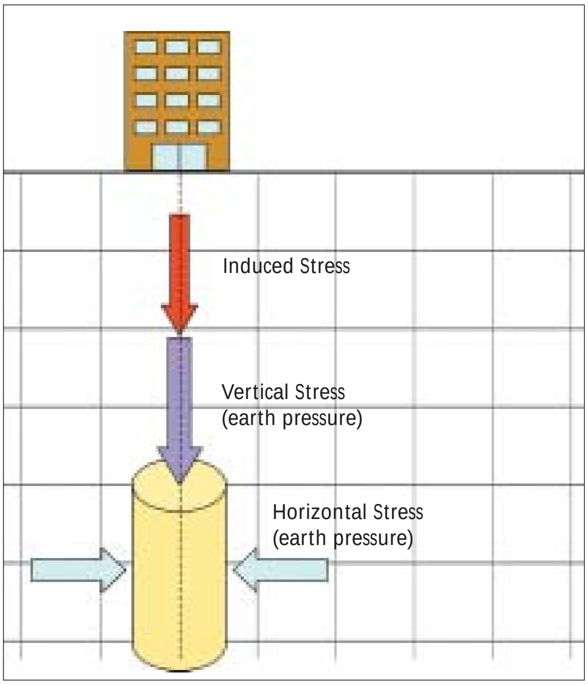
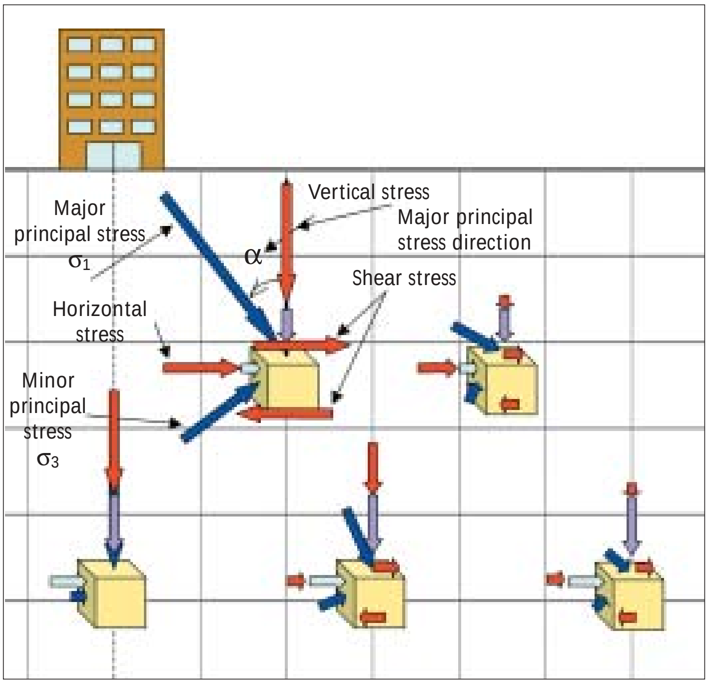
## Dynamic hollow cylinder apparatus

### Introduction

In a standard triaxial test the stress that we can apply on the sample, simulates for example the condition of a portion of soil below the central axis of a building. The induced stress (both axial and horizontal) are principal stresses, since on these planes only normal stresses acts and there are no shear stresses.
But, if we consider the general situation of the soil below the building, there are several different conditions of stress where on the vertical and horizontal surfaces of the soil samples, both normal and shear stress (red arrows) are induced at the same time by the construction.
The resultant of these different 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 (blue arrows) with a specific principal stress direction.
The standard triaxial tests (static and cyclic) allow to set up and control the magnitude and frequency of the applied stress (horizontal and vertical) but not the direction.




