History of Wykeham Farrance Ltd

- Over 60 years experience in the design and manufacture of geotechnical testing equipment.
- World wide reputation for quality of equipment sold to over 100 countries
- Continual new product design and development including the range of advanced dynamic testing systems.
History of Wykeham Farrance Ltd

- In July of 2004 Wykeham Farrance joined the Controls group of companies.
- Wykeham Farrance is now the Geotechnical section for advanced testing of Controls Italy.
Advanced Products from Wykeham Farrance

- Cyclic Triaxial, Cyclic Simple Shear,
- Unsaturated Systems
- “On Sample” Measurement Systems
- Bender Elements
- Hollow Cylinder Apparatus
- Data Acquisition and Spread Sheets
Cyclic Triaxial System
Cyclic Triaxial system

KHBO Laboratory in Belgium
Cyclic Triaxial

- Saturation in pressure steps
- Continuous saturation
- Isotropic consolidation
- Anisotropic consolidation
- Ko consolidation
- Stress Path
- Cyclic loading
- Monotonic loading
Cyclic Triaxial

- Liquefaction
- Blasting
- Shear Modulus & Damping Ratio
- Strength Degradation
Cyclic Triaxial

Earthquake

Rail track

Blasting
Cyclic Triaxial

Control and Data Acquisition System
Cyclic Triaxial

Double acting digitally controlled Pneumatic actuator

Piston Clamp
Cyclic Triaxial

The actuator connects to the triaxial cell ram via ball joint and horizontal adjustment flange.
Cyclic Triaxial

Displacement Transducer mounted in series with the actuator to show actuator position

Vertical displacement is measured with a +/- 25mm travel displacement transducer
Cyclic Triaxial

Submersible load cell
5kN as standard

Must be a submersible to achieve accurate loading on the sample
Cyclic Triaxial

Pore water pressure measured at the base of the triaxial
Cyclic Triaxial

Volume change is measured through a volume change transducer with change over valves to increase the range.
Cyclic Triaxial

Back pressure solenoid valve connects back pressure to the top of the sample.
Cyclic Triaxial

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell pressure increment (kPa)</td>
<td>50</td>
</tr>
<tr>
<td>Differential pressure (kPa)</td>
<td>10</td>
</tr>
<tr>
<td>Isotropic consolidation</td>
<td>On</td>
</tr>
<tr>
<td>Effective stress adjustment</td>
<td>10</td>
</tr>
<tr>
<td>Isotropic consolidation</td>
<td>On</td>
</tr>
<tr>
<td>Normal stress increment (kPa)</td>
<td>10</td>
</tr>
<tr>
<td>Axial stress increment (kPa)</td>
<td>0</td>
</tr>
</tbody>
</table>

Loading method:
- Non-standard (user-defined)
- ASTM D 3969 (Method A)
- ASTM D 3969 (Method B)

Control method:
- Stress
- Cycle
- Load
- Displacement
- Non-standard (user-defined)

Termination cycle count: 500
Termination strain: 0
Termination load: 15
Termination displacement: 0

Diagram showing cyclic triaxial test setup with various parameters and loadings.
Cyclic Triaxial
Cyclic Triaxial
Cyclic Triaxial
Cyclic Triaxial

- Deviator stress, \( q \) (kPa)
- Axial strain, \( a \) (%)
- Excess pore pressure ratio, \( \Delta u/p'_c \)

Number of cycles, \( N \)
\[ \sigma'_{v0} = 0 \]

\[ \sigma'_{h0} = 0 \]

\[ \sigma'_{c} = 100 \text{ kPa} \]

\[ f = 0.1 \text{ Hz} \]

\[ q_{\text{cyc}} = 30 \text{ kPa} \]
Cyclic Triaxial
Cyclic Simple Shear
Cyclic Simple Shear

- Liquefaction
- Blasting
- Shear Modulus & Damping Ratio
- Strength Degradation
Cyclic Simple Shear

