Geotechnical: Advanced Soil Testing

Advanced Soil Testing

Introduction

To design foundations, embankments and other soil structures, Geotechnical Engineers require methods of assessing the engineering properties of soils. For over 60 years Wykeham Farrance has been at the forefront of the development of test systems designed to give engineers the information they require.

Since the development of the first commercially produced shear box machine in the 1950s, WF has been working closely with leading academics and Universities to produce testing systems that further advance the understanding of soil mechanics.

Some of the more complex phenomena that occur in soils have often been difficult to recreate in the laboratory. Seismic activity, vibration, stress direction and slope stability are areas which have proven difficult to replicate, despite, their importance being understood. This was partly due to the lack of test systems capable of reproducing these effects and the complexity of test systems that were developed to carry out such work.

The following advanced controlled systems allow the geotechnical engineer to perform the most complex test regimes via a user-friendly software interface.

1. Stress Path Systems

To replicate the changes in stress experiences in situ during excavations, constructions that occour due to natural events (page 41)

2. Cyclic/Stress Path Triaxial Systems

To reproduce in the laboratory any vibration, shock and cyclic forces applied to the soil samples, to give engineers a better understanding of how a soil behaves in these situations (page 49)

3. Cyclic Simple Shear Apparatus

To simulate different shear strain and stress reversal histories and provide realistic descriptions of the accumulations of plastic shear strains and excess pore pressures during successive loading cycles (page 61)

4. Unsaturated Triaxial Testing

To investigate the behaviour of soil in an unsaturated state with the measurement of suction (page 66)

5. Dynamic Hollow Cylinder

A unique triaxial system that can control the magnitude and direction of principal stresses (page 71)

1. Stress Path Systems

Soils in general are non-elastic materials and their behaviour in-situ depends on many factors. These include the following:

- Magnitude and direction of the imposed stress changes
- The way in which the stress on the sample changes
- Previous history of loading, whether by natural causes or changes imposed by man.

Therefore, it is desirable to be able to trace the stress history of an element of soil. Stress path testing has previously been seen as a complicated research oriented procedure. With the introduction of closed loop servo-controlled pneumatic systems as proposed by WF, the stress path of a soil can be accurately reproduced and results collected and processed in a format that is easy to interpret.

Applications

The use of the stress path test in the laboratory enables field changes past present and future, to be modelled. The laboratory Stress Path Test allows the engineer to replicate the changes in stress conditions experienced during excavation, constructions that occur due to natural events.

Examples of applications

With the WF stress path system it is possible to recreate both compression and extension conditions.

Long term static stress conditions can also be replicated.

WF manufactures and supplies two stress path systems

a. ***Stress path system with advanced triaxial cells and 50 kN load frame***

b. ***Stress path system with Bishop Wesley triaxial cell***

The type of tests illustrated in the figures 1 and 2, which refer to both systems (a) and (b) here below cannot be performed in a conventional triaxial system.

