17.3.2 Preparation and assembly of apparatus

The procedure shall be generally as described in BS EN ISO 17892-5. Prepare the porous plates, as described in BS EN ISO 17892-5:2017, **5.2** depending on the type of soil.

NOTE In this stage of testing, water should not be added to the cell.

17.3.3 Test procedure

17.3.3.1 When the specimen is in equilibrium under the small seating load and the deformation gauge has been set and its reading recorded, add water to fill the consolidation cell. At the same instant start the timer.

NOTE An alternative procedure is to allow the specimen to reach equilibrium under a stress equal to the in-situ vertical effective stress before adding water to the cell.

17.3.3.2 Observe the deformation gauge and when it indicates that swelling occurs, add weights to the beam hanger to maintain the gauge reading within 0.01 mm of the corrected zero reading. Record the magnitude of each weight added and the corresponding time.

17.3.3.3 The corrected zero reading is the initial gauge reading adjusted by the correction necessary to allow for deformation of the apparatus due to the present load on the beam hanger. Obtain the correction from the calibration curve derived in BS EN ISO 17892-5:2017, **A.3.5**.

17.3.3.4 Continue to adjust the hanger weight until equilibrium is established with a deformation gauge reading within ±0.01 mm of the relevant corrected zero reading. This procedure could take several hours or days in some cases and the approach of equilibrium conditions can be seen by plotting a graph of the cumulative weight on the beam hanger against square root of elapsed time at which each adjustment was made.

NOTE If the test has to be left unattended for any length of time before equilibrium is established, further swelling should be prevented by loading the hanger with excess weights with the beam resting on its support, maintaining the compression gauge at the existing corrected zero reading.

17.3.3.5 When equilibrium is established, calculate the pressure, σ_s (in kPa), applied to the specimen from the weights on the beam hanger (including the initial seating load).

17.3.3.6 Either increase the pressure to the next convenient pressure in the required sequence for a consolidation test, as described in BS EN ISO 17892-5:2017, **6.5**, or reduce the pressure to a convenient value for a swelling test, as described in **17.4**, (if the specimen was suitably prepared). Do not reset the deformation gauge to zero.

17.3.4 Reporting result

When equilibrium is established, report the pressure on the specimen to two significant figures as the swelling pressure. Other data as listed in **16.2** shall be reported, as appropriate.

17.4 Measurement of swelling

17.4.1 Preparation of specimen

17.4.1.1 Prepare the test specimen in the consolidation ring by one of the methods described in BS EN ISO 17892-5:2017, **6.2**.

17.4.1.2 Determine the thickness of the upstand of the flanged disc to 0.01 mm.

17.4.1.3 Place the flanged disc on the flat, glass plate and place the prepared specimen in the consolidation ring, cutting edge downwards, centrally over the disc, with a disc of filter paper interposed.

17.4.1.4 Push the ring steadily downwards without tilting until the cutting edge is firmly in contact with the flange of the disc.

17.4.1.5 Cut off the extruded portion of soil and trim the specimen flat and flush with the upper end of the ring. Remove the flanged disc and filter paper.

17.4.1.6 Weigh the specimen in its ring on the watch glass or tray and determine the mass of the specimen to 0.1 g.

17.4.1.7 From the thickness of the disc and the measured thickness of the ring calculate the specimen height, H_0, in mm.

17.4.2 Preparation and assembly of apparatus

17.4.2.1 The procedure shall be as described in BS EN ISO 17892-5:2017, **6.4**, but the porous plates shall be air dried after saturation.

17.4.2.2 Mount the ring containing the specimen with the displaced face uppermost and fit the top porous plate centrally inside the ring. Make the necessary adjustments to bring the beam of the loading apparatus to a horizontal position.

17.4.2.3 Secure the deformation gauge in position to allow for measurement of swelling over a range at least equal to the thickness of specimen displaced.

