BS 1377-7:
1990

*Incorporating
Amendment No. 1*

Methods of test for

Soils for civil engineering purposes —

Part 7: Shear strength tests (total stress)

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Committees responsible for this British Standard

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Contents

Foreword

This Part of BS 1377 has been prepared under the direction of the Road Engineering Standard Policy Committee. It is a part revision of clause **5** of BS 1377:1975 which is superseded by amendment. BS 1377 was first published in 1948 and first appeared in metric form in 1975.

BS 1377:1975 which has now been withdrawn is replaced by the following Parts of BS 1377:1990:

— *Part 1: General requirements and sample preparation;*

— *Part 2: Classification tests;*

— *Part 3: Chemical and electro-chemical tests;*

— *Part 4: Compaction-related tests;*

— *Part 5: Compressibility, permeability and durability tests;*

— *Part 6: Consolidation and permeability tests in hydraulic cells and with pore pressure measurement;*

— *Part 7: Shear strength tests (total stress);*

— *Part 8: Shear strength tests (effective stress);*

— *Part 9: In-situ tests.*

Reference should be made to Part 1 for further information about each of the Parts.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced personnel.

A British Standard does not purport to include all necessary provisions of a contract. Users of British Standard are responsible for their correct application.

Compliance with a British Standard does not itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 48, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1 Scope

This part of BS 1377 describes methods of test for determining shear strength parameters of soils in terms of total stresses, or (in the case of drained direct shear tests) in terms of effective stresses which are equal to total stresses. None of these procedures therefore requires measurement of pore water pressure, which is covered in Part 8 of BS 1377. Shear strength is determined either by measuring the shearing force causing failure (direct shear tests), or by derivation from the measured compressive strength (unconfined or triaxial compression tests).

Reference is made to Part 1 of BS 1377 for general requirements that are relevant to all Parts of this standard, and to Parts 1 and 4 for methods of preparation of soil and of test specimens.

Direct shear tests (clauses **3** to **6**) comprise:

a) laboratory vane test procedure, for soft to firm cohesive soils;

b) small shearbox procedures for determining the angle of shear resistance of cohesionless soils, and the drained peak and residual shear strength parameters of cohesive soils;

c) large shearbox procedures for determining similar properties of gravelly soils, or on large block samples;

d) small ring shear procedure for drained residual shear strength parameters of remoulded clays.

Compression tests (clauses **7** to **9**) comprise:

e) unconfined compression test procedure, in the laboratory and in a portable apparatus for use on site;

f) triaxial compression test procedure from which the undrained shear strength is derived;

g) triaxial compression test procedure in several stages on one specimen, for deriving undrained shear strength.

The unconfined compression test procedure using portable apparatus, and the single-stage triaxial compression test, are similar in principle to those given in the 1975 Standard. All the other procedures are new additions.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 1377 the definitions given in **2.1** of BS 1377-1:1990 apply, together with the following.

2.1
unconfined compression strength (q_u)

the compressive strength at failure of a specimen subjected to uniaxial (unconfined) compression. For a saturated clay,

$$q_u = 2c_u$$

where

c_u is the undrained shear

2.2
sensitivity

the ratio of the undrained shear strength of an undisturbed clay specimen to that of the same specimen after remoulding at the same moisture content

2.3
vane shear strength (τ_v)

the shear strength of a soil as determined by applying a torque in the vane shear test

2.4
undrained shear strength (c_u)

the shear strength of a soil under undrained conditions, before drainage of water due to application of stress can take place

2.5
residual strength

the shear strength which a soil can maintain when subjected to large shear displacement after the peak strength has been mobilized

3 Determination of shear strength by the laboratory vane method

3.1 General

This method covers the measurement of the shear strength of a sample of soft to firm cohesive soil without having to remove it from its container or sampling tube. The sample therefore does not suffer disturbance due to preparation of a test specimen. The method may be used for soils that are too soft or too sensitive to enable a satisfactory compression test specimen to be prepared.

The shear strength of the remoulded soil, and hence the sensitivity, can also be determined.

The requirements of Part 1 of this standard, where appropriate, shall apply to this test method.

3.2 Apparatus

3.2.1 *Laboratory vane apparatus*, consisting essentially of the following. (A schematic arrangement is shown in Figure 1.)

a) A four-bladed cruciform vane mounted on a rod, the assembly being of stainless steel or plated steel and hard soldered. Typical blade dimensions are 12.7 mm wide and 12.7 mm long, but larger vanes may be used for measuring very low shear strengths. The design shall be such that it causes as little remoulding and disturbance as possible when inserted into a soil sample. The blades shall be as thin as possible, consistent with strength requirements. The area ratio of the vane, as expressed below, shall be as low as possible and shall not exceed 15 %.

$$\text{Area ratio} = \frac{8T(D-d)+\pi d^2}{\pi D^2} \times 100$$

where

D is the overall blade width measured to 0.1 mm (in mm);

T is the thickness of the blades measured to 0.01 mm (in mm);

d is the diameter of the vane rod, including any enlargement due to soldering measured to 0.1 mm (in mm);

b) A device for applying torque to the vane, such as a hand-operated or motorized worm and pinion drive with a suitable scale graduated in 1° intervals to indicate torque and fitted with a maximum reading indicator.

c) At least four calibrated open-coil torsion springs of different stiffnesses, capable of measuring applied torque up to 350 N·mm. Each spring shall be calibrated at least once per year to an accuracy of within 2 % of its indicated torque within its working range.

d) A scale graduated in 1° intervals for measuring the angular rotation of the vane relative to the soil in which it is placed.

e) A means of lowering the vane vertically into the soil sample in a continuous smooth movement to the desired depth, such as a hand-operated lead-screw mounted on a rigid frame.

f) A baseplate attached to the frame on which the soil sample in its container can be mounted.

NOTE The arrangement should allow for mounting a 100 mm diameter sampling tube, to enable a test to be carried out on the soil in the tube.

3.2.2 *Calibration curve for each torsion spring.*

3.2.3 *Means of attaching the sample container or tube to the base of the vane instrument.*

3.2.4 *Soil trimming tools.*

3.2.5 *Steel rule*, readable to 0.5 mm.

3.2.6 *Equipment for the determination of moisture content*, as given in **3.2** of BS 1377-2:1990.

3.2.7 *Stopclock*, readable to 1 s.

3.3 Procedure

3.3.1 Attach the sample container securely to the base of the vane apparatus, with the sample axis vertical and located centrally under the axis of the vane.

3.3.2 Trim the upper surface of the sample flat and perpendicular to the axis.

3.3.3 Select a torsion spring that is most appropriate for the estimated strength of the soil and assemble it into the vane apparatus.

3.3.4 Set the pointer and the graduated scale on the torsion head to their zero readings, and ensure that there is no backlash in the mechanism for applying torque.

3.3.5 Lower the vane assembly until the end of the vane just touches the surface of the sample. This provides the datum from which the depth of penetration of the vane can be measured.

3.3.6 Lower the vane assembly further to push the vane steadily into the sample to the required depth. The top of the vane should be at a distance not less than four times the blade width below the surface. Record the depth of penetration.

3.3.7 Apply torque to the vane by rotating the torsion head at a rate of 6 °/min to 12 °/min, until the soil has sheared.

NOTE This is indicated by a decrease in torque and an uncontrolled rotation of the vane.

3.3.8 Record the maximum angular deflection of the torsion spring and the angle of rotation of the vane at the instant of failure.

3.3.9 Rotate the vane rapidly through two revolutions so as to remould the soil in the sheared zone.

3.3.10 Immediately set the scales to zero as in **3.3.4**, and repeat **3.3.7** and **3.3.8** for the soil in the remoulded condition.

3.3.11 Raise the vane steadily. As it emerges from the sample prevent excessive disturbance due to tearing of the surface. Wipe the blades clean.

3.3.12 Repeat **3.3.4** to **3.3.11** with the vane positioned at two or more additional locations at the same level in the sample.

NOTE 1 In a 100 mm diameter sampling tube, four additional tests equally spaced at a radius of 30 mm from the centre can be performed using a 12.7 mm vane.

NOTE 2 The centre to centre distance between the points of measurement should be not less than 2.3 times the blade width.

3.3.13 Extrude the sample from its container and take specimens from the level at which the tests were carried out for determining the soil moisture content, using the procedure given in **3.2** of BS 1377-2:1990.

3.3.14 Record a visual description of the soil at the same level.

3.4 Calculations

3.4.1 For each determination calculate the torque applied to shear the soil, M(in N·mm), by multiplying the maximum angular rotation of the torsion spring (in degrees) by the calibration factor (in N·mm per degree).

3.4.2 Calculate the vane shear strength of the soil, τ_v in kPa) from the equation:

$$\tau_v = \frac{M}{K} \times 1000$$

where

K is a constant which depends on the dimensions of the vane.

NOTE 1 The value of K (in mm^3) is given by the following equation, which assumes that the distribution of shear stress is uniform around the perimeter and across the ends of the cylinder of soil at failure.

$$K = \pi D^2\left(\frac{H}{2} + \frac{D}{6}\right)$$

where

D is the overall width of the vane measured to 0.1 mm (in mm).

H is the length of the vane measured to 0.1 mm (in mm).

The value of K for the vane 12.7 mm wide and 12.7 mm long referred to in **3.2.1** a) is 4 290 mm^3.

NOTE 2 The vane dimensions should be checked periodically to ensure that the vane is not distorted or worn.

3.4.3 Calculate the average value of the vane shear strength of the undisturbed soil, τ_v (in kPa).

3.4.4 Calculate the average value of the vane shear strength of the remoulded soil, τ_{vr} (in kPa).

3.4.5 Calculate the moisture content of the soil at the test horizon.

3.5 Test report

The test report shall state that the test was carried out in accordance with clause **3** of BS 1377-7:1990. It shall contain the following, in addition to the information listed in clause **9** of BS 1377-1:1990.

a) statement of the method used, i.e. determination of shear strength by the laboratory vane method;

b) the average vane shear strength for the undisturbed soil, τ_v (in kPa), to two significant figures;

c) the average remoulded shear strength, τ_{vr} (in kPa), to two significant figures, if required;

d) the moisture content of the soil at the test horizon;

e) dimensions of the vane used in the test;

f) description of soil at the test horizon;

g) location of the test horizon in the sampling tube;

h) the type and diameter of the sampling tube.

4 Determination of shear strength by direct shear (small shearbox apparatus)

4.1 General

4.1.1 *Principle.* In the direct shear test a square prism of soil is laterally restrained and sheared along a mechanically induced horizontal plane while subjected to a pressure applied normal to that plane. The shearing resistance offered by the soil as one portion is made to slide on the other is measured at regular intervals of displacement. Failure occurs when the shearing resistance reaches the maximum value which the soil can sustain.

By carrying out tests on a set of (usually three) similar specimens of the same soil under different normal pressures, the relationship between measured shear stress at failure and normal applied stress is obtained.

The small shearbox apparatus referred to in this standard is designed for carrying out tests of this kind on soil specimens of 60 mm or 100 mm square and 20 mm to 25 mm high.

4.1.2 *Types of test.* The shearbox apparatus can be used only for carrying out drained tests for the determination of effective shear strength parameters. There is no control of drainage and the procedure cannot be used for undrained tests.

The test specimen is consolidated under a vertical normal load until the primary consolidation is completed. It is then sheared at a rate of displacement that is slow enough to prevent development of excess pore pressures. Test data enable the effective shear strength parameters c' and ϕ' to be derived.

The residual shear strength parameters c'_R, ϕ'_R can be obtained by extending the tests to give large cumulative displacements by reversals and re-shearing (see **4.5.5.5**).

The requirements of Part 1 of this standard, where appropriate, shall apply to this test method.

4.1.3 *Test conditions.* The following test conditions shall be specified before a series of tests is started:

a) size of test specimens;

b) whether undisturbed or remoulded specimens are to be tested;

c) for undisturbed specimens, the orientation of the specimens relative to the plane of shear;

d) for remoulded specimens the moisture content, and either the dry density to be achieved or the compactive effort to be applied;

e) number of test specimens to be tested as a set;

f) the normal pressures to be applied;

g) whether the residual strength is required, and if so the method of reversal (see **4.5.5.5**).

4.1.4 *Environmental requirements.* These tests shall be carried out in a laboratory in which the temperature is maintained constant to within ± 4 °C, in compliance with **6.1** of BS 1377-1:1990. All apparatus shall be protected from direct sunlight, from local sources of heat and from draughts.

4.2 Apparatus

4.2.1 *Shearbox apparatus.* The small shearbox apparatus enables a square specimen of soil of up to about 25 mm thickness to be sheared horizontally along its mid-height plane while subjected to a vertical stress. The whole apparatus shall be mounted on a rigid bed. The essential requirements are as follows.

a) A container for the specimen ("the shearbox") which is square in plan and divided horizontally into two halves. The lower half is fitted with a removable grooved baseplate which when fitted allows free movement of water. The shearbox shall be rigid enough to resist distortion under maximum load.

Arrangements shall be provided for locking the two halves of the shearbox securely together while the specimen is being placed, and for lifting the upper half of the box off the lower half by a small controlled vertical displacement without tilt, after applying vertical load to the specimen. When released the lower half shall be able to move freely relative to the upper half.

Typical details of a shearbox are shown in Figure 2. The shearbox is placed in a carriage [see **4.2.1** b)], in which the lower half of the box can be secured rigidly in place. The upper half shall be fitted with a central attachment which ensures that the applied horizontal shearing force is in the same plane as the plane of shear induced in the specimen.

b) An outer container (the carriage) in which the shearbox can be placed to enable the test specimen to be submerged under water during the test. The carriage is supported on the bed of the machine by a low-friction bearing which allows movement in the longitudinal direction only. A typical assembly is shown diagrammatically in Figure 3.

The materials comprising the shearbox, the outer container and all components which fit into it shall be resistant to corrosion by electro-chemical reaction with each other.

c) Two porous plates of corrosion-resistant material, about 0.5 mm smaller than the internal plan dimensions of the shearbox. Their porosity shall allow free drainage of water throughout the test but shall prevent intrusion of soil into their pores.

The thickness of the plates shall be sufficient to prevent breakage under load, and the material shall be of negligible compressibility under the loads applied during the test. The upper and lower surfaces shall be plane, clean and undamaged.

d) Two perforated spacer plates of about the same size in plan as the porous plates, if necessary.

e) A loading cap to cover the top spacer plate or porous plate, fitted with a central ball seating through which vertical load is applied to the specimen. The cap shall be about 0.5 mm smaller in plan than the internal dimensions of the shearbox, and shall be rigid enough to transmit the vertical load uniformly to the specimen without deformation.

f) A calibrated means of applying a vertical force to the loading cap such as a loading yoke, preferably counterbalanced, carrying calibrated masses. For high loads a mechanical lever system, preferably counterbalanced, may be used. The vertical force applied to the test specimen shall be known to an accuracy of 1 %. The loading device shall enable the vertical stress to be applied to the specimen without significant impact, for which a screwjack support is advantageous.

g) A motorized loading device capable of applying horizontal shear to the vertically loaded specimen at constant rates of displacement from which a rate to suit the soil being tested can be selected. The actual rate of displacement shall not vary by more than ± 10 % of the desired value. The machine shall be capable of applying a horizontal displacement to the specimen of at least 8 mm.

h) (For multi-reversal residual strength tests only.) Suitable fittings to enable the shearbox to be returned to its starting position when the drive motor is reversed.

i) A calibrated force-measuring device, suitably mounted.

NOTE The force-measuring device may be a load ring or load transducer. Several devices of this kind, of various capacities, should be available, and the one selected for test should be appropriate to the strength of the soil specimen.

j) A calibrated dial gauge or displacement transducer suitably mounted to measure the relative horizontal displacement of the two halves of the shearbox. The gauge shall be readable to 0.01 mm and shall have at least 10 mm travel.

NOTE Alternatively the horizontal displacement indicator can be used to measure the travel of the carriage, from which the relative displacement is obtained by deducting the deflection of the force measuring device. The relationship between dial divisions, or digits, and linear displacement of the force measuring device should be ascertained beforehand.

k) A calibrated dial gauge or displacement transducer capable of measuring the vertical deformation of the specimen during the test, readable to 0.002 mm.

4.2.2 *Specimen cutter* of suitable corrosion-resistant metal of the same internal dimensions as the required specimen size. The cutter shall be provided with sharp externally-chamfered cutting edges and smooth internal surfaces.

4.2.3 *Apparatus for obtaining and trimming a specimen in the cutter*, as described in **8.2** of BS 1377-1:1990.

4.2.4 *Tool for removing the specimen from the cutter.*

4.2.5 *Metal tamping rod* with a square end about 10 mm across flats.

4.2.6 (Optional). *Small hand-held vibrator* (an electric engraving tool has been found suitable), fitted with a suitable tamping foot, for vibrating dry cohesionless soil into the shearbox.

4.2.7 *Levelling template* for trimming the surface of the specimen in the shearbox to a known level.

4.2.8 *Calibrated vernier external/internal caliper* for measuring the internal dimensions and height of the cutting ring or test specimen to 0.1 mm.

4.2.9 *Calibrated vernier* depth-gauge or a micrometer gauge on a suitable comparator support for measuring the depth to the top of the specimen when in the shearbox, and the projection of the top cap, to an accuracy of 0.1 mm.

4.2.10 *Stopclock,* readable to 1 s.

4.2.11 *Balance*, readable to 0.01 g.

4.2.12 *Watch glass or metal tray* suitable for holding the specimen and cutter.

4.2.13 *Apparatus for determining moisture content,* in accordance with **3.2** of BS 1377-2:1990.

4.2.14 *Silicone grease or petroleum jelly.*

4.3 Checking and preparation of apparatus

4.3.1 *Measurements.*

NOTE See form 7(a) of Appendix A.

4.3.1.1 Ensure that the specimen cutter is clean and dry, and that the cutting edge is in good condition.

4.3.1.2 Determine and record the mass of the cutter to 0.01 g.

4.3.1.3 Determine the mass of the tray or watch glass to 0.01 g.

4.3.1.4 Verify and record the mean internal dimensions of the cutter to 0.1 mm.

4.3.1.5 Ensure that the shearbox components are clean and dry. Clamp the two halves of the box securely together with the clamping screws, fit the baseplate and assemble the shearbox securely in the carriage.

4.3.1.6 Determine the internal plan dimensions ($L_1 \times L_2$) of the shearbox to 0.1 mm, and calculate the plan area A (in mm^2). Determine the mean depth from the top surface of the upper half to the top of the baseplate (h_1) to 0.1 mm.

4.3.1.7 Measure and record the thickness of each porous plate and spacer plate to 0.1 mm. Determine the combined thickness of plates to be used for the test (t_p).

4.3.2 ***Preparation and assembly of shearbox***

4.3.2.1 Apply a thin coating of silicone grease or petroleum jelly to the inside faces of the shearbox and to the surfaces of contact between the two halves of the box.

4.3.2.2 Assemble the shearbox with two halves securely clamped together, fit the baseplate and place it securely in position in the carriage.

4.3.2.3 Place a spacer plate on the base of the box if necessary, followed by a porous plate.

4.4 Preparation of specimen

4.4.1 *General.* Specimens of either cohesive or non-cohesive soil may be tested in the shearbox. Preparation procedures depend on the type of soil, as indicated below. The size of the largest particle shall not exceed one-tenth of the height of the specimen.

Loss or gain of moisture by the sample shall be avoided at all stages of preparation, such as by carrying out these operations in a suitable humidified atmosphere if necessary.

Normally three similar specimens are prepared from an undisturbed or remoulded cohesive sample, for testing under three different normal pressures. A non-cohesive sample shall be large enough to provide three separate specimens to avoid having to re-use the same material.

Form 7(a) of Appendix A is suitable for recording specimen details and measurements.

4.4.2 ***Preparation of specimen of undisturbed cohesive soil***

4.4.2.1 Weigh the specimen cutter to 0.1 g.

4.4.2.2 Obtain and trim a specimen from the soil sample by using the cutter and guide jig, as described in **8.6** or **8.7** of BS 1377-1:1990.

NOTE For a very compressible soil the initial specimen thickness should be adequate to ensure that after consolidation the plane of the shear is formed near the mid-height.

4.4.2.3 Weigh the specimen in the cutter to 0.1 g, and calculate the initial mass (m_o) of the specimen.

4.4.2.4 Rest the cutter on the top surface of the assembled shearbox with its inside faces in exact alignment with the inside faces of the box.

4.4.2.5 Push the specimen out of the cutter and into the shearbox keeping its upper face horizontal, until it is bedded on to the lower porous plate.

NOTE Alternatively the top porous plate, spacer plate and loading cap could be placed on the specimen first, as described in **4.4.2.7** and **4.4.2.8**, and used to push the specimen into the box.

Avoid consolidating the specimen.

4.4.2.6 Place the upper porous plate firmly on the specimen. Ensure that there is an equal clearance all around the edges of the plates.