**Control of:**
- **Magnitude**
- **Frequency**
- **Direction of stress**

**Main features**
- **5 axis control**
- **Effects of principal stress rotation**
- **Effects of intermediate principal stress**
- **Anisotropy of soil samples**
- **Frequency up to 5 Hz (vertical and horizontal axes only)**
- **Up to 19 data acquisition channels**

## 5. Dynamic hollow cylinder apparatus *(continued)*

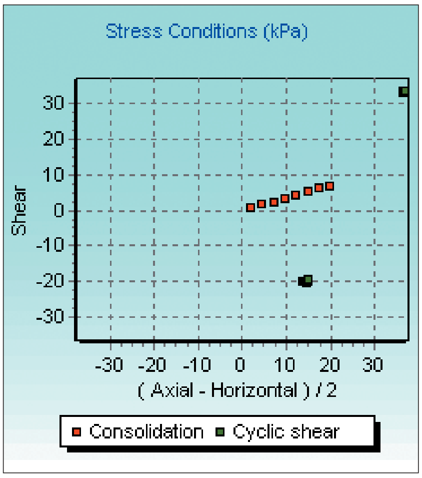
### Applications

The hollow cylinder apparatus is the only triaxial system that can control the magnitude and direction of principal stresses:

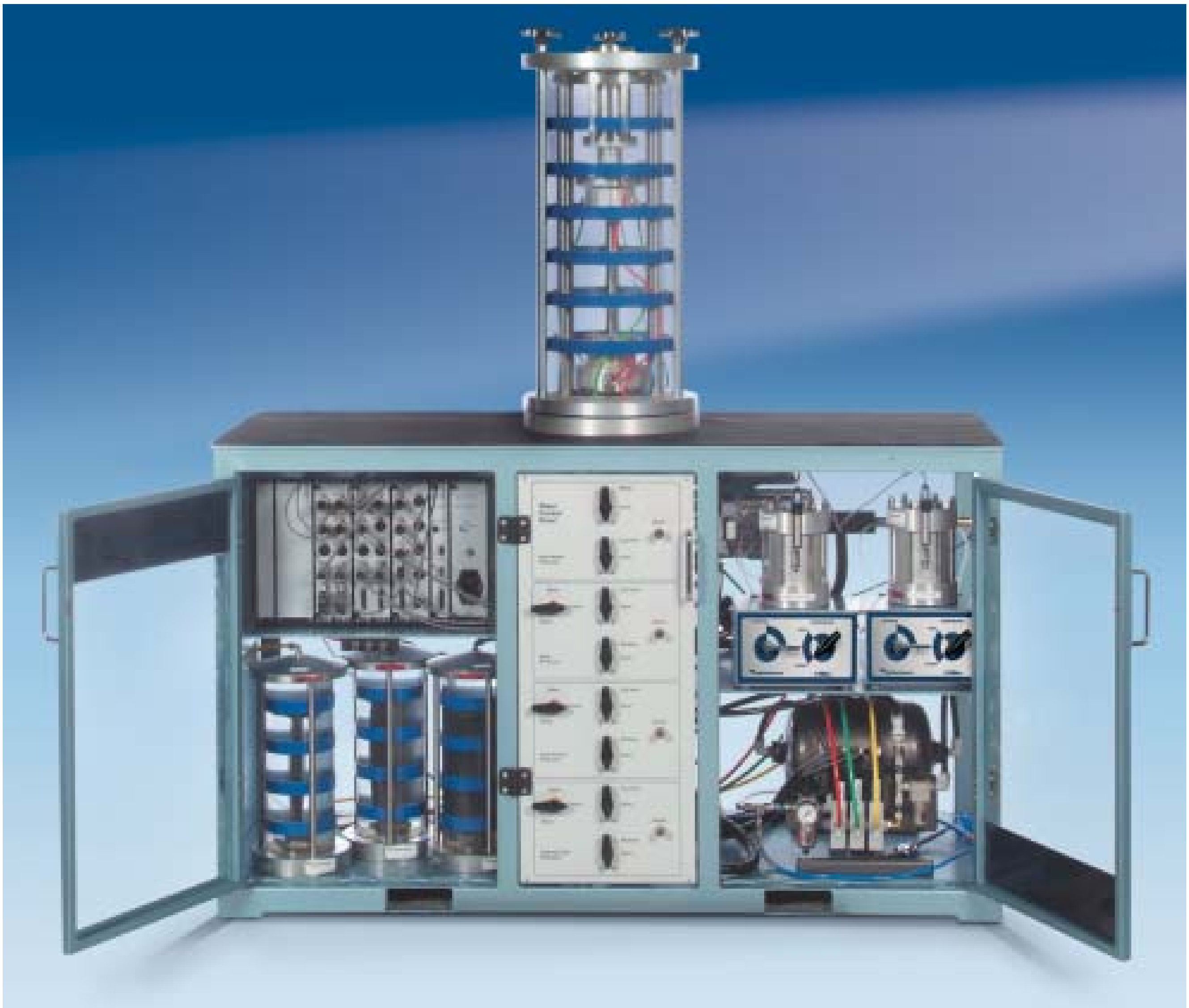
- Vertical and horizontal stress in cyclic mode
- Inner and outer cell pressure in cyclic mode
- Back pressure in static mode.

