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**DIGITAL TRIAXIAL TESTING SYSTEM**

**Implementation of the Digital Triaxial  
Testing System**

**Hassan M. El-Hage**

**A Report**

**Submitted under the supervision of**

**Dr. Bengt H. Fellenius**

**Professor**

**in partial fulfillment  
of the requirements for the degree of  
Master of Engineering**

**Department of Civil Engineering  
Faculty of Science and Engineering  
University of Ottawa  
Ottawa, Canada**

**January 27, 1986**



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UNIVERSITY OF OTTAWA  
FACULTY OF SCIENCE AND ENGINEERING  
C E R T I F I C A T E O F A P P R O V A L

The Report by

HASSAN M. EL-HAGE

entitled

Implementation of the Digital Triaxial  
Testing System

is accepted in partial fulfillment  
of the requirements (6 credits) for the  
degree of Master of Engineering

January 27, 1986

-----  
Dr. Vinod Garga, B. Eng.

Associate Professor

-----  
Dr. Bengt H. Fellenius, P. Eng.

Professor

Supervisor

## ACKNOWLEDGEMENTS

Special debt of appreciation for the help of Mr. R. J. Moore in the laboratory during the preparation of the specimens and setting up the GDS.

Sincere gratitude is also extended toward the staff and colleagues of the Civil Engineering Department for their encouragement and support during the realization of this project.

## SUMMARY

The GDS controllers, graphics plotter, and micro computer were connected to form a daisy-chain configuration.

The communication between the computer and the three GDS controllers was in two ways in accordance with the IEEE-488 communication standard.

Most of the tests, as the Unconsolidated Undrained, Consolidated Undrained, Drained,  $K_0$  Consolidation and Swelling, and Cyclic Loading were adequately performed, under total automatic control, except the Continuous Liner stress paths test (due to a problem with the available software).

Tests on selected sand and clay samples were documented with output examples. Optional Consolidation stage and checking of pore pressure parameter B were carried out prior to the selection of any test.

Test data, up to a maximum of 350 points, could be stored in computer memory. The data were displayed on the screen during the execution of the test and then saved on a tape for tabulation and plotting.

The description and operation of the DGS system were explained and clarified in order to provide a more straight forward guide for future use.



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## GLOSSARY

DAISY CHAIN	:	Serial Connection.
EPROM	:	Erasable Programmable Memory.
ESP	:	Effective Stress Path.
GDS	:	Geotechnical Digital System.
GDSFBP	:	GDS Tabulation and Plotting Program.
GDSTTS	:	GDS Triaxial Testing System.
IEEE	:	Institute for Electrical and Electronics Engineers.
INTERFACE BUS	:	Channel for Transferring Digital information.
NEUTRAL CONDITION:		State of Pore Water Stress.
LED	:	Light Emmitting Diode.
TSP	:	Total Stress Path.

## NOTATIONS

- a : Effective area of the Belloframe seal.
- $a'$  : Modified cohesion parameter.
- A : Pore pressure parameter for the case of non elastic material.
- $A_0$  : Original area of the sample.
- $A_c$  : Current average area of the sample.
- B : Pore pressure parameter in the case of isotropic conditions.
- c : Cohesion of the soil related to total stresses.
- $C_v$  : Compressibility of pore fluid.
- $C_s$  : Compressibility of soil skeleton.
- $C_{s0}$  : Uni-axial compressibility of soil skeleton.
- $c'$  : Cohesion of the soil related to effective stresses.
- $D_0$  : Mean original diameter of the sample.
- D : Current average diameter of the sample.
- f : Friction force correction.
- i : Stage.
- K : Earth pressure coefficient.
- $K_0$  : Coefficient of lateral earth pressure at rest.
- $L_0$  : Mean original height of the sample.
- p : Lower chamber pressure.
- $p'$  : Mean effective stress.
- P : Pressure generated by the pore water controller.
- $P_6^*$  : Generated pressure corresponding to address 6.