4.4.2.7 Measure the distance from the top of the shearbox to the surface of the porous plate to 0.01 mm (h_2).

4.4.2.8 Place a spacer plate if necessary, and the loading cap, on the porous plate with a uniform all-round clearance.

4.4.3 ***Preparation of specimen of compacted cohesive soil***

4.4.3.1 Prepare the soil at the desired moisture content, as described in **7.7.2** of BS 1377-1:1990.

4.4.3.2 Compact the soil with the required compactive effort, or to achieve the desired density, into a suitable container such as a 1 L compaction mould, using the appropriate procedure described in **7.7.4.2** of BS 1377-1:1990.

4.4.3.3 Seal and store the sample in accordance with **7.7.6** of BS 1377-1:1990.

4.4.3.4 Prepare a set of test specimens from the compacted sample and set up each specimen as in **4.4.2**.

NOTE For a very compressible soil the initial specimen thickness should be adequate to ensure that after consolidation the plane of the shear is formed near the mid-height.

4.4.3.5 If there is not enough soil available to fill a compaction mould the specimen may be prepared by compacting or remoulding the soil directly into the specimen cutter, or into the top half of the shearbox, which is first weighed empty. Hold the cutter or half shearbox firmly in contact with a flat surface while tamping the soil evenly into it in three approximately equal layers, using the square-ended tamper. Ensure that the level of the shear surface will pass through the mid-height of the middle layer. Trim, level and weigh the soil in the cutter or shearbox, seal it and allow it to stand for at least 24 h to enable any excess pore pressures to dissipate. Re-weigh before extruding into position in the shearbox.

4.4.4 ***Preparation of specimen of cohesionless soil***

4.4.4.1 *General*. The procedure depends on whether the soil is dry and can be poured, or damp and needs to be tamped, or saturated.

NOTE 1 For a dry sand the question of drainage does not arise and the cell is assembled with solid spacer plates. For a saturated sand adequate drainage is necessary, and perforated plates should be used.

Soil that is to be placed dry or saturated shall not contain a significant amount of material passing a 63 µm test sieve, to avoid segregation of fine particles, and is therefore referred to as sand.

NOTE 2 A silty soil that is placed in a damp condition and then inundated should not be subjected to a rapid test.

4.4.4.2 *Dry sand: loose*

4.4.4.2.1 Prepare a quantity of soil somewhat larger than that required for the test specimen, as described in **7.3.5** of BS 1377-1:1990, and determine its mass to 0.1 g.

4.4.4.2.2 Place or pour the sand directly into the assembled shearbox from the quantity of known mass.

NOTE A "loose" density is often achieved by rapid pouring from a small height. The method of placing to achieve the desired density consistently should be ascertained previously by trial.

4.4.4.2.3 Level the surface of the specimen using a suitable template to give a specimen of the appropriate thickness, without disturbing the main body of the placed soil.

4.4.4.2.4 Collect any spilled or removed material, weigh the total of the unused soil to 0.1 g and determine the initial mass of the specimen (m_o) by difference.

4.4.4.2.5 Place the porous plate on the specimen. Gently bed down the plate to form a level surface, ensuring there is a uniform clearance all round.

4.4.4.2.6 Measure the distance from the top of the shearbox to the top surface of the plate, to 0.1 mm (h_2).

4.4.4.2.7 Place the top spacer plate (if necessary) and the loading cap carefully on top of the porous plate, with a uniform clearance all round. Avoid jolting or bumping the shearbox during these operations.

4.4.4.3 *Dry sands: compacted*

4.4.4.3.1 Prepare a quantity of soil somewhat larger than that required for the test specimen, as described in **7.3.5** of BS 1377-1:1990, and determine its mass to 0.1 g.

4.4.4.3.2 Place the sand from the quantity of known mass evenly into the shearbox and apply a controlled amount of tamping with the square-ended tamper, or apply vibration to the specimen through the plate for as long as necessary, to achieve the desired density.

NOTE The amount of tamping or vibration required to give the desired density should be ascertained previously by trial.

4.4.4.3.3 Trim and measure the specimen and fit the top plates and loading cap as described in **4.4.4.2.2** to **4.4.4.2.7**.

4.4.4.4 *Saturated sands*

4.4.4.4.1 Prepare a quantity of soil somewhat larger than that required for the test specimen, as described in **7.3.5** of BS 1377-1:1990, and determine its mass to 0.1 g.

4.4.4.4.2 Fit the bottom spacer plate (if necessary) and porous plate in the shearbox, and fill it and the carriage with water to the level corresponding to the top of the specimen.

4.4.4.4.3 Place a known dry mass of sand in water, boil for about 10 min and allow to cool, or place under vacuum to remove air bubbles.

4.4.4.4.4 Place the saturated sand into the shearbox and compact it by vibration to achieve the desired density.

NOTE It is not practicable to obtain a saturated specimen of "loose" density under these conditions.

4.4.4.4.5 Collect all surplus sand, dry and weigh it to 0.1 g and determine the dry mass of the specimen (m_o) by difference.

4.4.4.4.6 Trim and measure the specimen and fit the top plates and loading cap as described in **4.4.4.2.3** to **4.4.4.2.7**.

4.4.4.5 *Partially saturated cohesionless soil*

4.4.4.5.1 Prepare a quantity of soil somewhat larger than that required for the test specimen, as described in **7.3.5** of BS 1377-1:1990, and determine its mass to 0.1 g.

4.4.4.5.2 If necessary adjust the moisture content of the prepared soil to the value required for the test specimen. Determine its mass to 0.1 g and verify its moisture content.

4.4.4.5.3 Place the material in the shearbox, fitted with bottom plates, and compact by tamping as described in **4.4.4.3.2**.

4.4.4.5.4 Trim and measure the specimen and fit the top plates and loading cap as described in **4.4.4.2.3** to **4.4.4.2.7**.

4.5 Test procedure

4.5.1 *Initial adjustments*

4.5.1.1 Position the carriage on its bearings on the machine bed, and adjust the drive unit to the correct starting point of the shear test. Secure the horizontal displacement gauge in position.

4.5.1.2 Measure the height of the top of the load cap above the top of the box (h_3) to 0.1 mm.

4.5.1.3 Assemble the loading system so that the loading yoke is supported by the ball seating on top of the load cap.

NOTE If provision is made for supporting the weight of the yoke when first placed on the ball seating, or the yoke is counterbalanced, the initial vertical settlement can be measured by the vertical movement gauge, and **4.5.1.2** and **4.5.1.4** are not necessary.

4.5.1.4 Measure the height of the top of the load cap above the top of the box again (h_4) to 0.1 mm. The difference ($h_3 - h_4$) gives the settlement of the specimen under the seating pressure provided by the loading yoke.

4.5.1.5 Secure the vertical deformation gauge in position so that it can measure the vertical movement of the centre of the loading cap, ensuring that it allows enough movement in either direction. Record the initial zero reading.

4.5.2 *Consolidation*

4.5.2.1 Apply a normal force to the specimen, to give the desired vertical (normal) stress, σ_n (in kPa), smoothly and as rapidly as possible without jolting. Start the clock at the same instant if consolidation readings are significant.

NOTE Dry sand or free-draining saturated sand consolidates very rapidly, therefore consolidation readings are not necessary and a rapid test is suitable. For all other soils, time readings should normally be recorded

If the consolidation readings are not significant, continue at **4.5.3**.

4.5.2.2 Except when testing dry soils, as soon as possible after applying the normal force fill the carriage with water to a level just above the top of the specimen, and maintain it at that level throughout the test.

4.5.2.3 Record readings of the vertical deformation gauge and elapsed time at suitable intervals to allow a graph to be drawn of vertical deformation as ordinate, against square-root of elapsed time as abscissa. A plot of vertical deformation against time to a logarithmic scale may also be made. Continue until the plotted readings indicate that primary consolidation is complete. Form 7(b) of Appendix A is suitable for recording and plotting these data.

4.5.2.4 Using the square-root time plot, extend the approximately linear portion of the graph (which normally lies between just after zero time to about 50 % of primary consolidation) downwards. Identify the point at which this line intersects the horizontal line through the final point on the curve of primary consolidation, and read off the value ($\sqrt{t_{100}}$) on the square-root time axis.

4.5.2.5 Calculate the value of t_{100} (min.), and the minimum time to failure, i.e. to mobilization of maximum shear resistance by the specimen, t_f (min.), from the equation.

$$t_f = 12.7t_{100}$$

NOTE This test does not permit the derivation of a reliable value of coefficient of consolidation, c_v .

4.5.2.6 Estimate the likely horizontal shear deformation of the specimen at failure (in mm). Divide it by t_f to obtain the maximum rate of displacement (in mm/min) to be applied during the shear test.

4.5.3 ***Final adjustments***

4.5.3.1 On completion of the consolidation stage and before shearing (see **4.5.4** or **4.5.5**) make the following checks and adjustments described in **4.5.3.2** to **4.5.3.7**.

4.5.3.2 Rate of displacement:

a) for a rapid test in which consolidation takes place very rapidly, the rate of displacement should induce failure within a period of 5 min to 10 min;

b) for a slow test set the constant rate of displacement device to give a rate of displacement not greater than that calculated in **4.5.2.5** and **4.5.2.6**.

NOTE The "machine displacement speed" is the speed as given by the manufacturer for each gear ratio when the machine is running under zero load. The actual speed under load may be less than this. The "closing gap speed" is less than the machine speed due to deformation of the load measuring device and of the load frame. The actual rate of relative displacement of the two halves of the specimen is the "closing gap speed" and allowance should be made for the difference between this and the nominal machine speed if greater accuracy is required.

4.5.3.3 Ensure that all adjacent components from the constant rate of displacement device through to the load measuring device and its point of restraint are properly in contact, but under zero horizontal load.

4.5.3.4 For a multi-reversal test only, ensure that the necessary components for providing reverse travel are correctly fitted, with minimum backlash.

4.5.3.5 Remove the clamping screws which lock the two halves of the shearbox together.

4.5.3.6 Raise the upper half of the box, keeping it level, by turning the lifting screws. The amount of clearance between the two halves should be enough to prevent them coming together during the test, but shall not permit extrusion of the soil between them. Retract the lifting screws.

NOTE For fine-grained soils, lifting by a half-turn of the screws is usually sufficient. For sandy soils the lift might need to be slightly greater but is should not exceed about 1 mm.

4.5.3.7 Record the initial readings of the horizontal displacement gauge, the vertical deformation gauge and the force measuring device.

4.5.4 ***Shearing: single stage tests***

NOTE See form 7(c) of Appendix A.

4.5.4.1 Shear the specimen to failure as described in **4.5.4.2** to **4.5.4.10**, using the rate of shear displacement selected in accordance with **4.5.3.2**.

4.5.4.2 Start the test and at the same instant start the timer. Record readings of the force measuring device, the horizontal displacement gauge, the vertical deformation gauge and elapsed time, at regular intervals of horizontal displacement such that at least 20 readings are taken up to the maximum load ("peak" shear strength).

NOTE Intervals of horizontal displacement of 0.1 mm often meet this requirement. For brittle specimens such as dense sand, sets of data should be recorded at frequent intervals of force, instead of displacement, to ensure that enough readings are taken. For plastic materials the intervals may be greater than normal.

4.5.4.3 Take additional readings as the maximum horizontal force is approached, so that if the "peak" occurs it can be clearly defined.

4.5.4.4 During the test, monitor the rate of relative displacement of the two halves of the shearbox against elapsed time regularly, if appropriate. If this rate exceeds the maximum rate calculated in **4.5.2.6**, reduce the speed of travel accordingly.

4.5.4.5 Continue shearing and taking readings beyond the maximum force, or until the full travel of the apparatus has been reached if there is no defined peak, then stop the test.

4.5.4.6 Reverse the direction of travel of the carriage and return the two halves of the shearbox to their original alignment.

4.5.4.7 If the specimen was sheared under water, siphon off the water from around the specimen and allow to stand for about 10 min to enable free water to drain from the porous plates.

4.5.4.8 Remove the vertical force and loading yoke from the specimen.

4.5.4.9 Transfer the specimen from the shearbox to a small tray, taking care not to lose any soil. Remove any free water with a tissue.

4.5.4.10 Weigh the specimen on the tray to 0.1 g.

4.5.4.11 Dry the soil in an oven at 105 °C to 110 °C and determine its dry mass (m_d) to 0.1 g, and its final moisture content.

4.5.5 ***Shearing: multi-reversal test***

NOTE 1 See form 7(c) of Appendix A.

NOTE 2 The multi-reversal shear test enables the residual shear strength as well as the peak strength of a soil to be determined.

4.5.5.1 Connect the reverse-travel attachments (see **4.5.3.4**).

4.5.5.2 Shear the specimen at the rate of shear displacement selected in accordance with **4.5.3.2** b). Take readings at suitable intervals as described in **4.5.4.2** and **4.5.4.3**.

4.5.5.3 During the test, monitor the rate of relative displacement as described in **4.5.4.4**.

4.5.5.4 Continue shearing and taking readings beyond the maximum force and until the full travel of the apparatus has been reached.

4.5.5.5 Return the shearbox to its starting position by one of the following reversal procedures:

a) Machine-drive reversal and re-shearing. Reverse the direction of travel until the two halves of the shearbox return to their original alignment. Adjust the rate of reverse displacement so that the reversing operation takes place over a period of time about equal to the time from the start of shearing to reaching peak shearing force.

NOTE Shear stresses during reverse travel have no significance.

b) Reversal by hand and re-shearing. Reverse the direction of travel as in **4.5.5.5** a) but by hand winding the machine within a period of a few minutes. Allow to stand at least 12 h to enable pore pressure equilibrium to be re-established.

c) Rapid multi-reversals by hand. Apply five to ten backward and forward traverses within a period of a few minutes by hand winding, to establish a shear plane, finishing with the original alignment. Allow to stand at least 12 h as in **4.5.5.5** b).

4.5.5.6 Verify that the horizontal displacement gauge and the force measuring device have returned to their initial zero readings, and record the reading of the vertical displacement gauge.

4.5.5.7 Re-shear the specimen as in **4.5.5.2** to **4.5.5.4**, applying the rate of displacement as used for the reverse travel in **4.5.5.5** a).

4.5.5.8 Repeat **4.5.5.5** to **4.5.5.7** as many times as necessary to obtain a repeatable residual value of the shear resistance. Stop the test at the end of the final forward shearing travel.

4.5.5.9 Siphon off the water from around the specimen and allow to stand for about 10 min to enable free water to drain from the porous plates.

4.5.5.10 Remove the vertical force and loading yoke from the specimen.

4.5.5.11 Separate the two halves of the specimen by pushing in the direction of shear during the test.

4.5.5.12 Record the significant features of both sides of the surface of shear, with the aid of sketches.

NOTE These features may be recorded photographically if required.

4.5.5.13 Transfer both halves of the specimen to a small tray, taking care not to lose any soil. Remove any free water with a tissue.

4.5.5.14 Weigh the specimen and tray to 0.1 g.

4.5.5.15 Dry the specimen to constant mass and determine the dry mass (m_d) to 0.1 g and the final moisture content, using the procedure of **3.2** of BS 1377-2:1990.

4.6 Calculations and plotting

4.6.1 General data

NOTE See form 7(a) of Appendix A.

4.6.1.1 Calculate the initial moisture content, w_o (in %), from the equation

$$w_o = \frac{m_o - m_d}{m_d} \times 100$$

where

m_o is the initial mass of the specimen (in g);

m_d is the final dry mass of the specimen (in g).

4.6.1.2 Calculate the initial dry density, ρ_d (in Mg/m^3) from the equation

$$\rho_d = \frac{m_d \times 1000}{AH_o}$$

where

A is the plan area of the specimen (in mm^2);

H_o is the initial height of the specimen (in mm).

NOTE For an undisturbed specimen trimmed in the specimen cutter, H_o is equal to the height of the cutter.
For a disturbed specimen formed in the shearbox, H_0 is calculated from h_1 (see **4.3.1.6**) h_2 (see **4.4.2.7**) and the appropriate plate thickness t_p (see **4.3.1.7**).

4.6.1.3 Calculate the initial bulk density, ρ (in Mg/m^3), from the equation

$$\rho = \frac{m_o \times 1000}{AH_o}$$

4.6.1.4 Calculate the initial voids ratio, e_o, (if required) from the equation

$$e_o = \frac{\rho_s}{\rho_d} - 1$$

where

ρ_s is the particle density (in Mg/m^3) (which may be measured, or assumed).

4.6.1.5 Calculate the initial degree of saturation, S_o, (if required) as percentage from the equation

$$S_o = \frac{w_o \rho_s}{e_o}$$

4.6.1.6 Calculate the voids ratio, e, at the end of the consolidation stage, and at the end of shearing (if required) from the equation

$$e = e_o - \frac{\Delta H}{H_o}(1 + e_o)$$

where

ΔH is the calculated change in height (vertical deformation) of the specimen (in mm) from the initial zero reading.

NOTE If the change in specimen height after shearing is required, the settlement under the seating pressure, $(h_3 - h_4)$ (see **4.5.1.4**) should be taken into account.

4.6.2 *Stresses and displacements*

NOTE See form 7(c) of Appendix A.

4.6.2.1 From each set of data obtained during the shear test calculate the horizontal shear force, P (in N), applied to the specimen.

4.6.2.2 Calculate the shear stress on the surface of shear, τ (in kPa), for each set of readings from the equation

$$\tau = \frac{P}{A} \times 1000$$

where

A is the initial plan area of the specimen (in mm^2).

NOTE The continual change in the area of contact is not normally taken into account.

4.6.2.3 The normal stress, σ_n, (in kPa), applied to the specimen (see **4.5.2.1**) is given by the equation

$$\sigma_n = \frac{9810m}{A}$$

where

m is the mass of the hanger and hanger weights (or equivalent mass if a lever-arm loading system is used) applied to the loading cap (in kg).

NOTE The continual change in the area of contact is not normally taken into account.

4.6.2.4 In the second and subsequent travels of a multi-reversal test, calculate forward displacement for each set of readings by adding the observed displacement to the cumulative forward displacement at the end of the previous travel.

4.6.2.5 Calculate the cumulative vertical deformation for each set of readings relative to the datum corresponding to the initial specimen height.

4.6.3 *Graphical plots: single stage tests*

NOTE 1 See form 7(d) of Appendix A.

For each specimen of a set of single-stage tests, plot the following graphs.

a) Shear stress (in kPa) as ordinates against horizontal displacement (in mm) as abscissae.

b) Change in height (vertical deformation) of the specimen (in mm) as ordinates against horizontal displacement (in mm) as abscissae, if required. If preferred the changes in height may be plotted in terms of voids ratio by using the equation given in **4.6.1.6**.

c) From each stress-displacement graph read off the value of the maximum shear stress (the "peak" strength) and the corresponding horizontal displacement and change in specimen height.

d) Plot each value of peak strength, τ_f (in kPa), as ordinates against the corresponding normal stress, σ_n (in kPa) applied for that test as abscissae, both to the same linear scale.

e) If it can be assumed that the relationship is linear, the slope of the line and its intercept with the shear strength axis can be derived from the line of best fit through the plotted points. The slope gives the angle of shearing resistance φ' (in degrees), and the intercept gives the apparent cohesion c' (in kPa), both in terms of effective stress.

NOTE 2 Peak and residual strength relationships may show non-linearity, and their interpretation requires further consideration.

4.6.4 *Graphical plots: multi-reversal tests*

NOTE 1 See form 7(d) of Appendix A.

For each specimen of a set of multi-reversal tests, plot the following graphs.

a) Shear stress (in kPa) as ordinates, against cumulative forward displacement (in mm) as abscissae, for each shearing stage in succession.

b) Change in height (vertical deformation) of the specimen (in mm) as ordinates, against cumulative forward movement (in mm) as abscissae, as above, if required.

c) From the first stage stress-displacement graph for each specimen read off the value of the maximum shear stress (the "peak" strength, τ_f (in kPa) and the corresponding cumulative displacement and change in specimen height (in mm).

d) From the later stages determine the residual value of shear stress τ_r (in kPa) which each stage tends to approach.

e) Plot each value of maximum strength, τ_f (in kPa), and residual strength, τ_r (in kPa), as ordinates against the corresponding normal stress, σ_n (in kPa), applied for that test as abscissae, both to the same linear scale.

f) If it can be assumed that the relationships are linear, the slopes of the lines and their intercepts with the shear strength axis can be derived from lines of best fit through the two sets of plotted points. The slope of the maximum strength envelope gives the angle of shearing resistance φ' (in degrees), and the intercept gives the apparent cohesion c' (in kPa), both in terms of effective stress for the maximum condition. The slope and intercept of the residual strength envelope give the residual angle of shearing resistance φ'_R (in degrees) and the residual cohesion value c'_R (in kPa).

NOTE 2 Peak and residual strength relationships may show non-linearity, and their interpretation requires further consideration.