**The WF Dynamic hollow cylinder apparatus** allows the investigation of the rotation of principal stresses within the soil sample.

It does this by independently controlling the direction and magnitude of the three principal stresses.




*Graph shows the stress conditions after consolidation and during cyclic shear*



*WF 12440*

## Dynamic hollow cylinder apparatus *(continued)*

### General description

**Sample characteristics**

**1. Sample dimensions**

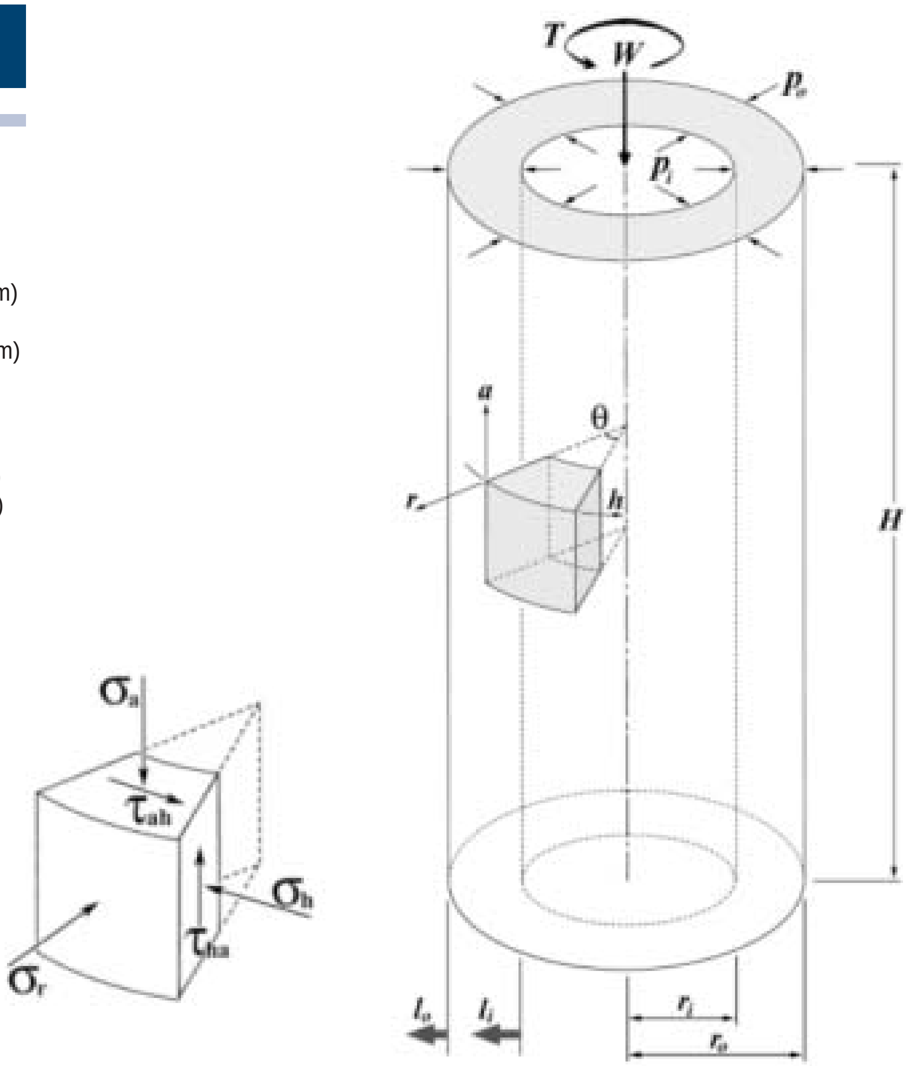
- H sample height 200 mm
- $r_i$ sample inner radius 30 mm
- $l_i$ radial movement of inner wall (mm)
- $r_o$ sample outer radius 50 mm
- $l_o$ radial movement of outer wall (mm)