17.4.2.4 Do not add water to the cell at this stage.

17.4.3 Test procedure

17.4.3.1 Determine the swelling pressure, as described in **17.3.3.1** to **17.3.3.5**.

17.4.3.2 Record the compression gauge reading. Do not reset it to zero.

17.4.3.3 Reduce the pressure on the specimen to a suitable value by removing weights from the beam hanger.

NOTE Pressures to which the specimen is unloaded could be those given in BS EN ISO 17892-5, or could be related to the swelling pressure, σ_s', in the sequence:

$$\sigma_s', \frac{\sigma_s'}{2}, \frac{\sigma_s'}{4}, \frac{\sigma_s'}{8}, \text{ etc.}$$

If other pressures are more appropriate, the sequence should normally be related to a constant ratio.

17.4.3.4 Record readings of the deformation gauge and plot the readings so that the completion of swelling can be identified. Record the final reading of the compression gauge.

17.4.3.5 Repeat **17.4.3.3** and **17.4.3.4** for further stages of the sequence of unloading down to the selected minimum pressure. The total height of the specimen shall not be allowed to exceed the height of the ring.

17.4.3.6 Reload the specimen back to the swelling pressure, following the same sequence of pressures in reverse.

17.4.3.7 If required, further loading stages can be applied following the procedure described in BS EN ISO 17892-5:2017, **6.5.2**.

17.4.3.8 Drain water from the cell and make final measurements, as described in BS EN ISO 17892-5:2017, **6.6**.

17.4.4 Calculation and plotting

The calculations and graphical plots shall be as described in BS EN ISO 17892-5:2017, Clause **7** and Annex B. Values of m_v and c_v shall be calculated only for the reloading stages.

17.4.5 Reporting results

The relationship between voids ratio or swelling and logarithm of pressure for the swelling/reloading cycle shall be plotted in a similar manner to that derived from a consolidation test.

Other data as listed in **16.2** shall be reported, as appropriate.

17.5 Measurement of settlement on saturation

17.5.1 Preparation of specimen

Prepare the test specimen in the consolidation ring by one of the methods described in BS EN ISO 17892-5:2017, **6.2** and weigh the soil and ring, as described in BS EN ISO 17892-5:2017, **6.3**.

17.5.2 Preparation and assembly of apparatus

The procedure shall be as described in BS EN ISO 17892-5:2017, **6.4**, however, the porous plates shall be air dried after saturation.

Do not add water to the cell at this stage.

17.5.3 Test procedure

17.5.3.1 Cover the consolidation cell to prevent the specimen drying out, e.g. by using damp cloth under plastic film.

17.5.3.2 Apply a suitable sequence of pressure to the specimen, as described in BS EN ISO 17892-5, **6.5** but omitting **6.5.2.3**, up to the specified pressure.

17.5.3.3 When equilibrium is established under the selected load, fill the cell with water so that the specimen is completely submerged and start the timer.

17.5.3.4 Record readings of the compression gauge at suitable intervals of time while the pressure on the specimen remains constant, until equilibrium is re-established.

17.5.3.5 Carry out further loading and unloading stages, as described in BS EN ISO 17892-5:2017, **6.5**, as required, with the specimen remaining saturated. Dismantle, as described in BS EN ISO 17892-5:2017, **6.6**.

17.5.4 Calculation and plotting

The calculations and graphical plots shall be as described in BS EN ISO 17892-5:2017, Clause **7**. On the plot of compression or void ratio against log pressure, the decrease in height of the specimen due to saturation shall be indicated by a vertical line at the constant applied pressure.

Calculate the decrease in height on saturation as a percentage of the specimen height under the same pressure immediately before saturation.

17.5.5 Reporting results

Test data as listed in **16.2** shall be reported, as appropriate.

The change in void ratio or height due to saturation shall be clearly shown on the plot of void ratio or compression against log pressure.

Report the corresponding change in height as a percentage of the specimen height immediately before saturation, to the nearest 0.1%. Report any collapse indices or other parameters as required by the engineer.

18 Determination of dispersibility

*COMMENTARY ON CLAUSE **18***

Certain fine-grained soils that are highly erodible are referred to as dispersive soils. Dispersive soils cannot be identified by means of conventional soil classification tests, but the qualitative tests described in this clause enable them to be recognized. However, it does not follow that soils classified by these tests as non-dispersive are not susceptible to erosion in some circumstances.

These methods are not applicable to soils with a clay content of less than 10% and with a plasticity index less than or equal to 4.

