

NEW ZEALAND STANDARD

METHODS OF TESTING SOILS
FOR CIVIL ENGINEERING
PURPOSES

Part 2
Soil classification tests

2.8
DETERMINATION OF THE PARTICLE-SIZE DISTRIBUTION

TEST 2.8.4
Subsidiary method for fine soils
(Hydrometer method)

2.8.4.1

Scope

This method covers the quantitative determination of the particle-size distribution in a soil from the coarse sand size down (see Note (1)). This test is not normally carried out if less than 10 % of the material passes the 63 μm test sieve as measured in Test 2.8.1.

2.8.4.2

Related documents

2.8.4.2.1

The provisions of Part 1 of this Standard are applicable to, and shall be read in conjunction with, this method of test. Reference is made to Tests 2.1, 2.8.1, 3.3.1 and 3.3.2 of this Standard.

2.8.4.2.2

Reference is made in this method of test to the following British Standards:

- BS 718:1979 Specification for density hydrometers
BS 1377:1975 Methods of test for soil for civil engineering purposes

2.8.4.3

Apparatus:

- (a) A hydrometer of the type illustrated in fig. 2.8.4 and otherwise fulfilling the following requirements of BS 718:
- (1) (The bulb and stem shall be made of glass as free as possible from visible defects.) The glass shall be resistant to chemicals and shall be well annealed.
 - (2) Where a solid loading material is used it

shall be fixed in the bottom part of the hydrometer by means of a cementing material which does not soften if heated to 80 °C. Where mercury is the loading material it shall be confined in the bottom part of the hydrometer.

- (3) The scale and inscriptions shall be marked clearly in permanent black ink on high quality paper having a smooth surface. It is recommended that the paper be an esparto paper (65 to 75 % esparto) and that the strips be cut with their length in the machine direction of the paper.
- (4) The stem and bulb shall be circular in cross section and shall be symmetrical about the main axis. There shall be no abrupt changes in cross-section such as will hinder cleaning or drying or permit air bubbles to be trapped.
- (5) At all points within its range the hydrometer shall float with the stem within 1.5° of vertical.
- (6) The graduation lines shall be fine, distinct and of uniform thickness; and shall show no evident irregularities in spacing. The scale shall be straight and without twist, with the graduation lines at right angles to the axis of the hydrometer.
- (7) The basis of the scale shall be density (g/ml) at 20 °C. The graduation lines shall be at intervals of 0.0005; every alternate line shall extend beyond the shortest lines; every tenth graduation shall exceed the length of all the intervening lines and shall be numbered in full. A

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recommended scale is shown in fig. 2.8.4.

- (8) The adjustment of the hydrometer shall be related to a liquid having a surface tension of 55 mN/m.
- (9) The maximum permissible scale error on the hydrometer is plus or minus one graduation interval.
- (10) The following inscriptions shall be legibly marked within the stem or bulb of each hydrometer and shall not encroach on the scale or the figuring.
 - (i) The basis of scale, that is, g/ml at 20 °C.
 - (ii) The maker's or vendor's name or mark.
 - (iii) An identification number.
 - (iv) The number of the corresponding British Standard, that is, BS 1377.
- (b) Two 1000 ml graduated glass measuring cylinders with parallel sides and rubber seals to fit, or two parallel sided glass cylinders with ground glass stoppers about 70 mm diameter and 330 mm high marked at 1000 ml volume as sedimentation cylinders.
- (c) A thermometer to cover the range 0 to 50 °C, readable and accurate to 0.5 °C.
- (d) A constant temperature bath or cabinet large enough to take the apparatus used, capable of being maintained constant to an accuracy of ± 0.5 °C (see Note (2)). The bath shall not vibrate the sample.
- (e) A water bath capable of being maintained at 100 °C for heating solutions and suspensions.
- (f) A mechanical shaker capable of keeping 75 g of soil and 200 ml of water in continuous motion.

(The type of shaker should be one that gives a gentle mixing action, for example, an end-over-end shaker or a vibratory shaker).
- (g) A flat glass or other smooth non-absorbent mixing plate (a convenient size is 10 mm thick and 500 mm square), and two palette knives with blade about 100 mm long and 10 mm wide.
- (h) Test sieves 2.00 mm, 600 μm , 212 μm , 63 μm , and a receiver.
- (j) A hand lens of $\times 10$ power.
- (k) A balance readable and accurate to 0.001 g.
- (m) A drying-oven complying with the requirements of 1.4.2 of Part 1.
- (n) Four porcelain evaporating dishes.
- (o) A timing device readable and accurate to 1 s.
- (p) A desiccator (a convenient size is 200 to 250 mm in diameter) containing anhydrous silica gel.
- (q) A 1 litre tall-form beaker and a cover glass to fit.
- (r) A scale readable and accurate to 0.5 mm and of nominal length 300 mm.
- (s) A source of vacuum, for example, a filter pump or a vacuum pump, capable of maintain-

ing an absolute pressure of less than 20 mm of mercury.