Fig. 1 - Stress path application

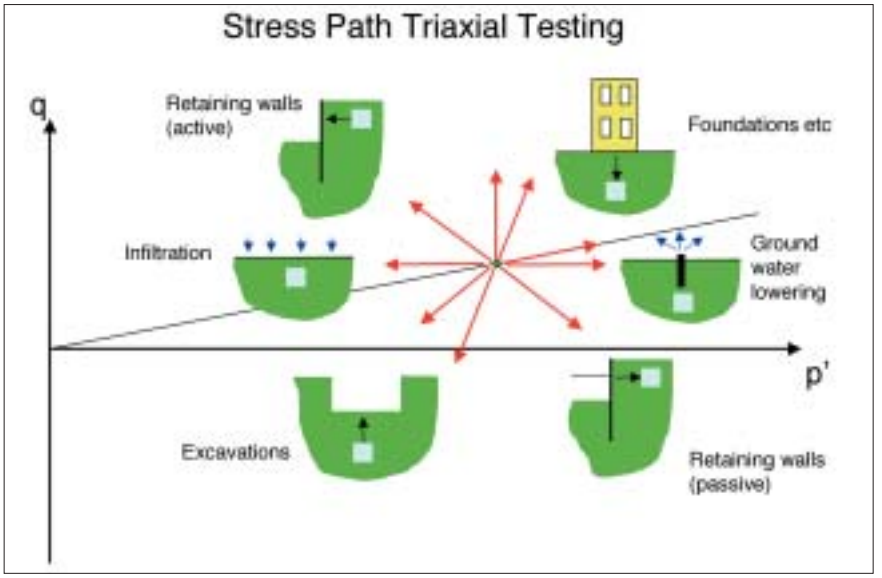
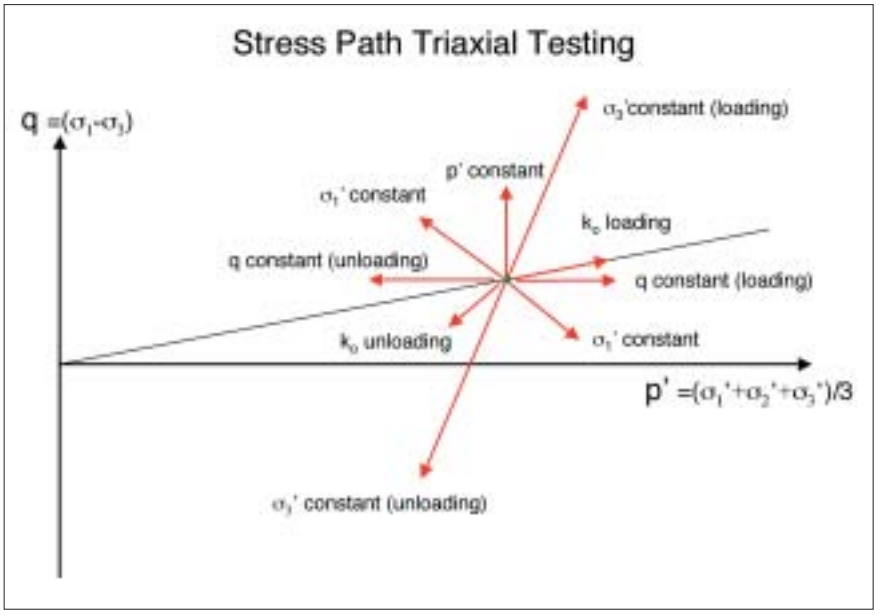


Fig. 2 - Stress path options



1. Stress Path Systems *(continued)*

a. System with advanced triaxial cells and 50 kN load frame

General description and Main Features

The system is configured to allow the testing of a range of materials from soft soils to soft rocks.
A range of triaxial cells can be used to test samples from 38 to 150 mm with a range of cell pressure up to 2000/3500 kPa.
All Wykeham Farrance submersible load cells can be interchanged between triaxial cells to meet the user's requirements according to the material to be tested.

Automatic pressure controllers are used to control both cell pressure and back pressure in the triaxial tests (UU, CU or CD) in order to perform different stages: saturation consolidation and shear. The pressure controllers, Tritech load frame and transducers are monitored and controlled by software via a data acquisition and control unit. With this system and using the special WF top cap (vacuum type) it is possible to perform either compression or extension tests (varying horizontal and vertical stress) on the soil sample.

The complete system includes the following:
- Triaxial machine, 50 kN capacity
- Advanced triaxial cell for samples from 38 to 150 mm diameter with accessories
- Control System & Data Acquisition
- Software

The different units are described here below.

The system includes the following:

Triaxial machine

WF 10056

Tritech triaxial load frame 50 kN cap., speed range 0 to 9.99999mm/min, digitally controlled complete with RS232 interface. 110-230 V, 50-60 Hz, 1ph.

WF 10056

Advanced triaxial cells

General description

The WF advanced triaxial cells accept samples of up to 150 mm dia. The design of the advanced triaxial cell ensure vertical alignment of the cell ram by clamping the perspex wall separately from the cell top. The cell wall is banded to prevent excessive expansion during the test and to protect against explosive failure when used with compressed air systems.
The WF advanced triaxial cells include a transducer axis ring with six outlets for on sample transducer cables. (i.e. radial and axial transducers, mid height pore water pressure transducers, bender elements).
See page 78-81
Space between the cell wall and sample needs to be greater when using on sample transducers. For this reason WF recommend using a sample one size down. For this reason conversion pedestal and top cap sets are shown on next page .