Tension

Foundation

Compression

Simple Shear
Cyclic Simple Shear
Simple Shear

Sample set up in rings showing simple shear

Vertical Stress is varied to maintain constant height $H$
Cyclic Simple Shear

Rigid cell top

Load cell 5kN measures shear force
Cyclic Simple Shear
Cyclic Simple Shear
Cyclic Simple Shear

Force - Displacement Relationship

- Force (kN)
- Displacement (mm)
Ring Shear
Ring Shear
Ring Shear

- Test for Residual Shear Strength
- Ultimate Shear strength

![Graph showing load and displacement with a peak at load and a plateau at displacement.](image)
Ring Shear

Failure of ground here

Material stabilizes due to residual shear strength

Slip circle

x metres
Shear Testing

Shearing Area is non constant
Normal Stress is non constant
Residual Shear?
Ring Shear

- Shear Area Varies
- Shear Area is Constant
- Normal Load (non constant)
- Normal Load is constant
- Shear Force

Direct Shear

Ring Shear
Ring Shear

Friction tests for piles

Soil

Steel
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus

Five feedback Load Pressure Actuators

Axial Compression & Tension

Radial Stress or Rotation

Internal Cell Pressure

External Cell Pressure

Back Pressure
Hollow Cylinder Apparatus

Sample dimensions:
- $H$: sample height (mm)
- $D_i$: sample inner diameter (mm)
- $t$: sample inner radius (mm)
- $D_o$: sample outer diameter (mm)
- $t_o$: sample outer radius (mm)
- $l$: radial movement of inner wall (mm)
- $l_o$: radial movement of outer wall (mm)

Applied force and pressures:
- $W$: applied axial load (N)
- $T$: applied torque (Nm)
- $P_i$: confining inner cell pressure (MPa)
- $P_o$: confining outer cell pressure (MPa)

Applied stresses:
- $\sigma_x$: axial (vertical) stress
- $\sigma_t$: radial stress
- $\sigma_h$: horizontal (circumferential) stress
- $\tau$: shear stress

\[
\begin{align*}
\sigma_x &= \frac{W}{\pi (D_i^2 - t^2)} - \frac{P_o}{D_i} + \frac{P_i}{t} \\
\sigma_t &= \frac{P_i - P_o}{D_i - t} \\
\sigma_h &= \frac{P_o - P_i}{t} \\
\tau &= \frac{3T}{2\pi(D_i - t)}
\end{align*}
\]

Strain:
- $\varepsilon_x$: axial strain
- $\varepsilon_t$: radial strain
- $\varepsilon_h$: horizontal (circumferential) strain
- $\gamma_{th}$: shear strain

\[
\begin{align*}
\varepsilon_x &= \frac{\Delta H}{H} \\
\varepsilon_t &= \frac{l_o - l}{r_o - r_t} \\
\varepsilon_h &= \frac{l_t + l_i}{r_o + r_t} \\
\gamma_{th} &= \frac{2T}{3H}(\frac{r_t - r_o}{r_o^2 - r_t^2})
\end{align*}
\]

Principal stresses:
- $\sigma_1$, $\sigma_2$, $\sigma_3$: principal stresses

\[
\sigma_1 = \frac{\sigma_x + \sigma_h}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_h}{2}\right)^2 + \left(\frac{\gamma_{th}}{2}\right)^2}
\]

\[
\sigma_2 = \sigma_x
\]

\[
\sigma_3 = \frac{\sigma_x + \sigma_h}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_h}{2}\right)^2 + \left(\frac{\gamma_{th}}{2}\right)^2}
\]

Octahedral shear strain:

\[
\gamma_{oct} = \frac{1}{2}\left(\sigma_1 - \sigma_2\right)^2 + \left(\sigma_2 - \sigma_3\right)^2 + \left(\sigma_3 - \sigma_1\right)^2
\]
Hollow Cylinder Apparatus

Standard Triaxial Test

The standard triaxial and cyclic trial tests allow the magnitude and frequency of the applied stress but not the direction.
The application of a concentrated vertical load to horizontal surface produces a set of vertical stresses on every horizontal plane. The magnitude of this stress is at its greatest at the centre directly below the load and decreases the further you move away from this point.