- (t) A Buchner or Hirsch funnel of nominal diameter, 70 mm hardened filter papers to fit, for example, Whatman No. 542, a cover glass, and a 2 litre filter flask and a length of suitable tubing to connect the vacuum source to the filter flask.
- (u) A shaking bottle, for example, a 300 ml cream bottle and rubber stopper to fit.
- (v) A 100 ml and a 250 ml measuring cylinder.
- (w) A 25 ml pipette.
- (x) A glass filter funnel of nominal diameter 100 mm and a wash bottle preferably of plastics containing distilled water.
- (y) A suitable stirrer such as a length of glass rod about 150 to 200 mm long and 4 to 5 mm diameter fitted at one end with a rubber policeman.
- (z) A means of measuring pH (see Tests 3.3.1 and 3.3.2).

2.8.4.4

Reagents

The reagents used shall be of recognized analytical reagent quality.

- (a) *Hydrogen peroxide*. A 20 volume solution (see Note (3)).
- (b) *Amyl alcohol*. Commercial Grade (optional).
- (c) *Sodium hexametaphosphate solution*. Dissolve 66 g sodium hexametaphosphate and 14 g sodium carbonate in distilled water to make one litre of solution.

NOTE – This solution is unstable. Prepare fresh solution approximately once a month. Record the date of preparation on the bottle (see Note (4)).

2.8.4.5

Procedure

2.8.4.5.1

Calibration of hydrometer

- (a) Pour sufficient water into the 250 ml measuring cylinder (usually about 170 ml) so that when the hydrometer is inserted, the water level does not rise above the 250 ml mark. Observe and record the reading at the water level. Immerse and steady the hydrometer in the water and again observe and record the reading at the water level. The difference between the readings may be taken as the volume of the hydrometer bulb (see Note (5)).
- (b) Slowly withdraw the hydrometer until the graduated cylinder reading at the water level indicates half the volume change on full immersion. Very carefully clamp the hydrometer in this position. Record the reading (R) on the hydrometer stem which is in line with the top of the cylinder (a ruler laid across the top provides a convenient datum).
- (c) Measure the distance from the water level (reading on the outside of the graduated

- cylinder) to the top of the cylinder to the nearest 0.5 mm and record as the distance (c) from the centre of volume of the hydrometer bulb to the hydrometer reading, R .
- (d) Remove the hydrometer from the cylinder. Measure the distances (y) from each of the major graduation marks on the hydrometer stem to the reading, R counting y positive towards the top of the stem and negative towards the bulb to the nearest 0.5 mm and record.
 - (e) Fill the 1000 ml sedimentation cylinder with water to the 1000 ml mark and immerse the hydrometer. Measure and record the change in level (L) in mm.
 - (f) Place the eye slightly below the plane of the surface of the liquid, raise it slowly until the surface, seen as an ellipse, becomes a straight line and determine the point where the plane intersects the hydrometer scale (see Note (6)).
 - (g) Place the eye slightly above the plane of the surface of the liquid and determine the point where the upper limit of the meniscus intersects the hydrometer scale.
 - (h) Record the difference between the two readings taken in steps (g) and (h) above as the meniscus correction (C_m) (see Note (7)).
 - (k) Calculate the effective depth (H_R) corresponding to each of the major graduations on the hydrometer stem (R_h) from the formula:

$$H_R = c + y - \frac{L}{2} \dots\dots\dots \text{mm}$$

where c = distance from the centre of volume of the bulb to reading R (mm).

y = distance from a reading R_h to the reading R taking account of direction (mm).

L = change in level of water in the cylinder when the hydrometer is immersed (mm).

- (m) Calculate values of $R'_h = R_h - C_m$ (where R'_h = hydrometer reading at the top of the meniscus for a true reading R_h .
 C_m = meniscus correction.)

Plot the relationship between H_R and R'_h as a smooth curve. Use this smooth curve to convert values of R'_h to H_R for the solution of Stokes' Law (see Note (8)).