$P_8$  : Generated pressure corresponding to address 8.  
 $P_9$  : Generated pressure corresponding to address 9.  
 $P_{9c}$  : Corrected pressure corresponding to address 9.  
 $q'$  : Half the deviator stress.  
 $R$  : Rate of volume.  
 $W$  : Weight of the loading ram.  
 $\omega_n$  : Water content.  
 $V_0$  : Original volume of the sample.  
 $u_0$  : Back pressure.  
 $\phi$  : Total angle of internal friction.  
 $\phi'$  : Effective angle of internal friction.  
 $\sigma_1$  : Major principal stress.  
 $\sigma_2$  : Intermediate principal stress.  
 $\sigma_3$  : Minor principal stress.  
 $\sigma'_1$  : Effective major stress.  
 $\sigma'_3$  : Effective minor stress.  
 $\sigma'_{1f}$  : Effective major stress at failure.  
 $\sigma'_{3f}$  : Effective minor stress at failure.  
 $\sigma_a$  : Axial stress.  
 $\sigma_r$  : Radial stress.  
 $\sigma_{a0}$  : Initial axial stress.  
 $\sigma_{r0}$  : Initial radial stress (all-round pressure).  
 $\sigma'_{a0}$  : Effective initial axial stress.  
 $\sigma'_{r0}$  : Effective initial radial stress.  
 $\sigma'_a$  : Effective axial stress.  
 $\sigma'_r$  : Effective radial stress.  
 $\sigma'_{af}$  : Effective axial stress at failure.

- $\sigma'_{rf}$  : Effective radial stress at failure.
- $\sigma_f$  : Total normal stress on the shear plane.
- $\sigma'_f$  : Effective normal stress on the shear plane.
- $\epsilon_a$  : Axial strain.
- $\theta$  : Failure angle.
- $\alpha'$  : Angle of the modified failure envelope with the horizontal.
- $\tau$  : Shear strength of the soil.
- $\Delta U$  : Change in pore water pressure.
- $\Delta U_f$  : Change in pore water pressure at failure.
- $\Delta\sigma$  : Deviator stress.
- $\Delta\sigma_f$  : Deviator stress at failure.
- $\Delta\sigma_1$  : Change in the major principal stress.
- $\Delta\sigma_3$  : Change in the minor principal stress.
- $\Delta\sigma_a$  : Change in axial stress.
- $\Delta\sigma_r$  : Change in radial stress.
- $\Delta p$  : Change in lower chamber pressure.
- $\Delta P_6$  : Pressure change corresponding to address 6.
- $\Delta P_8$  : Pressure change corresponding to address 8.
- $\Delta P_9$  : Pressure change corresponding to address 9.
- $\Delta V_6$  : Volume change corresponding to address 6.
- $\Delta V_8$  : Volume change corresponding to address 8.
- $\Delta V_9$  : Volume change corresponding to address 9.

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## Chapter I

### INTRODUCTION

#### 1.1 GENERAL

The confined cylindrical compression test (called triaxial test) was developed to overcome some of the disadvantages of the unconfined test and the direct shear test. The triaxial test has become the most widely used procedure to determine shear strength parameters of soils. In this test, drainage and rates of loading can be controlled adequately and no rotation of the major principal stress ( $\sigma_1$ ) and minor principal stress ( $\sigma_3$ ) is allowed. Furthermore, complex stress paths can be simulated and controlled.

In the early seventies, Bishop and Wesley (1975) introduced an improved design of the conventional triaxial apparatus to meet the needs of both practicing engineers and research scientists. The new design included a servo-mechanism controller (the GDS), which served as a pressure source and volume measuring device of great accuracy and reliability.

The GDS replaced mercury columns, compressed air, and dead weights devices used in the conventional equipment. A computerized Triaxial Testing System was introduced to provide a more accurate way of controlling the test.

## 1.2 STATEMENT OF THE PROBLEM

Recently, the Geotechnical division of the Civil Engineering Department at the University of Ottawa procured the GDS Triaxial Testing System and installed it in the geotechnical laboratory. Due to the lack of familiarity with the system, it was necessary to investigate its potential.

## 1.3 OBJECTIVES OF THE PROJECT

The objectives of this project were the following:

1. Set up of the GDS equipment in the most practical and usable way in the geotechnical laboratory.
2. Investigate the mechanism of the GDS system.
3. Explain the operation of the GDS controller under manual and computer control.
4. Implement the available software to the GDS system.
5. Test the different available options of the software.
6. Document the above activities with pretesting instructions and output examples of actual tests.
7. Assess the overall performance of the GDS system.