WF 12493

3500 kPa Advanced Triaxial Cell for 70 mm diameter samples with wire outlets for transducers

WF 12492

2000 kPa Advanced Triaxial Cell for 100 mm diameter samples with wire outlets for transducers

WF 12491

2000 kPa Advanced Triaxial Cell for 150 mm diameter samples with wire outlets for transducers

WF 12493

Advanced triaxial cells *(continued)*

Advanced triaxial cell accessories

Cell type	Sample size	Conversion set *	Top cap vacuum type **
WF 12493	1.4"	*WF 11122*	*WF 12401*
WF 12493	38 mm	*WF 11121*	*WF 12416*
WF 12493	50 mm	*WF 11125*	*WF 12417*
WF 12492	2.8"	*WF 11138*	*WF 12402*
WF 12492	70 mm	*WF 11139*	*WF 12418*
WF 12491	100 mm	*WF 11140*	*WF 12419*

* Conversion set consisting of pedestal, top cap & drainage lead,
** Required to perform extension tests (where the axial stress applied to the sample is less than cell pressure)

All other sample accessories are mentioned in the standard triaxial cell section (related to the same sample size) of the catalogue. *See page 29*

Control system and data acquisition

WF 12512

Closed loop stress path system , complete with 16 bit control and data acquisition system, cabinet, two screw control cylinders, pressure transducers, axial strain transducer, submersible load cell, volume change transducer, operating software and p.c. 230 V, 50 Hz, 1ph.

WF 12513

Same as above, but 110 V, 60 Hz, 1ph.

Specification

	capacity	resolution
Controllers		
Pressure:	2000 kPa	1 kPa
Capacity:	200 cc	0.001 cc
Transducers		
Volume:	100 cc	0,01 cc
Pressure:	2000 kPa	1 kPa
Submersible load cell:	5 kN	1N
Axial strain transducer:	50 mm	0,01 mm

Power supply: 230 V, 50 Hz, 1ph. or 110 v, 60 Hz, 1 ph.
Overall dimensions: 2000x2000x250 mm
Weight approx.: 250 kg

Software description

The Windows® software allows the following tests to be controlled and performed:
- Saturation ramps
- Isotropic Consolidation
- B check
- Anisotropic consolidation
- Ko consolidation
- Quick Undrained
- Consolidated undrained with pore water pressure measurement
- Consolidated drained with volume change measurement
- Extension tests
- Stress path

The systems WF 12512 and WF 12513 do not include the triaxial cells and accessories for 38 to 150 mm diameter, that must be ordered separately.

1. Stress Path Systems *(continued)*

b. System with Bishop –Wesley triaxial cell

General Description and Main Features

The system includes the following:

Stress path cell
Bishop-Wesley type

System Control
Computer controlled with pressures supplied via three motorised screw control cylinders.

Axial Pressure System
Consisting of stepper motor controlled screw cylinder, with pressure feedback from the axial force transducer.

Cell and Back Pressure Systems
Consisting of two stepper motor controlled screw cylinders, with pressure feedback from the cell pressure and back pressure transducers respectively.

Volume Change Transducer
The volume change is measured directly in the back pressure line. This method is more accurate than indirect ones, which are calculated from the stepper motor movement.

Pore Water Pressure Transducer
It is connected to the triaxial cell by a de-airing block.

Axial Load submersible load cell
This is fixed to the ram in the stress path cell. The load cell is oil filled to transmit the confining pressure into the load cell housing.
This ensures that the mesurements are not influenced by changes in the confining pressure.

Axial Strain Displacement Transducer
It is mounted on the triaxial cell, to monitor the axial ram movement.

Stress path triaxial cell

General description

The stress path cell is a Bishop-Wesley type with a large diameter chamber and includes two pore pressure and two back pressure ports. The cell includes also five electrical outlets to facilitate the use of on sample transducers for specimens from 38 to 50 mm diameter.
A rigid connection (the vacuum top cap) between the sample top cap and the internal submersible load cell is available *(see accessories)*.
Therefore both compression and extension tests, where the vertical stress is reduced with respect of the radial stress, can be easily performed.
A Bishop-Wesley triaxial cell for samples up to 100 mm diameter can be supplied on request.