4.7 Test report

The test report shall state that the test was carried out in accordance with clause **4** of BS 1377-7:1990. It shall contain the following, in addition to the information listed in clause **9** of BS 1377-1:1990:

a) statement of the method used, i.e. determination of the shear strength by direct shear in the small shearbox apparatus, using the procedure of **4.5.4** or **4.5.5**, as appropriate;

b) initial dimensions of the specimens;

c) initial moisture content, bulk density, and dry density;

d) particle density, indicating whether measured or assumed;

e) initial voids ratio and degree of saturation, if required;

f) tabulated values for each specimen of the applied normal stress, maximum shear stress, corresponding horizontal relative displacement and, if relevant, the residual shear stress, final cumulative displacement and number of traverses;

g) rate or rates of horizontal displacement;

h) method used for reversing the shearbox in multi-reversal tests;

i) whether the specimens were tested dry or submerged;

j) graphical plots of settlement against square-root time for each specimen, if relevant;

k) graphical plots of shear stress, and if required, the change in specimen thickness, against cumulative horizontal displacement for each specimen;

l) graphical plots of maximum shear stress, and residual shear stress if relevant, against normal applied stress, showing the derivation of c', φ', and c'_R, φ'_R if relevant;

m) (only if the plotted relationships are linear) angle of shearing resistance, φ', to the nearest ½°, and cohesion intercept, c' (in kPa) to two significant figures, for the maximum condition; and, if appropriate, φ'_R and c'_R for the residual condition.

5 Determination of shear strength by direct shear (large shearbox apparatus)

5.1 General

5.1.1 *Principle.* The principle of this method is the same as that described in clause **4** for the small shearbox apparatus.

The large shearbox referred to in this standard is designed for carrying out tests on soil specimens up to 305 mm square and 150 mm high.

5.1.2 *Types of test.* The same types of drained test can be performed with this apparatus as with the small shearbox, outlined in **4.1.2**. However, the dimensions of the specimen may enable some particles up to 20 mm in size to be included.

The requirements of Part 1 of this standard, where appropriate, shall apply to this test method.

5.1.3 *Test conditions.* The following test conditions shall be specified before starting a series of tests:

a) size of test specimen;

b) whether undisturbed or remoulded specimens are to be tested;

c) for undisturbed specimens, the orientation of the specimens relative to the plane of shear;

d) for remoulded specimens the moisture content, and either the dry density to be achieved or the compactive effort to be applied;

e) number of test specimens to be tested as a set;

f) the normal pressures to be applied;

g) whether the residual strength is required, and if so the method of reversal.

5.1.4 *Environmental requirements*. These tests shall be carried out in a laboratory in which the temperature is maintained constant to within ± 4 °C, in compliance with **6.1** of BS 1377-1:1990.All apparatus shall be protected from direct sunlight, from local sources of heat and from draughts.

5.2 Apparatus

5.2.1 *Shearbox apparatus*. The large shearbox apparatus is similar in principle to the small shearbox (see **4.2.1**), but it enables a soil specimen up to 305 mm square and 150 mm high to be tested. The apparatus shall be mounted on a substantial rigid bed.

The essential requirements are as follows:

a) A container for the specimen (the "shearbox"), square in plan and divided horizontally into two halves. The shearbox shall be constructed of steel sections rigid enough to resist distortion when supporting the specimen and when subjected to the maximum vertical and horizontal loads. Otherwise the requirements are the same as stated in **4.2.1** a) for the small shearbox.

b) An outer container (the carriage), suitably rigid, which fulfils the functions stated in **4.2.1** b).

c) Two spacer plates, about 2 mm smaller than the internal plan dimensions of the shearbox, are required, depending on the design of the apparatus. They shall permit drainage of water from the specimen.

d) A loading cap fitted with a central self-aligning seating through which vertical load is applied to the top surface of the specimen. The cap shall be about 2 mm smaller in plan than the internal dimensions of the shearbox, and shall be rigid enough to transmit the vertical load uniformly to the specimen. If integral with the top grid plate it shall permit drainage of water from the specimen.

e) A calibrated means of applying a vertical force to the loading cap, either a hydraulic system, or a mechanical lever loading system using calibrated hanger weights. Either type shall apply forces to the specimen known to an accuracy of 1 %, and shall enable the vertical stress to be applied to the specimen smoothly. The pressure if applied hydraulically shall be indicated by a pressure gauge of test grade complying with **4.2.1.7**, or by a transducerized force measuring device complying with **4.2.1.6**, of BS 1377-1:1990.

f) A motorized loading device capable of applying horizontal shear to the vertically loaded specimen at constant rates of displacement from which a rate to suit the soil being tested can be selected. The actual rate of displacement shall not vary by more than ± 10 % of the desired value. The machine shall be capable of applying a horizontal displacement of up to 50 mm.

g) (For multi-reversal residual strength tests only.) Suitable fittings to enable the shearbox to be returned to its starting position when the drive motor is reversed.

h) A calibrated force-measuring device.

NOTE 1 The force-measuring device may be a load ring or force transducer. Several devices of this kind, of various capacities, should be available, and the one selected for test should be appropriate to the strength of the soil specimen.

i) A calibrated dial gauge or displacement transducer suitably mounted to measure the relative horizontal displacement of the two halves of the shearbox. A gauge shall be readable to 0.01 mm and shall have at least 50 mm travel.

NOTE 2 Alternatively the horizontal displacement indicator can be used to measure the travel of the carriage, from which the relative displacement is obtained by deducting the deflection of the force measuring device. The relationship between dial divisions, or digits, and linear displacement of the force measuring device should be ascertained beforehand.

j) A calibrated dial gauge or displacement transducer capable of measuring the vertical deformation of the specimen during the test, readable to 0.01 mm.

5.2.2 *Stopclock,* readable to 1 s.

5.2.3 *Steel tamping rod* with a square end about 25 mm across flats.

5.2.4 *Vibrating hammer*.

NOTE A vibrating hammer of the type specified in **3.7.2.2** of BS 1377-4:1990 has been found to be suitable.

5.2.5 *Steel tamper* attached to the vibrating hammer, having a square foot, and a mass not exceeding 3 kg. A suitable size would be 100 mm square.

5.2.6 *Square steel plate,* about 16 mm thick, with sides about 4 mm smaller than the internal dimensions of the shearbox, with a removable lifting handle.

5.2.7 *Levelling template,* for trimming the surface of the soil in the shearbox to a known level.

5.2.8 *Straightedge scraper.*

5.2.9 *Steel rule,* at least 450 mm long, graduated to 1 mm.

5.2.10 *Sharp-bladed trimming knife.*

5.2.11 *Wire saw.*

5.2.12 *Two or more spatulas.*

5.2.13 *Metal scoop.*

5.2.14 *Garden trowel.*

5.2.15 *Supply of plaster of paris or other suitable filler.*

5.2.16 *Small pointing trowel.*

5.2.17 *Thin polyethylene sheet.*

5.2.18 *Silicone grease or petroleum jelly.*

5.2.19 *Balance,* of 25 kg capacity, readable to 5 g.

5.2.20 *Platform scales,* of 100 kg capacity, readable and accurate to 50 g.

5.2.21 (Optional). *Steel sample cutter,* square in plan, having sides about 1 mm less than the plan dimensions of the shearbox.

5.2.22 *Several containers such as buckets.*

5.2.23 *Small supply (a few kilograms) of dry medium sand.*

5.2.24 *Riffle box* of suitable size for medium to coarse gravels.

NOTE Items **5.2.3** to **5.2.6**, **5.2.13** and **5.2.14** are required only for the compaction of disturbed specimens.
Items **5.2.15** to **5.2.17**, **5.2.21** and **5.2.23** are required only for preparation of undisturbed specimens.

5.3 Measurement of apparatus

NOTE See form 7(a) of Appendix A.

5.3.1 Ensure that the shearbox components are clean and dry. Clamp the two halves of the box securely together, weigh the shearbox assembly to 50 g and record the mass.

5.3.2 Weigh each spacer plate to 50 g, and measure their thickness to 0.1 mm. Record the observations.

5.3.3 Determine the internal plan dimensions ($L_1 \times L_2$) of the shearbox to 0.5 mm, and calculate the plan area A (in mm^2). Determine the mean depth from the top surface of the upper half of the box to the top of the baseplate (h_1) to 0.5 mm.

5.4 Preparation of large shearbox specimen

5.4.1 *Preparation of undisturbed block sample*

5.4.1.1 Ensure that all dimensions of the block sample are greater than those of the required test specimen.

5.4.1.2 Orientate the block sample or shearbox specimen in the desired direction with respect to the soil stratum in-situ.

5.4.2 *Preparation of disturbed soil*

5.4.2.1 Take a representative quantity of disturbed soil that is large enough for the series of tests envisaged without having to re-use any part of it.

NOTE If it can be shown that no particle degradation occurs as a result of compaction and shearing, the same soil may be re-used for the series of tests.

5.4.2.2 Prepare the soil in accordance with **7.7** of BS 1377-1:1990. Any particles of a size larger than one-tenth of the specimen height should normally be removed and their proportion by dry mass determined.

NOTE It is sometimes unavoidable to include a proportion of larger particles upto a maximum size of 20 mm. The proportion of particles larger than one-tenth of the specimen height should not be more than 15 % by dry mass.

5.4.2.3 Weigh the whole prepared sample to 50 g so that the mass of soil used for each test specimen can be obtained by difference when necessary.

5.4.3 *Procedures for preparation of specimens.* Procedures are described for the preparation of the following types of specimen.

a) Undisturbed specimen of cohesive soil, usually prepared from a block sample (see **5.4.4**).

b) Remoulded specimen of cohesive soil, compacted into the large shearbox by means of a hand compaction rammer using a specified compactive effort (see **5.4.5**).

c) Remoulded specimen of cohesive soil, compacted into the large shearbox by means of a hand compaction rammer to achieve a specified dry density. Either the 2.5 kg rammer or the 4.5 kg rammer may be used, or some other suitable means of compaction (see **5.4.6**).

d) Remoulded specimen of cohesionless soil, compacted into the large shearbox by means of a vibrating hammer or by hand ramming, using a specified compactive effort (see **5.4.5**).

e) Remoulded specimen of cohesionless soil, compacted into the large shearbox by means of a vibrating hammer or by hand ramming, to achieve a specified dry density (see **5.4.6**).

f) Preparation of cohesionless soil to a loose state (see **5.4.7**).

Before placing a remoulded soil into the shearbox, locate the carriage of the apparatus on the roller bearings and position the shearbox correctly in the carriage. Fit the bottom plate.

Form 7(a) of Appendix A is suitable for recording specimen details and measurements.

5.4.4 ***Preparation of undisturbed specimen of cohesive soil***

NOTE 1 This procedure is for preparing a specimen for the large shearbox from a block sample received from site, which is of a larger size than the box.

NOTE 2 A similar procedure can be used for taking a specimen on site directly into the shearbox or cutter, if a suitable block of soil is first exposed, in which case **5.4.4.2** is omitted.

5.4.4.1 Weigh the shearbox or sample cutter empty to 50 g, and the spacer plates separately to 50 g.

5.4.4.2 Trim the lower face of the block sample, if necessary, to enable it to stand firmly on a flat surface such as the workbench top.

NOTE During the trimming process any large particles dislodged from a prepared face may be replaced by fine matrix material, well pressed into the resulting cavity.

5.4.4.3 Trim the upper face to provide a reasonably flat and level surface.

5.4.4.4 Place one half of the shearbox, or the sample cutter, on the top face, and mark the outline of the inside face of the box with a knife blade.

5.4.4.5 Remove the half box or cutter and carefully trim a square section about 5 mm outside the marked outline, to a depth about equal to the depth of the half box or cutter.

5.4.4.6 Cut to a depth of about 20 mm from the upper surface to the exact outline of the box or cutter.

5.4.4.7 Replace the half box or cutter and ease it over the portion trimmed to size.

5.4.4.8 Keeping the half box or cutter horizontal, ease it down gradually by cutting away the remaining soil just ahead of it, so that the container makes a close fit around the sample, until it is almost filled.

5.4.4.9 If appropriate place the other half of the box in position, and bolt or clamp the two halves together in correct alignment.

5.4.4.10 Cut the block to a depth slightly in excess of the required sample thickness to an outline about 5 mm outside the box size.

5.4.4.11 Allow the box to advance downwards by trimming ahead of it, until the surface of the sample just projects above the top flange of the box.

5.4.4.12 Cut off the surplus soil so that the top surface of the block is level and flush with the end of the container.

5.4.4.13 Trim to a level surface below the flange of the box a distance equal to the thickness of the bottom plate, which is then fitted in position with an equal clearance all round the edges.

5.4.4.14 Turn the block sample over, repeat **5.4.4.12** and fit the upper plate. If practicable, first separate the sample from the remainder of the block by under-cutting about 20 mm below the box.

5.4.4.15 Measure the distances from each face of the box to the trimmed specimen surface to determine its height (H_0) to 0.5 mm.

5.4.4.16 Weigh the box and trimmed specimen (with or without spacer plates) to 50 g. Calculate the initial mass (m_0) of the specimen.

5.4.4.17 Lift the box with the specimen and place it in the carriage of the shearbox.

5.4.4.18 Place the loading cap on the upper plate, allowing an equal all-round clearance.

5.4.4.19 *Use trimmings,* without delay, for determining the initial soil moisture content w_0 (in %), if appropriate.

5.4.5 ***Preparation of remoulded specimen using specified compactive effort***

5.4.5.1 *Determination of relevant density*. determine the density to be achieved by the specified compactive effort as follows.

a) Prepare a separate representative portion of the soil (similar to that prepared as in **5.4.2**) at the appropriate moisture content sufficient for compacting one batch into a CBR mould, in accordance with **3.2.5** of BS 1377-4:1990.

b) Compact the soil into the CBR mould in accordance with **3.4.4.1.1** to **3.4.4.1.8** or **3.5.4.1.1** to **3.5.4.1.8** of BS 1377-4:1990, or by applying any other compactive effort.

NOTE A dry density intermediate between the dry densities given by the 2.5 kg rammer method and the 4.5 kg rammer method at a given moisture content may sometimes be required. This can be obtained by using an intermediate compactive effort between these two levels of compaction. In order to reduce the variations in compactive effort to a minimum, it is suggested that this intermediate effort should be obtained by compacting the specimen in five equal layers, giving each layer the equivalent of 30 blows of a 4.5 kg rammer falling through 450 mm in the one litre compaction mould.

c) Determine the resulting dry density of the soil compacted in the mould.

5.4.5.2 *Preparation of specimen.* Prepare the specimen at the relevant dry density by the method as described in **5.4.6**.

5.4.6 ***Preparation of a remoulded specimen compacted to a specified dry density***

5.4.6.1 When a test specimen of soil is to be prepared as in **5.4.2** to a compaction-related dry density, or to a "medium" state in terms of density index follow the procedure described in **5.4.6.2** to **5.4.6.11**.

5.4.6.2 Calculate the dry mass of soil required to form a test specimen of the desired volume at the specimen dry density.

5.4.6.3 Calculate the corresponding mass of prepared soil, from the moisture content, and weigh out that mass to within 5 g.

5.4.6.4 Divide the weighed sample into three approximately equal portions, and place each portion in an airtight container until it is required for use.

5.4.6.5 Spread the first portion evenly in the shearbox and compact it using the 2.5 kg rammer, or the 4.5 kg rammer, or the vibrating hammer fitted with the square tamping foot (as appropriate) until the layer occupies one-third of the height of the shearbox. Ensure that the compaction is evenly distributed across the surface. Use the square tamper when compacting by rammer to compact soil into the corners of the shearbox.

5.4.6.6 Repeat **5.4.6.5** on two further equal layers in turn so that the final height of the specimen is equal to the nominal specimen height to within 5 mm. Ensure that the plane of shear of the shearbox lies within the middle third of the middle layer.

5.4.6.7 Trim the surface of the soil flat and level using the depth-gauge template. Any coarse particles which become dislodged should be removed and the resulting voids filled with the soil matrix material, well pressed in.

5.4.6.8 Determine the average height (H_0) of the specimen to 0.5 mm by measuring down to its surface from the top edge of the shearbox at a number of points including the four corners.

5.4.6.9 Calculate the resulting specimen density, which should be within the desired tolerance limits of the specified density.

5.4.6.10 Place the upper spacer plate on the specimen, followed by the loading cap if not integral with the plate. Ensure that there is a uniform clearance all around the edges of the plate.

5.4.6.11 Place the loading cap on the upper plate, allowing a uniform all-round clearance.

5.4.7 ***Preparation of cohesionless soil to a loose state***

NOTE This procedure applies to samples of dry gravelly cohesionless soil that are to be tested at a dry density as close as possible to the minimum dry density determined as in **4.5** of BS 1377-4:1990.

5.4.7.1 Calculate the dry mass of soil required to form the test specimen of the desired volume at the specified dry density.

5.4.7.2 Weigh out, to the nearest 5 g, that mass of soil, prepared as in **5.4.2** except that the material is dried.

5.4.7.3 Ensure that the soil is well mixed.

5.4.7.4 Place the soil in a number of suitable containers such as buckets without causing segregation of particles.

5.4.7.5 Pour the contents of each bucket steadily into the shearbox from a height of about 0.5 m, taking about 2 s for each. Spread the material as evenly as possible; avoid making a heap in the middle.

5.4.7.6 Carefully trim the surface of the soil as flat as possible without causing disturbance to the main body of the specimen. Check that the surface is level with the depth gauge, but do not dislodge any protruding gravel particles.

5.4.7.7 Collect together any unused or spilled soil, weigh to the nearest 5 g and determine the mass of the test specimen by difference.

5.4.7.8 Determine the average height (H_0) of the specimen to 0.5 mm by measuring down to its surface from the top edge of the shearbox at a number of points including the four corners.

5.4.7.9 Calculate the resulting specimen density.

5.4.7.10 If appropriate place a layer of medium sand over the surface to cover protruding gravel particles and form a smooth flat bed on which to place the top plate.

5.4.7.11 Place the upper spacer plate on the layer of sand followed by the loading cap if not integral with the plate. Ensure that there is a uniform clearance all around the edges of the plate.

5.4.7.12 Place the loading cap on the upper plate, allowing uniform all-round clearance.

5.5 Test procedure

5.5.1 ***Initial adjustments***

5.5.1.1 Position the carriage on its bearings on the machine bed and adjust the drive unit to the correct starting point for the shear test. Secure the horizontal displacement gauge in position.

5.5.1.2 Assemble the vertical loading system so that the cross-beam of the loading yoke is in contact with the self-aligning seating on the load cap with the weight of the yoke supported from below.

5.5.1.3 Apply a small known seating force to the load cap, which may be the force due to the weight of the loading yoke in a mechanically-loaded system.

5.5.1.4 Secure the vertical deformation gauge in position so that it can measure the vertical movement of the centre of the loading cap, ensuring that it allows enough movement in either direction. Record the initial zero reading.

5.5.2 *Consolidation*. Carry out the procedure as described in **4.5.2**.

5.5.3 *Final adjustments*. Carry out the procedure as described in **4.5.3**.

5.5.4 ***Shearing: single stage test***

NOTE See form 7(c) of Appendix A.

5.5.4.1 Carry out the procedure as described in **4.5.4.2** to **4.5.4.7**.

5.5.4.2 Remove the soil from the shearbox and obtain at least three representative samples from the vicinity of the sheared surface for determination of moisture content.

5.5.5 ***Shearing: multi-reversal test***

NOTE See form 7(c) of Appendix A.

5.5.5.1 Carry out the procedure as described in **4.5.5.2** to **4.5.5.4**.

5.5.5.2 Return the shearbox to its starting position by one of the following reversal procedures.

a) Machine-drive reversal and re-shearing. Reverse the direction of travel until the two halves of the shearbox return to their original alignment. Adjust the rate of reverse displacement so that the reversing operation takes place over a period of time about equal to the time from the start of shearing to reaching peak shearing load.

NOTE Shear stresses during reverse travel have no significance.

b) Rapid multi-reversals. Apply several backward and forward traverses within as short a time as possible, depending on the maximum rate of displacement of the machine, to establish a shear plane, finishing with the original alignment. Allow to stand overnight to enable pore pressure equilibrium to be re-established.

5.5.5.3 Carry out the procedure as described in **4.5.5.6** to **4.5.5.10**.

5.5.5.4 If practicable, separate the two halves of the specimen along the surface of shear. Record the significant features of both sides of the surface with the aid of sketches.

NOTE These features may be recorded photographically if required.

5.5.5.5 Obtain at least three representative samples from the vicinity of the sheared surface for determination of moisture content. Do this during the removal of soil from the shearbox if **5.5.5.4** is not practicable.

5.6 Calculations and plotting

5.6.1 *General data*

NOTE See form 7(a) of Appendix A.

5.6.1.1 Calculate the initial bulk density of the specimen, ρ (in Mg/m^3), from the equation

$$\rho = \frac{m_o \times 1\,000}{AH_o}$$

where

m_o is the initial mass of the specimen (in g);

A is the plan area of the specimen (in mm^2);

H_o is the initial height of the specimen (in mm).

5.6.1.2 Calculate the initial dry density, ρ_d (in Mg/m^3) from the equation

$$\rho_d = \frac{100}{100 + w_0}\rho$$

where

w_o is the initial moisture content of the specimen (in %).

