BRITISH STANDARD

BS 1377-6: 1990

Incorporating Amendement No. 1

Methods of test for

Soils for civil engineering purposes —

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

Confirmed January 2010

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Road Engineering Standards Policy Committee (RDB/-) to Technical Committee RDB/38, upon which the following bodies were represented:

Association of Consulting Engineers
British Civil Engineering Test Equipment Manufacturers' Association
County Surveyors' Society
Department of the Environment (Property Services Agency)
Department of the Environment (Building Research Establishment)
Department of Transport
Department of Transport (Transport and Road Research Laboratory)
Coopted members

This British Standard, having been prepared under the direction of the Road Engineering Standards Policy Committee, was published under the authority of Board of the BSI and comes into effect on 30 November 1990

The following BSI references relate to the work on this standard:
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Amendments issued since publication

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Contents

Foreword

This Part of BS 1377 has been prepared under the direction of the Road Engineering Standards Policy Committee. It is a part revision of clause **5** of BS 1377:1975 which is superseded by amendment.

BS 1377:1975 which has now been withdrawn is replaced by the following Parts of BS 1377:1990: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 the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of 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 64, 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.

1 Scope

This Part of BS 1377 specifies methods of test for determination of consolidation and permeability characteristics of saturated soils using apparatus which is more complex than that used for the tests described in Part 5.

Two types of equipment are used:

a) hydraulically loaded one-dimensional consolidation cell;

b) a triaxial consolidation cell.

The most significant capabilities of both types of apparatus are:

1) measurement of pore water pressure;

2) control of drainage;

3) application of back pressure to the specimen.

Consolidation or triaxial cells of large diameter enable large specimens to be tested so that some account can be taken of the effects of the soil fabric.

These procedures appear for the first time in this standard.

Reference should be made to BS 1377-1 for general requirements that are relevant to all Parts of this standard, and for methods of preparation of soil and specimens for testing.

2 Definitions

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

2.1
diaphragm pressure of a hydraulic consolidation cell

the pressure applied to the fluid above the flexible loading diaphragm

2.2
applied total stress

the mean pressure actually transmitted to the surface of the specimen

2.3
free strain loading

application of a uniformly distributed pressure to the surface of the specimen from the flexible diaphragm

2.4
equal strain loading

application of pressure to the surface of the specimen through a rigid disc so that the surface always remains plane

2.5
pore pressure ratio

the ratio of the incremental change in pore pressure to the applied increment of vertical stress when drainage is not allowed

2.6
cell pressure (σ_3)

the pressure of the cell fluid which applies isotropic stress to the specimen in a triaxial cell

2.7
back pressure (u_b)

pressure applied directly to the pore fluid in the specimen voids

2.8
effective cell pressure

the difference between the cell pressure and pore water pressure

2.9
effective consolidation pressure (σ'_3)

the difference between the cell pressure and the back pressure against which the pore fluid drains during the consolidation stage, calculated as:

$$\sigma'_3 = \sigma_3 - u_b$$

2.10
pore pressure coefficients A and B

changes in total stresses applied to a specimen when no drainage is permitted produces changes in the pore pressure in accordance with the equation

$$\Delta u = B\{\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)\}$$

where

Δu	is the change in pore pressure;
$\Delta\sigma_1$	is the change in total major principal stress;
$\Delta\sigma_3$	is the change in total minor principal stress;
$(\Delta\sigma_1 - \Delta\sigma_3)$	is the change in deviator stress;

A and B are the pore pressure coefficients.

NOTE In a saturated soil (except very stiff soils) the value of B is theoretically equal to 1.

3 Determination of consolidation properties using a hydraulic cell

3.1 General

3.1.1 *Introduction.* These procedures cover the determination of the magnitudes and rates of consolidation of soil specimens of relatively low permeability using hydraulically loaded apparatus. They provide a convenient means of testing large specimens, and enable drainage in either the horizontal or vertical directions to be investigated. The specimen is in the form of a cylinder confined laterally, subjected to vertical axial pressure applied hydraulically.

The apparatus and procedures described here are based on the extendable-bellows type of hydraulic cell. Specimen diameters typically range from 75 mm to 254 mm. Other types of hydraulically loaded cell, incorporating for instance a rolling-seal diaphragm, are also available. The test method is not restricted to a particular design of cell provided that the essential requirements are fulfilled.

3.1.2 *Types of test.* In this type of cell, pressure may be applied to the surface of the specimen either directly from the flexible diaphragm (giving a uniform stress distribution, the "free strain" condition), or through a rigid loading plate which ensures that the top surface remains plane (the "equal strain" condition). With either type of loading the following drainage conditions are possible. The various configurations are indicated diagrammatically in Figure 1, as follows:

a) vertical drainage to the top surface only, with measurement of pore pressure at the centre of the base [Figure 1(a) and Figure 1(b)];

b) vertical drainage to both top and bottom surfaces [Figure 1(c) and Figure 1(d)];

c) radial drainage outwards to the periphery only, with measurement of pore pressure at the centre of the base [Figure 1(e) and Figure 1(f)];

d) radial drainage inwards to a central drain with measurement of pore pressure at one or more points off centre [Figure 1(g) and Figure 1(h)].

Each method requires its own curve-fitting procedure and multiplying factors for deriving the relevant coefficient of consolidation. The factors also depend on whether data are derived from pore pressure measurements at a single point, or from "average" measurements (volume change or settlement) for the specimen as a whole.

3.1.3 *Test conditions.* The following test conditions shall be specified before starting a test:

a) size of test specimen;

b) drainage conditions;

c) loading conditions;

d) location of pore pressure measurement point (when required);

e) whether void ratios are to be calculated and plotted;

f) sequence of effective pressure increments and decrements;

g) criterion for terminating each primary consolidation and swelling stage;

h) whether secondary compression characteristics are required.

The requirements of Part 1 of this standard, where appropriate, shall apply to the test methods described in this clause.

3.1.4 ***Environmental requirements and safety***

3.1.4.1 *Temperature.* These tests shall be carried out in a laboratory in which the temperature is maintained constant to within ± 2 °C, in accordance with **6.1** of BS 1377-1:1990. All apparatus shall be protected from direct sunlight, from local sources of heat and from draughts.

3.1.4.2 *Hazard warning*

NOTE Users of this equipment should be conversant with regulations for pressure vessels.

Consolidation cells and ancillary equipment shall not be used at pressures above their safe working pressures.

3.2 Apparatus

3.2.1 *Hydraulic consolidation cell and accessories*

3.2.1.1 *General requirements for the cell*

3.2.1.1.1 All metal body components shall be impervious and corrosion resistant. The cell body, top and base shall all be of the same material to minimize the possible effects of electrolytic corrosion.

3.2.1.1.2 The cell when assembled shall be capable of withstanding sustained internal water pressures of up to 1 000 kPa without significant leakage or distortion.

NOTE The main features of the extending-bellows type of a 250 mm diameter cell are shown diagramatically in Figure 2.

3.2.1.2 *Components of the cell*

3.2.1.2.1 *Cell body,* the inside face of which shall be smooth and free from pitting.

NOTE The internal surface of the body and base may be lined with a thin smooth impervious layer of plastics material bonded on, to reduce wall and base friction and inhibit corrosion.