Three tests are described as follows:

a) the pinhole test, in which the flow of water under a high hydraulic gradient through a cavity in the soil is reproduced;

b) the crumb test, in which the behaviour of crumbs of soil in a static dilute sodium hydroxide solution is observed; and

c) the dispersion method (double hydrometer test), in which the extent of natural dispersion of clay particles is compared with that obtained with the use of standard chemical and mechanical dispersion.

Other factors which are significant in relation to soil erodibility include:

1) swelling potential;

*NOTE A test for measuring swelling pressure is described in Clause **17**.*

2) clay mineralogy;

3) chemical composition of dissolved cations in the pore water.

18.1 Pinhole method

18.1.1 General

*COMMENTARY ON **18.1.1***

In this test, distilled, deionized or de-mineralized water is caused to flow through a 1 mm diameter hole formed in a specimen of recompacted clay under a controlled hydraulic head. Where distilled, deionized or de-mineralized water is referred to in this test specification, the terms are interchangeable. The resistance to erosion of the clay is judged visually by the presence or absence of turbidity in the water which emerges and from measurements of rates of flow and the final hole diameter.

The specified test measures the dispersibility of clay in distilled water, which is considered to be a basic property of the soil. Clays are considered to be more likely to disperse in distilled water than in water containing dissolved salts.

The requirements of BS 1377-1, where appropriate, shall apply to this test method.

18.1.2 Apparatus

18.1.2.1 *Pinhole test apparatus,* as shown in Figure 19 a), consisting essentially of the following:

a) a rigid cylindrical body of corrosion-resistant material, approximately 100 mm long;

b) corrosion-resistant end plates, one fitted with water inlet and standpipe connections, the other with an outlet connection;

c) O-ring seals to make a watertight fit between the body and end plates;

d) three discs of appropriate diameter and with wire mesh having apertures of 1.18 mm; and

e) nipple of corrosion-resistant material, in the form of a truncated cone 13 mm long with a hole of 1.5 mm diameter [see Figure 19 b)].

18.1.2.2 *Standpipe tube of glass, or transparent plastics*, approximately 3 mm internal diameter and approximately 1 200 mm long.

18.1.2.3 *Scale for the standpipe tube marked in millimetres*.

18.1.2.4 *Hypodermic needle*, or similar, approximately 100 mm long, with an external diameter of (1.00 ±0.1) mm.

18.1.2.5 *Burette stand* for supporting the pinhole apparatus, standpipe and scale.

18.1.2.6 *Graduated glass measuring cylinders*, 10 mL, 25 mL, 50 mL (at least two of each).

18.1.2.7 *Stopclock, or timer,* readable to 1 s.

18.1.2.8 *Pea gravel,* consisting of single-size particles of approximately 5 mm.

18.1.2.9 *Constant-head supply tank*, adjustable between 50 mm and approximately 1 100 mm above the centreline of the pinhole apparatus.

18.1.2.10 *Supply of distilled water for the constant-head tank*.

18.1.2.11 *Test sieve*, with 2 mm aperture.