2.8.4.5.2

Pretreatment of soil

- (a) Take the sub-sample obtained in accordance with the method specified in 1.6.7 of Part 1 or 2.8.1.5 of Test 2.8.1 (see Notes (9) and (10)) and sieve through the 2.00 mm test sieve suitably protected by larger sieves if necessary. The sample must be sufficient to yield equivalent to 50 to 100 g oven-dry mass passing 63 μm test sieve.
- (b) Clean any particles retained on the sieve by

brushing or washing until the individual particles are clean of any finer material, taking care especially with weak materials to ensure that the treatment is not removing parts of larger particles.

- (c) Discard the material retained (see Note (9)) and transfer the material passing the 2.00 mm test sieve together with any washings into the tall beaker. Adjust the volume of the soil suspension to about 100 ml by evaporation or by adding distilled water.
- (d) Add 100 ml of 20 volume hydrogen peroxide (see Note (3)) to the suspension at room temperature and stir. Allow the reaction to proceed for about 30 min, stirring from time to time to reduce frothing and to break down aggregates.
- (e) Warm the beaker on the boiling water bath. The reaction may become vigorous so that frequent stirring, temporary removal from the bath, or the use of a few drops of amyl alcohol may be required to reduce excessive frothing. Leave the beaker on the water bath until the reaction has subsided and the suspension may safely be boiled for a few minutes.

When the organic matter has been oxidized to a sufficient degree the soil is usually a pale grey or buff colour. Some organic soils may require additions of further increments of hydrogen peroxide (see Note (11)) repeating steps (d) and (e).

- (f) Assemble the Buchner or Hirsch funnel and filter flask and connect the flask to the source of vacuum (see Note (12)). Wet a hardened filter paper with distilled water, place it on the funnel ensuring that it seals properly and apply the vacuum.
- (g) Slowly pour the contents of the beaker into the funnel. Wash the beaker with a jet of distilled water and scrub its sides with the rubber policeman. Make sure that all the soil is transferred into the funnel.
- (h) Keep the soil surface wet by adding further distilled water to the funnel as required. Except when adding water, keep a cover glass on the funnel.
- (j) Continue until nearly 2 litres of filtrate has been collected, finally allowing all free water in the funnel to be drawn through the soil but do not allow the surface of the soil to dry. Release the vacuum and remove the funnel from the flask.
- (k) Carefully remove the filter paper together with all the soil from the funnel and place on the mixing plate. Scrape the filter paper gently with a palette knife and finally wash the paper with a jet of distilled water using a minimum of water.
- (m) Thoroughly mix the soil to a uniform consistency, taking care not to grind coarser particles. Working quickly, transfer sufficient to

contain about 25 g oven-dry mass of material passing 63 μm test sieve to a weighed shaking bottle for dispersion and weigh to 0.01 g. Calculate by difference the wet mass of soil taken for dispersion (M_w). Use all the remaining material to make two determinations of water content as specified in Test 2.1.

2.8.4.5.3

Dispersion of soil

see Note (2))

- (a) Add about 100 ml of distilled water to the shaking bottle, stopper and shake the bottle vigorously until all the soil has been brought into suspension. Using the pipette, add 50 ml of the sodium hexametaphosphate solution. Shake the bottle on the mechanical shaking device for at least 4 h (when convenient the suspension may be left shaking overnight) (see Note (14)).
- (b) Transfer the suspension to the 63 μm test sieve placed on the receiver and wash the soil on the sieve using *only* a jet of distilled water until all the fine material has passed the sieve and been collected. Do not use more than about 300 ml of distilled water during this operation. Inspect the material retained on the sieve with the hand lens to check that it contains only clean sand grains (see Note (15)). Transfer all the suspension passing the sieve to the sedimentation cylinder using the glass funnel and a jet of distilled water and make the volume up to 1000 ml with distilled water. Seal the cylinder and shake vigorously until a uniform suspension is formed. Measure the pH of the suspension and record (see Note (4)).
- (c) Transfer the material retained on the 63 μm test sieve to an evaporating dish and dry in the oven at 105 to 110 $^{\circ}\text{C}$. After drying, re-sieve this material on the 600 μm , 212 μm and 63 μm test sieves (see Note (6)). Transfer the material retained on the 600 μm , 212 μm and 63 μm sieves after the second sieving to evaporating dishes of known mass and weigh to 0.001 g. Record the mass of dry material retained on these sieves as the mass of coarse, medium and fine sand in the sample (M_{cs} M_{ms} M_{fs}). Add the material passing the 63 μm sieve to the suspension.

