



TRIAXIAL TESTS

Standards

BS 1377:7, 8 / ASTM D2850, D4767, NF P94 070, P94 074

General information

The settlement of soil-supported foundations and the change in earth pressure due to small movement of retaining walls or other earth supports, the yield of soil caused by local application of load, are determined by the relation between stress and strain in soils. The experimental investigation used to determine the stress-strain relation is usually carried out with a triaxial compression test. During the test, the undisturbed soil samples are gradually stressed up to failure, which corresponds to the maximum shear strength. The test is performed placing a cylindrical soil sample, enclosed in a rubber membrane, in a triaxial cell and subjecting it to an isotropic fluid pressure. An axial load is subsequently applied on the specimen through a loading piston in such a way that the soil sample is deformed at a constant rate of strain. Generally speaking, the triaxial tests are performed to simulate different types of stress and drainage conditions that can occur in the subsoil because of the effect of building constructions, excavations, tunnelling etc. Three different triaxial tests are usually performed (see page 71) for total and effective stress measurement.

Our production of triaxial equipment

Controls manufactures a large sophisticated state of the art range of triaxial equipment which is detailed below. Automatic machines for compression and extension tests, computerized and integrated systems have also been developed for advanced testing laboratories, where not only conventional tests are carried out.

TRIAXIAL TEST METHODS

Total stress measurement

Unconsolidated Undrained (UU) tests

With this method the shear strength is measured with respect to total stress. The soil specimen (assumed saturated) is not allowed to consolidate, maintains its original structure and water content, so that its resistance only depends on the level of geostatic stress in the field.

Tests are usually carried out on three specimens of the same sample, subjected to different confining pressure. Provided that the soil is fully saturated, the effective stresses at failure is the same for each test.

The Mohr envelope, plotted with respect to total stress is horizontal and the shear strength is constant and equal to C_u (undrained shear strength).

Effective stress measurement

Consolidated Undrained (CU) tests

With this test method the shear strength is measured in terms of effective stress. At least three specimens are allowed to consolidate (i.e. to change its structure and water content) at different level of confining pressure before failure. Due to the fact that shear strength increases raising the effective stresses the Coulomb's model can be applied in terms of effective stress:

$$\tau = c' + \sigma'_n \operatorname{tg} \phi'$$

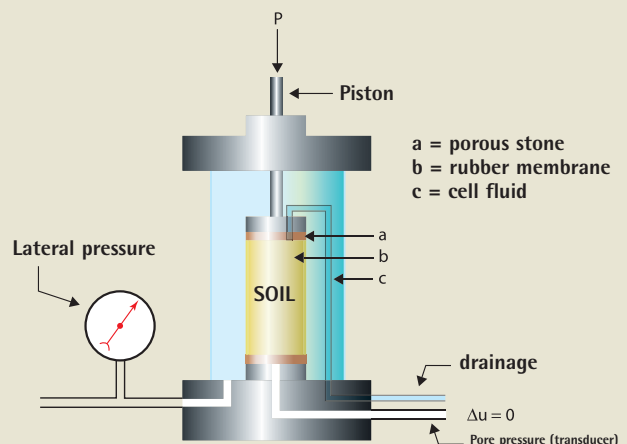
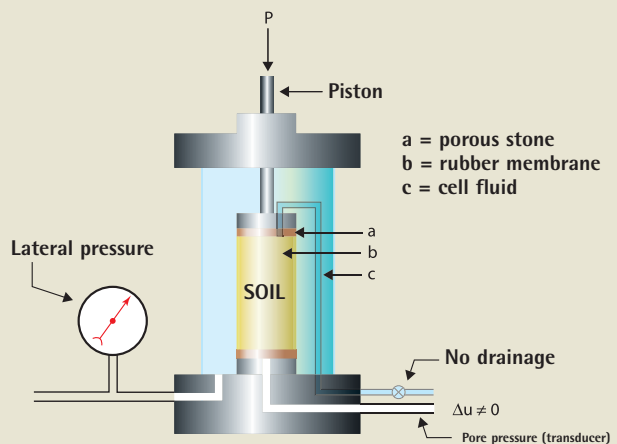
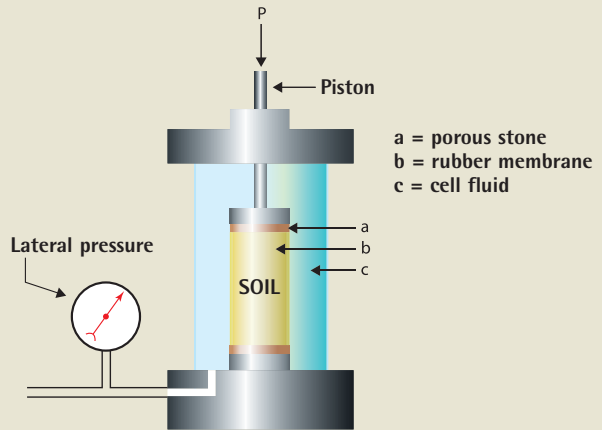
where: τ = shear resistance; σ'_n = effective normal stress
 c' , ϕ' = parameters of Mohr envelope in terms of effective stress