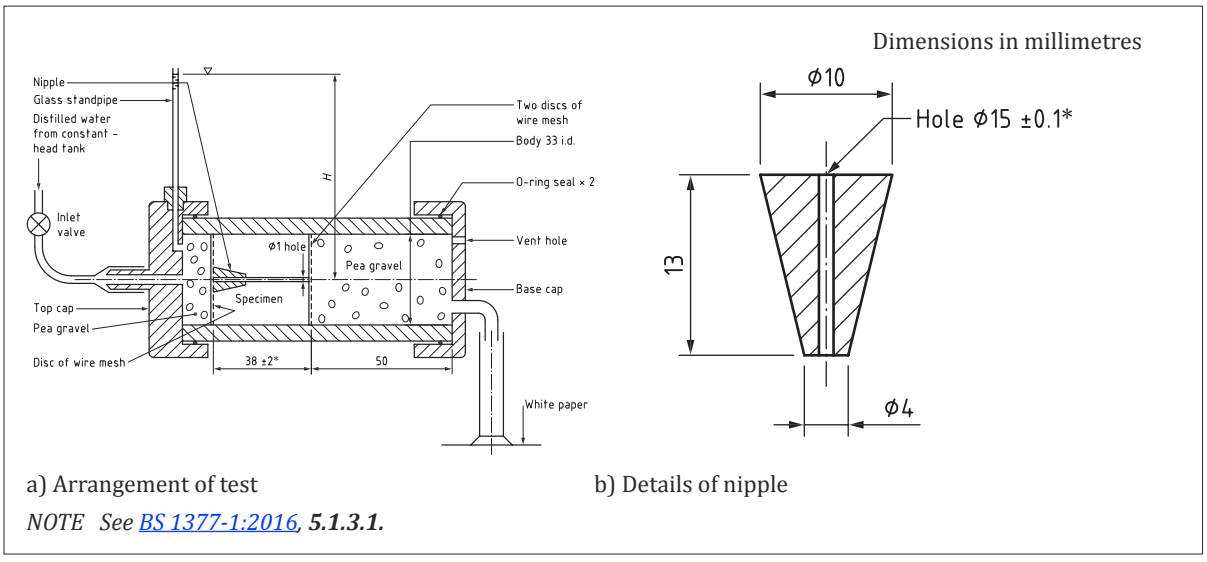
18.1.2.12 *Flat ended tamping rod*, or a spring loaded hand tamper.

18.1.2.13 *Apparatus for determination of water content* (see BS EN ISO 17892-1).

18.1.2.14 *Apparatus for determining the liquid and plastic limits of the soil* (see BS EN ISO 17892-12).

18.1.2.15 *Apparatus for the determination of the water/density relationship of the soil* (see Clause **11**).

Figure 19 — *Section of pinhole test apparatus*



a) Arrangement of test

b) Details of nipple

*NOTE See BS 1377-1:2016, **5.1.3.1.***

18.1.3 Specimen preparation and assembly

18.1.3.1 Do not allow the specimen to dry before testing.

NOTE Many soil results are affected by drying, especially if the soil after rewetting is not left long enough to mature in the compacted state, e.g. overnight.

18.1.3.2 Take a specimen of approximately 150 g of the soil to be tested, at its natural water content. Take a second similar specimen for the determination of the liquid limit and plastic limit, to be carried out as described in BS EN ISO 17892-12.

18.1.3.3 Remove any particles retained on a 2 mm test sieve from the test sample.

18.1.3.4 Increase or decrease the water content to bring the sample to approximately its plastic limit. Use the thread-rolling procedure described in BS EN ISO 17892-12 as an indication of the required consistency.

18.1.3.5 Determine the resulting water content of the specimen, as described in BS EN ISO 17892-1.

18.1.3.6 Fit the outlet end plate to the body of the pinhole apparatus, making a watertight joint.

18.1.3.7 Support the body of the apparatus vertically and place pea gravel to a depth of approximately 50 mm in the bottom of the apparatus, taking care not to block the outlet hole. Level the surface of the gravel and place two discs of wire mesh on top.

18.1.3.8 Compact the test specimen into the apparatus in five equal layers, to give a total sample depth of (38 ±2) mm. Apply an equal compactive effort to each layer such that the resulting dry density of the sample is approximately 95% of the dry density corresponding to the optimum water content, determined in accordance with Clause 11.

18.1.3.9 Level the surface of the specimen and push the nipple into the soil at the centre, using finger pressure, until the upper face is flush with the specimen surface.

18.1.3.10 Insert the needle through the nipple and through the compacted specimen to form a continuous hole and then remove the needle.

18.1.3.11 Place a disc of wire mesh over the specimen followed by pea gravel to the top of the body of the apparatus.

18.1.3.12 Fit the top plate to the body, making a watertight joint.

18.1.3.13 Support the apparatus in the burette stand with its cylindrical axis horizontal.

18.1.3.14 Set the constant-head reservoir of the distilled water supply so that the water level can be maintained at a height of (50 ±5) mm above the centre-line of the apparatus. Close the inlet valve.

Connect the inlet on the pinhole apparatus to the supply from the reservoir and connect the standpipe connection to the standpipe, supported by the burette stand. Place a glass measuring cylinder on a sheet of white paper under the outlet pipe.

