.



NOTE — Bore of tube to be 4 mm ϕ where possible.

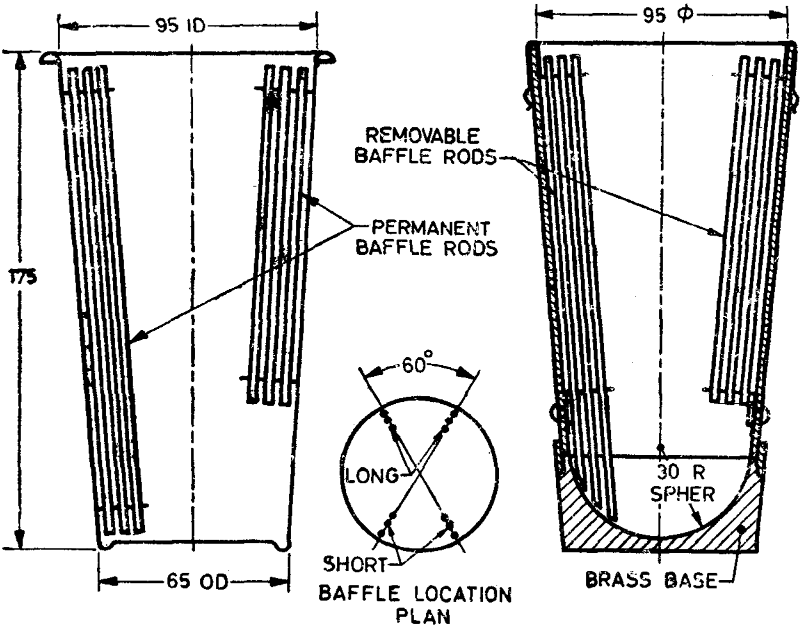
All dimensions in millimetres.

FIG. 1 SAMPLING PIPETTE



All dimensions in millimetres.

FIG. 2 STIRRING PADDLES FOR STIRRING APPARATUS



All dimensions in millimetres.

FIG. 3 DISPERSION CUPS

5.1.1.9 *Stop watch*

5.1.1.10 *Desiccator*

5.1.1.11 *Evaporating dish*

5.1.1.12 *Conical beaker* — 650 ml or one litre capacity and a cover glass to fit and a smaller beaker.

5.1.1.13 *Funnel* — Buchner or Hirch about 7 cm in diameter.

5.1.1.14 *Filter flask* — to take the funnel (about 500 ml).

5.1.1.15 *Measuring cylinder* — 100 ml capacity.

5.1.1.16 *Pipette* — 25 ml capacity.

5.1.1.17 *Glass filter funnel* — about 10 cm in diameter.

5.1.1.18 *Wash bottle* — containing distilled water.

5.1.1.19 *Filter papers*

5.1.1.20 *Blue litmus paper*

5.1.1.21 *Glass rod* — about 15 to 20 cm long, 4 to 5 mm in diameter fitted at one end with a rubber policeman.

5.1.1.22 *Thermometer* — 0 to 50°C, accurate to 0·5°C.

5.1.2 *Reagents* — The reagents shall be of analytical quality.

5.1.2.1 *Hydrogen peroxide* — 20 volume solution.

5.1.2.2 *Hydrochloric acid approximately N solution* — 89 ml of concentrated hydrochloric acid (specific gravity 1·18) diluted with distilled water to make one litre of solution.

5.1.2.3 *Sodium hexametaphosphate solution* — Dissolve 33 g of sodium hexametaphosphate and seven grams of sodium carbonate in distilled water to make one litre of solution.

NOTE 1 — This solution is unstable and shall be freshly prepared approximately once a month. The date of preparation shall be recorded on the bottle.

NOTE 2 — Solution hexametaphosphate has been found to be ineffective when dealing with certain highly flocculated soils. In such cases incomplete dispersion obtained is indicated by the formation of relatively large crumbs or flocks of soil which fall rapidly through the water leaving a sharply defined clear layer above the suspension and in such cases dispersion may be carried out by adding N sodium hydroxide solution at the rate of 4 ml per 10 g of soil.

NOTE 3 — Any other dispersing agent which has been proved suitable for dispersing soils may be used.

5.1.3 *Procedure*

5.1.3.0 If the soil fraction passing 75-micron IS Sieve during wet sieving specified in **4.3.1** has been collected, this can be oven-dried and used for pipette analysis, provided the soil has been pre-treated as specified in **5.1.3.2**. Where necessary, the oven-dried fraction shall be powdered in a mortar with a rubber covered pestle taking care that the individual grains are not crushed. 25 to 50 g (depending on the soil type) of this soil shall be used for the analysis. The other relevant portions of the procedure specified in **5.1.3, 5.1.3.1, 5.1.3.3** and **5.1.3.4,** shall be followed for further analysis.

5.1.3.1 *Calibration of sampling pipette* — The sampling pipette shall be thoroughly cleaned and dried and the nozzle shall be immersed in distilled water. The tap *B* shall be closed and the tap *E* opened (*see* Fig. 4). By means of a rubber tube attached to *C*, water shall be sucked up in the pipette until it rises above *E*. The tap *E* shall be closed and the pipette removed from the water. Surplus water drawn up into the cavity above *E*' shall be poured off through *F* into the small beaker by opening the tap *E* in such a way as to connect *D* and *F*. The water contained in the pipette and tap *E* shall be discharged into a glass weighing bottle of known mass and the mass determined. From this mass the internal volume (V_p ml) of the pipette and the tap shall be calculated to the nearest 0·05 ml. Three determinations of the volume shall be made and the average taken.

5.1.3.2 *Pre-treatment of soils* — The percentage of soluble salts in the soil shall be determined as specified in IS : 2720 (Part 21) - 1977*. In case it is more than one percent, the soil shall be washed with water before further treatment taking care to see that soil particles are not lost (*see* Note 1).

Two samples out of the soil passing 4·75-mm IS Sieve obtained as described in **3·2** weighing about 30 g shall be obtained by riffling from the bulk sample. The water content (*w*) of one sample shall be determined by the method prescribed in IS : 2720 (Part 2)-1973†.

The other sample shall be sub-divided by riffling. The actual mass of soil required may vary according to the type of soil, 50 g with a sandy soil and about 20 g with a clay soil. This sample shall be weighed to 0·001 g (W_a) and placed in the 650-ml conical beaker. 50 ml of distilled water shall be added to this and the soil suspension gently boiled until the volume is reduced to about 40 ml. After cooling 75 ml of hydrogen peroxide shall be added and the mixture allowed to stand overnight

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*Methods of test for soils: Part 21 Determination of total soluble solids (*first revision*).

†Methods of test for soils: Part 2 Determination of water content (*second revision*).

covered with cover glass. The suspension shall then be gently heated. Care shall be taken to avoid frothing over and the contents of the beaker shall be agitated frequently either by stirring or by shaking the beaker. As soon as vigorous frothing has subsided and when there is no further reaction by the addition of fresh hydrogen peroxide, the volume shall be reduced to about 30 ml by boiling.

In the case of soils containing calcium compounds (*see* Note 2) the mixture shall be allowed to cool and about 10 ml of hydrochloric acid shall be added. The solution shall be stirred with a glass rod for a few minutes and allowed to stand for about one hour or for longer periods, if necessary. The treatment shall be continued till the solution gives an acid reaction to litmus. If the soil contains considerable amount of calcium salts, more acid may be required.