2.8.4.5.4

Sedimentation

- (a) Add 50 ml of the sodium hexametaphosphate solution using the pipette to a graduated 1000 ml sedimentation cylinder and dilute with distilled water to 1000 ml. Seal the cylinder and agitate the solution thoroughly. Transfer this reference cylinder together with the sedimentation cylinder containing the soil suspension to the constant temperature bath. Allow them to stand immersed in water

up to the 1000 ml graduation mark for at least 1 h or until they have reached the temperature of the bath. Record the temperature, inspect for signs of flocculation and again measure the pH of the suspension and record (see Note (4)). When they have attained the bath temperature take the cylinder containing the soil suspension, thoroughly shake until a uniform suspension is formed, and finally invert end-over-end several times and immediately replace in the bath.

- (b) At the same instant as the cylinder containing the soil suspension is replaced in the bath start the timing device. Remove the rubber bungs carefully.
- (c) For each reading, dry the hydrometer with a clean cloth, especially the upper part of the stem. Lower the hydrometer into the suspension to slightly below its floating position, taking approximately 10 s. Allow it to float freely for a few seconds before taking the reading (R'_h) at the top of the fully formed meniscus (see Notes (6) and (7)). After taking each reading, remove the hydrometer, again taking approximately 10 s, rinse with distilled water and store the hydrometer in a cylinder of distilled water at the same temperature as the suspension. Avoid disturbing the suspension unnecessarily during insertion and withdrawal of the hydrometer. Keep the suspension at constant temperature (see Note (2)) away from radiant heat and free from vibration.
- (d) Take hydrometer readings after periods of 1 and 2 min. Reshake the suspension, restart the timing device and repeat these readings at 1 and 2 min (see Note (17)). Once again reshake the suspension, restart the timing device and take hydrometer readings at 4, 8, 15, 30 min and 1, 2, and 4 h. After 4 h sedimentation take readings, once or twice daily, noting the exact period of sedimentation (see Note (18)).
- (e) When convenient between any of the times at which hydrometer readings are taken in the suspension, insert the hydrometer into the reference cylinder, and take a hydrometer reading, r (at the top of the meniscus). Record the value $x = 1000 (1-r)$ as the composite correction (see Note (19)).

2.8.4.6

Calculations

(see Form 2.8.4).

2.8.4.6.1

Dry mass

Calculate the dry mass of the pretreated soil (M) from the formula:

$$M = \frac{100M_w}{100 + w} \quad \dots\dots\dots \text{g}$$

where M_w = wet mass of the pretreated soil (g)
 w = water content of the pretreated soil (%)

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Subsidiary method for fine soils (Hydrometer method)

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2.8.4.6.2

Fine sieving

(see Note (20)).

- (a) Calculate the percentage of coarse sand in the pretreated sample from the formula:

$$\text{Percentage coarse sand (2.0 to 0.6 mm)} = \frac{100 M_{cs}}{M} \dots\dots\dots \%$$

- (b) Calculate the percentage of medium sand in the pretreated sample from the formula:

$$\text{Percentage medium sand (0.6 to 0.2 mm)} = \frac{100 M_{ms}}{M} \dots\dots\dots \%$$

- (c) Calculate the percentage of fine sand in the pretreated sample from the formula:

$$\text{Percentage fine sand (0.2 to 0.06 mm)} = \frac{100 M_{fs}}{M} \dots\dots\dots \%$$

2.8.4.6.3

Sedimentation

- (a) Record the observed data and the calculated quantities in a table containing the following columns:

1	2	3	4	5	6	7	8	9
Date	Time	Temperature	Elapsed time <i>t</i> (min)	<i>R'_h</i>	<i>H_R</i> (mm)	<i>D</i> (mm)	<i>R'_h</i> + <i>x</i>	<i>P</i> (%)

where *t* = elapsed time after shaking (min)
R'_h = hydrometer reading at the upper rim of the meniscus. It is convenient to deal in whole numbers rather than decimals by reducing the value of the reading by 1.0 and multiplying by 1000 so that a density of 1.0255 g/ml for example becomes *R'_h* = 25.5.
H_R = effective depth corresponding to hydrometer reading *R'_h* (mm)
x = composite correction
D = equivalent particle diameter (mm)
P = percent by mass of particles smaller than size *D* (%)

- (b) Calculate the equivalent particle diameter (*D*) from the formula:

$$D = K \sqrt{H_R/t} \dots\dots\dots \text{mm}$$

where *K* = a constant depending on the temperature of the suspension and the solid density of the soil particles (see table 2.8.3)

H_R = effective depth corresponding to hydrometer reading *R'_h* (mm)

t = elapsed time after shaking (min)

Alternatively the equivalent particle diameter may be determined by means of the nomographic chart for the solution of Stokes' Law (fig. 2.8.5) (see Note (21)).