18.1.4 Test procedure

18.1.4.1 Open the inlet valve to allow water from the reservoir to enter the apparatus and to flow through the specimen until a steady rate of flow is obtained with H = (50 ±5) mm [see Figure 19 a)]. If there is no flow, disconnect the apparatus, reform the hole, and resume from **18.1.3.10**.

18.1.4.2 Within 5 min, measure the rate of flow, q (in mL/s), by observing the time required to fill the 10 mL measuring cylinder.

18.1.4.3 Observe and record the appearance, including colour, of the water collected in the measuring cylinder. If it is clear, record that fact.

18.1.4.4 Observe and record the clarity and colour of the collected water by looking through the side of the cylinder against a sheet of white paper and vertically through the water. If individual particles are discernible, record that fact, together with an indication of the turbidity of the water.

18.1.4.5 If the collected water is substantially clear after running for approximately 5 min, continue at **18.1.4.8**.

18.1.4.6 If the water is not substantially clear and the rate of flow has increased to between 1.0 and 1.4 mL/s the test is complete. Proceed to **18.1.4.16**.

NOTE The limiting rates of flow imposed by the apparatus itself are given approximately in Table 6.

Table 6 — *Typical limiting rates of flow imposed by the apparatus*

Inlet head	**Limiting rate of flow**
H	q_L
mm	mL/s
50	1.2 to 1.3
180	Approximately 2.7
380	Approximately 3.7
1020	5 or more

18.1.4.7 If the rate of flow in **18.1.4.6** is less than 1.0 mL/s, continue the test for a further 5 min. If the water is then clear or is only slightly turbid and the rate of flow is between 0.4 mL/s and 0.8 mL/s, continue at **18.1.4.8**. If the water is distinctly turbid stop the test and proceed to **18.1.4.16**.

18.1.4.8 Increase the head of water, *H*, to (180 ±5) mm and allow the flow to continue for 5 min. Repeat **18.1.4.3** and **18.1.4.4**.

18.1.4.9 If the collected water continues to be clear, or has only a slight trace of turbidity and the rate of flow is between 0.8 mL/s and 1.4 mL/s, record the fact and proceed to **18.1.4.11**.

18.1.4.10 If the water is not clear and the rate of flow increases to approximately the limiting value (see Note 3 to **18.1.4.6**), stop the test. Proceed to **18.1.4.16**.

18.1.4.11 Increase the head of water, *H*, to (380 ±5) mm and allow the flow to continue for 5 min. Repeat **18.1.4.3** and **18.1.4.4**.

18.1.4.12 If the water continues to be clear, or has only a slight trace of turbidity and the rate of flow is between 1.0 mL/s and 1.8 mL/s, record the fact and continue at **18.1.4.14**.

18.1.4.13 If the water is not clear, or the rate of flow has increased to between 1.4 mL/s and 2.7 mL/s (see Note 3 to **18.1.4.6**), stop the test. Proceed to **18.1.4.16**.

18.1.4.14 Increase the head of water, *H*, to (1 020 ±5) mm and allow the flow to continue for 5 min. Repeat **18.1.4.3** and **18.1.4.4**.

18.1.4.15 Observe and record the rate of flow and whether the collected water continues to be clear, or the extent of turbidity, then stop the test.