#### 1.4 SCOPE OF THE PROJECT

The scope of the project included the following:

1. Connection of the GDS controllers, graphics plotter, and micro computer to form a daisy-chain\* configuration by means of interfacing bus\* cables.
2. Connection of the Bishop-Wesley triaxial apparatus to the GDS controllers by means of 4 mm plastic tubes.
3. Calibration of each GDS controller to have an IEEE\* address corresponding to the last digit of the controller's serial number.
4. Ensuring that the equipment intercommunication is conducted in two-ways via the interface bus in accordance with the IEEE-488 communication standard.
5. Implementation of the GDSTTS\* program and execution of all the available tests by using selected soil samples (sand and clay).
6. Providing representative examples useful for understanding and clarifying the description and mechanism of the GDS system.

\* = Technical word explained in the glossary of this report.

## 1.5 OUTLINE OF THE REPORT

Chapter.2 introduces the theoretical background of the Mohr-Coulomb failure criterion, unconsolidated undrained test, consolidated undrained test, drained test, stress path, and pore pressure parameters of soils.

Chapter 3 describes the GDS system, including the triaxial apparatus, and the GDS pressure controller, control unit, graphics plotter, and equipment intercommunication.

Chapter 4 presents the operation and functioning of the GDS Triaxial Testing System (GDSTTS) program. This chapter includes the preliminary operation that must be undertaken before executing the GDSTTS program. The initial operations of the program, friction calculations, pore pressure parameter "B" evaluation, optional consolidation stage, available tests execution, tabulation and plotting of results and the GDSFBP program operation are described in detail.

Chapter 5 gives examples of most available tests.

Conclusions of this study are presented in Chapter 6 and a list of references is given in Chapter 7. Tables and figures are presented at the end of the report.

## Chapter II

### THEORETICAL BACKGROUND

#### 2.1 INTRODUCTION

The triaxial test is the most versatile test to determine the external load required to engage the shear strength of soil and to predict its deformation under an applied load.

In the triaxial test, load is applied to a cylindrical soil specimen under conditions of axial symmetry. When the applied load increases, deformations increase progressively. Soil failure is obtained when excessive deformations are developed. At this point, the strength of the soil reflects the ultimate stress that the material can sustain.

In triaxial testing, basic assumptions are made to simulate actual situations to testing conditions (e.g., isotropic consolidation). Therefore, before the testing procedure is employed, the limitation of the theory must be known.

## 2.2 MOHR COULOMB FAILURE CRITERION

When a soil specimen is subjected to a compressive or tensile stress, shear stresses will be induced in the soil. As soon as the induced shear stress has become equal to the shear strength of the material at any point on any plane within the soil mass, failure occurs at that particular point. Therefore, to solve a geotechnical stability problem, the shear strength of the soil must be known. The shear strength of the soil depends on the friction and the cohesion of the soil. Coulomb showed that at a point on a particular plan, the shear strength of a soil can be expressed by a linear function, in terms of the applied normal stress on the plane at the same point at failure by the following expression:

$$\tau = c + \sigma_f \tan \phi \quad (2.1)$$

and in terms of effective stresses, Coulomb's expression can be written as:

$$\tau = c' + \sigma_f' \tan \phi' \quad (2.2)$$

Where  $\tau$  = shear strength of the soil

$\sigma_f$  = total normal stress on the shear plane

$\sigma_f'$  = effective normal stress on the shear plane

- $c$  = total stress cohesion intercept of the soil
- $c'$  = effective stress cohesion intercept of the soil
- $\phi$  = total angle of internal friction
- $\phi'$  = effective angle of internal friction

The shearing stress is a stress caused by forces acting along or parallel to the area resisting the forces and normal stresses, represented by tensile and compressive stresses, are caused by forces acting perpendicular to shearing plane. Maximum and minimum normal stresses occur on planes of zero shearing stress. These maximum and minimum normal stresses are called major principal stress ( $\sigma_1$ ) and minor principal stress ( $\sigma_3$ ), respectively.

When a soil specimen is subjected to an externally applied load, major principal stress ( $\sigma_1$ ), and minor principal stress ( $\sigma_3$ ), a Mohr's circle can be constructed for a graphical determination of the shear and normal stresses acting on a point within the soil mass as shown in Fig. 2.1.

The failure envelope is generally not linear, but a straight line approximation is made for a given stress range of interest. Despite the inherent weakness of this assumption, it describes adequately for use in practice the shear strength of the particular soil and can be easily used to solve normally occurring problems.