WF12407

Stress Path Cell for 38-50 mm samples with two pore pressure and two back pressure ports and five electrical outlets for "on sample" transducers. Complete with load cell 5 kN* capacity

* Upon request the 5 kN submersible load cell can be replaced by 1 kN submersible load cell WF 17091

Specification

Sample diameter: 38 – 50 mm
Cell pressure: 2000 kPa
Axial load: 5 kN, 1N resolution
Ram travel: 25 mm
Ports : 2 extra drainage ports
Outlets: 5 electrical outlets
Height of the cell: 690 mm
Diameter of the cell: 420 mm
Weight: 30 kg approx.

Vacuum top cap for extension tests available for all models (see accessories)

WF 12407

b. System with Bishop –Wesley triaxial cell (continued)

Triaxial cells accessories
The stress path cell can receive two sample sizes 38 and 50 mm. Therefore the cells are supplied without internal accessories, these must be ordered separately.

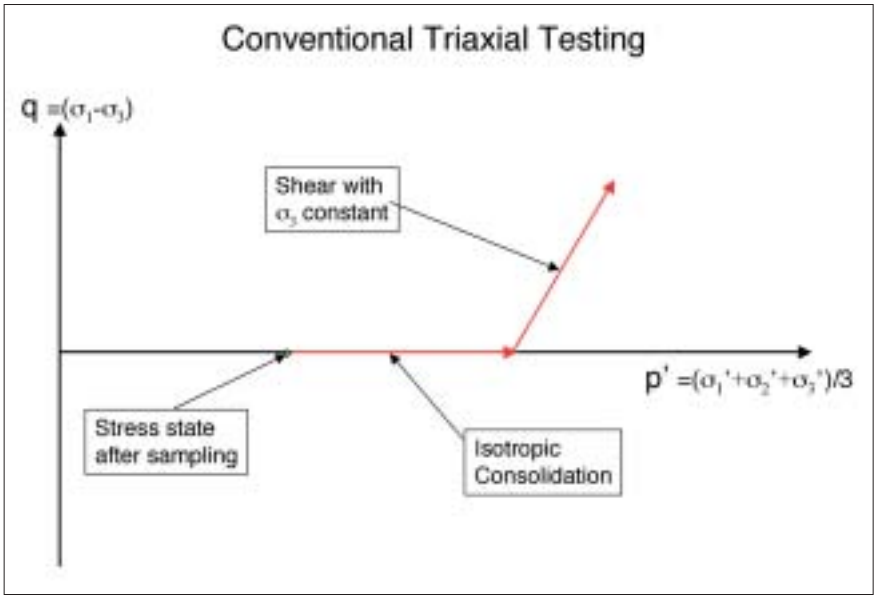
Cell type	Max. working pressure (kPa)	Sample size	Pedestal and top cap sets	Top cap vacuum type*	Porous disc	Membrane	O ring
WF 12407	2000	38 mm	***WF 12414***	***WF 12416***	***WF 10560***	***WF 10500***	***WF 10530***
WF 12407	2000	50 mm	***WF 12415***	***WF 12417***	***WF 10571***	***WF 10510***	***WF 10540***

* Complete with drainage lead

Sample accessories

Sample size	Suction device	O ring placing tool	Three part split former	Two part split mould	Filter drains	Hand sampler and extrusion dolly
38 mm	***WF 10460***	***WF 10542***	***WF 10410***	***WF 10440***	***WF 10670***	***WF 10623***
50 mm	***WF 10480***	***WF 10544***	***WF 10421***	***WF 10451***	***WF 10671***	***WF 10624***

WF 12416, WF 12417



Control system and data acquisition

WF 12476

Closed loop stress path system complete with 24 bit control and data acquisition system, cabinet, three screw control cylinders, pressure transducers, axial strain transducer, volume change transducer, operating software and p.c. 110-230 V, 50-60 Hz, 1 ph.