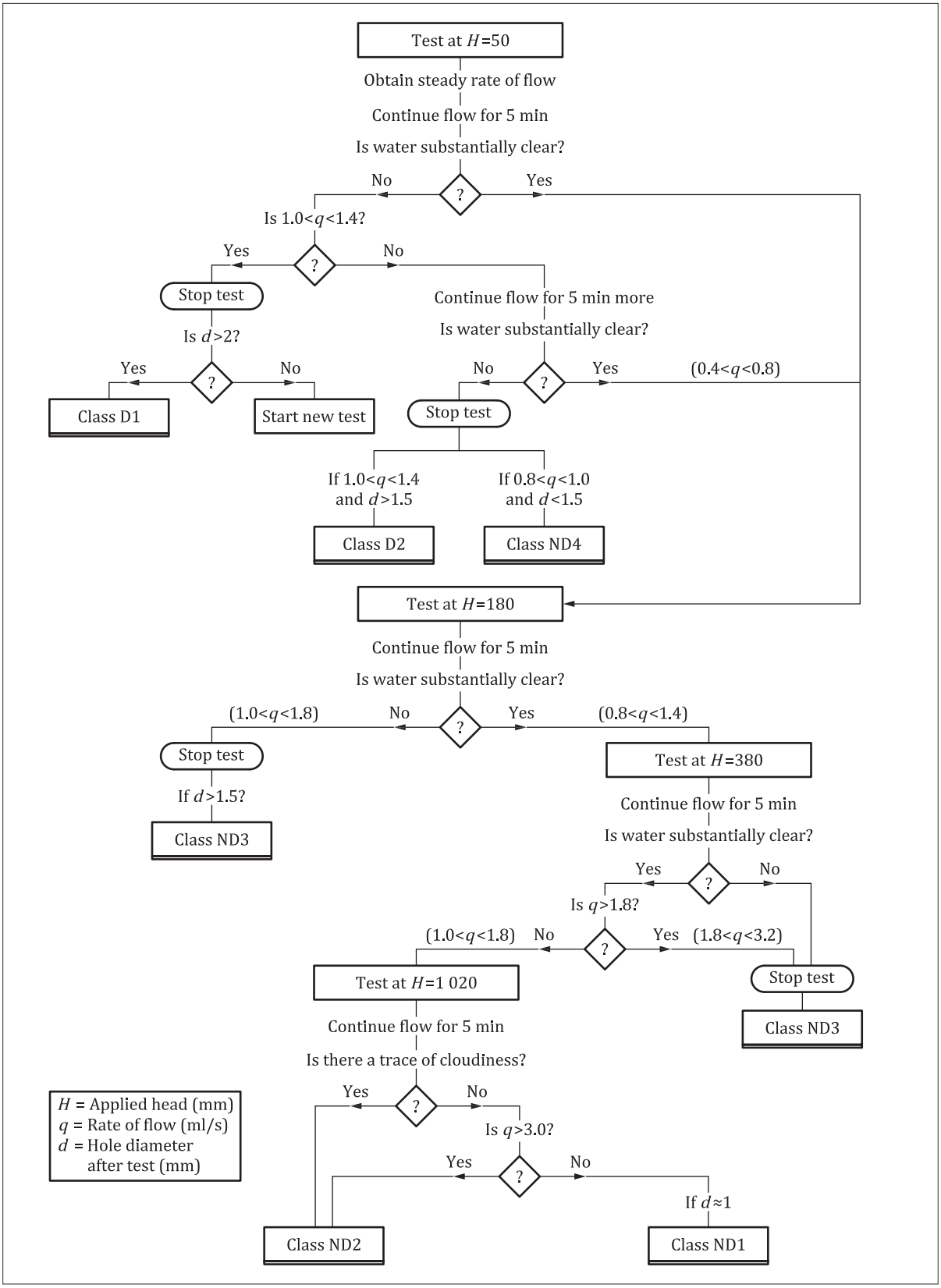
18.1.4.16 When the flow tests are completed disconnect the distilled water supply, dismantle the apparatus and remove the specimen intact from the body of the apparatus.

18.1.4.17 Cut the sample in half through its axis.

18.1.4.18 Examine the hole and estimate its diameter, d (in mm), by comparison with the needle, or measure its diameter to 0.5 mm using a steel rule. Sketch the configuration of the hole, with measurements, if it is not of uniform diameter.

NOTE ***18.1.4.3*** *to* ***18.1.4.15*** *are illustrated as a flow chart in Figure 20.*

Figure 20 — *Flowchart for pinhole test procedure*



18.1.5 Analysis of test data

The following test data shall be used for classifying the soil:

a) appearance of the collected water;

b) rate of flow of water; and

c) final diameter of the hole in the specimen.

Classify the soil as dispersive soil (category D1 or D2) or non-dispersive soil (categories ND1 to ND4) in accordance with Table 7.

NOTE These categories are also indicated in Figure 20.

The results from the test at 50 mm head of water shall be used as the principal means of differentiating dispersive from non-dispersive soils as defined by this test.