Any state of stress can be presented by a stress point rather than by a Mohr-circle by plotting  $(\sigma_1 - \sigma_3)/2$ , designated by  $q$ , along the vertical axis versus  $(\sigma_1 + \sigma_3)/2$ , designated by  $p$ , along the horizontal axis, as shown in Fig. 2.2. A modified failure envelope can be obtained, where  $a'$  is called the modified cohesion intercept of the soil and  $\alpha'$  the angle of the modified failure envelope with respect to the horizontal.

### 2.3 TRIAXIAL TEST

To perform a triaxial test, a cylindrical specimen is encased in a rubber membrane and enclosed in the triaxial cell. The specimen is pressurized by means of water under axial symmetry conditions, as shown in Fig. 2.3.

The triaxial test allows a symmetrical biaxial loading (i.e.,  $\sigma_2$  is always equal to  $\sigma_3$ ) only, in spite of the name given to it.

The soil specimen inside the cell is first subjected to an all-round pressure (i.e. the radial stress,  $\sigma_r$ ). Thereafter, the axial load is gradually increased by means of a loading ram until the failure of the specimen is reached. Failure usually occurs along an inclined plane within the specimen. An optional consolidation stage is allowed to take place prior to increasing the axial load. Under undrained

conditions, the porewater pressure is measured, whereas under drained conditions the specimen volume change is measured. Failure usually occurs along an inclined plane within the specimen.

The applied deviator stress ( $\Delta\sigma$ ) is the difference between the major principal stress ( $\sigma_1$ ) and the minor principal stress ( $\sigma_3$ ). The cell pressure is set equal to the minor principal stress and the major stress is set equal to the sum of cell pressure and the difference between major and minor principal stresses (called deviator stress).

An extension test is also allowed by taking the axial stress as minor principal stress and the cell pressure as major principal stress.

To simulate actual behaviour with regard to both drainage and loading rate, three types of test are normally carried out:

- Unconsolidated Undrained test
- Consolidated Undrained test
- Consolidated Drained test

The first term refers to the state of stress of the specimen when  $\sigma_2 = \sigma_3$  and the second term refers to the drainage conditions during the shearing.

### 2.3.1 UNCONSOLIDATED UNDRAINED TEST

The unconsolidated undrained test applies to a short term behaviour of soils in place. The specimen is subjected to an axial loading immediately after the application of the all-round pressure. No drainage of the soil specimen is allowed at any stage of the test. This means that the sample is sheared at a constant water content and no volume change occurs during testing (provided the soil is 100% saturated). The total, neutral\*, and effective conditions in the test specimen at each stage of the unconsolidated undrained test are illustrated in Fig. 2.4. The effective-stress Mohr circle at failure is presented in Fig. 2.5.

### 2.3.2 CONSOLIDATED UNDRAINED TEST

The consolidated undrained test applies to long-term behaviour of soils in place. Drainage is allowed under an all-round pressure, reflecting the in-situ effective stress at the site, until complete consolidation is achieved. The volume of the specimen is reduced due to the reduction in water content within the soil mass. The completion of the consolidation stage is indicated by the cessation of further expulsion of water. A gradually increasing axial load is then applied on the specimen with no drainage being allowed until it shears. No volume change takes place during the

shearing phase. The total, neutral, and effective stresses at each phase of the consolidated undrained test are illustrated in Fig. 2.6. The corresponding effective Mohr circles are presented in Fig. 2.7. A fully saturated soil is required in order to obtain an accurate measurements of the pore water pressure. The saturation of the specimen can be achieved by applying an estimated back pressure (Bishop and Henkel, 1969).

### 2.3.3 CONSOLIDATED DRAINED TEST

The consolidated drained test applies to long term behaviour of soils in place. Drainage of the specimen is allowed under a state of stress reflecting the in-situ stresses until consolidation is completed. A gradually increasing axial load is then applied slowly, with drainage still allowed, to ensure there is no build-up of excess pore pressure until shearing. Continual reduction in water content is associated with a continual volume change of the specimen during both consolidation and shearing stages of the test. The total, neutral, and effective stresses during each phase of the consolidated drained axial compression triaxial test are illustrated in Fig. 2.8 and the Mohr failure envelope in Fig. 2.7. Pore water pressure should be maintained equal to zero during the test if no back pressure is applied. This implies that the total stresses are equal to the effective stresses.