During the failure stage the specimen is not allowed to drain and pore pressure is measured, so that the effective stresses are calculated as the difference between the total stress and the pore pressure.

Effective stress measurement

Consolidated Drained (CD) tests

This test method is similar to the "CU" test as the shear strength can be related to the applied level of stress. At least three specimens are allowed to consolidate at different levels of confining pressure. The failure stage is carried out very slowly to prevent the increase of pore pressure inside the specimen, which is allowed to drain. The total and effective stresses are the same. Mohr circles are drawn for effective stresses at failure and the parameters c' and ϕ' are determined from the Mohr envelope.



For typical configuration of complete test system:

Total stress measurement
 Unconsolidated Undrained (UU) tests

Effective stress measurement
 Consolidated Undrained (CU) and
 Consolidated Drained (CD) tests

Effective stress measurement
 Consolidated Undrained (CU) and
 Consolidated Drained (CD) tests
 (electronic measurement). See pages 92.

TRIAXIAL LOAD FRAMES

STANDARD

BS 1377:8 / ASTM D2850, D4767
NF P94 070, P94 074

Two versions available: 50 and 100 kN capacity. General specifications and features are identical except the capacity and physical dimensions as specified.

28-T0401

Digital triaxial frame, 50 kN cap.
110-230 V, 50-60 Hz, 1 ph.

28-T0403

Digital triaxial frame, 100 kN cap.
110-230 V, 50-60 Hz, 1 ph.

General description and specifications

This versatile digital loading frame features a microprocessor controlled drive system with an advanced stepper motor enabling the operator to easily set any test speed via the keyboard. The machine can be fitted with an optional RS 232 port so it can be remotely controlled. The upper and lower limits of platen travel are set by use of automatic safety cut-out switches and by an audible overtravel alarm. Other important features include pause and speed reset during the test and the automatic self check diagnostic. All load rings, cells, dial gauges, etc. have to be ordered separately.



28-T0401 with cell and accessories

28-T0403 28-T0401 with cell and accessories

- Microprocessor controlled
- Advanced stepper motor drive
- Infinitely variable speed from 0.00001 to 9.99999 mm/min
- Audible overtravel alarm
- Automatic self check diagnostic
- Waterproof membrane keyboard
- LCD 4-row by 20 character display
- Easy to operate via the membrane keyboard

Specifications	28-T0401	28-T0403
Load capacity	50 kN	100 kN
Max. sample size	100 mm dia.	150 mm dia.
Rate of strain	from 0.00001 to 9.99999 mm/min	from 0.00001 to 9.99999 mm/min
Rapid approach speed	25 mm/min	25 mm/min
Horizontal clearance	380 mm	458 mm
Max. vertical clearance	850 mm	1060 mm
Platen dia.	160 mm	160 mm
Max. platen travel	100 mm	100 mm
Motor power W	250	250
Overall dimensions	1266x500x273 mm	1390x590x450 mm
Weight approx.	95 kg	150 kg

Note. Upon request the machines can be supplied with RS 232 C output.

**AUTOMATIC TRIAXIAL MACHINES
50 AND 100 KN CAPACITY**

STANDARD

ASTM D2850-95 /
BS 1377: Part 7, Part 8: 1990
NF P94 070, NF P94 074

28-T0401/AC

**Automatic digital triaxial frame
50 kN cap.** 110-230 V, 50-60 Hz, 1 ph.

28-T0403/AC

**Automatic digital triaxial frame 100
kN cap.** 110-230 V, 50-60 Hz, 1 ph.

Introduction

This new series of automatic machine has been designed to perform compression triaxial tests both in consolidation and failure stage.