Table 7 — *Classification of soils from pinhole test data*

Dispersive classification	**Head**	**Test time for given head**	**Final flow rate through specimen**	**Cloudiness of flow at end of test**		**Hole size after test**
	mm	min	mL/s	From side	From top	mm
D1	50	5	1.0 to 1.4	Dark	Very dark	≥2.0
D2	50	10	1.0 to 1.4	Moderately dark	Dark	>1.5
ND4	50	10	0.8 to 1.0	Slightly dark	Moderately dark	≤1.5
ND3	180	5	1.4 to 2.7	Barely visible	Slightly dark	≥1.5
	380	5	1.8 to 3.2			
ND2	1020	5	>3.0	Clear	Barely visible	<1.5
ND1	1020	5	≤3.0	Perfectly clear	Perfectly clear	1.0

NOTE Based on ASTM standard D4647/D4647M-13 (re-approved 2020).

18.1.6 Reporting results

The test report shall affirm that the test was carried out in accordance with **18.1**, and contain the following information, in addition to the relevant information listed in BS 1377-1:2016, Clause **10**:

a) a statement of the method used, i.e. the pinhole test in accordance with **18.1**;

b) identification details, type and source of the soil sample;

c) the soil description, including whether any coarse particles were removed for the test;

d) the liquid limit, plastic limit and water content of the test specimen;

e) the density and dry density to which the specimen was compacted for test;

f) the rates of flow, duration of flow and appearance of the collected water, during each hydraulic head applied;

g) the diameter and configuration of the hole after test; and

h) whether the soil is classified according to this test as dispersive (categories D1, D2); moderately to slightly dispersive (categories ND4, ND3); or non-dispersive (categories ND2, ND1).

18.2 Crumb method

*COMMENTARY ON **18.2***

In this method, dispersive clay soils are identified by observing the behaviour of a few crumbs of soil placed in a dilute solution of sodium hydroxide.

18.2.1 General

The requirements of BS 1377-1, where appropriate, shall apply to this test method.

18.2.2 Apparatus and reagent

18.2.2.1 *100 mL glass beaker*.

18.2.2.2 *0.001 M solution of sodium hydroxide* (1 milli-equivalent per litre).

Dissolve 0.04g of anhydrous sodium hydroxide in distilled water to make 1 L of solution.

NOTE For many soils, distilled or deionized water provides as good an indicator as the sodium hydroxide solution. The soil is dispersive if a test with distilled water indicates dispersion, but many dispersive clays do not show a dispersive reaction in distilled water even though they do in the solution.

18.2.3 Procedure

18.2.3.1 Prepare a few crumbs, each approximately 6 mm to 10 mm diameter, from representative portions of the soil at the natural water content.

18.2.3.2 Drop the crumbs into a beaker about one-third full of the sodium hydroxide solution.

18.2.3.3 Observe the reaction after allowing to stand for 5 min to 10 min.

18.2.4 Observations

Observe the behaviour of the crumbs in accordance with the following guidelines.

a) Grade 1: No reaction. Crumbs might slake or run out to form a shallow heap on the bottom of the beaker, but there is no sign of cloudiness caused by colloids in suspension.

b) Grade 2: Slight reaction. A very slight cloudiness can be seen in the water at the surface of a crumb.

c) Grade 3: Moderate reaction. There is an easily recognizable cloud of colloids in suspension, usually spreading out in thin streaks at the bottom of the beaker.

d) Grade 4: Strong reaction. A colloidal cloud covers most of the bottom of the beaker, usually as a thin skin. In extreme cases all the water becomes cloudy.

Grades 1 and 2 represent a non-dispersive reaction, and grades 3 and 4 a dispersive reaction.

18.2.5 Test report

The test report shall affirm that the test was carried out in accordance with **18.2**, and contain the following information, in addition to the relevant information listed in BS 1377-1:2016, Clause **10**:

a) a statement of the method used, i.e. the crumb test in accordance with Clause **18**;

b) identification details, type and source of the soil specimen;

c) whether the soil is classified according to this test as non-dispersive and the relevant group from **18.2.4**; and

d) details of the reagent used.