**2. Applied force and pressures**

- W applied axial load (N)
- T applied torque (N · m)
- $P_i$ confining inner cell pressure (kPa)
- $P_o$ confining outer cell pressure (kPa)

**3. Applied stresses**

- $\sigma_a$ axial (vertical) stress
- $\sigma_r$ radial stress
- $\sigma_h$ horizontal (circumferential) stress
- $\tau_{ah}$ shear stress




### Basic equipment

**Base frame**

The hollow cylinder cell is mounted on a base frame, which gives excellent rigidity for axial and radial loading of the sample. The base frame also supports the axial and torsional actuators, control and data acquisition system and the air water interfaces.

**Inner cell pressure**

The inner cell pressure is applied through digitally controlled air valves in closed loop with the cell pressure transducer.

**Outer cell pressure**

The outer cell pressure is applied through digitally controlled air valves in closed loop with the outer cell pressure transducer.

**Back pressure**

Back pressure is applied through digitally controlled air valves in closed loop with the back pressure transducer.

## 5. Dynamic hollow cylinder apparatus *(continued)*

### Dynamic hollow cylinder apparatus *(continued)*

#### Triaxial cell

150 mm triaxial cell for 100 mm outside dia. and 60 mm inside dia. x 200 mm long samples. The cell has an internal frame, which holds the load/torque transducer. All the fill, empty and drainage ports from the top cap and base pedestal are positioned in the triaxial cell base. All internal transducer cables exit through the base. This allows the sample to be accurately set up, with all transducers placed, before the cell top is positioned.

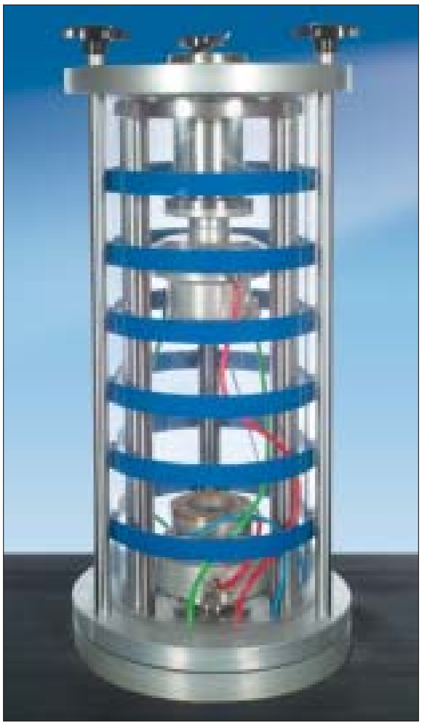
#### Axial actuator

The axial double acting pneumatic actuator is mounted on the base of the triaxial cell ensuring good alignment. It is fitted with a digital servo valve, which controls the force displacement frequency and wave shape. The actuator can apply an axial load of ± 10 kN, with a stroke of ± 25 mm, up to a maximum frequency of 5 Hz.

#### Torsional actuator

The torsional double acting pneumatic actuator is mounted on a platform in the base frame. It is fitted with a digital servo valve, which controls the force displacement frequency and wave shape. The actuator can apply a torsional force of ± 200 N · m, with 90 degrees of rotation, up to a maximum frequency of 5 Hz.

**Axial and radial force actuators**



*Triaxial cell*


*Base pedestal*

*1 Triaxial cell base*
*2 Torque arm*
*3 Thrust bearing*
*4 Axial actuator*

#### Top cap and base pedestal set

Special top cap and base pedestal set 100 mm with 60 mm inside dia. Both are designed to accept the special internal membranes. Porous discs with fins are fixed to the top cap and base pedestal for gripping the sample when the rotational stresses are applied. Both are supplied with two ports for drainage and pore water pressure.

#### Hardware

The hollow cylinder cell is mounted on a base frame, which provides the support and reaction to all the applied stresses to the sample. It also houses the vertical and torque actuators, air water interfaces, the control and data acquisition system, the auxiliary air cylinder on which is mounted the control valves for the inner, outer and back pressures. All transducers, except the load/torque transducer, are positioned in the base frame.