5.6.1.3 Calculate the initial voids ratio, e_o, (if required) from the equation

$$e_o = \frac{\rho_s}{\rho_d} - 1$$

where

ρ_s is the particle density (in Mg/m^3), (which may be measured or assumed).

5.6.1.4 Calculate the initial degree of saturation, S_o, (if required) as a percentage from the equation

$$S_o = \frac{w_o \rho_s}{e_o}$$

5.6.1.5 Calculate the voids ratio, e, at the end of the consolidation stage, and at the end of shearing, if required, from the equation

$$e = e_o - \frac{\Delta H}{H_o}(1 + e_o)$$

where

ΔH is the cumulative change in height (vertical deformation) of the specimen (in mm) from the initial zero reading.

5.6.2 *Stresses and displacements*

NOTE See form 7(c) of Appendix A.

5.6.2.1 From each set of data obtained during the shear test calculate the horizontal shear force, P (in N), applied to the specimen.

5.6.2.2 Calculate the shear stress on the surface of shear, τ (in kPa), for each set of readings from the equation

$$\tau = \frac{P}{A} \times 1\,000$$

where

A is the initial plan area of the specimen (in mm^2).

NOTE The continual change in the area of contact is not normally taken into account.

5.6.2.3 The normal stress, σ_n (in kPa), applied to the specimen by a hydraulically-loaded system is obtained from the relationship between measured pressures and load cell readings obtained by calibration. Alternatively a load cell may be used to measure the applied vertical force directly; or the force may be calculated from the pressure gauge reading if the area of the ram is known. For a mechanical lever system the stress on the specimen is calculated from the masses applied to the hanger and the lever magnification ratio (see note to **5.6.2.2**).

5.6.2.4 In the second and subsequent travels of a multi-reversal test, calculate the cumulative forward displacement for each set of readings by adding the observed forward displacement to the cumulative displacement at the end of the previous travel.

5.6.2.5 Calculate the cumulative vertical deformation for each set of readings relative to the datum corresponding to the initial zero reading.

5.6.3 *Graphical plots: single stage test*

NOTE See form 7(d) of Appendix A.

Plot the graphs as described in **4.6.3**.

5.6.4 *Graphical plots: multi-reversal tests*

NOTE See form 7(d) of Appendix A.

Plot the graphs as described in **4.6.4**.

5.7 Test report

The test report shall state that the test was carried out in accordance with clause **5** of BS 1377-7:1990. It shall contain the following, in addition to the information listed in clause **9** of BS 1377-1:1990.

a) statement of the method used, i.e. determination of the shear strength by direct shear in the large shearbox apparatus, using the procedure of **5.5.4** or **5.5.5** of BS 1377-7:1990 whichever is appropriate.

b) the information given in items b) to m) of **4.7**.

6 Determination of residual strength using the small ring shear apparatus

6.1 General

6.1.1 *Principle*. The ring shear apparatus enables an annular specimen of remoulded cohesive soil of 5 mm thickness with internal and external diameters of 70 mm and 100 mm to be subjected to rotational shear while subjected to a vertical stress. In this test it is assumed that c'_r is zero.

The requirements of Part 1 of this standard, where appropriate, shall apply to this test method.

6.1.2 *Test conditions*. The following test conditions shall be specified before a series of tests is started:

a) the moisture content at which the soil is to be remoulded;

b) the number of specimens to be tested as a set;

c) the normal pressures to be applied;

d) the procedure for forming the shear plane.

6.1.3 *Environmental requirements*. These tests shall be carried out in a laboratory in which the temperature is maintained constant to within ± 4 °C, in compliance with **6.1** of BS 1377-1:1990. All apparatus, shall be protected from direct sunlight, from local sources of heat and from draughts.

6.2 Apparatus

6.2.1 *Ring shear apparatus,* consisting of the following:

a) A container for the specimen (the “cell”) which has two concentric rings for rigidly confining the specimen radially with an integral water bath which allows the sample to be submerged during the test. The cell shall be removable from the vertical loading system to allow sample preparation. During shear the lower half of the cell is rotated while the upper is held stationary. The upper and lower rings shall be fitted with porous platens, with clean roughened surfaces to prevent slip at the platen-soil interface. These platens shall be sufficiently rigid to withstand the vertical force without distortion. A typical arrangement is shown in Figure 4(a).

b) A calibrated means of applying a vertical force to the specimen, such as a counter-balanced lever loading system, or a hydraulic or pneumatic loading system.

c) A calibrated deformation dial gauge or displacement transducer readable to 0.002 mm with at least 5 mm travel.

d) A device capable of producing relative rotary motion at a uniform rate between the confining rings and the upper platen by means of a motor and gearbox or other suitable drive system. The device shall provide a range of rates of displacment suitable for the test.

NOTE 1 A suitable machine should cover the speed range 0.03 °/min to 60 °/min.

e) A torque-measuring device, such as one which uses calibrated force measuring rings complying with **4.2.1.6** of BS 1377-1:1990, but other devices may be used.

NOTE 2 The force-measuring devices should be matched so that they have similar characteristics and are substantially linear over the range of forces to be measured.

f) A scale graduated at 1° intervals fixed to the apparatus for measuring the angular rotation of the lower half of the specimen.

A typical general arrangement is shown diagrammatically in Figure 4.

6.2.2 *Thin-bladed palette knife.*

6.2.3 *Balance,* readable to 0.01 g.

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

6.2.5 *Apparatus for moisture content,* as detailed in **3.2** of BS 1377-2:1990.

6.2.6 *Supply of water at laboratory temperature.*

6.2.7 *Evaporating dish.*

6.3 Preparation of test specimen

6.3.1 Weigh the cell assembly empty to 0.1 g.

6.3.2 Prepare a sample of soil weighing at least 400 g, and thoroughly remould it. Remove any particles retained on a 1.18 mm test sieve. If the test moisture content is substantially different from the natural moisture content of the sample it shall be left sealed for 24 h after remoulding to allow the water added to permeate throughout the soil mass. Samples used for this test shall not be oven dried.

6.3.3 Knead the remoulded sample evenly to fill the annular cavity between the confining rings, using a small spatula.

6.3.4 Strike off the excess soil level with the top of the confining rings.

6.3.5 Weigh the cell to 0.1 g with the soil specimen.

6.3.6 Place the cell on the frame of the apparatus.

6.3.7 Determine the moisture content of the excess soil.

6.4 Test procedure

6.4.1 *Initial adjustments*

6.4.1.1 Position the loading yoke on the upper platen and adjust it so that the apparatus is ready for the consolidation stage of the test.

6.4.1.2 Bring the dial gauge or transducer for measurement of vertical deformation into position to bear on top of the load hanger assembly.

6.4.1.3 Record the initial (zero datum) reading of the gauge.

6.4.2 *Consolidation*

6.4.2.1 Apply a suitable vertical force to produce a vertical stress, σ_n' (in kPa), on the specimen, and allow the specimen to consolidate.

NOTE When testing soft clay or when using high normal effective stresses, it will be necessary to consolidate the soil in several stages up to the required normal effective stress. This is to avoid soft soil being squeezed out between the confining rings and the upper platen.

Start the timer at the instant the load is applied to the specimen.

6.4.2.2 Record and plot readings, and determine t_{100} and the maximum rate of displacement (in mm/min) to be applied during the shear test, as described in **4.5.2.3** to **4.5.2.6**. If required calculate the maximum rate of angular displacement (in degrees/min), which is equal to

$$\frac{57.3\ v}{r}$$

where

v is the calculated maximum rate of displacement (in mm/min);

r is the mean radius of the test specimen (in mm).

6.4.3 *Formation of shear plane.* When the consolidation stage is complete align the force rings in accordance with the manufacturers instructions.

6.4.4 *Final adjustments*

6.4.4.1 Form the shear plane by using the motor drive or handwheel (if fitted) to rotate the specimen by one to five revolutions within a period of approximately 2 min.

6.4.4.2 Ensure that any load remaining on the force rings is removed by slightly winding back the handwheel.

6.4.4.3 Allow a period of not less than t_{100} min (as derived in the consolidation stage) for dissipation of the excess pore pressures generated during **6.4.4.1** before proceeding further.

6.4.5 *Shearing*

NOTE See form 7(e) of Appendix A.

6.4.5.1 Adjust the machine to give a rate of displacement not exceeding that calculated in **6.4.2.2**.

NOTE A speed that has been found satisfactory for a large range of soils is 0.048 degrees/min. A rapid assessment of the strain rate sensitivity of the soil can be made during the test by switching off the machine. If the specimen can hold the applied torque, then the test has been made at a rate to which the soil is insensitive and may be deemed satisfactory. A significant loss of torque indicates that the strain rate was too fast and the test should be repeated.

6.4.5.2 Record the initial readings of the shear force, the vertical deformation, and the angular rotation θ (in degrees).

6.4.5.3 Start the machine and record readings of the shear force, the vertical deformation gauge, elapsed time and the angular rotation θ (in degrees) at regular intervals of the latter. The intervals should be such that at least 20 sets of readings are taken in the shear stages.

6.4.5.4 For each set of readings calculate the values of the corrected average linear displacement, D_1, (in mm), and the mean shear stress τ (in kPa), as described in **6.5.1** and **6.5.2**. Plot the values of τ as ordinates against D_1 as abscissae, as the test proceeds.

6.4.5.5 Continue shearing the specimen until the above plot indicates that the residual state has been reached, then stop the machine. Reduce the load on the force-measuring devices to zero.

6.4.5.6 Consolidate the specimen to the next normal effective stress, as described in **6.4.2**, and repeat the procedures given in **6.4.3** and **6.4.4**.

6.4.5.7 Shear the reconsolidated specimen as described in **6.4.5.3** to **6.4.5.5**. (see notes to **6.4.2.1** and **6.4.5.1**).

6.4.5.8 Repeat **6.4.5.6** and **6.4.5.7** to give at least three test stages under normal stresses which cover the desired range of stress.

NOTE In some circumstances it might not be possible to carry out more than three stages.

6.4.6 ***Unloading***

6.4.6.1 When the test is completed switch off the machine and reduce the load on the shear force measuring devices to zero.

6.4.6.2 Siphon the water out of the water container.

6.4.6.3 Remove the vertical stress.

6.4.6.4 Remove the specimen and examine the shear surface.Record any significant features, with the aid of sketches or photographs, or both, if appropriate.

6.4.6.5 Determine the final moisture content of the specimen.

6.5 Calculations

6.5.1 ***Corrected average linear displacement***

6.5.1.1 Calculate the apparent average linear displacement, D (in mm), for each set of readings during the shear test, from the equation

$$D = \frac{\theta r}{57.3}$$

where

- r is the mean specimen radius (in mm);
- θ is the measured angular displacement (in degrees).

6.5.1.2 Calculate the average linear displacement of the upper platen, d (in mm), for each set of readings taken during the shear test, from the equation

$$d = \frac{(A + B)\ Fr}{L}$$

where

- A is the reading of force device A (in divisions or digits);
- B is the reading of force device B (in divisions or digits);
- F is the mean displacement factor for the force device (in mm/division or digits);
- L is the distance between the points of application of the force rings on the torsion beam (in mm) [see Figure 4(b)].

6.5.1.3 Calculate the corrected relative average displacement, D_1 (in mm), from the equation

$$D_1 = D - d$$

6.5.2 *Average shear stress*

NOTE In calculating the stresses it is assumed that the normal stress and the shear stress are uniformly distributed across the plane of relative rotary motion.

Calculate the average stress, τ (in kPa), on the plane of shear for each set of readings taken during the test from the equation

$$\tau = \frac{0.239(A + B)L\ R_F \times 10^3}{(r_2^3 - r_1^3)}$$

where

- A is the reading of force dial A (in division or digits);
- B is the reading of force dial B (in divisions or digits);
- R_F is the mean force ring factor (in N/divisions or digits);
- L is the distance between the points of application of the force rings on the torsion beam (in mm);
- r_1 is the inside specimen radius (in mm);
- r_2 is the outside specimen radius (in mm).

6.5.3 *Residual strength*

6.5.3.1 For each test run determine the residual shear stress, τ_r (in kPa), from the graphical plot of τ against D_1.

6.5.3.2 Plot each value of τ_r from the set of tests as ordinates against the corresponding normal applied effective stress σ_n' (in kPa) as abscissae, both to the same linear scale.

6.5.3.3 Derive the value of residual strength φ'_R from this plot on the assumption that c'_R is zero.

6.6 Test report

The test report shall state that the test was carried out in accordance with clause **6** of BS 1377-7:1990. It shall contain the following, in addition to the information listed in clause **9** of BS 1377-1:1990.

a) statement of the method used, i.e. the ring shear test method;

b) dimension of test specimen (inner and outer radii and initial thickness);

c) initial and final moisture contents of the specimen;

d) rate of angular displacement (in radians/min), (or average linear displacement, in mm/min), applied during the shear test;

e) tabulated values of the applied normal effective stress, σ_n', the residual shear stress, τ_r, and the cumulative angular, or mean linear, displacement at the end of each shearing stage;

f) graphical plots of residual shear stress against applied normal effective stress;

g) the angle of residual shear resistance, to the nearest 0.5°;

h) graphical plots of change in specimen thickness against square-root time for each consolidation stage;

i) graphical plots of mean shear stress, and change in specimen thickness, against relative average linear displacement for each shearing stage.

7 Determination of the unconfined compressive strength

7.1 General

7.1.1 *Principle.* In the unconfined compression test a cylindrical specimen of cohesive soil is subjected to a steadily increasing axial compression until failure occurs. The axial force is the only force applied to the specimen. The test is normally carried out on 38 mm diameter specimens, but can also be performed on specimens up to 100 mm diameter.

The test provides an immediate approximate value of the compressive strength of the soil, either in the undisturbed or the remoulded condition, it is carried out within a short enough time to ensure that no drainage of water is permitted into or out of the specimen. It is suitable only for saturated, non-fissured cohesive soils.

7.1.2 *Failure criteria.* The maximum value of the compressive force per unit area which the specimen can sustain is referred to as the unconfined compressive strength of the soil.

In very plastic soils in which the axial stress does not readily reach a maximum value, an axial strain of 20 % is used as the criterion of failure.

7.1.3 *Types of test.* Two methods are given for determining the unconfined compressive strength. The first is the definitive method using a load frame, in which specimens of any suitable diameter can be tested. The second makes use of an autographic apparatus.

7.2 Load frame method

7.2.1 *General.* This test covers the determination of the unconfined compressive strength of cohesive soil using a load frame apparatus. The test is normally carried out on cylindrical specimens of a length equal to about twice the diameter.

NOTE Nominal specimen diameters normally range from 38 mm to 100 mm. The specimen length should be as close to twice the diameter as the nature of the soil and the end preparation will permit. The length may vary from 8 % under-size to 12 % over-size without significantly affecting the results.

The requirements of Part 1 of this standard, where appropriate, shall apply to this test method.

7.2.2 ***Apparatus***

7.2.2.1 *Hand-operated or motorized machine,* capable of applying axial compression to the specimen at a suitable rate of displacement. The actual rate of platen displacement shall not vary by more than ± 20 % of the rate specified in **7.2.4.7**. The machine shall be capable of providing an axial compression of about one-third of the height of the specimen tested.

NOTE 1 Essential requirements of the compression test apparatus are shown in Figure 5.

NOTE 2 An alternative arrangement would be to mount the specimen in a triaxial cell as described in clause **8**, without the addition of pressurizing fluid to the cell, provided that piston friction can be taken into account.

7.2.2.2 *Calibrated means of measuring the axial compression of the specimen*, readable to 0.01 mm, such as a suitably mounted micrometer dial gauge (the axial strain gauge).

7.2.2.3 *Calibrated force-measuring device*

NOTE The force-measuring device may be a load ring or force transducer. Several devices of this kind, of various capacities, should be available, and the one selected for test should be appropriate to the strength of the soil specimen.

The device shall be supported by the crosshead of the compression machine so as to prevent its own weight being transferred to the test specimen.

7.2.2.4 *Two flat smooth solid platens* of the same diameter of the test specimen or larger, through which the axial force is transmitted.

NOTE Plastics end caps of not less than 20 mm thickness are usually satisfactory for specimens up to 50 mm diameter for soft or very soft soils. Metal end caps 10 mm to 20 mm thick are preferable for stiff soils.

The platens may be attached to the compression machine.

7.2.2.5 *Timer*, readable to 1 s.

7.2.2.6 *Balance*, readable to 0.1 g.

7.2.2.7 *Apparatus for determination of moisture content* in accordance with **3.2** of BS 1377-2:1990.

7.2.2.8 *Calibrated means of measuring the specimen dimensions*, to an accuracy of 0.5 %.

7.2.3 *Preparation of test specimens*. Prepare the undisturbed cylindrical specimens for compression tests using the procedure described in **8.3** of BS 1377-7:1990.

7.2.4 ***Test procedure***

NOTE See form 7(f) of Appendix A.

7.2.4.1 Determine the mass of the prepared test specimen to the nearest 0.1 g.

7.2.4.2 Make at least three measurements of the length and of the diameter of the specimen to the nearest 0.1 mm, and determine the average dimensions.

7.2.4.3 Place the specimen centrally on the pedestal of the compression machine between the upper and lower platens. Avoid disturbance especially if the specimen is soft, and avoid loss of moisture from the soil.

7.2.4.4 Adjust the machine so that contact is just made between the specimen, upper platen and the force measuring device.

NOTE A small seating force indicated by the force-measuring device confirms when contact is made. This force is included as part of the force applied to the specimen.

7.2.4.5 Adjust the axial deformation gauge to read zero or a convenient initial reading.

7.2.4.6 Record the initial readings of the force and compression gauges.

7.2.4.7 Select a rate of axial deformation such that the rate of axial strain does not exceed 2 %/min.

NOTE Stiff soils which fail at small deformations should be tested at a lower rate of strain than soft soils which require large deformations to produce failure. A suitable rate of strain usually lies between 0.5 % and 2 %/min.

7.2.4.8 Apply compression to the specimen at the selected rate and record simultaneous readings of the force-measuring device and the axial deformation gauges at regular intervals of compression, e.g. corresponding to each 0.5 % strain. Obtain at least 12 sets of readings in order to define the stress-strain curve.

NOTE Stiff and brittle soils fail at small strains, therefore readings of deformation should be recorded at frequent intervals of force, otherwise not enough readings will be taken before failure.

7.2.4.9 Continue the test until the maximum value of the axial stress (calculated as in **7.2.5.3**) has been passed, or the axial strain reaches 20 %.

NOTE It is convenient to make a plot representing axial stress versus compressive strain as the test proceeds, to enable the point at which failure occurs to be seen. A special barrelling-correction grid of the type shown in Figure 6 enables this to be done directly from readings of the force-measuring device without the need for calculations.

7.2.4.10 Remove the load from the specimen and record the final reading of the force measuring gauge as a check on the initial reading.

7.2.4.11 Make a sketch of the test specimen to indicate its mode of failure.

7.2.4.12 Remove the whole of the specimen from the apparatus, and determine its moisture content using the procedure of **3.2** of BS 1377-2:1990. Alternatively, for a large specimen take selected portions of material for this purpose.

7.2.5 ***Calculations and plotting***

NOTE See form 7(f) of Appendix A.

7.2.5.1 Calculate the axial strain, ϵ, of the specimen for each set of readings from the equation

$$\epsilon = \frac{\Delta L}{L_o}$$

where

ΔL is the change in length of the specimen as indicated by the axial deformation gauge (in mm);

L_o is the initial length of the specimen (in mm).

7.2.5.2 Calculate the force, P (in N), applied to the specimen for each set of readings by multiplying the change in reading of the force-measuring device from zero load (in divisions of digits) by the relevant load calibration factor (in N/division or N/digit).

7.2.5.3 Calculate the axial compressive stress, σ_1 (in kPa), in the specimen for each set of readings, on the assumption that the specimen deforms as a right cylinder, from the equation

$$\sigma_1 = \frac{P\,(1-\epsilon)}{A_o} \times 1000$$

where

A_o is the initial cross-sectional area of the specimen (in mm^2).

7.2.5.4 Plot calculated values of compressive stress as ordinates against corresponding values of strain (expressed as a percentage) as abscissae, and draw the stress-strain curve through the points.

7.2.5.5 Ascertain the point on the graph representing the failure condition, which is the point at which the maximum compressive stress sustained by the specimen occurs, or the point corresponding to a strain of 20 % if that occurs first.

NOTE If either of these points lies between two sets of observed readings their values should be interpolated from the graph.

7.2.5.6 Using that point, determine the compressive stress in the specimen at failure, referred to as the unconfined compressive strength, q_u (in kPa).

7.2.5.7 Determine the axial strain of the specimen at failure.

7.2.5.8 Calculate the moisture content, bulk density and dry density of the test specimen.

7.2.6 *Test report.* The test report shall state that the test was carried out in accordance with **7.2** of BS 1377-7:1990. It shall contain the following, in addition to the information listed in clause **9** of BS 1377-1:1990.

a) statement of the method used, i.e. determination of the unconfined compressive strength using the load frame method;

b) the unconfined compressive strength of the specimen, q_u (in kPa), to two significant figures;

c) the strain at failure (in %), to two significant figures;

d) rate of strain (in %/min) applied;

e) dimensions of the test specimen;

f) moisture content (in %) and bulk density (in Mg/m^3) of the test specimen;

g) sketch indicating the mode of failure of the specimen;

h) method of preparation of the test specimen;

i) if required, the stress/strain curve.