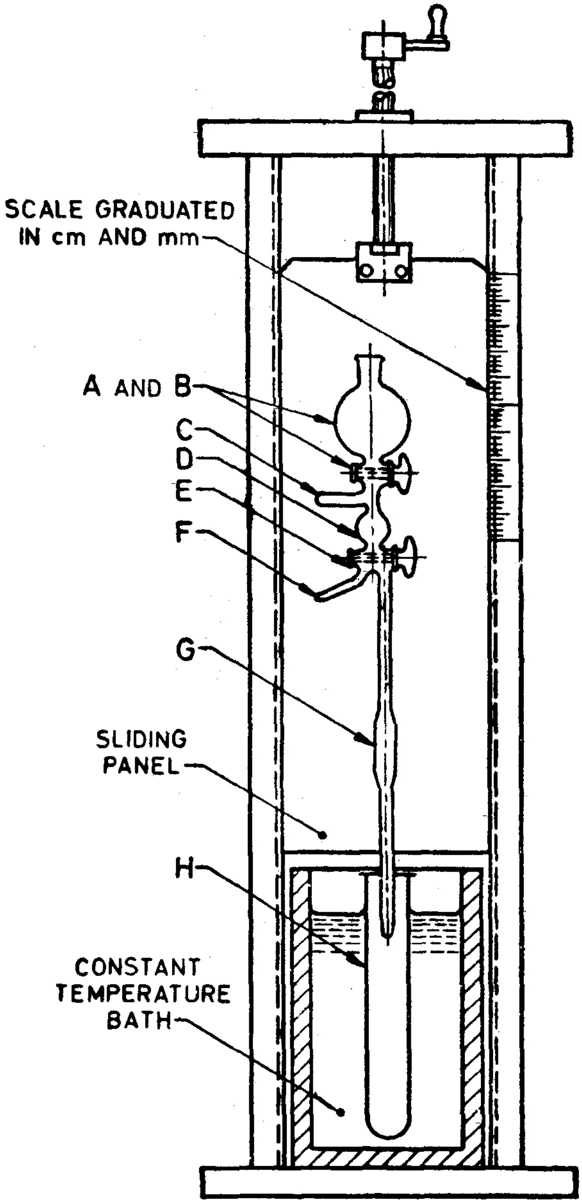
In the case of soils containing no calcium compounds or soluble salts and having a low organic content (less than 2 percent) the pre-treatment prescribed may be omitted and the dispersing agent shall be added as prescribed in **5.1.3.3** direct to the soil taken for analysis.

The mixture after pre-treatment with peroxide and acid or acid alone shall be filtered using the Buchner or Hirch funnel and washed with warm water until the filtrate shows no acid reaction to litmus. The wet soil on the filter paper and funnel shall be transferred without any loss whatsoever to the glass evaporating dish (weighed to 0·001 g) using a jet of distilled water. Only a minimum quantity of distilled water shall be used. The dish and contents shall be dried in an oven maintained at 105 to 110°C. The dish and contents shall then be cooled in a desiccator and weighed to 0·001 g. The mass of the soil remaining after pre-treatment shall be recorded (W_b).

NOTE 1 — Owing to the removal of calcium, iron, etc, by the acid during the pre-treatment of the soil, the above method is not suitable for the determination of the particle size distribution in soils predominantly containing chalk or lime and it may, therefore, be necessary to adopt different methods of treatment with these and other soils having similar special characteristics. Dispersion may be assisted by rubbing the particles of soil in the suspension against the side of the evaporating dish with a glass rod fitted with a rubber policeman. In some cases a longer mixing time may help.

Lateritic soils will also be attacked by the acid but unless they contain calcium they need not be given the acid treatment.

NOTE 2 — Acid treatment shall be carried out only for soils containing insoluble calcium salts.



NOTE — *G* — Sampling pipette, and
H — Sedimentation tube.

FIG. 4 ARRANGEMENT FOR LOWERING THE SAMPLING PIPETTE

5.1.3.3 *Dispersion of soil* — 25 ml sodium hexametaphosphate solution shall be added to the soil in the evaporating dish together with about 25 ml of distilled water and the soil brought into suspension by stirring with a glass rod. The mixture shall be warmed gently for 10 minutes and then transferred to the cup of the mechanical mixer using a jet of distilled water to wash all traces of the soil out of the evaporating dish. Any soil adhering to the dish shall be rubbed off with the rubber policeman. The amount of water used shall not exceed 150 ml. The soil suspension shall then be stirred well for 15 minutes or longer in the case of highly clayey soils (*see* Note).

The suspension shall then be transferred to 75-micron IS Sieve placed on a receiver and the soil shall be washed on this sieve using a jet of distilled water from a wash-bottle. Particular care shall be taken to wash off all traces of suspension adhering to the dispersion cup. The amount of distilled water used during the operation shall not exceed 150 ml. The suspension, that has passed through this sieve shall then be transferred to the sedimentation tube using the glass funnel and the volume of liquid is made up to 500 ml with distilled water.

The material retained on the 75-micron IS Sieve may be oven-dried and treated as prescribed in **4.3.2** and the cumulative percentages of the soil fraction retained on each sieve shall be calculated.

NOTE — Any other suitable stirring device other than the one specified in **5.1.1.5**, such as the bottle shaker, may be used and the stirring time shall be adjusted suitably.

5.1.3.4 *Sedimentation* — 25 ml of sodium hexametaphosphate solution shall be added from a pipette to a graduated 500-ml sedimentation tube (comparison tube) and diluted with distilled water to exactly 500 ml. This sedimentation tube together with the tube containing the soil suspension shall be immersed in the constant temperature bath (where used), the temperature of the bath noted (*see* Notes 1 and 2), the rubber bungs inserted and the tubes allowed to stand until they have reached the temperature of the bath. The tubes with their contents shall then be thoroughly shaken by inverting the tubes several times. They shall then be replaced in the apparatus, simultaneously starting the stop watch. The rubber bungs shall then be carefully removed without agitating the tubes.

The pipette with the tap E closed shall be lowered vertically into the soil suspension until the end is 100 ± 1 mm below the surface of the suspension. It shall be lowered with great care some 15 seconds before the sample is due to be taken. Approximately 10 seconds shall be taken to complete this operation. The tap E shall be opened and a sample (V_p ml) drawn up into the pipette. The pipette and the bore in the tap

E shall be filled with solution and tap *E* then closed. This operation shall take 10 seconds to complete.

After each sampling operation the pipette shall be withdrawn from the suspension, taking approximately 10 seconds to complete the operation.

During the sampling a small amount of the suspension may have been drawn up into the bulb *D* above the bore of the tap *E*. This surplus shall be washed away into the beaker down the outlet tube *F* by opening the tap *E* in such a way as to connect *D* and *F*. Distilled water shall then be allowed to run from the bulb funnel *A* into *D* and out through *F* until no solution remains in the system.

A tared weighing bottle shall be placed under the end of the pipette and the tap *E* opened so that the contents of the pipette are delivered into the bottle. Any suspension left on the inner walls of the pipette shall be washed into the weighing bottle by allowing distilled water from the bulb *A* to run through *B*, *D* and *E* into the pipette. This procedure shall be repeated at the end of each time corresponding to particle diameters 0·02 mm, 0·006 mm, 0·002 mm, 0·001 mm calculated on the basis of equation given in **5.1.4.3** (a). Table 1 gives the time of settling to a depth of 100 mm of particles of various diameters for temperatures ranging from 10 to 35°C for an average specific gravity of soil of 2·68. The weighing bottles and contents shall be placed in the oven maintained at 105 to 110°C and the sample evaporated to dryness. After cooling in a desiccator the weighing bottle and contents shall be weighed to the nearest 0·001 g and the mass of the solid material in the sample determined (W_1, W_2, W_3, and W_4 for each respective sampling time).