- (c) Calculate the percentage by mass (*P*) of particles smaller than the corresponding equivalent particle diameters from the formula:

$$P = \frac{100 \rho_s}{M (\rho_s - 1)} (R'_h + x) \dots\dots\dots \%$$

where *M* = total dry mass of soil after pretreatment (g)
 ρ_s = solid density of soil particles (t/m³) (see Note (22))
R'_h = hydrometer reading at upper rim of meniscus in the form 1000 (reading - 1)
x = composite correction.

- (d) Calculate the values of *P* for all values of *D* obtained and express as percentage by mass of particles smaller than the corresponding values of *D*.

2.8.4.7

Reporting of results

2.8.4.7.1

Report the following values:

- (a) The results in the form of a table showing to the nearest 1 % the percentage by mass of each of the size fractions defined in 1.3.1 of Part 1.
- (b) If required, the results on a semi-logarithmic chart of the type shown in fig. 2.8.1 of Test 2.8.1 (see Note (23)).

2.8.4.7.2

State the history of the sample, for example, natural state, air-dried, oven-dried or unknown.

2.8.4.7.3

State the pH of the suspension and if other than sodium hexametaphosphate were used state the dispersant.

2.8.4.7.4

State that the hydrometer method was used.

2.8.4.7.5

State that the result was obtained in accordance with this Standard Test Method.

NOTES ON TEST 2.8.4

- (1) *Hydrometer method particle size analysis.* The pipette method of particle size analysis is specified as a primary standard method for laboratory purposes, as it has been widely used for a number of years in many soil laboratories, and has a sound theoretical basis. The apparatus required is, however, expensive and delicate and is not convenient for running control tests during construction or for field work. On the other hand, the hydrometer method has been shown to give results which for all practical purposes are the same when carefully carried out, and the apparatus required is simpler and more convenient to operate. It is therefore specified as an alternative method.
- (2) *Sedimentation temperature.* Although it is important to maintain the suspension temperature reasonably constant during sedimentation, the absolute temperature is not important and may be selected at a convenient value depending on ambient conditions. A very slow drift in temperature of a few degrees over the period of the test is probably acceptable provided regular temperature readings are taken which are used to adjust the value of the composite correction by the change in density of the suspension as well as the value of B in the nomogram, if used (see Note (21)).
- (3) If the organic content of the soil is very low there is no need for peroxide pretreatment.

Asymmetrical heating of the suspension causes convection currents which affect the sedimentation process. The suspension must therefore be kept out of direct sunlight and away from any local source of heat. A cover shall be kept on the measuring cylinder between readings to retard evaporation.

Hydrogen peroxide is a fairly efficient oxidant and 20 volume has been specified as a reasonably stable, effective, and safe concentration. Even at this concentration it should not be allowed to come in contact with clothes or skin. Any accidental contact should be washed off reasonably quickly. Sometimes a higher concentration such as 100 volume may be used with advantage but greater care is required in handling and

of course quantities must be reduced pro rata.

- (4) *Dispersing agent.* Sodium hexametaphosphate has been specified as the dispersing agent in view of the success with which it has been employed in the analyses of a large number of soils. However, it has been found to be ineffective when dealing with some soils derived from volcanic ash or rock and also certain highly aggregated soils especially those of tropical origin. When using sodium hexametaphosphate it is important to maintain the pH of the soil suspension reasonably high, for example, above 8.0. If after mechanical shaking the pH is below this level, a further 25 ml increment of sodium hexametaphosphate solution should be added and the suspension again shaken. If the pH still falls below this level it may be maintained with a small amount of sodium hydroxide. However, there will still be occasions when partial or complete flocculation persists, shown by large crumbs or 'flocs' of soil settling out rapidly and perhaps leaving a sharply defined relatively clear layer above the suspension. The sediment of a well dispersed soil remains firm at the bottom of the sedimentation tube when tilted but flocculated material flows to maintain a horizontal line. Under these conditions some other method of pretreatment and/or dispersion shall be tried*. Of course, if any modification to the standard amount or type of dispersing agent is made similar changes must be made to the reference solution described in 2.8.4.5.4 (a).
- (5) It has been common practice to weigh the hydrometer and take the weight in grams as the volume in millilitres. Both this and the method given include a part of the volume of the stem in the measured volume of the bulb, but the error involved may be neglected for practical purposes. It is not necessary for the hydrometer to be floating for the calibration.
- (6) *Meniscus formation on the hydrometer stem.* In order to obtain an accurate reading on the hydrometer scale, the meniscus round the stem must be fully developed; the stem must be perfectly clean.
- (7) *Meniscus correction.* Hydrometers are calibrated to read correctly at the surface of a liquid. However, soil suspensions are not transparent enough to permit a reading to be taken at the surface, and the reading (R'_h) must be made at the upper rim of the meniscus. The meniscus correction (C_m), which must be added to R'_h in order to obtain the true reading R_h is a constant for each hydrometer.
- (8) *Location of the effective depth of a hydrometer bulb.* This relation gives the effective depth of the suspension, the density of which is given by the hydrometer reading. It allows for the rise of the liquid in the sedimentation cylinder as the hydrometer is inserted, as well as the meniscus correction for density readings taken at the top of the meniscus.
- (9) In this method it has been assumed that a sample obtained in accordance with the method specified in 1.6.7 of Part 1 instead of the method specified in 2.8.1.5 of Test 2.8.1 will contain no significant material retained on 2.00 mm standard test sieve. If there is such material but insufficient to justify Test 2.8.1, it shall be dried after the initial separation, weighed, and allowed for in the final calculations. With certain volcanic and tropical soils it may be difficult to remove all the finer fractions from the material retained on the 2.00 mm test sieve. In such cases it may be necessary to use a dispersing agent as in Test 2.8.1 before wet sieving on the 2.00 mm sieve.