7.3 Autographic method

7.3.1 *General.* This test covers the determination of the unconfined compressive strength of cohesive soil by means of a portable apparatus, and is intended as a site test. The test is normally carried out on cylindrical specimens 38 mm in diameter and 76 mm long and is suitable for saturated non-fissured cohesive soil such as soft clays.

NOTE The length of the specimen should be as close to 76 mm as the nature of the soil and the end preparation will permit. The length may vary from 70 mm to 85 mm without significantly affecting the results but appropriate allowance should be made when calculating strain.

The requirements of Part 1 of this standard, where appropriate, shall apply to this test method.

7.3.2 ***Apparatus***

7.3.2.1 *Portable autographic compression apparatus,* comprising the following.

a) A portable compression apparatus for applying force manually by a rotary handle and lead screw through a calibrated spring (see item d) of **7.3.2.1**) to a specimen mounted between two flat smooth metal platens of about 50 mm diameter. A suitable apparatus is illustrated in Figure 7. The force applied to the specimen and the corresponding compression of the specimen shall be recorded autographically on a chart.

b) A supply of charts to suit the recording device of the instrument. A chart for the type of instrument illustrated is shown in Figure 8.

c) If the graduations printed on the chart do not make allowance for the effect of the assumed increase in cross-sectional area occurring in the test, an overlay mask of transparent material, of the form shown in Figure 9, shall be used. The curves on the mask enable a value to be read off from the test curve which is directly related to the maximum compressive stress applied to the specimen.

d) A selection of calibrated springs. Four springs having nominal stiffnesses of about 2 N/mm, 4 N/mm, 8 N/mm and 16 N/mm are normally adequate. Calibration to an accuracy of 5 % of the indicated force for the upper 90 % of the working range is acceptable.

e) Apparatus for determination of moisture content in accordance with **3.2** of BS 1377-2:1990.

f) A balance, readable to 0.5 g.

7.3.2.2 *Sample extruder.*

7.3.2.3 *Split mould* nominally 38 mm internal diameter by nominally 76 mm long with machined ends (optional).

7.3.2.4 *Knife or wire* for cutting the sample.

7.3.2.5 *Steel rule* readable to 0.5 mm, or vernier calipers.

7.3.2.6 *Metal straightedge.*

7.3.2.7 *Lubricating oil of a light grade.*

7.3.3 *Preparation of test specimen.* Prepare the test specimen using the procedure described in **8.3** of BS 1377-1:1990.

7.3.4 *Test procedure*

7.3.4.1 Assemble the test apparatus, fitting a spring appropriate to the anticipated strength of the specimen such that failure will occur within the calibrated range.

NOTE The spring selected should have sufficient stiffness to cause the specimen to fail within the range of deformation permitted by the apparatus but should not be stiffer than necessary in order to achieve a reasonable sensitivity.

7.3.4.2 Place the test chart in the chart frame to the correct alignment.

7.3.4.3 Place the specimen centrally on the lower platen, and rotate the handle to bring the top of the specimen into contact with the top platen and in correct alignment.

7.3.4.4 Adjust the apparatus to bring the recording pencil on to the zero deflection line of the chart, and mark the datum corresponding to zero load.

7.3.4.5 Apply axial force to the specimen by rotating the handle at a steady rate until the specimen fails. Ensure that the rate of deformation of the specimen is approximately 8 mm/min, the aim being to achieve a test time of about 2 min for a specimen failing at 20 % strain.

7.3.4.6 Continue the test until the maximum compressive stress has been passed, or in the event of plastic failure which does not exhibit a maximum strength, until a strain of 20 % has been reached.

7.3.4.7 Remove the load from the specimen and sketch its mode of failure. Remove the chart from the frame.

7.3.4.8 Determine the moisture content of the specimen in accordance with **3.2** of BS 1377-2:1990.

7.3.5 ***Calculations***

7.3.5.1 From the test chart ascertain the point representing the failure condition, which is the point at which the maximum compressive stress sustained by the specimen occurs, or the point corresponding to a strain of 20 % if that occurs first.

NOTE The overlay mask may be used, or some other means which makes allowance for the increase in cross-sectional area of the specimen during the test (see **7.2.5.3**).

7.3.5.2 Derive the compressive stress in the specimen at failure, referred to as the unconfined compressive strength, q_u (in kPa) (see note to **7.3.5.1**).

7.3.5.3 Determine the axial deformation of the specimen at failure, and calculate the corresponding strain.

7.3.5.4 Calculate the moisture content, bulk density and dry density of the test specimen.

7.3.6 *Test report.* The test report shall state that the test was carried out in accordance with **7.3** of BS 1377-7:1990. It shall contain the following, in addition to the information listed in clause **9** of BS 1377-1:1990.

a) statement of the method used, i.e. determination of the unconfined compressive strength using the portable autographic apparatus;

b) the unconfined compressive strength, q_u (in kPa), of the soil specimen, to two significant figures;

c) strain at failure, as a percentage of the original length, to two significant figures;

d) dimensions of the test specimen;

e) moisture content (in %) and bulk density (in Mg/m^3) of the test specimen;

f) mode of failure of the specimen;

g) the autographic plot.

8 Determination of the undrained shear strength in triaxial compression without measurement of pore pressure (definitive method)

8.1 General

8.1.1 *Principle.* This method covers the determination of the undrained strength of a specimen of cohesive soil when it is subjected to a constant confining pressure and to strain-controlled axial loading, when no change in total moisture content is allowed. Tests are usually carried out on a set of similar specimens, subjected to different confining pressures.

8.1.2 *Type of test.* The test is carried out in the triaxial apparatus on specimens in the form of right cylinders of height approximately equal to twice the diameter. Specimen diameters range from 38 mm to about 110 mm.

NOTE The diameter of the specimen should be selected with regard to the character of the soil and the maximum size of particle present in the sample. Specimens of 38 mm diameter are usually suitable only for homogeneous fine-grained cohesive soils. In general the largest practicable specimen size should be used. This test is not applicable to specimens of less than 35 mm diameter.

In the test the specimen is confined in an impervious membrane between impervious end caps in a triaxial cell which can be pressurized by water. The axial load is increased by applying a constant rate of strain until the specimen fails, normally within a period of 5 min to 15 min.

The requirements of Part 1 of this standard, where appropriate, shall apply to this test method.

8.1.3 *Test conditions.* The following test conditions shall be specified before starting a series of tests:

a) size of test specimens;

b) number of specimens to be tested;

c) cell confining pressures;

NOTE For a set of tests on three similar specimens of undisturbed normally-consolidated soil, cell pressures of about $0.5\sigma_v$, σ_v and $2\sigma_v$ might be appropriate, where σ_v is the total vertical in-situ stress. The pressure used should cover the range of vertical stress likely to be experienced by the soil in-situ.
For compacted soils the cell pressures should be related in a similar manner to the estimated total stresses likely to occur in the field conditions.
For over-consolidated clays the lowest cell pressure should not normally be less than the total vertical in-situ stress.

d) whether undisturbed or remoulded specimens are to be tested;

e) for remoulded specimens the moisture content, and either the dry density to be achieved or the compactive effort to be applied.

8.2 Apparatus

8.2.1 *Triaxial cell,* of dimensions appropriate to the size of the test specimen, suitable for use with water at internal working pressures required to perform the test. A gas shall not be used for pressurizing the cell.

The main features of the cell are shown diagrammatically in Figure 10 and are as follows

a) Cell top plate of corrosion-resistant material fitted with an air bleed plug and close-fitting piston guide bushing.

b) Loading piston for applying axial compressive force to the specimen. Lateral bending of the piston during a test shall be negligible. Friction between the piston or seal and its bushing shall be small enough to allow the piston to slide freely under its own weight when the cell is empty.

NOTE 1 The piston should be perfectly clean and lightly oiled.

The clearance between the piston and its bushing or seal shall minimize leakage from the cell.

c) Cylindrical cell body which shall be removable for inserting the specimen, and shall be adequately sealed to the top plate and base plate.

NOTE 2 The cylinder should preferably be made of a transparent material, or fitted with viewing ports, so that the specimen can be observed during the test.

d) Cell base of corrosion-resistant rigid material incorporating a connection port as shown in Figure 10.

8.2.2 *Apparatus for applying and maintaining the desired pressure* on the water within the cell to an accuracy of ± 5 kPa with a gauge of test grade for measuring the pressure.

NOTE Pressure systems dependent on air pressure regulators, self- compensating mercury pots (see warning, **5.3.2** of BS 1377-1:1990), dead-weight pressure cells and oil pressure regulators have been successfully used. Their capacity to supply or take in water should be enough to compensate for cell leakage.

The gauge shall comply with **4.2.1.7** of BS 1377-1:1990.

8.2.3 *Machine capable of applying axial compression at a uniform rate* to the specimen at a convenient speed within the range 0.05 mm/min to 4 mm/min. The machine shall be capable of applying an axial deformation of about one-third the height of the specimen tested.

8.2.4 *Means of measuring the axial deformation of the specimen,* readable to 0.01 mm, complying with **4.2.1.3** of BS 1377-1:1990.

NOTE The axial deformation measuring device may consist of a dial gauge or a displacement transducer.

8.2.5 *Calibrated force-measuring device,* supported by the crosshead of the compression machine so as to prevent its own weight being transferred to the test specimen.

NOTE 1 The force-measuring device may be a load ring, a force transducer, or a submersible transducer mounted inside the triaxial cell.

NOTE 2 A range of calibrated force-measuring devices should be available so that the one best suited to the specimen strength can be selected.

8.2.6 *Rigid corrosion resistant or plastics end caps* of the same diameter as the test specimen. A self-aligning seating shall be provided between the top end cap and the loading ram.

8.2.7 *Tubular membrane* of high density latex to enclose the specimen and provide protection against leakage from the cell fluid. The unstretched internal diameter shall not be less than 90 % of the specimen diameter nor greater than the specimen diameter. The length shall be sufficient to cover the specimen and end caps. The membrane thickness shall not exceed 1 % of the specimen diameter.

NOTE Membranes of natural latex rubber are generally used. For specimens up to 50 mm diameter a thickness of 0.2 mm is suitable, and for larger specimens a greater thickness is desirable. Two or more membranes separated by silicone grease or rubber may be fitted where there is danger of puncturing by angular particles.

Before use the membrane shall be checked visually for imperfections, and faulty membranes shall be discarded.

8.2.8 *Membrane stretcher,* to suit the size of the specimen.

8.2.9 *Two rubber O-rings,* for sealing each end of the membrane on to the top cap and base pedestal. The O-rings shall be of an unstretched diameter of between 80 % and 90 % of the specimen diameter. They shall be free from flaws and necking when stretched.

8.2.10 *Apparatus for determination of moisture content,* as described in **3.2** of BS 1377-2:1990.

8.3 Preparation of specimens

8.3.1 *General.* The specimen shall have a height equal to about twice the diameter, with plane ends normal to the axis.The size of the largest soil particle shall not be greater than one-fifth of the specimen diameter.

NOTE If after test a specimen is found to contain larger particles the size and mass of these inclusions should be reported.

Specimens may be of undisturbed soil, or of disturbed soil that has been prepared under specified conditions.

8.3.2 *Preparation of undisturbed specimens*

8.3.2.1 Remove the soil from its sampling tube or container and make a careful inspection to ascertain its condition. Report any indication of local softening, disturbance, presence of large particles, or other non-uniformity. If these features cannot be avoided use an alternative sample for preparing the test specimens.

NOTE If features such as these occur naturally a larger specimen would be more representative of the soil as a whole.

8.3.2.2 Protect the soil from loss of moisture during preparation.

8.3.2.3 Prepare the specimen in accordance with clause **8** of BS 1377-1:1990.

NOTE The method of preparation depends on the type of sample received and the size of test specimen required. Methods for the following categories of specimen are described in Part 1.

a) Specimen of the same diameter as the sampling tube (see **8.3** of BS 1377-1:1990).

b) Specimen or set of specimens of smaller diameter than the sampling tube (see **8.4** of BS 1377-1:1990).

c) Specimen hand-trimmed from a block sample (see **8.5** of BS 1377-1:1990).

8.3.2.4 When a set of specimens is required for testing at different confining pressure select the specimens so that they are all similar. Record the location and orientation of each specimen within the block sample.

8.3.2.5 Measure the length L_0 (in mm), diameter D_0 (in mm) and mass m (in g) of each prepared specimen with sufficient accuracy to enable the bulk density to be calculated to an accuracy of ± 1 %.

8.3.2.6 Place the specimen that is to be tested first between end caps in the membrane (as described in **8.4.1**) as quickly as possible to prevent loss of moisture. Seal the specimens that are not to be tested immediately to prevent loss of moisture.

NOTE Moisture loss from soil not being used immediately should be prevented by wrapping in thin clinging plastics film.

8.3.2.7 After preparing the test specimens, break open the remainder of the sample and record a detailed description of the soil fabric.

8.3.3 *Preparation of compacted and remoulded specimens*

NOTE Specimens of a compacted soil are normally prepared in the laboratory by compaction into a mould.

8.3.3.1 Prepare the soil for compaction as described in **7.7.2** of BS 1377-1:1990.

NOTE 1 The degree of compaction to be applied when compacting the soil to form specimens should relate to field conditions (see **7.7.3** of BS 1377-1:1990).

NOTE 2 The compactive effort applied is usually equivalent to that used in one of the compaction tests described in clause **3** of BS 1377-4:1990.

8.3.3.2 Prepare the test specimens by one of the following procedures.

a) For a compacted sample from which a set of specimens of smaller diameter is taken, either compaction criterion a) or b) of **7.7.3** of BS 1377-1:1990 is suitable. Carry out the procedure as described in **7.7.4** and **8.4** of BS 1377-1:1990.

b) For a compacted single specimen of large diameter (e.g. 100 mm), either compaction criterion a) or b) of **7.7.3** of BS 1377-1:1990 is suitable. Carry out the procedure as described in **7.7.5** of BS 1377-1:1990. Mount the specimen on the triaxial base pedestal (see **8.4.1**) before removing the split mould.

c) For a compacted single specimen, or remoulded specimen, of small diameter (e.g. 38 mm), compaction criterion a) may be difficult to control, but criterion b) is suitable (see **7.7.3** of BS 1377-1:1990). Place the soil in the split mould in at least three layers and compact each layer with the tamping rod. Use a controlled effort, determined by trial beforehand, to achieve the desired specimen density. Mount the specimen on the triaxial pedestal (see **8.4.1**) before removing the split mould.

8.3.3.3 Measure the length L_0 (in mm), diameter D_0 (in mm) and mass m_0 (in g) of each prepared specimen to an accuracy of ± 2 %.

NOTE If necessary, weigh the specimen in the split mould, and the mould separately. Determine the specimen dimensions from the internal measurements of the split mould.

8.3.3.4 When a set of similar specimens has been prepared for testing at different effective confining pressures, mount the specimen that is to be tested first on the triaxial base pedestal (as described in **8.4.1**) as quickly as possible. Seal the specimens that are not to be tested immediately to prevent loss of moisture.

8.4 Test procedure

8.4.1 *Setting up*

8.4.1.1 Mount a triaxial test specimen prepared by one of the procedures given in **8.3.2** to **8.3.3** as described in **8.4.1.2** to **8.4.1.8**.

8.4.1.2 Place the specimen on the base end cap and place the top cap on the specimen.

NOTE Alternatively, **8.4.1.2** to **8.4.1.5** may be carried out after placing the base end cap on the triaxial pedestal.

8.4.1.3 Fit the membrane evenly on the stretcher.

8.4.1.4 Place the membrane around the specimen while applying suction to the stretcher.

8.4.1.5 Seal the membrane to the end caps by means of rubber O-rings, without entrapping air.

8.4.1.6 Place the specimen centrally on the base pedestal of the triaxial cell, ensuring that it is in correct vertical alignment.

8.4.1.7 Assemble the cell body with the loading piston well clear of the specimen top cap. Check alignment by allowing the piston to slide down slowly until it makes contact with the bearing surface on the top cap, then retract the piston. If necessary remove the cell body and correct any eccentricity.

8.4.1.8 Fill the triaxial cell with water, ensuring that all the air is displaced through the air vent (Figure 10).

8.4.2 ***Pressurizing the cell***

8.4.2.1 Pressurize the triaxial cell and make final adjustments as described in **8.4.2.2** to **8.4.2.5**.

8.4.2.2 Raise the water pressure in the cell to the desired value with the loading piston restrained by the load frame or force-measuring device.

8.4.2.3 Adjust the loading machine to bring the loading piston to within a few millimetres of its seating on the specimen top cap. Record the reading of the force-measuring device during steady motion as the initial reading.

8.4.2.4 Adjust the machine further to bring the loading piston just into contact with the seating on the top cap. Record the reading of the axial deformation gauge.

NOTE Where the type of gauge permits, the scale of the axial deformation gauge may be adjusted to read zero so that the axial compression is then registered directly as a gauge reading.

8.4.2.5 Select a rate of axial deformation such that failure is produced within a period of 5 min to 15 min. Engage the appropriate gear on the compression machine.

8.4.3 ***Compression test***

NOTE See form 7(g) of Appendix A.

8.4.3.1 Start the test by switching on the machine.

8.4.3.2 Record readings of the force-measuring device and the deformation gauge at regular intervals of the latter, so that at least 15 sets of readings are recorded up to the point of failure.

NOTE 1 Suitable intervals for a soil of medium compressibility are typically 0.25 % strain up to 1 % strain, and 0.5 % strain thereafter. For a very stiff soil which is likely to fail suddenly at a small strain, readings should be taken at frequent intervals of force rather than of strain to obtain the required number of readings.

NOTE 2 It is convenient to make a plot representing axial stress versus compressive strain as the test proceeds, to enable the point at which failure occurs to be seen. A special barrelling-correction grid of the type shown in Figure 6 enables this to be done directly from readings of the force-measuring device without the need for calculations.

Verify that the cell pressure remains constant.

8.4.3.3 Continue the test until the maximum value of the axial stress has been passed and the peak is clearly defined, or until an axial strain of 20 % has been reached.

8.4.4 ***Unloading and removal***

8.4.4.1 Stop the test and remove the axial force.

8.4.4.2 Drain the water from the cell, dismantle the cell and remove the specimen.

8.4.4.3 Remove the rubber membrane from the specimen and record the mode of failure with the aid of a sketch.

8.4.4.4 Break open the specimen and record a description of the soil including its fabric.

NOTE **8.4.4.3** and **8.4.4.4** should be completed without delay to avoid loss of moisture from the specimen.

8.4.4.5 Determine the moisture content of the whole specimen, or of representative portions, using the procedure described in **3.2** of BS 1377-2:1990. If there are surfaces of failure, moisture content specimens should be taken from zones adjacent to them.

8.5 Plotting and calculations

8.5.1 Individual specimens

NOTE See form 7(g) of Appendix A.

8.5.1.1 From each set of readings calculate the axial force, P (N), applied to the specimen by multiplying the difference between that reading and the initial reading (see **8.4.2.3**) of the gauge on the force-measuring device (divisions or digits) by its calibration factor (in N/division or N/digit).

8.5.1.2 Calculate the cross-sectional area, A (mm^2), of the specimen, on the assumption that it deforms as a right cylinder, from the equation:

$$A = \frac{A_o}{1 - \epsilon}$$

where

A_o is the initial cross-sectional area of the specimen (in mm^2) calculated from the initial diameter D_o;

ϵ is the axial strain, equal to $\frac{\Delta L}{L_o}$

where

L_o is the initial length of the specimen (in mm);

ΔL is the change in length measured by the axial deformation gauge (in mm).

8.5.1.3 Calculate the principal stress difference, i.e. the deviator stress, $(\sigma_1 - \sigma_3)$ (in kPa), for sufficient sets of readings to enable the maximum value to be derived, from the equation

$$(\sigma_1 - \sigma_3) = \frac{P}{A} \times 1\ 000$$

NOTE For some applications a graphical plot of deviator stress (in kPa) against axial strain (in %) may be required.

8.5.1.4 Apply a correction to the calculated maximum deviator stress to allow for the restraining effect of the membrane, if appropriate. The correction is obtained directly from Figure 11, at the strain corresponding to failure, for specimens 38 mm diameter fitted within a membrane of latex rubber 0.2 mm thick when a predominantly barrelling type of deformation occurs. For specimens of any other diameter, D (in mm), and latex rubber membranes of any other thickness, t (in mm) (which may be made up of more than one membrane), multiply the correction derived from Figure 11 by a factor equal to

$$\frac{38}{D} \times \frac{t}{0.2}$$

Subtract the membrane correction from the calculated maximum deviator stress $(\sigma_1 - \sigma_3)_{max.}$, to give the corrected deviator stress, denote by $(\sigma_1 - \sigma_3)_f$.