## Dynamic hollow cylinder apparatus (continued)

### Integrated Multi-Axis System (IMACS)

The IMACS system is identical to that one described *on page 53*

### Software

**The software sections the test into five stages**

**1. General**
This is where you enter:
- Operator
- Sample identification
- Dimensions
  Initial inner sample diameter
  Initial outer sample diameter
- Initial sample height
- File name

**2. Saturation**
- Inner/Outer pressure increment (stepped or continuous)
- Back pressure differential
- Target time

**3. Consolidation**
Three types of consolidation are offered
**Isotropic consolidation**
Data entered for:
- Initial mean normal stress
- Target mean normal stress
- Target time

**Anisotropic consolidation - Type A**
Data entered for:
- Initial mean normal effective stress
- Target axial stress
- Earth pressure coefficient
- Intermediate principal stress coefficient
- Target time

**Anisotropic consolidation - Type B**
Data entered for:
- Initial mean normal effective stress
- Target mean normal effective stress
- Target deviator stress
- Initial major principal stress direction
- Target major principal stress direction
- Initial intermediate principal stress coefficient
- Target intermediate principal stress coefficient
- Target time

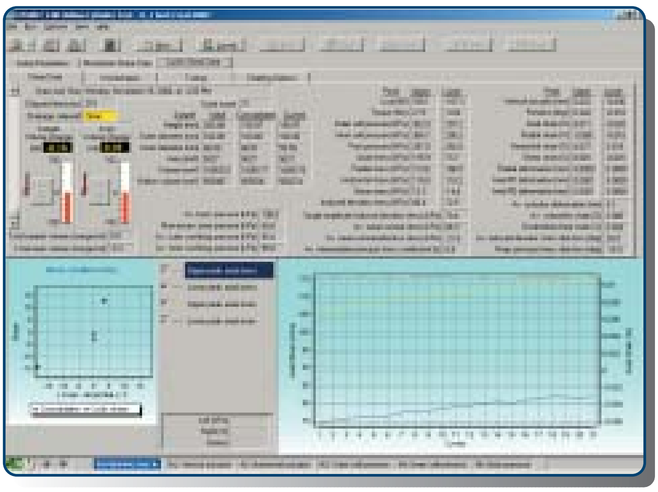
**4. Monotonic shear (Stress control)**
Data entered for:
- Drainage condition:
  • Drained or Undrained
- Intermediate principal stress coefficient during shear
  • Monotonic shear direction
    - Isotropically consolidated
      Major principal stress direction
    - Anisotropically consolidated
    - Induced deviator stress direction
  • Loading rate of induced deviator stress
    - Termination octahedral shear strain

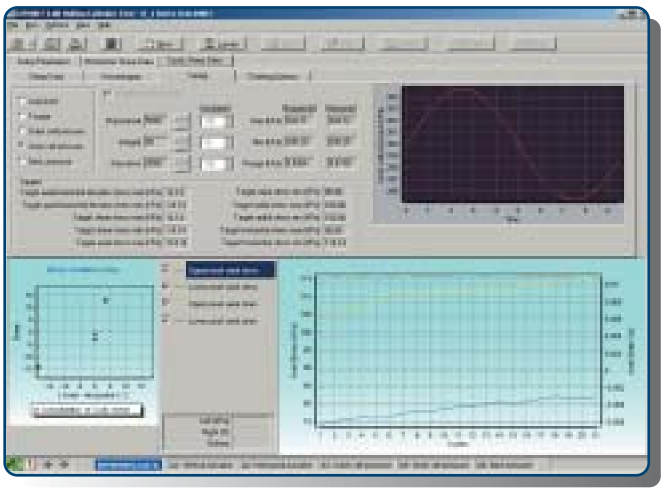
**5. Cyclic shear**
Data entered for:
- Drainage condition:
  • Drained or Undrained
- Intermediate principal stress coefficient during shear:
  • Cyclic shear direction
    - Isotropically consolidated
      Major principal stress direction
    - Anisotropically consolidated
      - Induced deviator stress direction
      - Induced cyclic deviator stress (Asymmetric cyclic loading is possible) forward from the starting point backward from the starting point
      - Frequency
- Termination octahedral shear strain
- Termination number of cycles

The software also includes the following ancillary sections:

- **Transducer Library**, stores all transducer calibration data, serial numbers. Reallocating a transducer is just a stroke on the keyboard.
- **Wave Shape Library** stores all wave shapes standard and user defined.
- **Test Library** stores all test set up data. Tests can be reproduced at any time with the same routine as previously used.
- **Universal Tuning Program** allows you to tune the system to obtain the best wave shape.