## 2.4 STRESS PATH

As the state of stress is presented in a series of Mohr circles, it can also be presented by a series of stress points. Each stress point is defined by its corresponding  $q'$  and  $p'$  coordinates as was shown in Fig. 2.2.

However, the successive states of stress, that a soil element undergoes during testing, can be presented by connecting all the successive stress points rather than presenting a series of Mohr circles as shown in Fig. 2.9.

The successive states of stress in a test specimen can be represented by a series of stress points. By connecting the stress points, a stress path is obtained. Any given stress path can be drawn in terms of either total or effective stress. Fig. 2.10(a) shows that in the drained test, with no back pressure is applied, the total stress path (TSP) and the effective stress path (ESP) coincide. Whereas in the undrained test, Fig. 2.10(b) and Fig. 2.10(c) show that the TSP and ESP do not coincide and the porewater pressure is represented by the horizontal distance between the total stress path and the effective stress path.

Lambe and Whitman (1969) showed a representative example for different stress paths under initial hydrostatic conditions (where the initial vertical stress was equal to the initial horizontal stress). The slope of the axial stress paths

depends on the magnitude of the axial stress increment ( $\Delta\sigma_a$ ) and radial stress increment ( $\Delta\sigma_r$ ) as shown in a plot of half the deviator stress ( $q$ ) versus the mean total stress ( $p$ ) in Fig. 2.11.

## 2.5 BACK PRESSURE

The purpose of applying a back pressure is to dissolve the air bubbles remaining in the pore water and between the sample and the rubber membrane during consolidation. This provides a fully saturated sample, which may better reflect the in-situ pore water pressure conditions prior to the application of the axial loading. The back pressure is generated by raising the pore water pressure artificially by applying a constant pressure. It is necessary to ensure that the total stress is increased by exactly the same value in order to keep the effective consolidation stresses constant.

## 2.6 PORE PRESSURE PARAMETERS

It is essential in engineering practice to estimate the response of pore water pressure to changes in total stress under undrained conditions. For isotropic conditions, Skempton (1954) expressed these changes in terms of the pore pressure parameter,  $B$ , by the following expression:

$$B = \frac{\Delta U}{\Delta \sigma_3} = \frac{1}{1 + n \frac{C_v}{C_s}} \quad (2.3)$$

Where       $n$  = porosity  
               $C_v$  = compressibility of pore fluid  
               $C_s$  = compressibility of soil skeleton

If the soil is 100% saturated, the compressibility of pore fluid (water) becomes negligible compared to the compressibility of soil skeleton. Therefore, the ratio  $C_v/C_s$  will tend to zero and the value of  $B$  will be equal to 1. If the soil is not 100% saturated, the value of  $B$  will be smaller than 1.

In the case of an increase of total stress along the major principal axis only, and for elastic material, the pore pressure parameter,  $B$ , is given as follows:

$$B = \frac{\Delta U}{\Delta \sigma_1} = \frac{1}{3} \left[ \frac{1}{1 + n \frac{C_v}{C_s}} \right] \quad (2.4)$$

For the case of non-elastic material, for an increase of total stress along the major principle axis, the second Skempton parameter,  $A$ , is introduced by the following relationship:

$$A = \frac{1}{B} \frac{\Delta U}{\Delta \sigma_1} \quad (2.5)$$

The value of the parameter, A, for a fully saturated soil at any stage of the test can be obtained by means of measuring pore water pressure during the application of the deviator stress under undrained conditions.

For the case of zero lateral strain condition in the soil element, reduction in volume is possible in the direction of major principal stress only. The value of A in this case is presented by the following relationship:

$$A = \frac{\Delta U}{\Delta \sigma_1} = \left[ \frac{1}{1 + n \frac{C_v}{C_{s0}}} \right] \quad (2.6)$$

Where  $C_{s0}$  = uni-axial compressibility of the soil skeleton.

If the soil is 100% saturated, and for zero lateral strain condition only, the ratio  $C_v/C_{s0}$  will tend to zero and the value of A will be equal to 1.

## Chapter III

### THE GDS SYSTEM DESCRIPTION

#### 3.1 BISHOP AND WESLEY TRIAXIAL APPARATUS

Early development of triaxial testing was limited to cylindrical compression tests (i.e cell pressure is kept constant and axial load is varied).

To perform the simulation of stress paths designated in the field more readily, Bishop and Wesley (1975) developed a hydraulically operated triaxial apparatus.