Between any of the times in which the above sampling is taking place, a sample (V_p ml) shall be taken from the tube containing the sodium hexametaphosphate solution. The mass of solid material in the sample shall be determined (W_s).

The specific gravity of the soil fraction passing the 75-micron IS Sieve shall be determined by the method specified in IS : 2720 (Part 3/Sec 1)-1980*.

NOTE 1 — If a constant temperature bath is not available for the test, the test may be performed at room temperature. The temperature shall be noted at the time of sampling and suitable correction made in the calculation of the equivalent diameter of soil grains on the basis of equation in **5.1.4.3** (a).

NOTE 2 — Asymmetrical heating of the suspension causes convection currents which affect the sedimentation process. The suspension should, therefore, be kept

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*Methods of test for soils : Part 3 Determination of specific gravity, Section 1 Fine grained soils (*first revision*).

out of direct sunlight and away from any local source of heat. Evaporation should be retarded by keeping a cover on the measuring cylinder between readings.

NOTE 3 — It is not necessary to measure the specific gravity of every sample used for fine analysis. An average value for samples from the same area or soil type in an area may be used without loss of accuracy. It is essential that the specific gravity used is that of the fraction passing 75-micron IS Sieve.

5.1.4 *Calculations*

5.1.4.1 *Loss in mass in pre-treatment* — The loss in mass in pre-treatment of the soil in percentage shall be calculated as follows:

$$P = 100 - \frac{W_b\,(100 + w)}{W_a}$$

where

P = loss in mass in percentage,

W_b = mass of soil after pre-treatment,

w = air dry moisture content of the soil taken for analysis, and

W_a = mass of air dry soil used.

5.1.4.2 *Sieving* — The percent of soil sample passing each of the sieves used in the analysis shall be calculated using the mass of the pre-treated soil (W_b).

5.1.4.3 *Sedimentation*

a) *Diameter of particle* — The diameter of the particle in suspension at any sampling time t shall be calculated from the formula:

$$D = \sqrt{\frac{30\,\mu}{980\,(G - G_1)}}\;\sqrt{\frac{H}{t}}$$

where

D = diameter of particle in suspension, in mm;

μ = coefficient of viscosity of water in poises at the temperature of suspension at the time of sampling;

G = specific gravity of the soil fraction used in the sedimentation analysis, in g/cm^3;

G_1 = specific gravity of water, in g/cm^3;

H = height of fall of the particles or sampling depth, in cm; and

t = time elapsed before sampling, in minutes.

TABLE 1 RATE OF SETTLING OF PARTICLES AT VARIOUS TEMPERATURES

(Average Specific Gravity of Soil Assumed As 2·68)

(*Clause* 5.1.3.4)

Temperature °C	Diameter, mm																		
	·001	·002	·003	·004	·005	·006	·007	·008	·009	·01	·02	·03	·04	·05	·06	·07	·08	·09	·1
	(Time				for		a		fall		of		100			mm)			
	h				min						s								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
10	40·80	10·19	4·53	2·55	98·0	68·0	53·0	38·3	30·2	24·5	367	163	92	59	40·8	31·8	22·9	18·1	14·7
11	39·64	9·91	4·40	2·48	95·2	66·1	51·5	37·2	29·3	23·8	357	158	89	57	39·6	30·9	22·3	17·6	14·3
12	38·55	9·63	4·28	2·41	92·6	64·2	50·1	36·1	28·5	23·1	347	154	87	55	38·5	30·0	21·7	17·1	13·9
13	37·48	9·37	4·16	2·34	90·0	62·5	48·7	35·1	27·7	22·5	337	150	84	54	37·5	29·2	21·1	16·7	13·5
14	36·39	9·10	4·04	2·28	87·6	60·8	47·3	34·2	27·0	21·9	328	146	82	52	36·4	28·4	20·5	16·2	13·1
15	35·45	8·86	3·93	2·22	85·1	59.2	46·1	33·3	26·2	21·3	319	142	80	51	35·4	27·6	19·9	15·8	12·7
16	34·49	8·62	3·83	2·16	82·8	57·6	44·9	32·4	25·5	20·7	310	138	78	50	34·5	26·9	19·4	15·3	12·4
17	33·64	8·41	3·73	2·10	80·8	56·1	43·7	31·5	24·9	20·2	302	134	76	48	33·6	26·2	18·9	14·8	12·1
18	32·73	8·18	3·64	2·04	78·6	54·6	42·5	30·7	24·2	19·6	294	131	74	47	32·7	25·5	18·4	14·5	11·8
19	31·89	7·98	3·54	1·99	76·6	53·2	41·4	29·9	23·6	19·1	287	127	72	46	31·9	24·8	17·9	14·1	11·5
20	31·10	7·77	3·45	1·94	74·6	51·8	40·4	29·1	23·0	18·6	280	124	70	45	31·1	24·2	17·5	13·8	11·5
21	30·28	7·57	3·36	1·89	72·7	50·6	39·4	28·4	22·4	18·2	273	121	68	44	30·3	23·6	17·0	13·4	10·9
22	29·55	7·38	3·28	1·85	70·9	49·3	38·4	27·7	21·8	17·7	266	118	66	42	29·5	23·0	16·6	13·1	10·6
23	28.81	7·21	3·20	1·80	69·2	48·1	37·5	27·0	21·3	17·3	259	115	65	41	28·8	22·4	16·2	12 8	10·4
24	28·12	7·03	3·12	1·76	67·5	46·9	36·6	26·4	20·8	16·9	253	113	63	40	28·1	21·9	15·8	12·5	10·1
25	28·78	6·86	3·05	1·72	65·9	45·8	35·7	25·8	20·3	16·5	247	110	62	39	27·8	21·4	15·5	12·2	9·9
26	26·81	6·71	2·98	1·68	64 4	44·7	34·8	25·2	19·8	16·1	241	107	60	39	26·8	20·9	15·1	11·9	9·6
27	26·19	6·54	2·91	1·64	62·9	43·7	34·0	24·6	19·4	15·7	236	105	59	38	26·2	20·4	14·7	11·6	9·4
28	25·60	6·40	2·84	1·60	61·4	42·7	33·2	24·0	19·0	15·4	231	102	58	37	25·6	19·9	14·4	11·4	9·2
29	25·04	6·25	2·78	1·56	60·1	41·7	32·5	23·4	18·5	15·0	226	100	56	36	25·0	19·4	14·1	11·1	9·0
30	24·46	6·12	2·72	1·53	58·8	40·8	31·8	22·9	18·1	14·9	221	98	55	35	24·5	19·0	13·8	10·8	8·8
31	23·95	5·98	2·66	1·50	57·5	39·9	31·1	22·4	17·7	14·4	216	96	54	34	23·9	18·6	13·5	10·6	8·6
32	23·44	5 86	2·60	1·47	56·3	39·1	30·4	21·9	17·3	14·1	221	94	53	34	23·4	18·2	13·2	10·4	8·5
33	22·95	5·74	2·55	1·44	55·1	38·3	29·8	21·5	17·0	13·8	206	92	52	33	22·9	17·8	12·9	10·2	8·4
34	22·50	5·62	2·50	1·41	54·0	37·5	29·2	21·1	16·6	13·5	202	90	51	32	22·5	17·5	12·6	10·0	8·1
35	22·01	5·50	2·45	1·38	52·9	36·7	28·6	20·7	16·3	13·2	198	89	50	32	22·0	17·2	12·4	9·8	7·9