8.5.1.5 Calculate the value of the shear strength, C_u (in kPa), from the equation

$$C_u = ½(\sigma_1 - \sigma_3)_f$$

NOTE For some applications a graphical plot of deviator stress (in kPa) against axial strain (in %) may be required.

8.5.1.6 Calculate the bulk density of the specimen ρ (in Mg/m^3), from the equation

$$\rho = \frac{1000\ m_o}{A_o L_o}$$

where

m_o is the mass of the specimen (in g).

8.6 Test report

The test report shall state that the test was carried out in accordance with clause **8** of BS 1377-7:1990. It shall contain the following, in addition to the information listed in clause **9** of BS 1377-1:1990.

a) statement of the method used, i.e. determination of the undrained shear strength in triaxial compression;

b) initial specimen dimensions;

c) whether undisturbed or remoulded specimens, and the method of specimen preparation;

d) initial moisture content, bulk density and dry density of the specimen;

e) depth and orientation of test specimen within the original sample;

f) rate of strain (in %/min) applied during the test;

g) thickness and type of membrane used, and correction applied;

h) tabulated data relating to the specimen at failure, comprising:

1) cell pressure, σ_3 (in kPa);

2) corrected maximum deviator stress at failure, $(\sigma_1 - \sigma_3)_f$ (in kPa), to the nearest whole number;

3) strain at failure (in %);

4) mode of failure;

5) value of $c_u = ½(\sigma_1 - \sigma_3)_f$ (in kPa) to the nearest whole number;

i) when two or more similar specimens are tested as a set, the above data for each specimen shall be tabulated.

9 Determination of the undrained shear strength in triaxial compression with multistage loading and without measurement of pore pressure

9.1 General

9.1.1 *Principle.* This method covers the determination of the undrained compressive strength of a specimen of cohesive soil when it is subjected to a constant all-round confining pressure and to strain-controlled axial loading, when no change in total moisture content is allowed. The method provides a means of determining the relationship between undrained shear strength and confining pressure from a single specimen.

The method shall not be used for brittle or sensitive soils.

9.1.2 *Type of test.* The test is carried out in the triaxial apparatus on a specimen in the form of a right cylinder of a height approximately equal to twice the diameter. The specimen is usually of the same diameter (typically about 100 mm) as the undisturbed sample taken from the ground, or of a suitably large diameter if obtained by other means.

In the test the specimen is confined in an impervious membrane between impervious end caps in a triaxial cell which can be pressurized by water. The axial load is increased in (usually three) stages by applying a constant rate of strain until the maximum vertical stress is virtually reached, each stage under a different confining pressure.

The requirements of Part 1 of this standard, where appropriate, shall apply to this test method.

9.1.3 *Test conditions.* The following test conditions shall be specified before starting the test:

a) size of test specimen;

b) cell confining pressure for each stage;

NOTE Cell pressures of about $0.5\sigma_v$, σ_v and $2\sigma_v$ might be appropriate, where σ_v is the total vertical in-situ stress. The pressure used should cover the range of vertical stress likely to be experienced by the soil in-situ.
For compacted soils the cell pressures should be related in a similar manner to the estimated total stresses likely to occur in the field conditions.

For over-consolidated clays the lowest cell pressure should not normally be less than the total vertical in-situ stress.

c) whether an undisturbed or remoulded specimen is to be tested;

d) for a remoulded specimen the moisture content, and either the dry density to be achieved or the compactive effort to be applied.

9.2 Apparatus

The apparatus is the same as that described in **8.2**.

9.3 Preparation of specimens

Prepare undisturbed samples for test as described in **8.3.1** and **8.3.2**. Prepare compacted and remoulded specimens as described in **8.3.1** and **8.3.3.2** a) or b) of this Part, and in **7.7.5** of BS 1377-1:1990. Ensure that the length of the specimen is twice the specimen diameter.

9.4 Test procedure

9.4.1 *Setting up.* Carry out the procedure as described in **8.4.1**.

NOTE Because the multistage test is likely to extend to a large strain, and especially if the soil contains gravel-sized material, it is desirable to fit two membranes to the test specimen.

9.4.2 *Pressurizing the cell.* Carry out the procedure as described in **8.4.2.1** to **8.4.2.4**.

9.4.3 *Multistage compression test.*

NOTE See form 7(g) of Appendix A.

9.4.3.1 Start the test by switching on the machine.

9.4.3.2 Record readings of the force gauge and the compression gauge at regular intervals of the latter, so that at least 15 sets of readings are recorded up to the point of failure.

NOTE Suitable intervals for a soil of medium compressibility are typically 0.25 % strain up to 1 % strain, and 0.5 % strain thereafter. Readings should be recorded at closer intervals when approaching the maximum load.

If it is convenient, as the test proceeds make a plot of calculated deviator stress against strain, or of force gauge reading against strain on a barrelling correction grid sheet of the type shown in Figure 6 so that impending failure can be identified.

9.4.3.3 When the readings or the plotted points show that a maximum stress is imminent, increase the cell pressure to the next value and continue taking readings without stopping the machine. Record the point at which the cell pressure is changed.

NOTE For a soil that does not show a pronounced maximum stress by the time 20 % strain is reached, the test should be terminated and reported as for a single-stage test.

9.4.3.4 Repeat **9.4.3.3** when the next maximum stress is indicated.

9.4.3.5 Continue the test until the maximum deviator stress is clearly defined with the stress decreasing, or until a strain of 20 % is reached.

9.4.4 ***Unloading and removal***

9.4.4.1 At the end of the final loading stage remove the axial force from the specimen and lower the machine platen so that the top cap is well clear of the ram.

9.4.4.2 Re-start the machine in the upward direction and record the reading of the force measuring device when it becomes steady. This is the initial force reading for the final loading stage.

9.4.4.3 Reduce the cell pressure in turn to each of the other pressures that were used in the test, and repeat **9.4.4.2** at each pressure.

9.4.4.4 Reduce the cell pressure to zero, drain the water from the cell, dismantle the cell and remove the specimen.

9.4.4.5 Take off the membrane from the specimen and record the mode of failure with the aid of a sketch.

9.4.4.6 Break open the specimen and record a description of the soil including its fabric.

NOTE **9.4.4.5** and **9.4.4.6** should be completed without delay to avoid loss of moisture from the specimen.

9.4.4.7 Determine the moisture content of the specimen from representative portions, in accordance with the procedure described in **3.2** of BS 1377-2:1990.

9.5 Plotting and calculations

NOTE See form 7(g) of Appendix A.

9.5.1 For each stage of the test calculate the difference between each reading of the gauge on the force-measuring device (in divisions or digits) and the corresponding initial force reading, derived as in **9.4.4.2** and **9.4.4.3**.

9.5.2 Multiply that difference by the appropriate calibration factor (in N/division or N/digit) of the force-measuring device to obtain the axial force P (in N), applied to the specimen.

9.5.3 Calculate the cross-sectional area, A (in mm^2), of the specimen, on the assumption that it deforms as a right cylinder, from the equation

$$A = \frac{A_o}{1 - \epsilon}$$

where

A_o is the initial cross-sectional area of the specimen (in mm^2) calculated from the initial diameter D_o;

ϵ is the cumulative axial strain, equal to $\frac{\Delta L}{L_o}$

where

L_o is the initial length of the specimen (in mm);

ΔL is the cumulative change in length of the specimen measured by the axial deformation gauge (in mm).

9.5.4 Calculate the principal stress difference, i.e. the deviator stress, $(\sigma_1 - \sigma_3)$ (in kPa), for each set of readings from the equation

$$(\sigma_1 - \sigma_3) = \frac{P}{A} \times 1000$$

Plot values of deviator stress (in kPa) as ordinates against cumulative strain (in %) as abscissae for each stage of loading on one graph sheet.

Alternatively, plot values of the axial force, P (in N), against cumulative strain for each stage directly on to a special barrelling-correction grid sheet of the type shown in Figure 6.

9.5.5 From each stage plot, read off the maximum value, or the extrapolated maximum value, of the deviator stress $(\sigma_1 - \sigma_3)_{max.}$ (in kPa). Alternatively, read off the deviator stress at each relevant limit of strain, if strain criteria are specified. Record the relevant cumulative strain in each case.

NOTE These conditions represent the limiting state for each stage.

9.5.6 Apply a correction to the maximum deviator stress derived in **9.5.4** to allow for the restraining effect of the rubber membrane, if appropriate. The correction is based on the curve in Figure 11 at the appropriate cumulative strain. Multiply the value obtained from the curve by

$$\frac{38}{D} \times \frac{t}{0.2}$$

to obtain the required correction, where

D is the specimen diameter (in mm);

t is the total thickness of membrane (which may be made up of more than one) (in mm)

Subtract the correction from $(\sigma_1 - \sigma_3)_{max.}$ for each stage to obtain the corrected maximum deviator stress, denoted by $(\sigma_1 - \sigma_3)_f$.

9.5.7 Calculate the value of the shear strength, c_u (in kPa), for each stage of the test from the equation

$$c_u = ½(\sigma_1 - \sigma_3)_{max.}$$

9.5.8 Calculate the bulk density of the specimen, ρ (in Mg/m^3), from the equation

$$\rho = \frac{1000 m_o}{A_o L_o}$$

where

m_o is the mass of the specimen (in g).

9.6 Test report

The test report shall state that the test was carried out in accordance with clause **9** of BS 1377-7:1990. It shall contain the following, in addition to the information listed in clause **9** of BS 1377-1:1990:

a) statement of the method used, i.e. a multistage undrained triaxial compression test using the procedure of clause **9** on a single specimen;

b) the reason that the definitive procedure of clause **8** could not be used;

c) method of preparation of test specimen and its orientation and depth;

d) initial specimen dimensions;

e) initial moisture content, bulk density and dry density;

f) rate of strain (in %/min) applied during the test;

g) thickness and type of membrane used;

h) any unusual features likely to affect the interpretation of the tests;

i) tabulated data relating to each loading stage at failure, comprising:

1) cell pressure, σ_3 (in kPa);

2) corrected maximum deviator stress at failure, $(\sigma_1 - \sigma_3)_f$ (in kPa), to the nearest whole number;

3) cumulative strain at failure (in %);

4) mode of failure;

5) values of $c_u = ½(\sigma_1 - \sigma_3)_f$ (in kPa) for each stage, to the nearest whole number;

j) graphical plot of deviator stress against strain for each stage, if required.