In the Bishop and Wesley apparatus, controlled stress and controlled strain tests can be carried out using 45 mm, 65 mm, and 95 mm cylindrical samples with a wide range of stress paths, and applying axial compression and axial extension.

Fig. 3.1 shows a diagrammatic layout of the apparatus. In this figure, the specimen is loaded axially by moving the loading ram upward from below and pushing the specimen top cap against a stationary load cell. The increase in axial stress is due to the increase in lower chamber pressure.

Two belloram seals are used to provide the possibility of performing an extension test (by making the axial stress smaller than the horizontal stress).

The design provides a self-contained apparatus, suited for strain-controlled and stress-controlled loading under optional drained or undrained conditions.

To operate the apparatus, the operator has the option of varying the axial stress or the radial stress depending on what controlled manner is followed. Disregarding what type of test the operation is going to execute, the following expression is obtained:

$$\sigma_a = p \left( \frac{a}{A_c} \right) + \sigma_r \left( 1 - \frac{a}{A_c} \right) - \frac{W}{A_c} \quad (3.1)$$

Where  $\sigma_a$  = axial stress

$\sigma_r$  = radial stress

$A_c$  = current average area of the sample

$a$  = belloram seal area.

$W$  = weight of the loading ram

$p$  = lower chamber pressure

The above equation is valid whether the radial stress is smaller or greater than the axial stress. It can be used to indicate in which way the pressure (p) must be varied in order to follow a given stress path. For this reason, it is more convenient to rewrite Eq. 3.1 in terms of stress change as follows:

$$\Delta\sigma_a = \Delta p \left( \frac{a}{A_c} \right) + \Delta\sigma_r \left( 1 - \frac{a}{A_c} \right) \quad (3.2)$$

For a general linear stress path, the relationship between the axial stress and radial stress is defined as follows:

$$\Delta\sigma_r = K\Delta\sigma_a \quad (3.3)$$

Substituting Eq. 3.3 into Eq. 3.2 the following is obtained:

$$\Delta p = \Delta\sigma_r \left[ 1 + \frac{A_c}{a} \left( \frac{1}{K} - 1 \right) \right] \quad (3.4)$$

The above four equations can be also expressed in terms of effective stresses by simply replacing the total stresses by the effective stresses.

Note, The available triaxial apparatus is limited to a working maximum pressure of 1700 KPa.

### 3.2 THE GDS PRESSURE CONTROLLER

The GDS pressure controller It is an accurate pressure source and volume measuring device. It replaces mercury column, compressed air, and dead weight devices for applying load; Bourdon pressure gauges, pressure transducers and associated signal conditioning units for measuring stress; paraffin volume burettes, and displacement transducer-based volume change gauges.

#### a) Description

The GDS Digital Pressure Controller is a microprocessor, hydraulic servo-mechanism. It is an automated constant pressure source accurate to 1 KPa and volume change gauge accurate to 1 mm<sup>3</sup>. It contains an in-built IEEE-488 computer interface for transmission of digital information (data) between a computer and several instruments in the bus. A

pressure of 1 KPa is displayed while a volume change of  $1 \text{ mm}^3$  is displayed over a range of  $20 \text{ mm}^3$ . Data logging of pressure and volume change is available via the GDS controller computer interface. It can be also controlled by separate computer having the same type of interface as the IEEE-488 interface.

#### b) Operation

The layout of the principle of operation of the GDS controller is shown in Fig. 3.2. The system is composed of two main elements - a pressure cylinder and a piston.

The pressure cylinder is composed of two parts with the piston forming a barrier between them. The right hand part contains the de-aired water and provides pressure outlet. The left hand side contains air and provides a hole where a shaft can pass through to connect the piston to a stepper motor and gearbox (seated on a number of ball bearings to minimize friction).

Each step of the stepper motor corresponds to  $1 \text{ mm}^3$  of volume displacement. The whole operation is controlled by a circuit connecting the left hand side of the stepper motor to the pressure transducer.

The system may become rigid due to dissolved residual air. Therefore, the microprocessor is designed to measure continuously the stiffness of the entire testing assembly in

order to achieve the target pressure within a tolerance of pressure change (measured by the pressure transducer) equivalent to  $0.25 \text{ mm}^3$  of piston displacement.