b) *Percentage finer than D*

1) The mass of solid material in 500 ml of suspension for each respective sampling time shall be calculated from the formula:

$$M_1 \text{ or } M_2 \text{ or } M_3 \text{ or } M_4, \text{ etc, or } M_s, \text{ in g} = \frac{W_1 \text{ or } W_2 \text{ or } W_3 \text{ or } W_4, \text{ etc, or } W_s}{V_p} \times 500$$

where

$\left.\begin{matrix} M_1 \\ M_2 \\ M_3 \\ M_4 \\ \text{etc} \end{matrix}\right\}$ = mass of material in 500 ml from respective samplings,

M_s = mass of sodium hexametaphosphate in 500 ml of solution,

$\left.\begin{matrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ \text{etc} \end{matrix}\right\}$ = mass of material in V_p ml from respective samplings,

W_s = mass of sodium hexametaphosphate in V_p ml of solution, and

V_p = volume in ml of sample pipetted for respective samplings.

2) The percentage by mass (W), of particles finer than diameter D shall be calculated from the formula:

$$W = \frac{(M_1 \text{ or } M_2 \text{ or } M_3 \text{ or } M_4, \text{ etc}) - M_s}{W_b} \times 100$$

where

$\left.\begin{matrix} M_1 \\ M_2 \\ M_3 \\ M_4 \\ \text{etc} \end{matrix}\right\}$ = mass of material in 500 ml from respective samplings,

M_s = mass of sodium hexametaphosphate in 500 ml of solution, and

W_b = mass of soil after pre-treatment.

5.1.4.4 *Combined gradation* — Combined gradation for each of the particle sizes covered by **5.1.3.4** shall be calculated on the basis of the total soil sample taken for analysis.

5.2 Hydrometer Method (Subsidiary Method)

5.2.0 This method is not applicable, if less than 10 percent of the material passes 75-micron IS Sieve.

5.2.1 *Apparatus*

5.2.1.1 *Hydrometer* — of the type illustrated in Fig. 5 and fulfilling the following requirements:

a) There shall be no abrupt changes in the cross section of the hydrometer, such as will hinder cleaning or drying or permit air bubbles to be trapped.

b) The hydrometer shall be graduated on the basis of a liquid having a surface tension of 55 dynes/cm.

c) The graduation lines shall be at intervals of 0·000 5, every alternate line shall extend beyond the shortest lines, every tenth graduation shall exceed that of all the intervening lines and shall be numbered in full. A recommended scale is shown in Fig. 5.

d) The basis of the scale shall be density (g/ml) at 27°C.

e) The maximum permissible scale error on the hydrometer is plus or minus one scale division.

f) The other general requirements shall satisfy those specified in IS : 3104-1965*.

5.2.1.2 *Glass measuring cylinders* — two of 1 000 ml capacity with ground glass or rubber stoppers about 7 cm diameter and 33 cm high marked at 1 000 ml volume.

5.2.1.3 *Thermometer* — to cover the range 0·50°C accurate to 0·5°C.

5.2.1.4 *Water-bath or constant temperature room (optional)* — for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature. Such a device is illustrated in Fig. 6.

5.2.1.5 *Stirring apparatus* — as specified in **5.1.1.5**.

5.2.1.6 *Sieves* — as specified in **5.1.1.6**.

5.2.1.7 *Balance* — accurate to 0·01 g.

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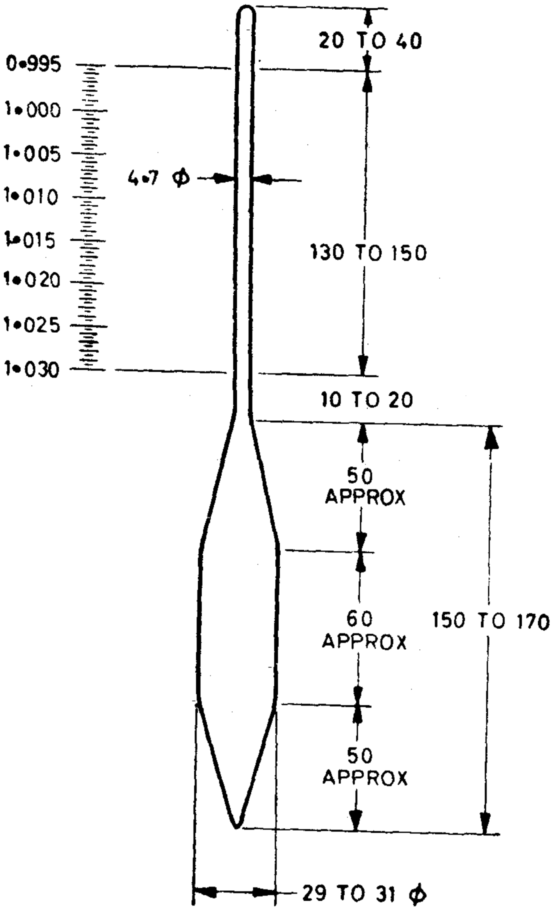
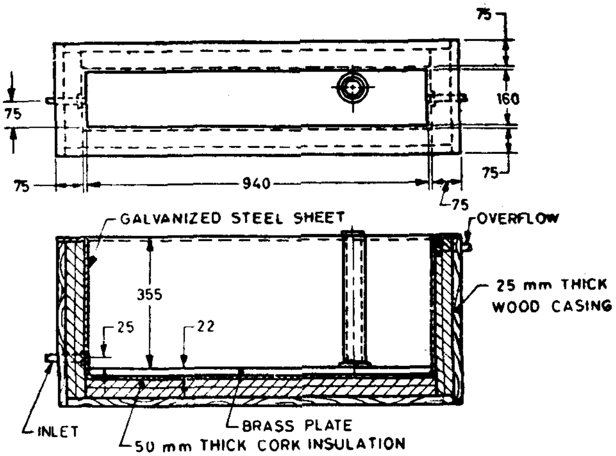
*Specification for density hydrometers.



All dimensions in millimetres.

FIG. 5 HYDROMETER



All dimensions in millimetres.

FIG. 6 ILLUSTRATED WATER BATH

5.2.1.8 *Oven* — thermostatically controlled to maintain a temperature of 105 to 110°C, with interior of non-corroding material.

5.2.1.9 *Stop watch*

5.2.1.10 *Desiccator*

5.2.1.11 *Centimetre scale*

5.2.1.12 *Porcelain evaporating dishes* — four, about 15 cm in diameter.

5.2.1.13 *Wide-mouth conical flask or conical beaker* — of 1 000 ml capacity.

5.2.1.14 *Buchner or Hirch funnel* — about 10 cm in diameter.

5.2.1.15 *Filter flask* — to take the funnel.

4.2.1.16 *Measuring cylinder* — of 100 ml capacity.

5.2.1.17 *Wash bottle* — containing distilled water.