The three screw control cylinders are required to apply and control the level of cell pressure, axial pressure and back pressure during the different steps of triaxial tests: saturation, consolidation and shear.
The control of the stepper motors and data acquisition is managed by software via a 24 bit-16 channels data logger.

Specification

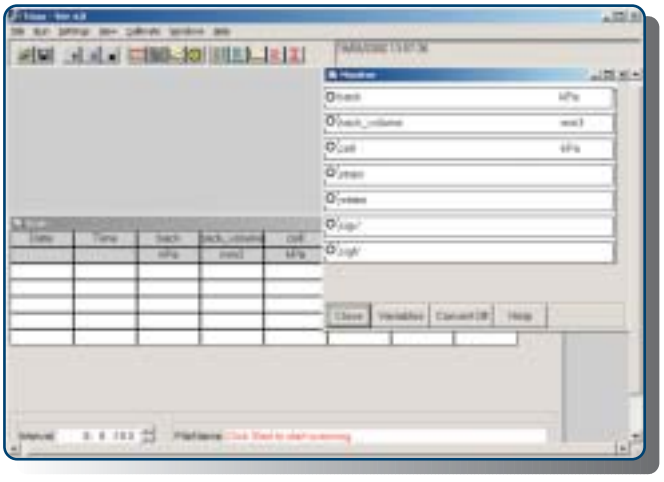
	capacity	resolution
Controllers		
Pressure:	2000 kPa	1 kPa
Capacity:	200 cc	0.001 cc
Transducers		
Volume:	100 cc	0,01 cc
Pressure:	1000 kPa	0,1 kPa
Axial strain transducer:	25 mm	0,01 mm

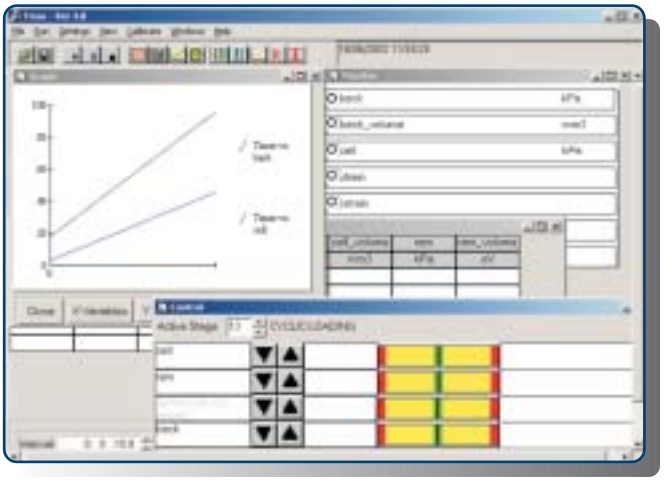
Overall dimensions: 2000x2000x250 mm (complete apparatus)
Weight approx.: 250 kg

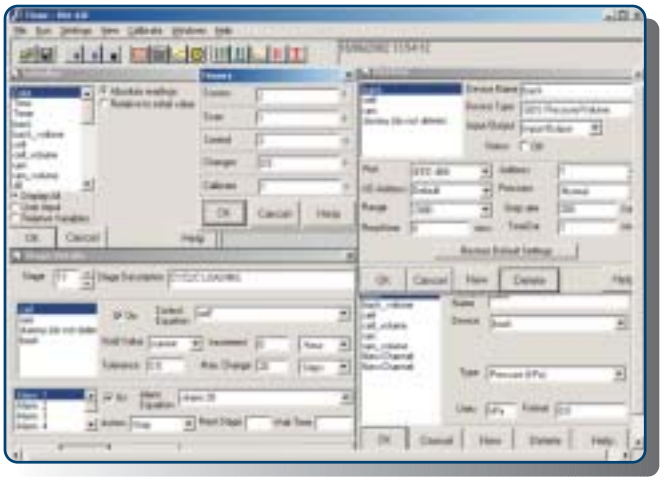
Software description

Windows software for control and data acquisition, to perform UU, CU, CD, and stress path tests.
The Windows® software allows the following tests to be controlled and performed:

- Saturation
- Consolidation
- B check
- Anisotropic consolidation
- K_0 consolidation
- Quick Undrained
- Consolidated undrained with or without pore water pressure measurement
- Consolidated drained with or without pore water pressure measurement
- Extension tests
- Stress path







b. Stress Path System (Bishop-Wesley) (continued)

Transducers *

Pressure transducers

For monitoring the cell, back and pore pressure. To be completed with de-airing blocks for connecting to the triaxial cell.