The stepper motor is designed to operate at 200 steps per revolution (where each step makes the piston to move  $1 \text{ mm}^3$ ). The shaft connecting the gearbox to the piston is coupled to a ball screw which generates the movement in the pressure cylinder. The operation of the motor is done in a half step mode i.e in a  $0.5 \text{ mm}^3$  change.

If the movement direction is to be changed, a few motor steps are required before the piston engages any change in its direction. This phenomenon is called back-lash. The microprocessor provides an automated correction during the period of back-lash.

### 3.2.1 HARDWARE FUNCTIONING

The hardware within the GDS controller is composed of a servo loop updated every millisecond according to a logic procedure described as follows:

1. The generated pressure is measured by means of the pressure transducer.
2. The measured pressure is converted by means of an analogue to digital converter (A-D) 50 times per second.

3. The obtained pressure is compared with the expected pressure.
4. The stepper motor is commanded to generate the required pressure by performing a number of steps.
5. An A-D cycle is performed and the new measured pressure will be used to initiate the next pressure controller cycle.

The target pressure is set manually by means of the 4 digit thumbwheel switch on the control panel of the GDS controller.

The target pressure is achieved, by means of a manual displacement of the piston in the required direction at 380 steps per second. Further movement is prevented by the holding force exerted by the stepper motor.

The piston is allowed to be driven only a limited distance in order to prevent overrunning. If it approaches the limit, the LED\* display labelled 'PRESSURE LIMIT', will light up and a buzzer sounds. The same will happen when the pressure becomes -40 KPa if the REVERSE push button is generated. Whenever the buzzer is on, the motor will be driven in the direction appropriate to correct the error.

The movement of the motor to attain the required pressure is associated with certain amount of volume change. The counter is initially set to zero to indicate the volume change associated to the corresponding motor movement.

The whole operation is controlled by means of a computer, using the IEEE-488 interface that exists within the controller. The computer commands the controller to ignore the thumbwheel setting (on the control panel) and seeks to apply the computer specified pressure. In this case, the stepper motor is driven at a maximum speed of 380 steps per second in the required direction.

The results are recorded automatically and ready to be saved for future analysis. The control by the computer is cancelled as soon as the push button labelled 'ZERO/RESET' is engaged.

### 3.2.2 APPLICATIONS

The GDS Digital Pressure controllers are capable to carry out the following actions:

1. Achieve and maintain a required cell pressure within the triaxial cell.
2. Provide back pressure within the test specimen.

3. Provide measurement of the porewater pressure generated in the porewater ducts of the Bishop-Wesley triaxial cell.
4. Provide measurement of both pressure and volume change in the lower chamber of the Bishop-Wesley triaxial cell.
5. Perform  $K_0$  consolidation and swelling under computer control in the Bishop-Wesley triaxial cell.
6. Perform stress-path testing by changing axial and radial stresses simultaneously in the Bishop-Wesley triaxial cell.
7. Under total automatic control, it can perform a cyclic testing in the Bishop-Wesley triaxial cell.
8. Under total automatic control it can perform the Unconsolidated-Undrained test, Consolidated-Undrained test with pore pressure measurement, and Drained test with volume change measurement in the Bishop-Wesley triaxial cell.

### 3.2.3 EPROMS AND RAMS

A. small chip called EPROM (Erasable Programmable Memory), plugged into the printed circuit board, is programmed to perform the features of the GDS controller (eg. back-lash

correction, variable motor speed). Four EPROMs are allowed to be plugged within each controller and provide a combined storage capacity of 8 kilobytes. Four RAMs (Random Access Memory) are also plugged in, the same locations with the EPROMs, for loading down programs from the control unit to the GDS controller.

#### 3.2.4 CONTROL PANEL DESCRIPTION

The control panel layout shown in Fig 3.3 presents 14 keys necessary to proceed the operation of the GDS Triaxial System. Each key plays its role in the operation as follows:

1. THUMBWHEEL SWITCH: Four digit thumbweel switch on the front panel of the controller, labelled 'PRESSURE KPa', are used to dial up the desired target pressure when the controller is under manual control.
2. ZERO OFFSET KNOB: It is located on the top left-hand corner of the control panel, labelled 'ZERO', and enables the display of pressure to be offset (e.g. adjustment for datum of pressure measurement).
3. LED NEGATIVE PRESSURE INDICATOR: A small LED\*, fixed to the left of the pressure display, will light up as soon as the pressure becomes negative. A warning buzzer will sound when the tension pressure exceeds 40 KPa.