Hollow Cylinder Apparatus

- Vertical stress
- Horizontal stress
- Shear stress

The resultant of those stresses (Vertical earth pressure, Horizontal earth pressure, Induced vertical stress, Induced horizontal stress and Induced shear stress) can be represented by major and minor principal stresses with a specific principal stress direction.
Hollow Cylinder Apparatus

Major and Minor principal stresses with a specific principal stress direction.

$\sigma_1$: major principal stress

$\sigma_3$: minor principal stress

$\alpha$: major principal stress direction

Vertical stress

Horizontal stress

Shear stress

Major and Minor principal stresses with a specific principal stress direction.
Hollow Cylinder Apparatus

Axial & Radial Force Actuators

Triaxial cell base

Torque Arm

Thrust Bearing

Axial Actuator
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus

Combined Load and Torque Transducer
Hollow Cylinder Apparatus

Base pedestal showing the porous stone, fins for gripping the sample and Pore water pressure port.
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus

Sample set up ready for placing the triaxial cell top
Hollow Cylinder Apparatus

Standard Wykeham Farrance Cell Top

All transducer cables and pipe work pass Through the cell base
Hollow Cylinder Apparatus

Vertical soil lathe & drill
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus
Hollow Cylinder Apparatus

Sample Preparation

Trimming the outside diameter

Drilling the Centre hole

Finished Sample
Hollow Cylinder Apparatus
Unsaturated Triaxial
To test an unsaturated sample in the triaxial requires some changes to its design.

We need to measure new parameters.
Unsaturated Triaxial

- Measuring negative pore pressure
- Measuring total volume change
- Measuring sample volume change
- Preventing cavitation in pore water measuring system
Unsaturated Triaxial cell
Unsaturated Triaxial

Double Wall Triaxial Cell

Outer cell wall expands

Inner cell wall does not change

Cell Pressure
Unsaturated Triaxial

High air entry stone

Pedestal
Unsaturated Triaxial cell

- Air Pressure
- Pore Pressure
- Axis Translation
**Unsaturated Triaxial**

- Undisturbed test this is no good
- We need to measure the suction
- Atmospheric pressure in the pore space
Unsaturated Triaxial

Spacer

Ceramic Transducer

Transducer Housing

15 bar high air entry stone

Suction Transducer
Unsaturated Triaxial cell

- Back Pressure Water
- Cell Pressure
- Suction Transducer
Unsaturated Triaxial
Unsaturated Stress Path
On Sample Transducers
On Sample Transducers

Top Cap → Porous Disc → Stress Disturbance → Sample → Stress Disturbance → Porous Disc → Pedestal

Middle Third

Bedding Errors
On Sample Transducers
On Sample Transducers
On sample Transducers

Access ring to allow transducer cables to exit the triaxial cell
On Sample Transducers

Submersible Displacement Transducers
On Sample Transducers

Mid height pore water pressure Transducer
Bender Elements

Function Generator

Oscilloscope

Amplitude Volts

Time t

G_{max} = V{s}^2 \cdot p
where
V{s} = Velocity
p = Density
Bender Elements

Sand
Bender Elements

Clay
Bender Elements

Triaxial cell with bender elements
Data Acquisition

16 channel
24 bit A/D
RS232, USB & Blue Tooth interface
Stand alone data logger

PC control
Software for calibration and
Live data display
Data Exports to spreadsheets
Cell Handling Device
For all your advanced Geotechnical testing requirements.

Wykeham Farrance Ltd

Provides

Quality Innovation Expertise