WF 17060

Pressure transducer 1000 kPa, 3 metre cable, 0,1 kPa resolution

WF 17029

De-airing block for pressure transducers complete with on-off valve

Displacement transducers

WF 17006

Linear displacement potentiometric transducer 25 mm travel 0,01 mm resolution. Mounting bracket available separately

WF 17082

Mounting block for connecting WF 17006 displacement transducers to the stress path cell

Volume change transducer

For monitoring sample volume change. Supplied complete with a change over valve system and transducer.

WF 12499

Volume change apparatus 100 cc capacity, 0,1 cc resolution complete with change over valves and transducer
(see page 36)

Load transducer

WF 17104**

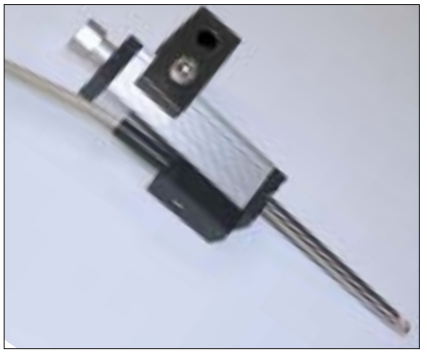
Submersible load cell 5 kN cap., 1 N resolution

* Included in the stress path systems WF 12512 and WF 12476

** Included in the stress path triaxial cell WF 12407

Transducer specifications

Type of measurement	Pressure	Displacement
Model	***WF 17060***	***WF 17006***
Range	1000 kPa	25 mm
Input voltage	10 V DC	10 V DC
Output	100 mV full scale	from 0 to input voltage
Repeatability	better than 0.25%	better than 0.002 mm
Accuracy	better than 0.1 kPa	better than 0.002 mm



WF 17006 with WF 17082

WF 17060

WF 12499

WF 17082

Geotechnical: Advanced soil testing

1. Stress Path Systems. "On sample" Transducers

Introduction

The Stress Path Triaxial test can be upgraded and improved by the accurate measurement of sample deflections and stiffness evaluation of the soil using on sample strain transducers and Bender elements.

Description	Sample size		
	70 mm	100 mm	150 mm
On sample transducer kit including 2 linear, 1 radial transducers and all plugs used with DataMan loggers (page 38)	WF 17072	WF 17073	WF 17075

"On sample" transducers

These are displacement transducers supplied in a set for axial and radial measurement of sample size, fitted directly on the soil sample. On sample measurements of small deflections eliminate the errors in measurement due to the bedding effect of the porous stones on either end of the sample. Different kits are available for different size of samples, 38 - 50 mm sample size are too small for this applications.

WF 17072 - On sample transducer kit

Bender elements

Fitted in the top cap and base pedestal, the bender elements are used to determine the sample stiffness. The stiffness of a soil can be measured using bender elements. This system, consisting of a transmitter, which is energised to produce a shear wave through the sample and a receiver, measures the stiffness of the soil sample as calculated by the equation:

$$G_{max} = \rho \cdot (V_s)^2$$

where

V_s = shear wave velocity

ρ = mass density of the soil sample

This stiffness value is a constant when the shear strain applied to the sample does not exceed its elastic limit. Gmax is a key parameter in small strain dynamic analysis, such as those to predict soil behaviour or soil structure interaction during earthquakes, explosions or machine and traffic vibrations. *For more details see pages 78-79*

WF 17320

PC based oscilloscope and signal generator for driving and recording data from bender elements. PC not included

Top cap and base pedestal with bender elements

These accessories can be mounted into the different models of triaxial cells (advanced type) to perform the tests. Please make reference to the table *on page 78* where the accessories codes are given relative to the sample size and triaxial cell model.

Bender elements