5.2.1.18 *Filter papers*

5.2.1.19 *Blue litmus paper*

5.2.1.20 *Glass rod* — about 15 to 20 cm long and 4 to 5 mm in diameter.

5.2.2 *Reagents* — The reagents shall be of analytical quality.

5.2.2.1 *Hydrogen peroxide* — *See* **5.1.2.1.**

5.2.2.2 *Hydrochloric acid N solution* — *See* **5.1.2.2.**

5.2.2.3 *Sodium hexametaphosphate solution* — *See* **5.1.2.3** and Notes 1, 2 and 3 thereunder.

5.2.3 *Calibration of Hydrometer*

5.2.3.1 *Volume* — The volume of the hydrometer bulb (V_h) shall be determined in one of the following ways:

a) *From the volume of water displaced* — Approximately 800 ml of water shall be poured into the 1 000 ml measuring cylinder. The reading of the water level shall be observed and recorded.

The hydrometer shall be immersed in the water and the level shall again be observed and recorded.

The difference between the two readings shall be recorded as the volume of the hydrometer bulb in millilitres plus the volume of that part of the stem that is submerged. For practical purposes the error due to the inclusion of this stem volume may be neglected.

b) *From the mass of the hydrometer* — The hydrometer shall be weighed to the nearest 0·1 g.

The mass in grams shall be recorded as the volume of the hydrometer in millilitres. This includes the volume of bulb plus the volume of the stem below the 1·000 graduation mark. For practical purposes the error due to the inclusion of this stem may be neglected.

5.2.3.2 *Calibration*

a) The sectional area of the 1 000 ml measuring cylinder in which the hydrometer is to be used shall be determined by measuring the distance between two graduations. The sectional area (A) is equal to the volume included between the two graduations divided by the measured distance in centimetres between them.

b) The distance from the lowest calibration mark on the stem of the hydrometer to each of the other major calibration marks (R_h) shall be measured and recorded.

c) The distance from the neck of the bulb to the nearest calibration mark shall be measured and recorded.

d) The distance H corresponding to a reading R_h is the sum of the distances measured in (b) and (c).

e) The distance (h) from the neck to the bottom of the bulb shall be measured and recorded as the height of the bulb.

NOTE — The distance $h/2$ locates the centre of volume of asymmetrical bulb. If an asymmetrical bulb is used, the centre of volume can be determined with sufficient accuracy by projecting the shape of the bulb on to a sheet of paper and locating the centre of gravity of the projected area.

f) The effective depth (H_R) corresponding to each of the major calibration marks (R_h) shall be calculated from the following formula :

$$H_R = H_1 + \frac{1}{2}\left[h - \frac{V_h}{A}\right]$$

where

H_R = effective depth;

H_1 = length from neck of bulb, to graduation R_h, in cm;

h = twice the length from neck of bulb to its centre of volume, in cm;

V_h = volume of hydrometer bulb, in ml; and

A = area of measuring cylinder in cm^2.

NOTE — The factor $\frac{V_h}{A}$ in the above equation shall not be applied to hydrometer reading taken after periods of sedimentation of half, one, two and four minutes as specified in **5.2.4.3**(a).

g) The relationship between H_R and R_h may be plotted as a smooth curve which may be used for finding the effective depth (H_R) corresponding to hydrometer readings (R_h) obtained during test.

5.2.3.3 *Meniscus correction* — The hydrometer shall be inserted in a 1 000-ml measuring cylinder containing about 700 ml water. By placing the eye slightly below the plane of the surface of the liquid, and then raising it slowly until the surface seen as an ellipse becomes a straight line, the point where the plane intersects the hydrometer scale shall be determined. By placing the eye slightly above the plane of the surface of the liquid, the point where the upper limit of the meniscus intersects the hydrometer scale shall be determined. The difference between the two readings shall be recorded as the meniscus correction C_m. This is a constant for a given hydrometer.

5.2.4 *Procedure*

5.2.4.1 *Pre-treatment of soil* — The percentage of soluble salts shall be determined. In case it is more than one percent, the soil shall be washed with water before further treatment, taking care to see the soil particles are not lost (*see* Note 1 under **5.1.3.2**).

Two samples each of mass 50 to 100 g approximately shall be obtained by riffling from the air dried sample passing the 4·75-mm IS Sieve obtained as in **3.3**. The actual amount of soil required will vary according to the type of soil, 50 g with a clay soil and 100 g with a sand soil. The moisture content (w) of one sample shall be determined by the method given in IS : 2720 (Part 2)-1973*. The other sample shall be accurately weighed (W_a) to the nearest 0·01 g and placed in the wide mouth conical flask. 150 ml of hydrogen peroxide shall then be added and the mixture stirred gently with a glass rod for a few minutes after which it shall be covered with a cover glass and left to stand overnight. The mixture in the conical flask shall be gently heated. Care shall be taken to avoid frothing over and the contents of the dish shall be periodically stirred. As soon as vigorous frothing has subsided the volume shall be reduced to about 50 ml by boiling. With very organic soils additional peroxide may be required to complete the oxidation.

In the case of soils containing calcium compounds (*see* Note 2 under **5.1.3.2**) the mixture shall be allowed to cool and about 50 ml of hydrochloric acid added. The solution shall be stirred with a glass rod for a few minutes and allowed to stand for one hour or for longer periods, if necessary. If the soil contains a considerable amount of calcium salts more acid may be required. When the treatment is complete the solution shall have an acid reaction to litmus.

In the case of soils containing no calcium compounds or soluble salts and having a low organic content (less than 2 percent) the pre-treatment prescribed may be omitted and the dispersing agent shall be added as in **5.2.4.2** direct to the soil taken for analysis.

The mixture shall then be filtered and washed with warm water until the filtrate shows no acid reaction to litmus. The damp soil on the filter paper and funnel shall be transferred without any loss whatsoever to the evaporating dish (weighed to 0·01 g) using a jet of distilled water. Only the minimum quantity of distilled water shall be used. The dish

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*Methods of test for soils : Part 2 Determination of water content (*second revision*).

and contents shall be placed in an oven and dried at 105 to 110°C. The dish and contents shall then be transferred to the desiccator and allowed to cool. They shall then be weighed to 0·01 g, and the mass of soil remaining after pre-treatment shall be recorded (W_b).

5.2.4.2 *Dispersion of soil* — To the soil in the evaporating dish 100 ml of sodium hexametaphosphate solution shall be added and the mixture shall then be warmed gently for about 10 minutes and then transferred to the cup of the mechanical mixer using a jet of distilled water to wash all traces of the soil out of the evaporating dish. The amount of water used may be about 150 ml. The soil suspension shall then be stirred well for 15 minutes.

The suspension shall then be transferred to the 75-micron IS Sieve placed on a receiver and the soil shall be washed on this sieve using a jet of distilled water from a wash bottle. Particular care shall be taken to wash off all traces of suspension adhering to the dispersion cup. The amount of distilled water during this operation may be about 500 ml. The suspension that has passed through the sieve shall be transferred to the 1 000 ml measuring cylinder and made up to exactly 1 000 ml with distilled water. This suspension shall then be used for the sedimentation analysis.

The material retained on the 75-micron IS Sieve may be over-dried and analysed as specified in **4.3.2.1** and the cumulative percentages of the soil fraction retained on each sieve shall be calculated.