The consolidation stage can also be performed in anisotropic conditions, with $k_0 < 1$ (i.e. vertical stress higher than horizontal stress).

All the tests are carried out automatically either in controlled rate of displacement (as the traditional compression machines) or in controlled rate of load (particularly suitable for consolidation stage) and terminated automatically at pre-set test conditions.

The 28-T0403/AC machine can be upgraded to perform also extension tests (extension-unload). See upgrading options.

General description

Two threaded column highly stable frame with upper crosshead beam, adjustable in height by means of a simple locking-nut system, that assures correct application of the axial stress within the triaxial chamber. The lower box of the compression machine contains the stepper motor with servo control drive, the control panel with large graphic displays, for input of servo control parameters, test data and calibration factors, the display of recorded data in real time, the battery backed data storage and the serial output to PC. Stand alone model for automatic triaxial tests control (Unconfined UU, CU, and CD) with store of test data and possibility to download via serial port in real time or deferred time for data analysis, processing and printing.

The following triaxial tests can be automatically performed:

- Pre-axial load before the failure stage, to recreate or carry out the consolidation



Main features

- Servo controlled drive through stepper motor
- Application for compression tests
- Test velocity adjustment from 0.00001 to 9.99999 mm/min

Main advantages compared to the standard models 28-T0401 and 28-T0403

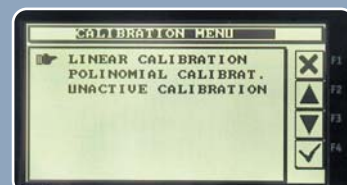
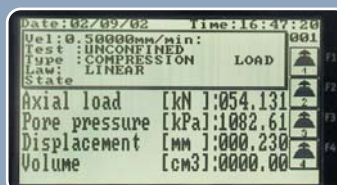
- Stand alone machine (servocontrolled with built in data acquisition unit)
- Automatically controlled rate of load
- Automatic anisotropic consolidation and failure
- Large graphic display 240x128 pixel
- Data recording and display in physical units in real time
- Temporary connection to PC via RS 232 port to download recorded data in physical units
- Special software available to download and convert recorded data, to be compatible with our GEOLAB 2000 package
- Upgradable for extension tests (see 28-T0403/UP1)

28-T0403/AC with triaxial cell and accessories

stage in anisotropic conditions (with $K_0 < 1$)

- Failure stage in conditions of compression (increasing axial pressure)
- Triaxial (UU, CU, CD) and unconfined tests are carried out either in controlled stress or in controlled strain conditions and terminated automatically at pre-set conditions.

**Detail of some screens
play on the large display of 248x124 pixel**



TECHNICAL DATA

Same as model 28-T-T0401 and 28-T0403 shown on page 72

Characteristics common to both models 28-T0401/AC and 28-T0403/AC

Configuration	- servo controlled drive through stepper motor
Servo-control parameters	- Axial load (load controlled tests) - Axial displacement (displacement controlled tests)
Control Unit	- 4 channel built-in stand alone digital unit for data acquisition and control of stepper motor - Microprocessed based design with 16 bit A/D converter
Control panel	- Incorporates a large graphic display (240x128 pixel), a touch sensitive 10 keys membrane keypad - Use of programmed keys F1, F2, F3, F4 allows different menu to be activated and linked together at different levels for immediate access to the required functions
Digital display	- display in real time of test data in physical units: axial load (N), axial displacement (mm compression/extension), pore pressure (kPa), volume change (cm ³)
Resolution	- 1/65.000 full range
Connection of transducers for data acquisition⁽¹⁾	a) To the compression machine - Strain gauge load cell for axial load measurement - Potentiometric transducer for axial displacement b) To the triaxial cell - Strain gauge transducer for pore pressure c) To volume change control panel - Potentiometric transducer for volume change measurement
Excitation supply of the transducers	- built-in within the compression machine
Data storage	- battery backed with real time clock
Scanning time of data	- Data recording can pre-set by the operator: - at intervals of time linear polynomial, exponential - at intervals of recorded stress - at interval of recorded displacement
Data maximum capacity	- 2000 readings per channel for each test
Transducers calibration	- Automatic linear calibration (5 points) - Input of parameters of polynomial equation for non linear calibration - Non-volatile storage of channels calibration data
RS 232 C Serial port	- For temporarily connection to PC to download recorded data in physical units: - with serial data communication program (e.g. Hyperterminal D Terminal code 82-P0800/TRM) - with our Geolab 2000 dedicated software

*(1) See accessories***Software application**

The machine is fully automatic, controlled via the front panel with digital display of test measurements (axial pressure, axial displacement, pore pressure and volume change) in real time.