* See Birrell, K.S. *Determination of clay contents in soils containing allophane*. New Zealand Journal of Agricultural Research 9(3):554-64 (1966); 17(3):333-8 (1974).

Wintermeyer, A.M., and Kinter, E.B. *Dispersing agents for particle size analysis of soils*, Highway Research Board Bulletin 95, 1955 (National Research Council Division, Engineering and Industrial Research, Washington D.C.), 1-14.

- (10) *Size of sedimentation sample.* Stokes' Law is derived for a single sphere falling in a large body of liquid. It is not applicable to a highly concentrated suspension, when the particles are close enough to influence each other. It has been established that if the mass of solid matter in the suspension is not too large, the deviation from Stokes' Law is negligible.
- (11) A rough guide to the amount of hydrogen peroxide which may be required is 5 to 10 ml of 20 volume hydrogen peroxide per 10 g dry soil per 1 % organic matter.
- (12) Filtration has been specified as the means of washing and recovering the soil after pretreatment since the equipment is widely available. Centrifuging, which is a very rapid and convenient method, is an acceptable alternative.
- (13) Extreme care is needed with the procedure from this point on, as any loss of material is recorded in the coarse silt fraction since this is obtained by difference.
- (14) Other means of mechanical dispersion may be used provided they are as effective as 4 h end-over-end shaking without causing undue degradation of coarser particles.
- (15) If any aggregates are found they must be broken down and dispersed, but not on the sieve. Transfer the material retained on the sieve to a mortar with a little distilled water, and gently rub with a rubber covered pestle, taking care not to break down individual grains. After resieving, the further material passing must be added to the suspension.
- (16) *Wet sieving of sand.* In the wet sieving operation for the separation of sand particles, grains with diameters just slightly smaller than the apertures of the 63 μm test sieve tend to be retained due to the surface tension of the water held between the sieve meshes. The absence of such particles from the suspension should be of no consequence to the sedimentation analysis, since, by definition, they will fall into the grade of coarse silt, which is the fraction determined by difference. However, as a precaution the material passing the 63 μm sieve should be added to the suspension. In order that the various percentages of the 'sand' fractions can be accurately determined, it is necessary to dry the material retained on the 63 μm sieve, and re-sieve it. The particles retained on the sieve after this second operation are subsequently classified as 'coarse', 'medium' and 'fine' sand. The effect of surface tension can be lessened by placing the sieve in a tray of water so that the wire mesh and the soil particles are completely immersed.
- (17) Since the density of the suspension is generally changing rapidly in the early stages of sedimentation, the initial 1 and 2 min readings are taken as a guide to the point to which the hydrometer should be lowered before allowing it to float freely. Calculations are made on the repeated readings only.

In some methods of determination of particle size distribution using a soil hydrometer the hydrometer is left in the suspension between early readings. Sedimentation on the shoulders of the hydrometer, the formation of a shadow zone of lower density below the hydrometer and the need for a different calibration, generally lead to larger errors than those caused by careful insertion and removal of the hydrometer for each reading.