5.2.4.3 *Sedimentation*

a) A rubber bung shall be inserted in the mouth of the measuring cylinder which shall then be shaken vigorously and finally be inverted end over end. Immediately the shaking has ceased, the measuring cylinder shall be allowed to stand (in the constant temperature bath, if used) and the stop watch started. The hydrometer shall be immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings shall be taken after periods of half, one, two and four minutes. The hydrometer shall then be removed slowly, rinsed in distilled water and kept in a cylinder of distilled water at the same temperature as the soil suspension.

b) The hydrometer shall be re-inserted in the suspension and readings taken after periods of 8, 15 and 30 minutes, one, two and four hours after shaking (*see* Note). The hydrometer shall be removed, rinsed and placed in the distilled water after each reading. After 4 hours hydrometer readings shall be taken once or twice within 24 hours, the exact periods of sedimentation being noted. Finally a reading may be taken at the end of 24 hours. In taking all readings, insertion and withdrawal of the hydrometer before and after taking a reading shall be done carefully to avoid disturbing the suspension unnecessarly. Ten seconds shall be allowed for each operation. Vibration of the sample shall be avoided.

NOTE — Other suitable time intervals may be used, provided they give nearly equally spaced points on the grain size distribution curve.

c) The temperature of the suspension shall be observed and recorded once during the first 15 minutes and then after every subsequent reading. The temperature shall be read with an accuracy of at least ± 0·5°C. Hydrometer readings shall also be taken in pure distilled water at the corresponding temperatures and the temperature correction (M_t) calculated as the difference between this reading and the reading corresponding to the density of water at the calibration temperatures. A chart of such corrections for all temperatures may also be prepared for ready use.

NOTE — The temperature of the suspension over the period of the test should not differ from the mean temperature by more than ±2°C in order not to cause an error in the particle size of more than 2 percent. This requirement will generally be fulfilled if the maximum difference in room temperature is not greater than about 8°C. If the variation in temperature is likely to be greater than this the constant temperature bath should be used (*see also* Note 2 under **5.1.3.4**).

d) The correction (x) to be applied for the dispersing agent shall be ascertained by placing exactly 50 ml of the sodium hexameta-phosphate solution in a previously weighed glass weighing bottle and after evaporating the water by drying at 105 to 110°C in an oven, the mass of dispersing agent (W_d) shall be calculated.

The dispersing agent correction (x) shall then be calculated from the formula:

$$X = 2\,W_d$$

This correction is independent of the temperature.

Alternatively, the correction may be obtained directly by making up a 1 000 ml cylinder full of distilled water containing the same proportion of dispersing agent and at the same temperature, and placing the hydrometer in this solution. The corrected zero reading may then be read directly. This correction shall be corrected for temperature.

5.2.5 *Calculations*

5.2.5.1 *Loss in mass in pre-treatment* — The loss in mass in pre-treatment of the soil shall be calculated using the formula given in **5.1.4.1**.

5.2.5.2 *Sieving* — The percent of soil sample passing each of the sieve used in the analysis shall be calculated using the mass of the pre-treated soil and as percentages of the total soil sample taken for analysis.

5.2.5.3 *Sedimentation*

a) *Diameter of the particles* — The diameter of the particle in suspension at any sampling time t shall be calculated from the formula:

$$D = \sqrt{\frac{30\mu}{980\,(G - G_1)}}\ \sqrt{\frac{H_R}{t}}$$

where

D = diameter of particle in suspension, in mm;

μ = coefficient of viscosity of water at the temperature of the suspension at the time of taking the hydrometer reading, in poises;

G = specific gravity of the soil fraction used in the sedimentation analysis;

G_1 = specific gravity of water;

H_R = effective depth corresponding to R_h (*see* **5.2.3.2**), in cm [*see* Note under **5.2.3.2** (f)]; and

t = time elapsed between the beginning of sedimentation and taking of hydrometer reading in minutes.

The hydrometer reading corrected for meniscus (R_h) shall be calculated from the following formula:

$$R_h = R'_h + C_m$$

where

R_h = hydrometer reading corrected for meniscus,

R'_h = hydrometer reading at the upper rim of the meniscus, and

C_m = meniscus correction.

NOTE — A nomographic chart for solving the above equation is given in Fig. 7.

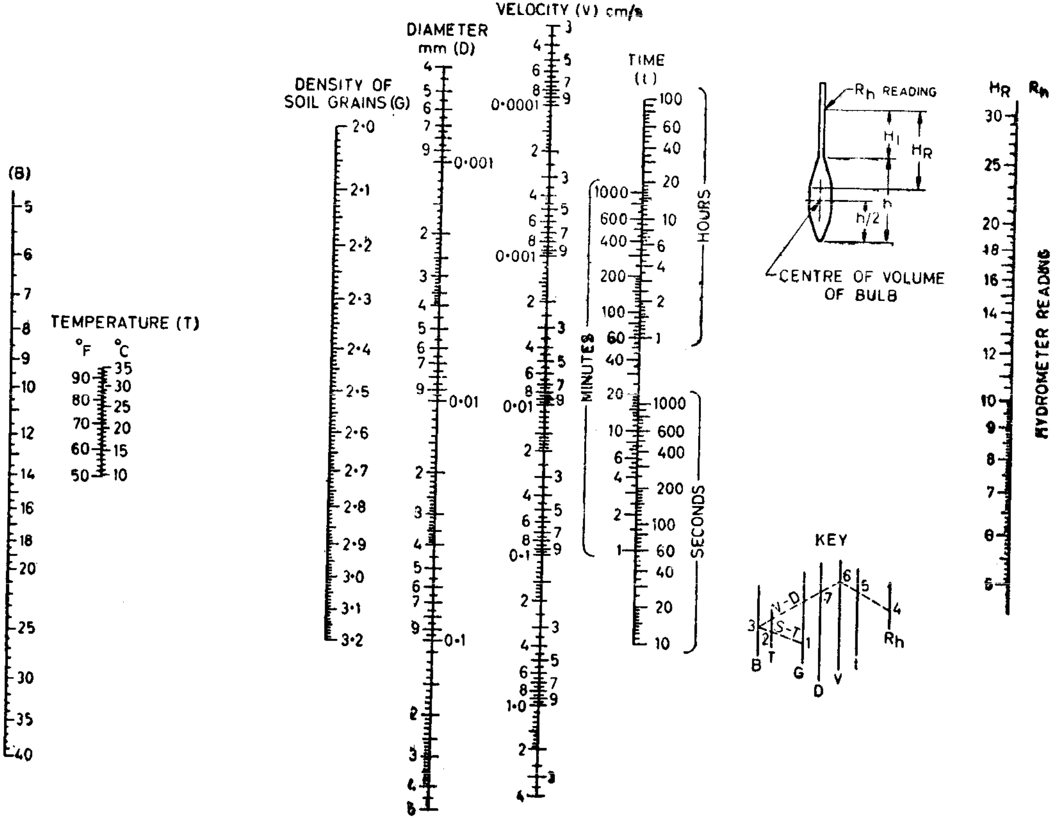


Fig. 7 Nomographic Chart

b) Percentage finer than D — The percentage by mass (W) of particles smaller than corresponding equivalent particle diameters shall be calculated from the formula:

$$W = \frac{100\, G_s}{W_b\, (G_s - 1)} (R_h + M_t - x)$$

where

G_s = specific gravity of soil particles,

W_b = weight of soil after pre-treatment;

R_h = hydrometer reading corrected for meniscus (for the type of hydrometer graduations illustrated in Fig. 5, R_h is obtained by reading the decimals only and placing the decimal point between the third and the fourth decimal places);

M_t = temperature correction; and

x = dispersion agent correction.