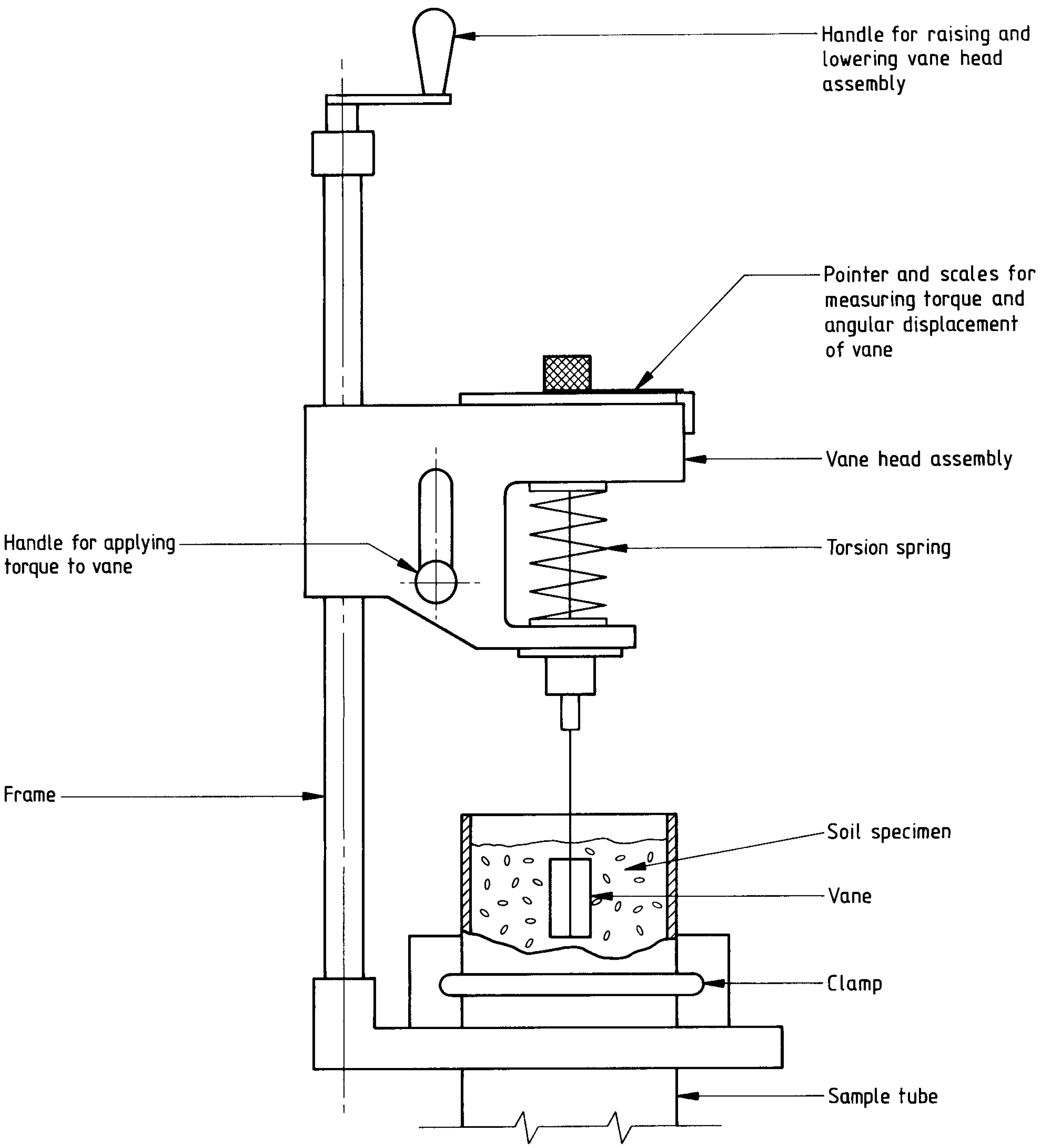


Figure 1 — Laboratory vane apparatus

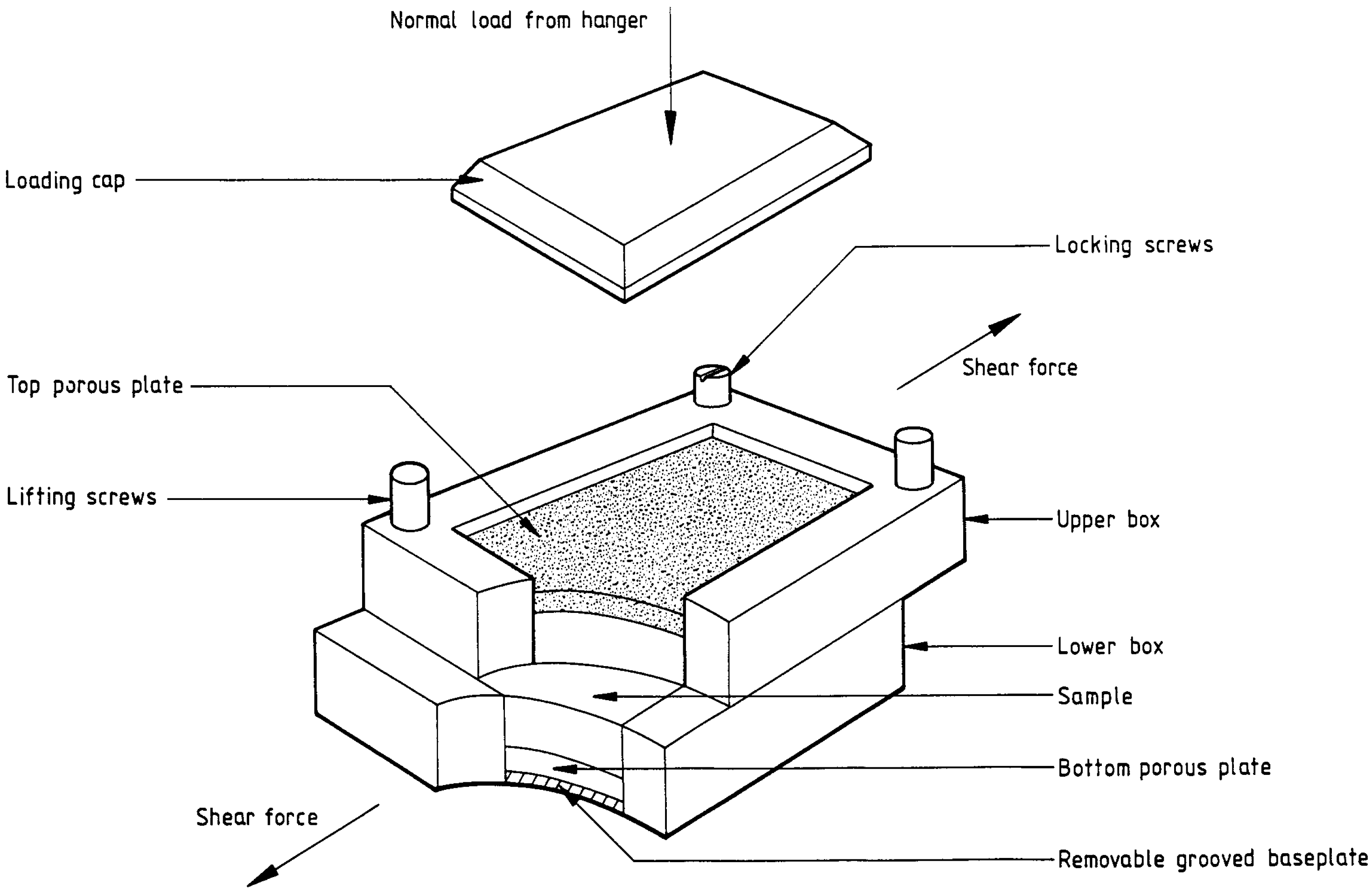


Figure 2 — Details of shearbox

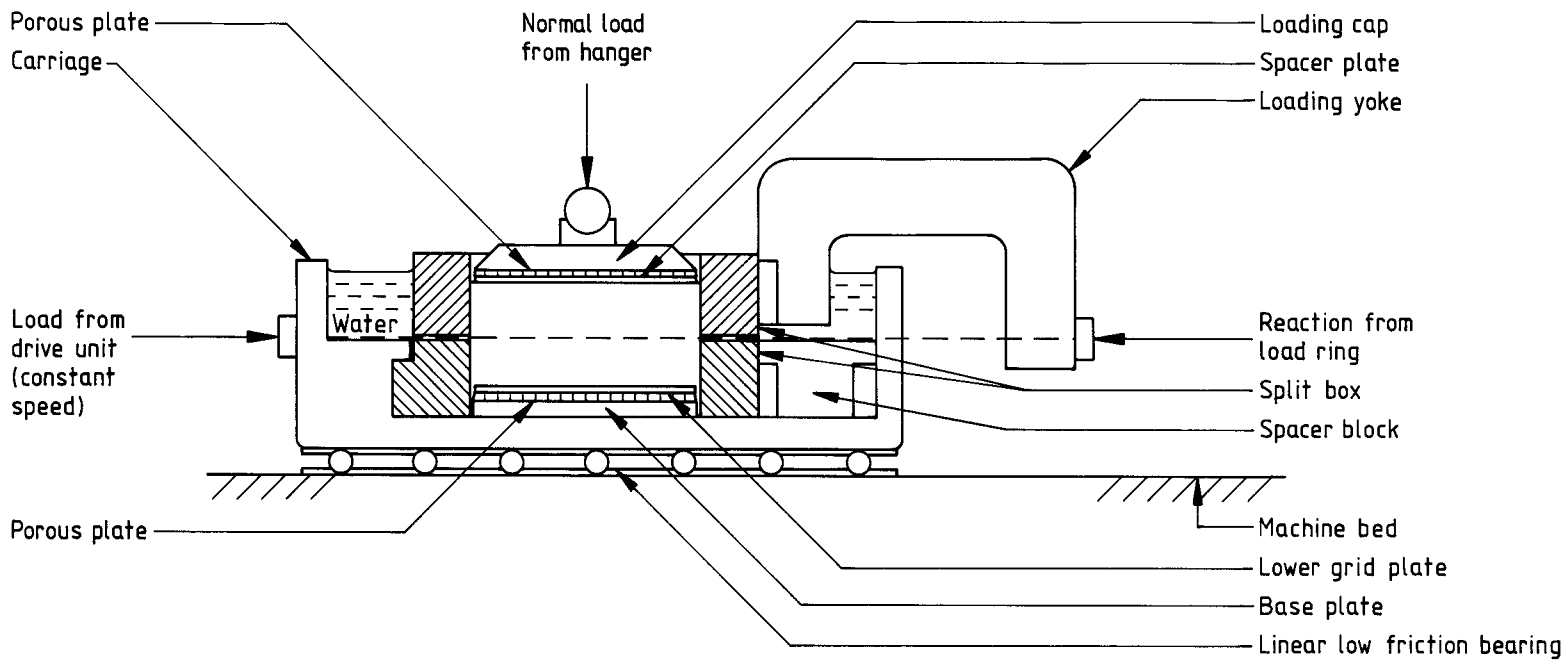


Figure 3 — Typical general arrangement of shearbox apparatus

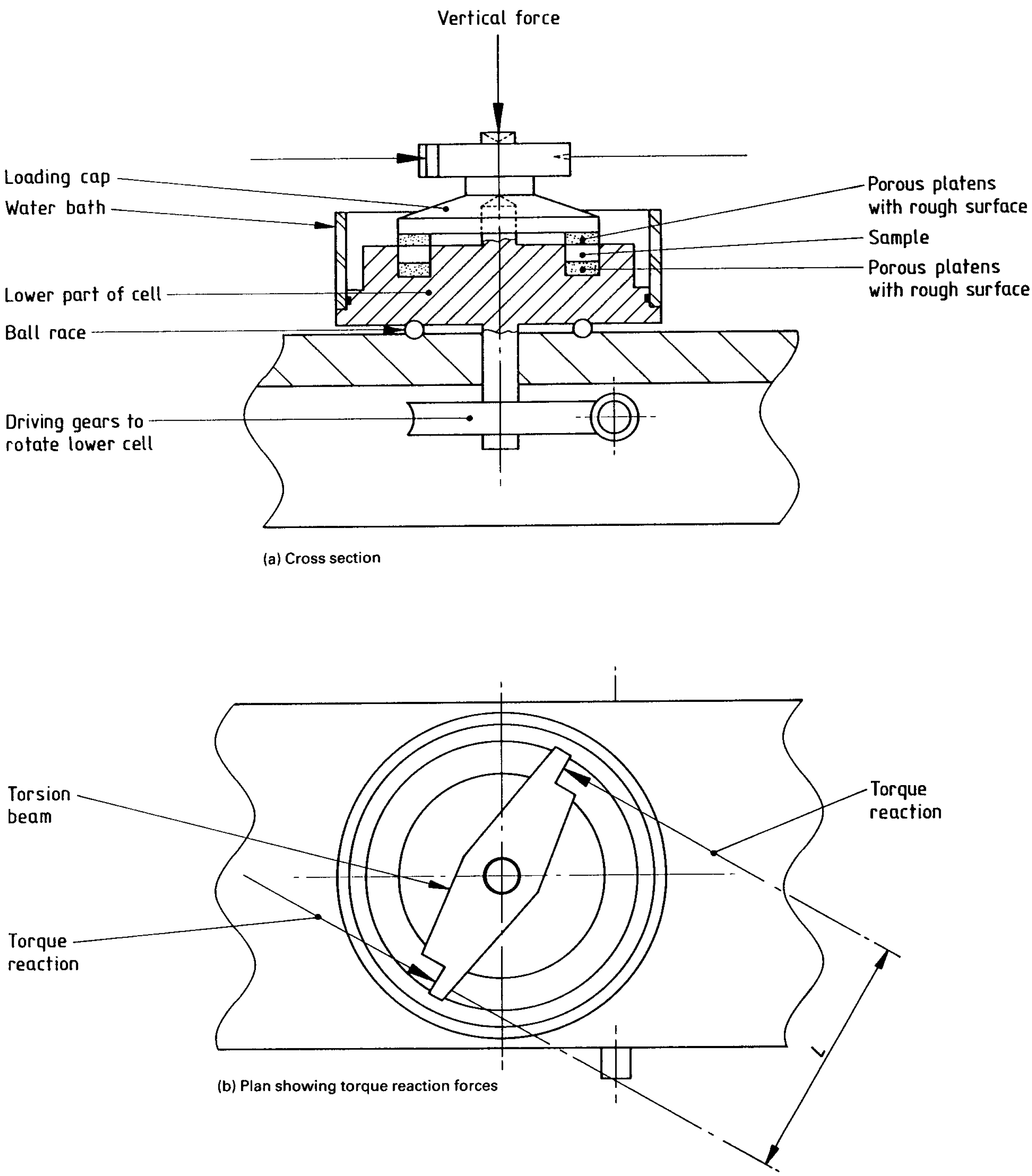


Figure 4 — Typical arrangement of ring shear apparatus

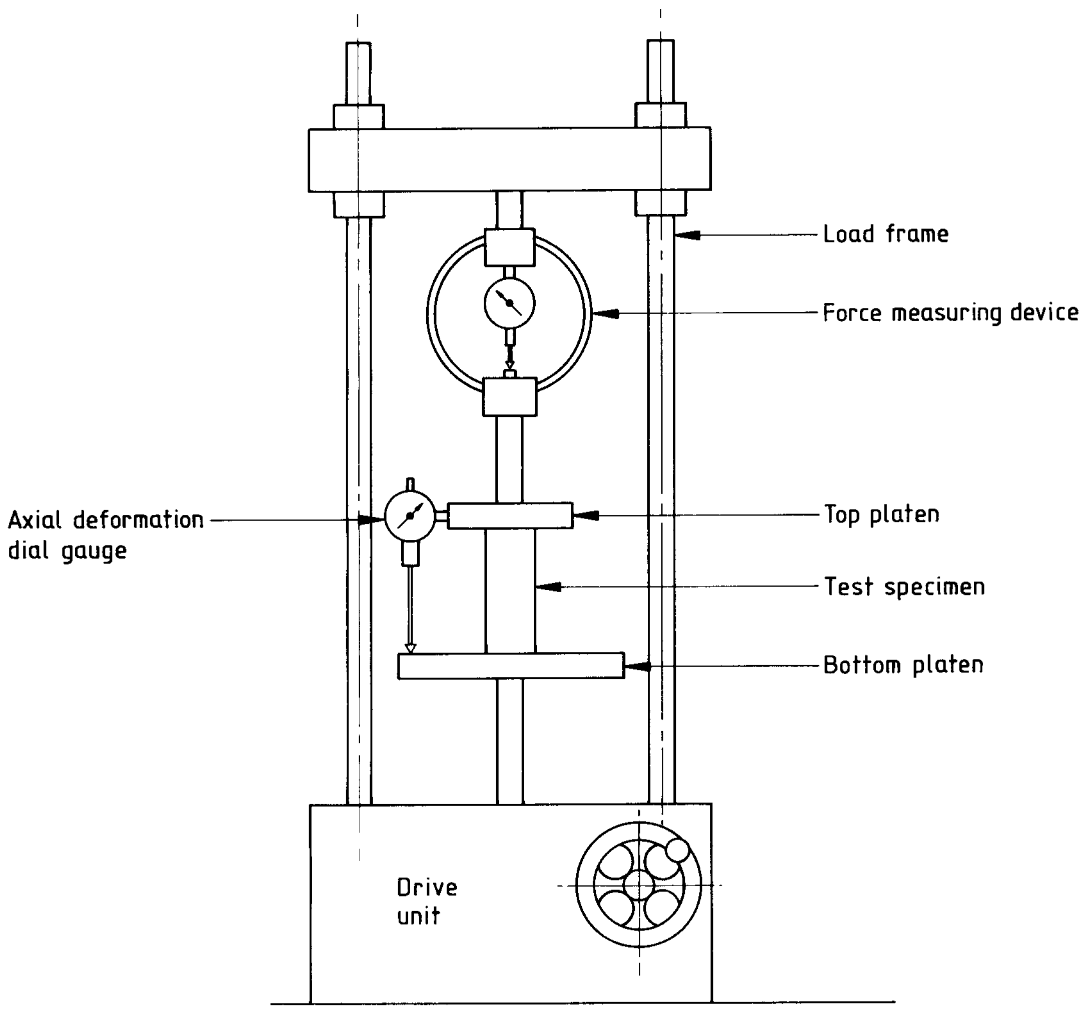


Figure 5 — Typical load frame for unconfined compression test

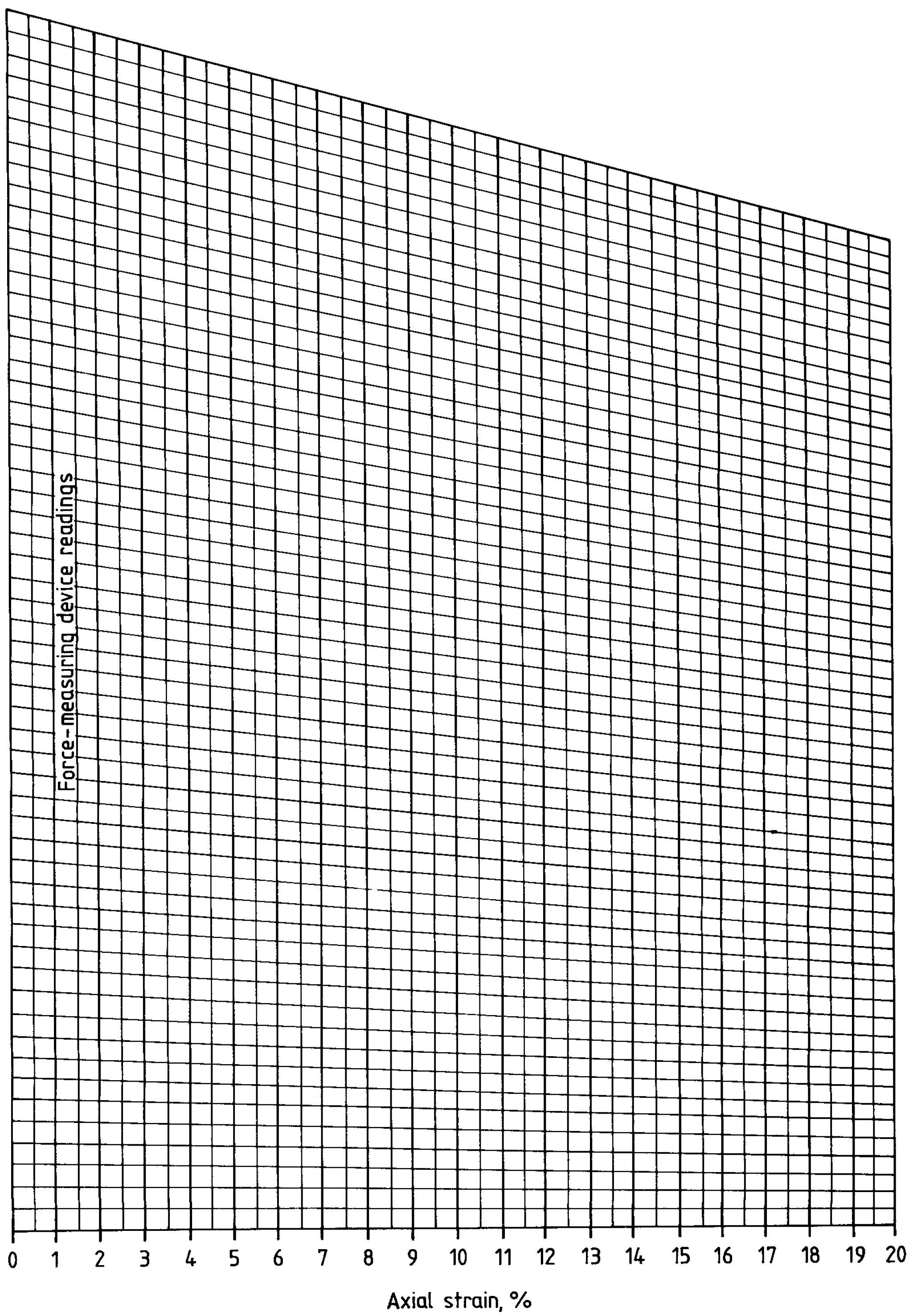


Figure 6 — Barrelling correction grid sheet

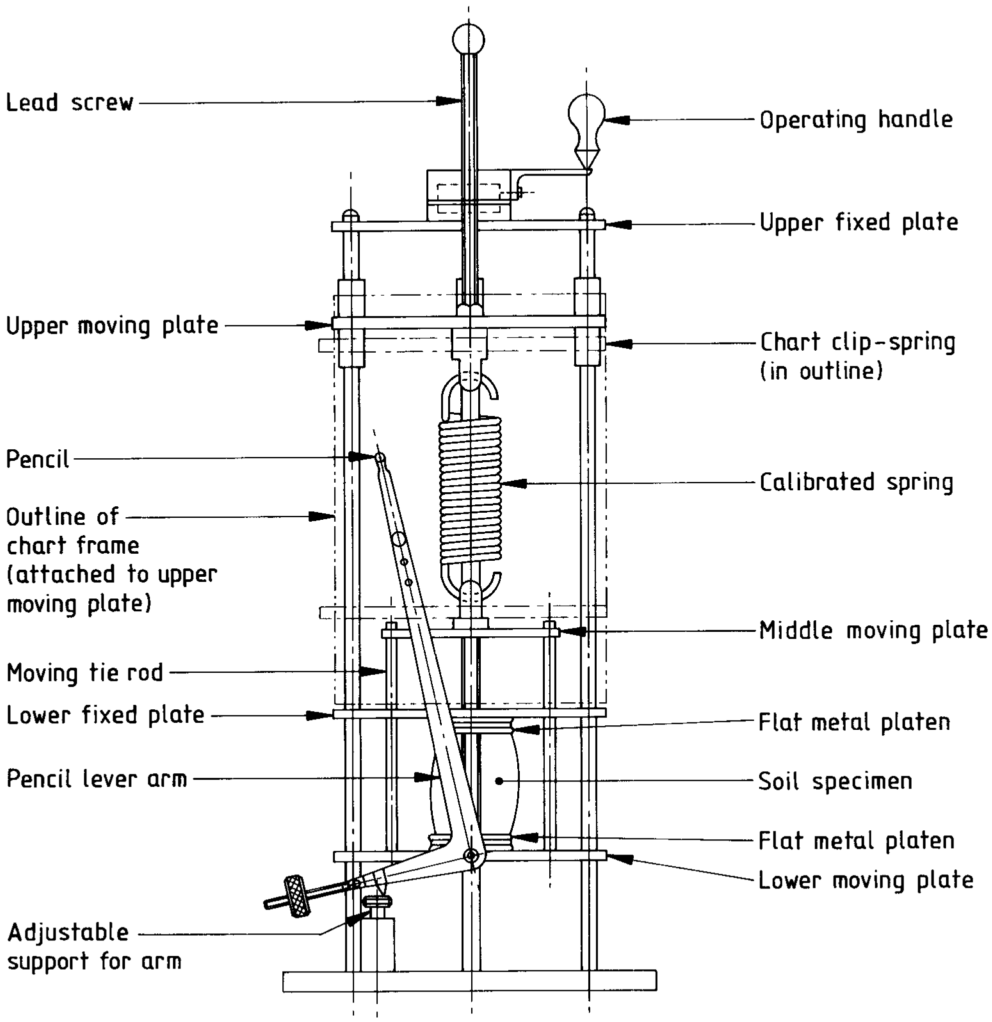
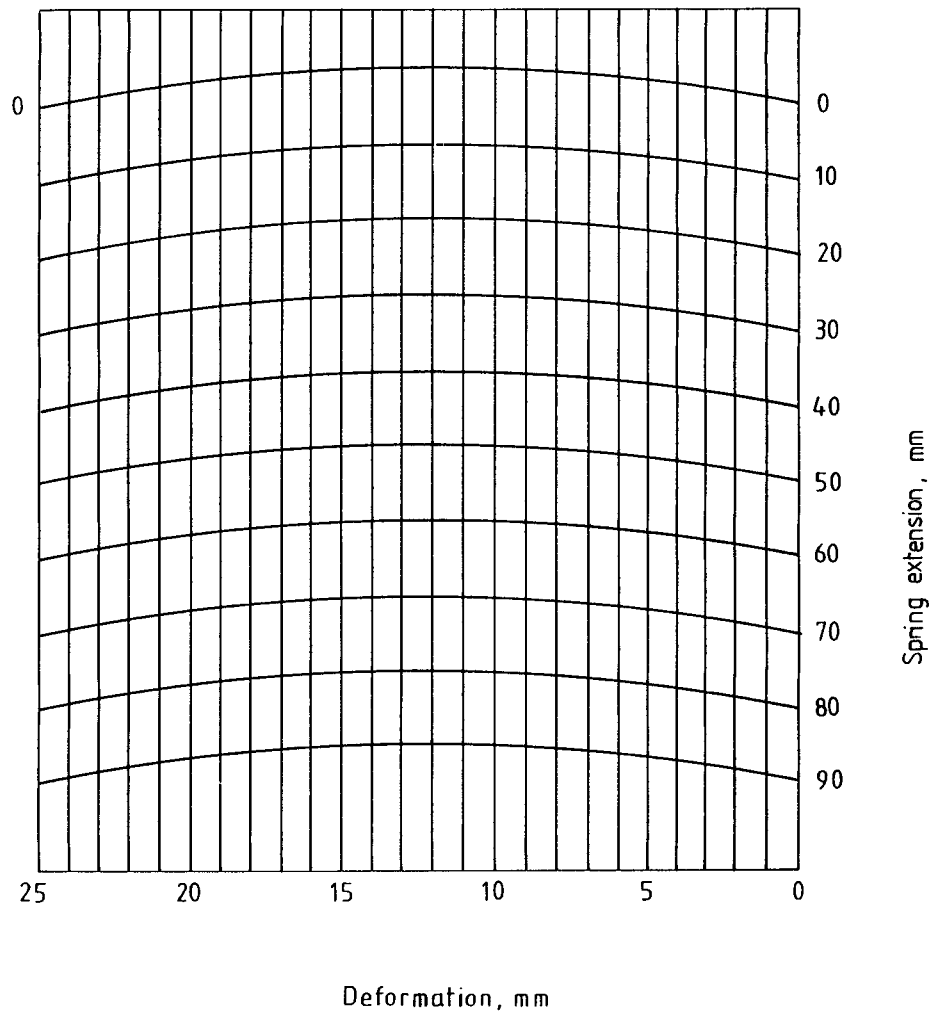
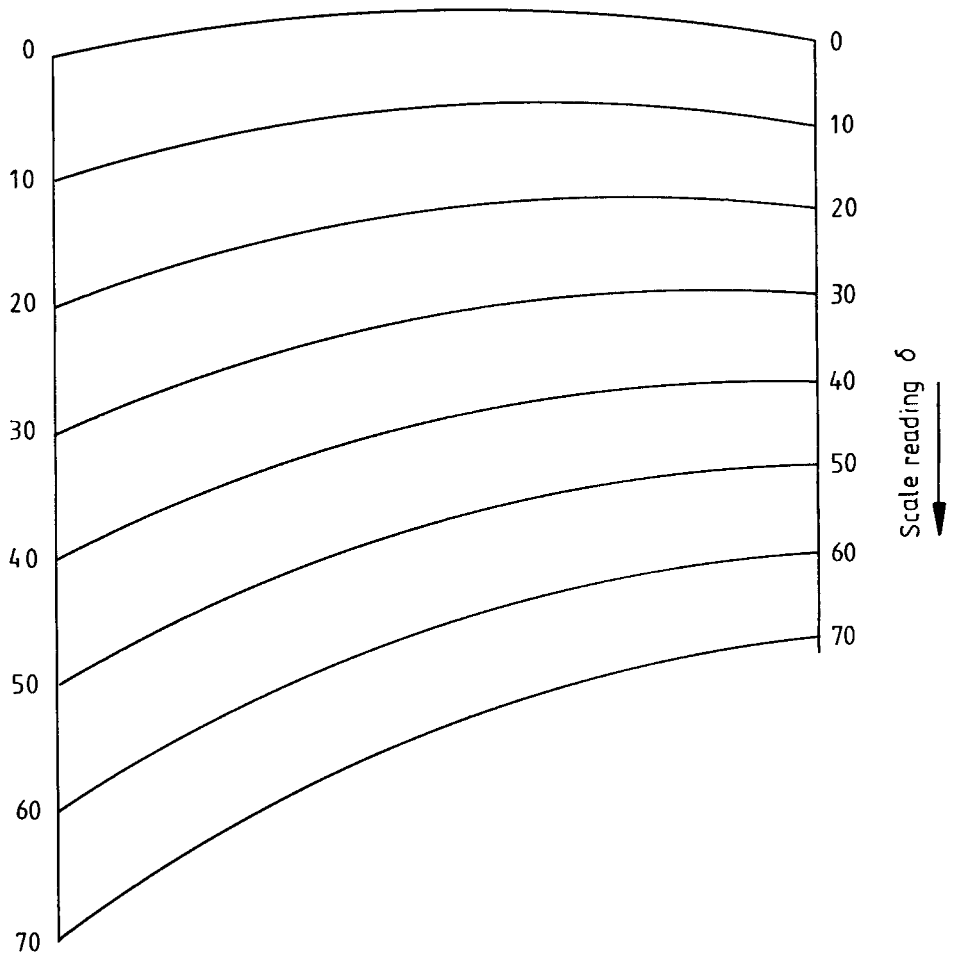


Figure 7 — Typical autographic unconfined compression test apparatus



NOTE 1 Arcs are of equal radius, 10 mm apart; the radius is equal to the length of the pencil level arm (see Figure 7).
NOTE 2 This example relates to a pencil level arm radius of 226 mm and a horizontal movement scale factor of 4.