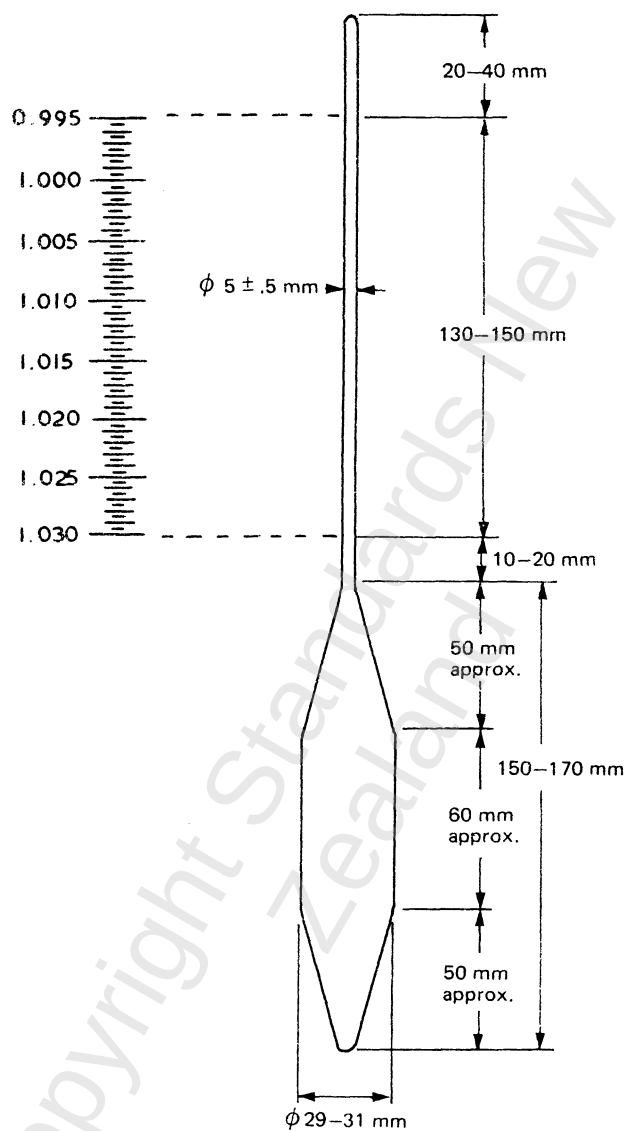
- (18) The sedimentation times given, at which hydrometer readings are to be taken, are quite arbitrary. Provided the exact times are noted and used in calculations any similar pattern of times may be employed. There is a considerable advantage in arranging that dispersion be carried out in late afternoon so that on the following day a full day's readings can be obtained. Such a procedure ensures that the time between dispersion and sedimentation is not unduly delayed and that the bulk of the readings, generally down to about 3 μm can be completed in a working day.
- (19) *Composite correction.* Generally there are 3 corrections to be made to a hydrometer reading before calculating the amount of soil still left in suspension. There is a temperature correction if the sedimentation temperature is different from that at which the hydrometer was initially calibrated, a dispersing agent correction to account for the increased density of the suspending solution compared with water at the same temperature, and a meniscus correction to allow for readings taken in opaque suspension at the top of the meniscus. By making up a reference solution the overall correction can be accomplished with a single measurement.

As noted in 2.8.4.6.2 (a), it is common practice to read a soil hydrometer on a scale of -5 to $+30$ instead of 0.995 to 1.030 . In this case the composite correction x is $-r'$ where r' is the hydrometer reading in the reference cylinder on a scale -5 to $+30$.
- (20) The sieves used do not relate exactly to the sizes of the sand fractions, but the differences are negligible for all practical purposes.
- (21) *Alternative determination of equivalent particle diameter (D).* The equivalent particle diameter (D) may also be determined by means of the nomographic chart for the solution of Stokes' Law (fig. 2.8.5). However users of the chart are warned that reproduction can cause distortion of scale which may cause inaccuracy in the determination of D .

Obtain a value of the constant B by placing a straight-edge across the solid density ρ_s and temperature (T) scales at the appropriate values. Mark the value of B so obtained (see Note (22)).

Obtain a value of velocity (v) by placing a straight-edge across the hydrometer reading (R'_h) and time (t) scales at the appropriate values.

Obtain a value for the equivalent particle diameter (D) by placing a straight-edge across the velocity and B scales at points corresponding to the values of v and B found above. Enter the values of the equivalent particle diameter so obtained in column 7 of the table.
- (22) It is not necessary to measure the solid density of soil particles for 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 solid density used is that of the silt and clay fraction and not that of the whole sample of soil.
- (23) If a coarse analysis has been carried out on the sample the complete analysis should be shown on the chart. Allowance should be made for material greater than the 2.00 mm test sieve size in the calculation of the percentages.



NOTE - Calibrations in g/ml to read 1.000 at 20 °C.

All dimensions in millimetres.