The computer is only temporarily connected for data transmission of stored data for monitoring of the test in progress, processing and printing of results.

For complete processing according to the International standards (BS 1377, ASTM, ISSMGE) and customised printout of test reports a special software, Windows com-

patible, is available for triaxial tests (see Geolab 2000, code 30-T0601/P3).

The following diagrams and printouts are available for a single or for a group of tests:

- Mohr's circle plots and Mohr-Coulomb linear failure envelope
- Stress path plots and failure envelope (according to MIT analysis)
- Axial stress vs. axial strain
- Pore pressure vs. axial strain (for CU triaxial tests)
- Volume change vs. axial strain (for CD triaxial tests)

- Stress ratio vs. strain
- Skempton's A parameter vs. axial strain (for CU triaxial tests).

A special section of the software is devoted to the customised printout, 30-T0601/R0. The user can introduce all the information and general data to printout each test certificate (logo of the laboratory, name of the technicians involved in the tests, file of the test, number of the certificate, reference standards, etc.).

UPGRADING OPTIONS COMPRESSION AND EXTENSION TESTS (EXTENSION-UNLOAD)

Introduction

The 28-T0403/AC machine can be upgraded to perform extension tests (extension-unloaded), where the axial stress can be reduced below the horizontal stress.

This condition (where the factor K_0 is >1) can be automatically carried out either in the consolidation or in the failure stage, at constant rate of stress. The maximum tensile capacity is 8 kN. Data recording, downloading to PC, processing and printing are carried on in the same way described above.

note

To perform extension tests it is necessary to substitute the porous caps model T0420/A3, T0422/A3, T0425/A3, T0428/A3, T0432/A3 respectively with the following appropriate models: T0420/A3T, T0422/A3T, T0425/A3T, T0428/A3T, T0432/A3T, for dia. 35-38-50-70-100 mm. Furthermore the modification of the upper flange of the triaxial cell is also required. This modification can be factory made on your existing triaxial cells or programmed in case of a complete laboratory supply. For new modified triaxial cells ask for the following codes:

28-T0410/AT Triaxial cell up to 50 mm dia.

28-T0411/AT Triaxial cell up to 70 mm dia.

28-T0416/AT Triaxial cell up to 100 mm dia.

■ 28-T0403/UP1

Upgrading system for the 28-T0403/AC machine to perform extension test (extension-unload)

Including firmware and the following mechanical accessories:

Extension testing kit comprising:

- Bidirectional spherical seat for upper crosshead
- Fast clamping device load cell/triaxial cell piston
- Clamping device triaxial cell/lower platen to triaxial frame (suitable for models: 28-T0410/A, 28-T0411/A, 28-T0416/A).

The extension testing kit is also proposed when using the 28-T0403 machine for stress path triaxial tests with the code 28-T0403/A1. See page 84.

Accessory

- ▼ 28-T0403/A2 Triaxial cell piston for extension tests. It is interchangeable with the standard piston part of 28-T0410/A, 28-T0411/A, 28-T0416/A cells



Detail of the locking system of the triaxial cell to the lower platen for extension tests



Detail of the triaxial cell and rigid connection to the piston for extension tests

Measurement accessories

Electronic transducer

Same as those shown on page 76.

ACCESSORIES FOR TRIAXIAL FRAMES

Mechanical accessories

▀ **28-T1048** Mounting bracket to be connected to the ram of the triaxial cell for measurement of vertical strain. Compatible with all models of transducers

▀ **28-T0477/4** De-airing block for pore pressure measurement transducer. It must be connected to the triaxial cell

▀ **28-T0494/1** Panel with reversing valve system, to reverse the water flow. Used in conjunction with the 28-T0494 Automatic volume change apparatus

Electronic accessories

All the transducers are fitted with 6-pins male plugs for direct connection to the rear panel of the compression machine. Linear and polynomial calibration parameters can be input directly via the keypad.