Figure 8 — Test chart for unconfined compression test



$q_u = \delta \times$ spring stiffness (in N/mm) kPa

Figure 9 — Overlay mask for unconfined compression test chart

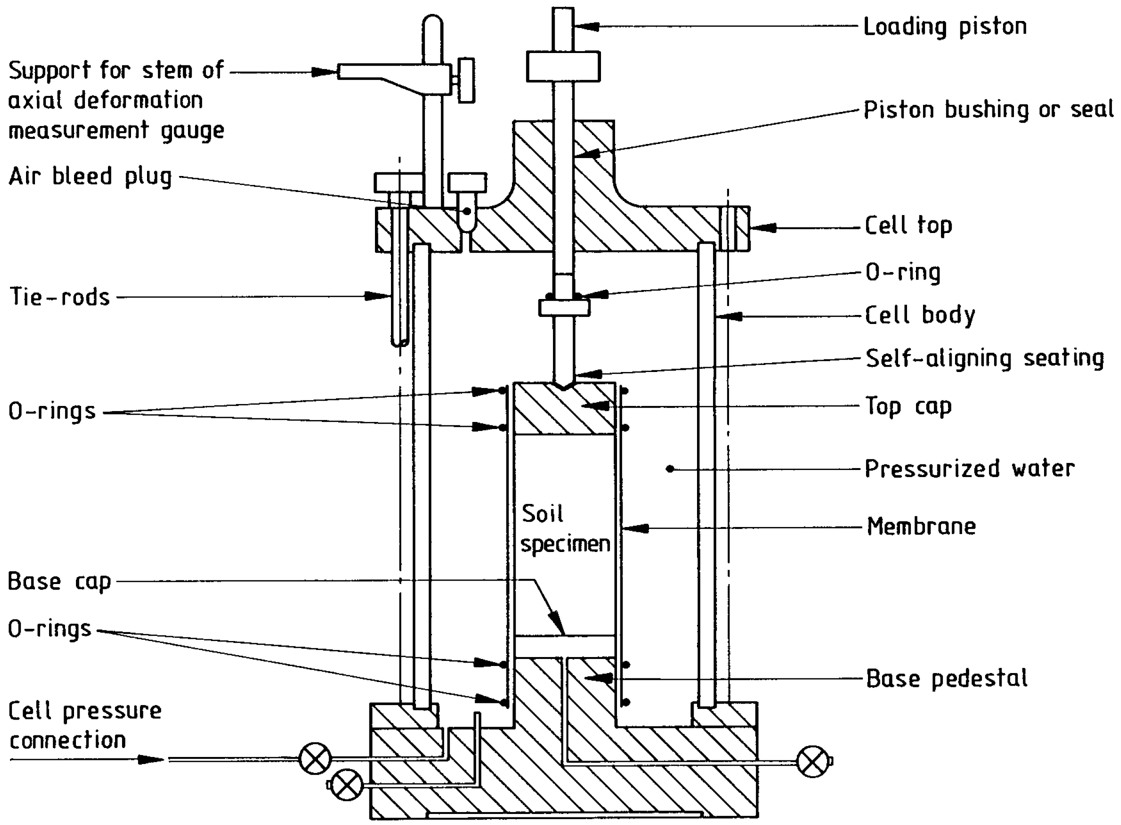


Figure 10 — Typical details of triaxial cell

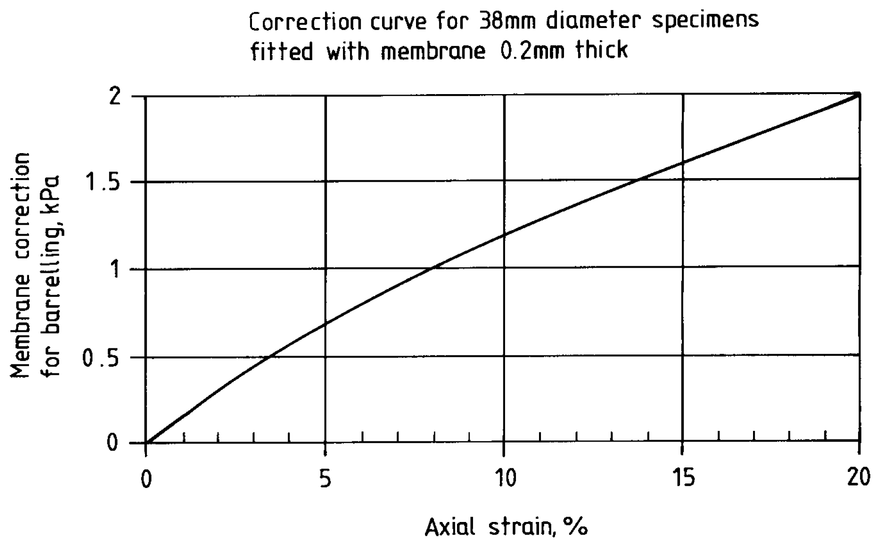


Figure 11 — Membrane correction graph

Appendix A Typical test data and calculation forms

The following test sheets are given as examples only, other suitable forms may be used.

Form 7(a) Shearbox test: specimen data
Form 7(b) Shearbox test: consolidation
Form 7(c) Shearbox test: shearing
Form 7(d) Shearbox test: graphical data
Form 7(e) Ring shear test
Form 7(f) Unconfined compression test
Form 7(g) Undrained triaxial compression test

Form 7(a). Shearbox test: specimen data

Shearbox test: specimen data			
Location	job ref:		
	Borehole/pit ref:		
Solid description	Sample no:		
	Depth		m
	Date		
Test method	BS 1377-7:1990: **4/5**[a]		
Procedure	**4.5.4/4.5.5/5.5.4/5.5.5**[a]		
Machine no.	Type of specimen undisturbed / compacted / loosely deposited[a]		

Preparation procedure				
Weighings	Initially	After test	**Nominal dimensions**	
Wet soil + cutter + tray[a] g			Length L_1 mm	
Dry soil + cutter + tray[a] g			L_2 mm	
Cutter + tray g			Area A mm^2	
Wet soil g			Height H mm	
Dry soil g			Volume V cm^3	
Water g			Particle density ρ_s Mg/m^3	
Moisture content: measured %				
trimmings %			Sketch showing specimen location in original sample	
Density Mg/m^3				
Dry density Mg/m^3				
Voids ratio e				
Degree of saturation %				
Initial mass of disturbed soil[a] g				
Mass of soil remaining g				
Mass of specimen g				

Shearbox details and setting up			
Top of box to top of baseplate h_1 mm		Top of load cap above top of box, unloaded h_3 mm	
Top of box to top porous plate h_2 mm		Top of load cap above top of box, with yoke h_4 mm	
Combined thickness of plate t_p mm			
Sample thickness $H_0 = h_1 - (h_2 + t_p)$ mm		Settlement under loading yoke mm	
Mass of load hanger m_1 kg		Initial reading of vertical deformation gauge R_1	
Lever ratio r ; mass on hanger m^2 kg ; $r \times m_2 =$ kg		Zero reading of gauge $R_0 = R_1 \pm (h_3 - h_4)$	
Total mass on specimen m kg			
Normal stress $\sigma_n = \dfrac{9810m}{A} =$	kPa		
		Operator	Checked	Approved

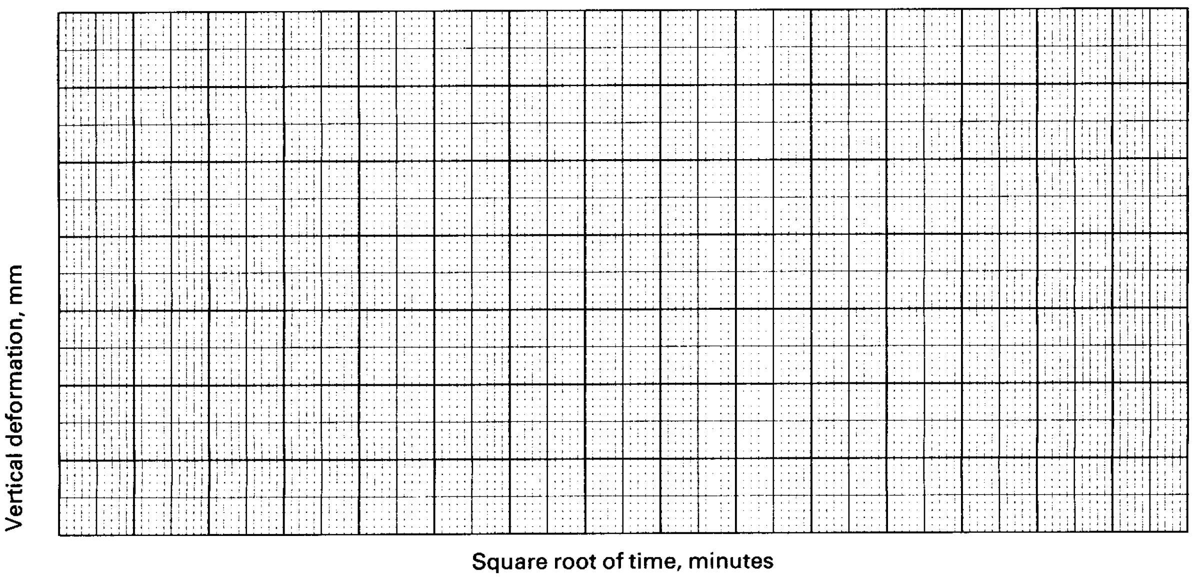
[a] Delete as appropriate

Form 7(a)

Form 7(b). Shearbox test: consolidation

Shearbox test: consolidation			
Location	Job ref:		
	Borehole/pit ref:		
Soil description	Sample no:		
	Depth		m
	Date		
Test method	BS 1377-7:1990: **4/5**[a]		
Machine no.	Dated started	Normal stress	kPa

Clock time	Elapsed time h	min	s	$t$min	$\sqrt{t}$	Gauge reading		Deformation ΔH mm	
				0	0			(Zero reading)	
									From graph,
									$\sqrt{t_{100}}$ =
									t_{100} = min
									$t_f = 12.7 \times t_{100}$ = min
									Estimated displacement at failure
									= mm Calculated rate of displacement = mm/min
									At end of consolidation $e = e_o - \frac{\Delta H}{H_o}(1 + e_o)$ =



	Operator	Checked	Approved

[a] Delete as appropriate

Form 7(b)

Form 7(c). Shearbox test: shearing.

Shearbox test: shearing		
Location	Job ref:	
	Borehole/pit ref:	
Soil description	Sample no:	
	Depth	m
	Date	
Test methods	BS 1377-7:1990: **4/5**[a]	

Type of test	Single stage/Multiple reversals[a]		Run no.
Force device no.	Mean calibration N/division	Specimen size × mm	Stress factor kPa/division
Machine no.	Rate of displacement mm/min	Normal stress	kPa

Time	Elapsed time min	Force gauge reading	Shear stress kPa	Horizontal displacement measured mm	Horizontal displacement cumulative mm	Vertical deformation gauge reading	Vertical deformation cumulative mm

Remarks	Sketches of shear surfaces at failure

	Operator	Checked	Approved

[a] Delete as appropriate

Form 7(c)

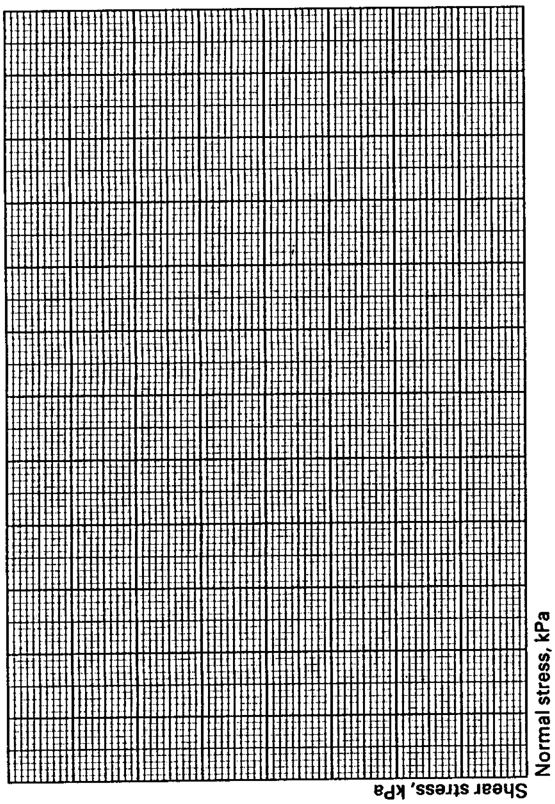
Form 7(d). Shearbox test: graphical data

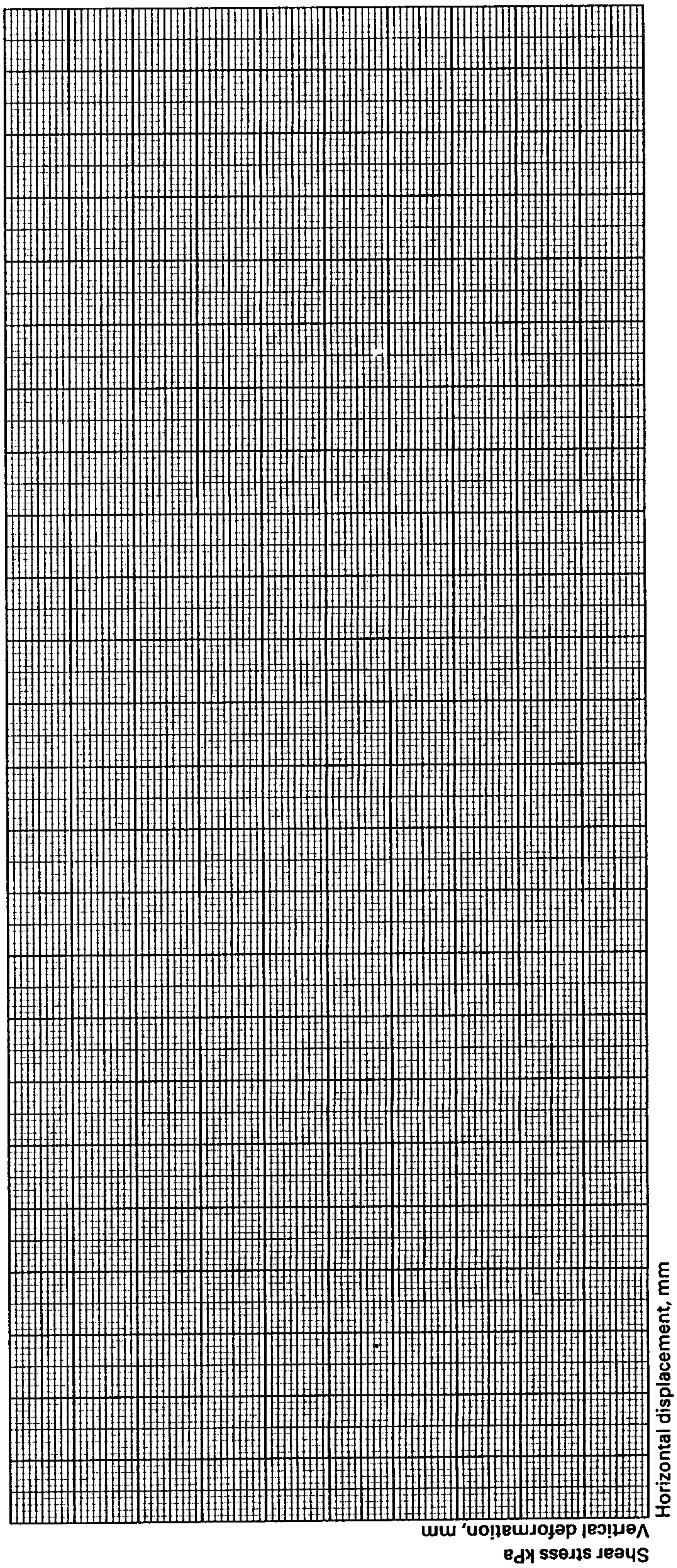
Shearbox test: graphical data							
Location		job ref:					
Solid description		Borehole/pit ref:					
		Sample no:					
		Depth					m
		Date					
Test method BS 1377-7:1990: **4/5**[a]							
Test references							
Normal stress		kPa					
Rate of displacement		mm/min					
Peak	Shear stress	kPa					
	Displacement	mm					
Residual	Shear stress	kPa					
	No. of travels						
	Displacement	mm					
Shear strength parameters							
Maximum	c' kPa						
	φ' deg						
Residual	c'_R kPa						
	φ_R' deg						
		Operator	Checked	Approved			

[a] Delete as appropriate

Form 7(d)

Form 7(d) (*concluded*)





Form 7(e). Ring shear test

Ring shear test			
Location	Job ref:		
	Borehole/pit ref:		
Soil description	Sample no:		
	Depth		m
	Date		
Test method	BS 1377-7:1990: **6**		
Sample preparation procedure			
Machine no.	Torque arm radius R mm		
Distance between points of application of force rings L mm			

Weighings			**Specimen dimensions**		
Wet soil + cell	g		Inside radius	r_1 mm	
Cell	g		Outside radius	r_2 mm	
Wet soil	g		Mean radius	r mm	
Moisture content from trimmings	%		Height	H mm	
Density	Mg/m^3		Volume cm^3	$\frac{2\pi r(r_2 - r_1)H}{1000}$	
Dry density	Mg/m^3		Particle density Mg/m^3 measured/assumed[a]		
Voids ratio	e				
Degree of saturation	%				

Shear test		
Single stage/Multiple stage[a]	Run no.	Normal stress kPa

Force device	A	B	Average
Mean calibration N/division			
Displacement factor F mm/division			

Time	Elapsed time min	Force device reading A	Force device reading B	Force device reading average	Angular displ. θ deg.	$D = \frac{\theta r}{57.3}$ mm	$d = \frac{(A+B)Fr}{L}$ mm	$D_1 = D - d$ mm	Shear stress τ kPa	Vertical deformation mm

	Operator	Checked	Approved

[a] Delete as appropriate

Form 7(e)

Form 7(f). Unconfined compression test

Unconfined compression test							
Location			Job ref:				
			Borehole/pit ref:				
Soil description			Sample no:				
			Depth				m
			Date				
Test method			BS 1377-7:1990: **7.2**				
Type of specimen Undisturbed/compacted[a]					Nominal diameter mm		
Preparation procedure							
Specimen details	Initially	After test			Sketch showing specimen location in original sample		
Diameter D mm		Mass g					
Area A_0 mm^2		Dry mass g					
Length L_0 mm		Moisture content %					
Volume cm^3							
Mass g							
Density Mg/m^3							
Compression test							
Machine no.			Rate of deformation mm/min				
Force device no.				Mean calibration N/division		Stress factor kPa/division	

Deformation gauge reading	Compression of specimen ΔL mm	Strain $\epsilon = \frac{\Delta L}{L_0}$	Force gauge reading	Axial force P N	Corrected area $A = \frac{A_0}{1-\epsilon}$ mm^2	Axial stress $\sigma_1 = \frac{1000P}{A}$ kPa

Sketch of failure conditions	Maximum axial stress kPa		
	Axial strain at failure %		
Inclination of shear surface	Unconfined compressive strength q_u kPa		
	Operator	Checked	Approved

[a] Delete as appropriate

Form 7(f)

Form 7(g). Undrained triaxial compression test

Undrained triaxial compression test		
Location	Job ref:	
	Borehole/pit ref:	
Soil description	Sample no:	
	Depth	m
	Date	

Test method	BS 1377-7:1990: **8/9**[a]		
Type of specimen Undisturbed/compacted[a]		Nominal diameter mm	
Preparation procedure			

Specimen details	Initially	After test		Sketch showing specimen location in original sample
Diameter D mm		Mass g		
Area A_0 mm^2		Dry mass g		
Length L_0 mm		Moisture content %		
Volume cm^3				
Mass g				
Density Mg/m^3				

Compression test Single stage/Multistage, Stage[a]			
Machine no.	Rate of deformation mm/min	Cell pressure kPa	
Membrane thickness mm	Force device no.	Mean calibration N/division	Stress factor kPa/division

Deformation gauge reading	Compression of specimen ΔL mm	Strain $\epsilon = \frac{\Delta L}{L_0}$	Force gauge reading	Axial force P N	Corrected area $A = \frac{A_0}{1-\epsilon}$ mm^2	Measured deviator stress $(\sigma_1 - \sigma_3) = \frac{1\,000P}{A}$ kPa

Sketch of failure conditions	Measured deviator stress	kPa	
	Membrane correction	kPa	
	Corrected deviator stress	kPa	
Inclination of shear surface	Axial strain	%	
	Shear strength c_u	kPa	
	Operator	Checked	Approved

[a] Delete as appropriate

Form 7(g)

Publications referred to

BS 1377, *Method of test for soils for civil engineering purposes.*
BS 1377-1, *General requirements and sample preparations.*
BS 1377-2, *Classification tests.*
BS 1377-4, *Compaction-related tests.*

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