Fig. 2.8.4
HYDROMETER FOR THE DETERMINATION OF PARTICLE-SIZE DISTRIBUTION IN SOIL

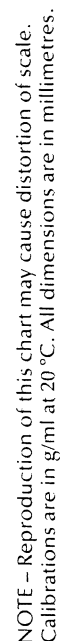


Fig. 2.8.5
NOMOGRAPHIC CHART FOR USE WITH HYDROMETERS

Table 2.8.3
VALUES OF K FOR A RANGE OF TEMPERATURES AND SOLID DENSITIES OF SOIL PARTICLES

Temp. °C	Solid density of soil particles (t/m^3) of silt and clay fraction								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	.00484	.00476	.00468	.00461	.00454	.00447	.00441	.00434	.00429
17	.00478	.00470	.00462	.00455	.00448	.00441	.00435	.00429	.00423
18	.00472	.00464	.00456	.00449	.00442	.00436	.00430	.00423	.00418
19	.00466	.00458	.00451	.00444	.00437	.00430	.00424	.00418	.00413
20	.00460	.00453	.00445	.00438	.00432	.00425	.00419	.00413	.00408
21	.00455	.00447	.00440	.00433	.00426	.00420	.00414	.00408	.00403
22	.00449	.00442	.00434	.00428	.00421	.00415	.00409	.00404	.00398
23	.00444	.00437	.00429	.00423	.00416	.00410	.00404	.00399	.00393
24	.00439	.00432	.00424	.00418	.00411	.00405	.00400	.00394	.00389
25	.00434	.00427	.00420	.00413	.00407	.00401	.00395	.00390	.00384
26	.00429	.00422	.00415	.00408	.00402	.00396	.00391	.00385	.00380
27	.00424	.00417	.00410	.00404	.00398	.00392	.00386	.00381	.00376
28	.00420	.00412	.00406	.00400	.00393	.00387	.00382	.00377	.00372
29	.00415	.00408	.00401	.00395	.00389	.00383	.00378	.00373	.00367
30	.00410	.00404	.00397	.00391	.00385	.00379	.00374	.00368	.00363
Col. 1	2	3	4	5	6	7	8	9	10

NOTE – The figures in this table have been calculated from the following formula, which may be used to extend the limits beyond those given in the table:

$$K = \sqrt{\frac{18 \mu}{\gamma_s - \gamma_w}}$$

where μ = dynamic viscosity of water for the relevant temperature
(Ns/m²)

γ_s = solid weight-density of soil particles (kN/m³)

γ_w = weight-density of water (kN/m³)

K must be expressed in units of (mm.min)^{1/2} to be compatible with:

D in mm

L in mm

T in min.

DETERMINATION OF THE PARTICLE-SIZE DISTRIBUTION
Subsidiary method for fine soils (Hydrometer method)

NZS 4402 : 1986
 Test 2.8.4

Form 2.8.4
DETERMINATION OF THE PARTICLE-SIZE DISTRIBUTION – HYDROMETER METHOD
(Test 2.8.4)

Job: _____ Sample no.: _____
 Location: _____ Tested by: _____
 Depth: _____ Date: _____
 Test details: * _____ Checked by: _____
 _____ Date: _____
 Test made on fraction passing test sieve.
 History: Natural/air-dried/oven-dried/unknown.
 Soil density of soil particles in silt and clay
 fraction t/m^3 measured/assumed.
 Dispersant used: Sodium hexametaphosphate/
 other (specify)

Determination of water content of wet soil for dispersion		
Container number		
Mass of container and wet soil	g	
Mass of container and dried soil	g	
Mass of container	g	
Mass of water	g	
Mass of dried soil	g	
Water content	%	w %
Mass of wet soil for dispersion	M_w	 g
Mass of dry pretreated soil	$M = \frac{100 M_w}{100 + w}$	 g

Sieving				
Standard test sieve		600 μm	212 μm	63 μm
Container number				
Mass of container and soil retained	g			
Mass of container	g			
Mass of soil	g	$M_{CS} =$	$M_{ms} =$	$M_{fs} =$
Percentage of soil retained	%			
Percentage of soil finer	%			

Sedimentation
 pH of suspension initial final
 Hydrometer no. ... Reference cylinder reading r/r'
 Composite correction $x = 1000 (l - r) = - r'$

Date	Time	Temperature °C	Elapsed time t(min)	Hydrometer reading (R'_h)	Effective depth corresponding to R'_h H_R (mm)	Equivalent particle diameter D (mm)	$R'_h + x$	Percentage of particles finer than the corresponding particle diameter $P(\%)$

* Delete appropriate words.

NOTES