**IMACS system**





## 5. Dynamic hollow cylinder apparatus (continued)

### Dynamic hollow cylinder apparatus (continued)

**Transducers used in the dynamic hollow cylinder**

| Type of measurement | Full scale | Resolution | Description |
|---|---|---|---|
| Axial load and torque | ± 10 kN<br>± 300 N · m | 1 N<br>0.01 N · m | Submersible type fitted to the internal frame of the triaxial cell. The reaction of the applied forces is transmitted through the internal triaxial cell frame into the base frame; it measures the load and torque applied to the sample independently |
| Volume change | 100 cc | 0.1 cc | Mounted on a shelf in the base frame, it monitors the sample volume change. This volume change value is used with the inner cell volume change to calculate the sample volume change and outer diameter |
| Radial displacement | ± 50 mm | 1.5 micron<br>5” of arc | Mounted on the radial torque actuator, has a dual purpose of being the part of the closed loop system for controlling the position of the actuator and monitoring the radial movement or rotation of the sample |
| Axial displacement | ± 25 mm | 0.01 mm | Mounted on the axial actuator it has a dual purpose of being the part of the closed loop system for controlling the position of the actuator and monitoring the axial movement of the sample |
| Pore water pressure | 1000 kPa | 0.1 kPa | Mounted close to the triaxial cell base |
| Inner cell pressure | 1000 kPa | 0.1 kPa | Mounted close to the triaxial cell base, it is in a closed loop with the digital servo valve for control of the inner cell pressure |
| Outer cell pressure | 1000 kPa | 0.1 kPa | Mounted close to the triaxial cell base, it is in a closed loop with the digital servo valve for control of the outer cell pressure |
| Inner cell volume change | 100 cc | 0.1 cc | Mounted on a shelf in the base frame, it monitors the inner cell volume change, to calculate the sample inner diameter |

All transducers are fitted with an in-line calibration module, which normalises all the transducer outputs. This means that transducers can be changed or moved without the need to re-calibrate.

**Ordering information**

*WF 12440*

**Dynamic hollow cylinder apparatus, PC controlled with IMACS and hollow cylinder triaxial cell.** 230-115 V, 50-60 Hz, 1 ph.

The system includes:
- Hollow cylinder triaxial cell mounted on the base frame
- Computer control and data acquisition system (IMACS)
- Transducers for load, displacement, pore pressure, and volume change
- Software package
- Personal computer.

The system requires a source of compressed air: 10 bar max. pressure, 100 litres capacity. See accessories

## Accessories

### Sample preparation

### WF 12445

**Sample preparation kit for Hollow cylinder apparatus to produce samples with 60 mm ID and 100 mm OD from cohesive and non-cohesive soils. The kit includes the dummy sample.** 230 V, 50 Hz, 1 ph.

### WF 12447

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

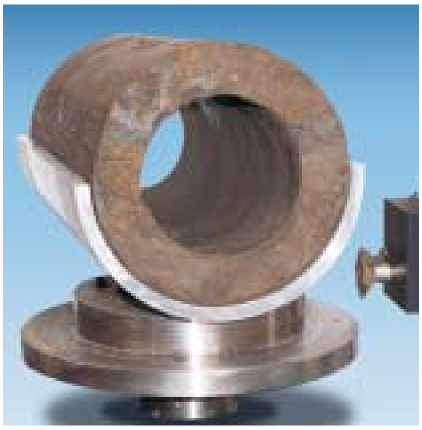
This kit consists of the following:

- Motorised soil lathe to allow an extruded or a block sample to be machined to 100 mm dia. This device has a drilling attachment, which will allow a 60 mm dia. hole to be drilled in stages
- Three part split former to allow trimming of the sample ends and allowsample movement without damage
- A set of internal and external moulds for preparing unbound samples:

• The external mould is a three-part mould, which sits on the triaxial cell base. It has a vacuum connection to suck the membrane onto the inner wall of the mould. Essential when preparing low density samples

• The inner mould is in segments to allow it to contract and be withdrawn after the sample has been prepared.

*Drilling the centre hole*



*Finished sample*

*Trimming the outside diameter*