Displacement transducers

Used to measure the compression of the specimen in the triaxial cells:

Code	Travel (mm)
82-P0332	25
82-P0334	50
82-P0336	100

Note. They are connected to the triaxial cell by the accessory 28-T1048.

Strain gauge load cells

Used to measure the axial force applied to the specimen in the triaxial cells:

Code	Full scale	Thread
82-P0370/T	2.5 kN	Female M20x1.5
82-P0373/T	10 kN	Female M20x1.5
82-P0375/T	50 kN	Female M30x2.0
82-P0376/T	100 kN	Female M30x2.0

Note. All the load cells are supplied complete for connection to the upper beam of the triaxial frame.

Pressure transducers for pore pressure measurement

Code	Max
82-P0349	10 bar
82-P0350	20 bar

Note. They are connected to the triaxial cell by the de-airing block 28-T0477/4.

Potentiometric transducers for volume change measurement

Code	Capacity
28-T0494	100 cm ³

Note. The 28-T0494 Volume change transducer has to be used with the 28-T0494/1 Panel with reversing valve system.

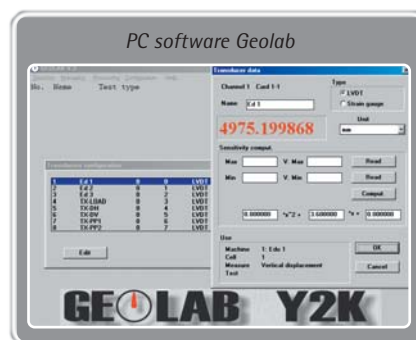


PC software for data processing

Code	Description
30-T0601/P3	PC software Geolab: data acquisition and processing for triaxial UU, CU, CD tests
30-T0601/R0	Additional software package for customised printout
82-Q0800/2	Serial cable for PC connection



82-P0334 fitted to the triaxial cell by the 28-T1048 mounting bracket and 82-P0370/T load cell fitted to the frame by the spherical attachment



SOIL TESTING

Load rings / Submersible precision load transducers Accessories for Triaxial frames

LOAD RINGS

General description

All Controls load rings are supplied ready for direct connection to the adapter supplied with our triaxial load frames and by the simple fixing of a 28-T1049 connector can be adapted for use with our complete range of triaxial cells.



82-T1001 to 82-T1009



Detail of the 28-T1049 fitted on top of a load ring

Models	Code		Max. load capacity kN						
	1	2	5	10	15	20	30	40	50
Standard	82-T1001	82-T1002	82-T1003	82-T1004	82-T1005	82-T1006	82-T1007	82-T1008	82-T1009
Electronic	82-T1001/E	82-T1002/E	82-T1003/E	82-T1004/E	82-T1005/E	82-T1006/E	82-T1007/E	82-T1008/E	82-T1009/E

Accessories

► **28-T1049** Connector with conical seat for load rings. Screwed to the lower base of the load ring to receive the steel sphere. Weight approx. 50 g



82-T1001/E to 82-T1009/E

AXIAL STRAIN MEASUREMENT

■ **82-D1257**
Dial indicator 30x0.01 mm

■ **82-D1259**
Dial indicator 50x0.01 mm

General description

58 mm dia. clockwise rotation. Supplied complete with mounting bracket. For connection to load rings.

⚖ Weight approx.: 200 g



82-D1257 fitted to the load ring

SUBMERSIBLE PRECISION LOAD TRANSDUCERS

Mounted inside the triaxial cells models 28-T0410/A, 28-T0411/A, and 28-T0416/A provide an electrical signal proportional to the axial load assuring accurate strength measurement. Supplied complete with loading piston.

⚖ Weight approx.: 1 kg



28-T0418/1 with 28-T0418/5 fitted inside the triaxial cell

Code	Description	Max. load
28-T0418/1	Submersible load transducer	10 kN
28-T0418/2	Submersible load transducer	26.5 kN

AXIAL STRAIN TRANSDUCERS AND MOUNTING BRACKET

■ **82-P0332**
Axial strain transducer 30 mm displacement

■ **82-P0334**
Axial strain transducer 50 mm displacement

■ **82-P0336**
Axial strain transducer 100 mm displacement

■ **28-T1048**
Mounting bracket for axial strain transducers

General description

The axial strain transducers are used to measure the deformation of the sample during the triaxial test. They need the mounting bracket 28-T1048 to fit the triaxial cell.

⚖ Weight approx.: 575 g