The values of W shall be calculated for all the values of D obtained and shall be expressed as percentages of particles finer than the corresponding value of D. These percentages shall then be expressed as combined percentages of the total soil sample taken for analysis.

5.3 PLUMMET BALANCE (Alternative Method)

5.3.1 *Principle* — Plummet balance is essentially a specific gravity balance and is designed on the principle that adjustment for depth of immersion of the plummet is more rapid requiring less precision than adjustment for weight. The only manipulation is adjustment of the height of the balance so that the plummet sinks to the right depth. This permits, at any time, to directly read percentage of soil in suspension with easy computation of diameter of the particle by Stoke's law.

5.3.2 *Apparatus*

5.3.2.1 *Plummet balance* — Figure 8 illustrates the basic components. The plummet balance consists of a base with three levelling screws over which an upright pillar is fixed. A light weight pointer beam mounted with the help of steel pivot and jewel bearings on to the scale arm. At the end of this scale arm a scale shall be fixed. The pointer shall be allowed on to move over the scale. The scale arm shall be fixed on two blocks acting as guides to move on the upright pillar. A pinion knob and a rack and pinion arrangement facilitates easy movement of this scale arm assembly to move up and down as desired.

The pointer has two adjusting screws allowing the adjustment of the zero reading. A plummet made of perspex with a string and hook for hanging to the pointer shall be provided. This plastic plummet shall weigh 3 gm in water. A plumb bob shall be provided on the scale arm carrier for adjustment of the level of the instrument.

5.3.2.2 *Glass measuring cylinders* — Two 1 000 ml capacity with ground glass or rubber stoppers about 7 cm diameter and 33 cm high marked at 1 000 ml volume.

5.3.2.3 *Thermometer* — to cover the range up to 50°C accurate up to 0·5°C.

5.3.3 *Procedure* — *see* Fig. 8.

5.3.3.1 Initial setting and adjustment level the instrument with the help of plumb bob and levelling screws. Two rider weights provided with the apparatus shall be used for checking calibration and for any adjustment. The weight marked 100 when hung on to the hook provided for hanging the plummet on the beam should read 100 and when the weight marked zero is hung the pointer should read zero. If adjustments are necessary at any time to obtain 0 and 100 readings, adjusting screws shall be used for changing the range and the other screw for setting the zero. Then the plummet shall be hooked to the beam after lowering in a container filled with distilled water. The pinion knob is then operated to bring the centre of the plummet at a depth of 9 cm or any other specified depth at which the usual readings are taken. Make a mark on the string. If the pointer does not read zero then adjust the screw. Do not tamper with the adjustment of the screw for doing this adjustment. The balance is now ready for use.

5.3.3.2 *Pre-treatment of soil* — The material retained on the 75 micron IS Sieve is oven dried and analysed as specified in **4.3.2.1**. The pretreatment is done as per the procedure as in **5.2.4**.

5.3.3.3 *Dispersion of soil* — The procedure is same as in **5.2.4.2**.

5.3.3.4 *Sedimentation* — A rubber bung shall be inserted into the mouth of the measuring cylinder which shall then be shaken vigorously and finally be inverted end over the end. Immediately after the shaking has ceased the measuring cylinder is placed on the stand of the plummet balance and the stop watch is started. This marks the beginning of sedimentation.

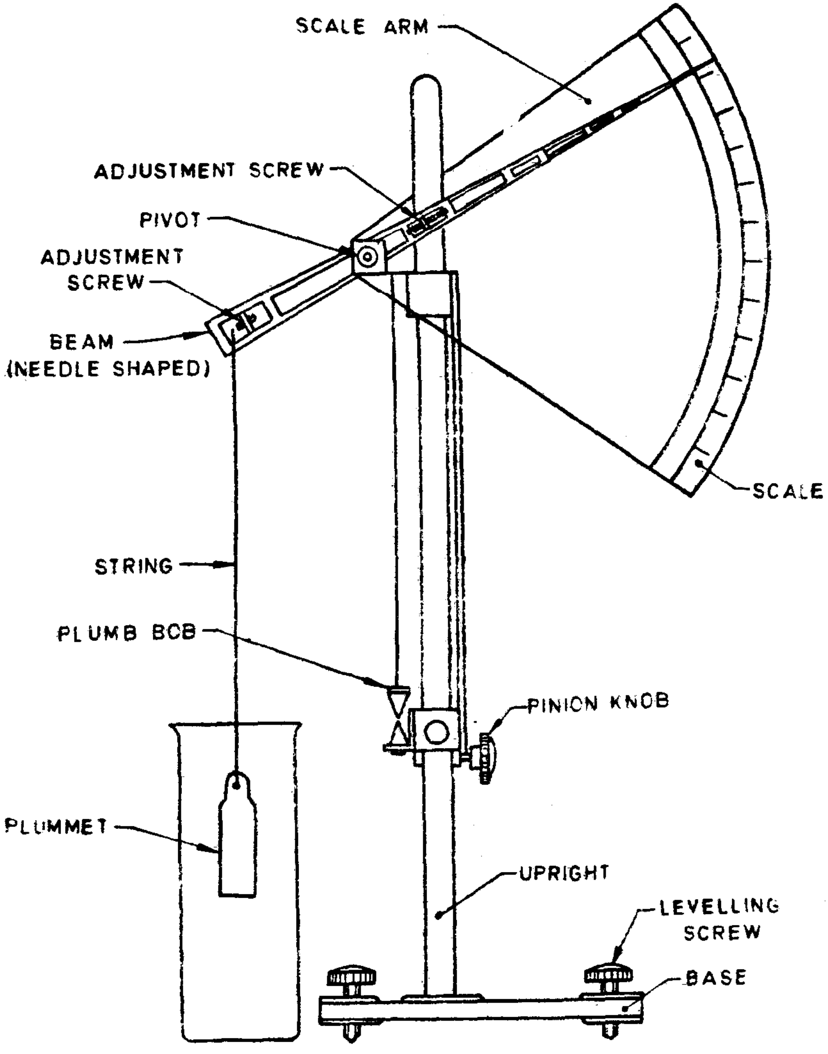


FIG. 8 DETAILS OF PLUMMET BALANCE

5.3.3.5 *Data* — The plummet then shall be lowered into the suspension and hooked on to the balance. The plummet is brought to the present depth by turning the pinion. The percentage of soil in suspension is directly read by the pointer and noted down at half, one, two, four minutes and subsequently at further intervals lasting over up to six to seven hours. The balance is sufficiently sensitive to allow readings to be made to the nearest percentage unit in 2 percent suspensions.

5.3.3.6 *Computations* — Particle diameter D in mm is computed as detailed below for each of the percentages read out by the pointer;

$$D\,(\text{mm}) = k\sqrt{\frac{Z_c\,(\text{cm})}{t\,(\text{min})}}$$

where

Z_c = effective depth of immersion of the plummet which is the depth in cm, from the surface of the suspension to centre of the plummet, that is, predetermined distance (say 9 cm) from the mark on the string to centre of the plummet;

t = time in minutes when pointer readings are taken. Time intervals are adjusted such that square root of time can directly be computed; and

k = coefficient from Fig. 9 to aid in solving Stoke's equation for known temperature condition and specific gravity of particles either determined or assumed (range 2·65 to 2·8).

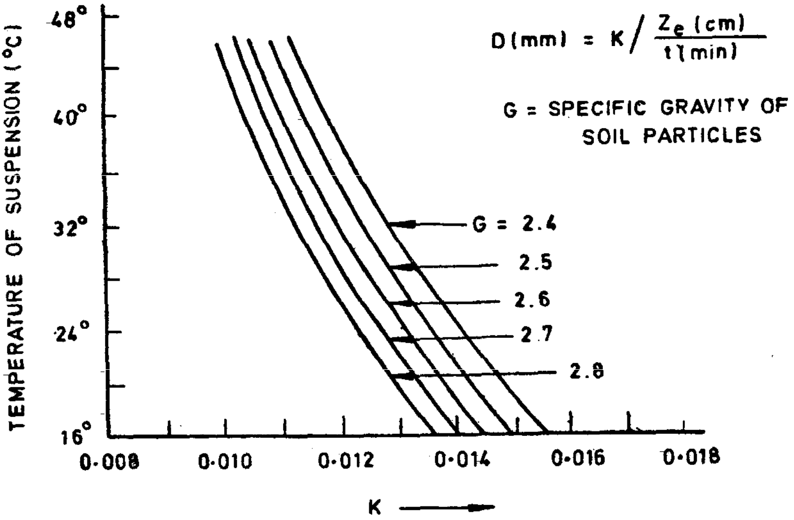
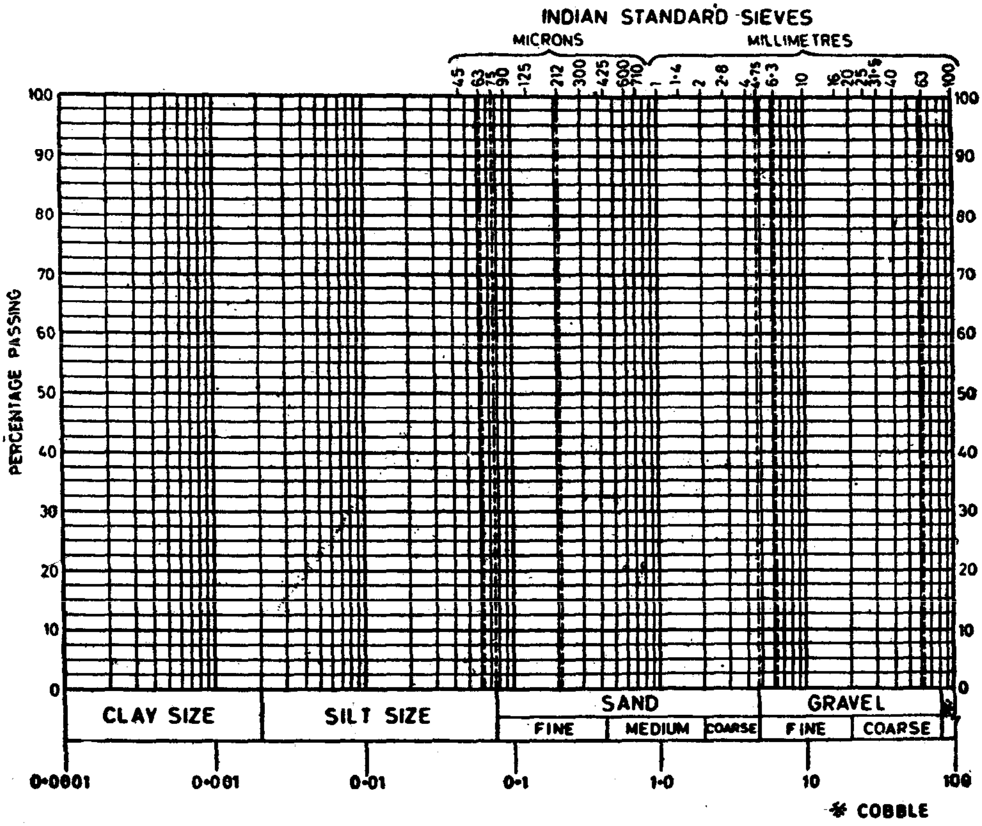


FIG. 9 CHART FOR AID IN SOLVING STOKES EQUATION

6. REPORT

6.1 The results of the grain size analysis shall be reported in a suitable form. A recommended *pro forma* is given in Appendix A. A grain size distribution curve shall be drawn on a semi-logarithmic chart, plotting particle size on the log scale against percentage finer than the corresponding size on the ordinary scale. A chart for showing grain size distribution is shown in Fig. 10.



Grain size in millimetres.

FIG. 10 CHART FOR RECORDING GRAIN SIZE DISTRIBUTION

APPENDIX A

(*Clause* 6.1)

FORM FOR THE RECORD OF RESULTS OF GRAIN SIZE ANALYSIS

PROJECT . ... DETAILS OF SOIL SAMPLE..........

SIEVE ANALYSIS OF FRACTION RETAINED ON 4·75-mm IS SIEVE

Weight of total soil sample taken for analysis..

Water content..

IS Sieve Designation	Mass of Soil Retained + Mass Container	Mass of Container	Mass of Soil Retained	Cumulative Mass Retained	Soil Retained as Percentage of Soil Taken	Soil Passing as Percentage of Soil Taken	Combined Percentage Passing as Percentage of Total Soil Sample

SIEVE ANALYSIS OF FRACTION PASSING 4·75-mm IS SIEVE BUT RETAINED ON 75-MICRON IS SIEVE

Mass of partial sample taken for analysis...... ....

Water content...... ....

IS Sieve Designation	Mass of Soil Retained + Mass of Container	Mass of Container	Mass of Soil Retained	Cumulative Mass Retained	Soil Retained as Percentage of Partial Soil Taken	Soil Passing as Percentage of Partial Soil Sample Taken for Analysis	Combined Percentage Passing as Percentage of Total Soil Sample

ANALYSIS OF SOIL PASSING 75-MICRON IS SIEVE

Mass of air dry soils (W_s) ....

Water content of air dry soil (w)..

Mass of ovendry soil after pre-treatment (W_b)..

Loss in mass in pre-treatment in percent,..

Pipette Analysis

Specific gravity of soil..

Volume of suspension taken in pipette (V_p)..

Depth at which sample was taken..

Mass of dispersing agent in the volume of suspension sampled..

Date	Time Elapsed Before Sampling	Temperature of Suspension	Mass of Container + Oven Dry Soil Fraction	Mass of Bottle	Mass of Solid Material in Bottle in Volume V_p	Mass of Solid Material in 500 ml	Correct Mass of Soil Material in 500 ml	Diameter D of Soil Grain in mm	Percentage Finer than D as Percentage of W_b	Combined Percentage Finer than D as Percentage of Total Soil Sample

Hydrometer Analysis

Hydrometer No. ....

Meniscus correction (C_m)..

Temperature correction (M_t)..

Dispersing agent correction (x)..

Density of soil G..

$$W = \frac{100\ G}{W_b\ (G-1)} (R_h + M_t - x) \text{ (percent)}$$

Date	Time	Temperature	Elapsed Time	Hydrometer Reading R'_h	Corrected Hydrometer Reading $R_h = R'_h + C_m$	Equipment Diameter, D (mm)	$R_h + M_t - x$	Percentage of Particles Finer than D, W Percentage	Combined Percentage of Finer than D as Percentage of Total Sample

(*Continued from page* 2)

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