4. LED DISPLAY OF PRESSURE: A 4 digit LED display of pressure, located directly above the control thumbwheel switch, are updated 50 times per second. It is used also to check the evolution of the axial pressure, cell pressure and porewater pressure during the test.
5. LED PRESSURE LIMIT INDICATOR: If the piston is engaged to the limits, the LED labelled 'PRESSURE LIMIT', located in the top right-hand corner of the control panel, will light up and a buzzer will sound. Simultaneously, the piston will be driven automatically backward to decrease (or increase) the applied pressure.
6. LED COMPUTER CONTROL INDICATOR: If the GDS controller is controlled by the computer, the LED, labelled 'COMPUTER CONTROL', will light up to indicate that the computer is controlling at the present moment otherwise the LED remains off.
7. MOMENTARY PUSH BUTTON "FAST FORWARD": The piston will drive forward toward the outlet at  $380 \text{ mm}^3$  per second when the switch, labelled 'FORWARD', is pushed down.
8. MOMENTARY PUSH BUTTON "FAST REVERSE": The piston will drive backward toward the control panel at  $380 \text{ mm}^3$  per second when the switch labelled 'REVERSE' is pushed down.

Note, prior to any test, these forward/reverse operations are always done to place the piston at the appropriate position relative to its role during the test execution and to set up the initial pressures (cell pressure and back pressure), as soon as the test specimen is ready to be tested. It is suggested to place the piston of the cell and back-pressure controllers close to the outlet side and of the axial-pressure controller close to the control panel side.

9. HOLD VOLUME PUSH-BUTTON: The latching type push-button, labelled 'HOLD VOLUME', is used to lock and unlock the stepper motor and place the piston at a certain position. It has to be engaged at the beginning of the testing until the program asks the operator to ensure that the 'HOLD VOLUME' button is disengaged at the current stage of testing.
10. LED VOLUME HELD PUSH-BUTTON: A LED to indicate that the volume is held, labelled 'VOLUME HELD', will light up as soon as the latching push-button for hold volume is engaged otherwise it remains off.
11. VOLUME LIMIT INDICATOR: To protect the GDS from overrunning, a LED to indicate the volume limit, labelled 'VOLUME LIMIT' and located at the bottom

right-hand corner of the control panel, will light up as soon as the piston reaches either end of the pressure cylinder. Directly, the piston will start moving in the opposite direction.

12. ZERO RESET PUSH-BUTTON: A momentary push-button for zeroing volume and disengaging computer control, labelled 'ZERO/RESET' and located in the bottom left-hand corner of the control panel. The adjacent volume change display is set directly to zero and the LED for computer control is off as soon as the button is pushed down.
13. VOLUME CHANGE INDICATOR: A LED display of volume change ( $\text{mm}^3$ ) consists of 6 characters, labelled 'VOLUME CHANGE  $\text{mm}^3$ ' and located directly below the thumbwheel switch. It displays the volume change that the piston generates in the pressure cylinder. If the volume of water in the cylinder is decreasing from the zero, just after the ZERO/RESET push-button is engaged, the volume change involved is considered to be a negative quantity. It is positive if the volume of water is increasing.
14. LED NEGATIVE VOLUME CHANGE: A LED to indicate the negative volume change, labelled 'NEGATIVE' is located immediately above the ZERO/RESET push-button. This LED will light up when the quantity of water in

the cylinder, at zero from reset, is increasing and is off when the quantity of water is decreasing.

### 3.2.5 MOTOR SPEED CONTROL

The GDS controller has been design to generate target pressure at a flexible rate of volume change. To carry out an accurate triaxial test, the GDS pore pressure controller must be operated at a slower rate.

The GDS cell pressure controller has to maintain a constant all-round pressure within the cell at a faster rate during the rapid axial loading of the test specimen.

To achieve a target pressure higher than 1000 KPa and a particular rate, the first digit of the thumbwheel switch on the control panel must be dialed in a special sequence. By varying the first digit setting from 0 to 9, corresponding first digit of equivalent pressure are obtained equal to 0 or 1, as shown in table 3.1. Maximum volume change rate, varying between  $12.5 \text{ mm}^3/\text{sec}$  and  $200 \text{ mm}^3/\text{sec}$  are also obtained. If the first digit of the pressure setting is odd, the equivalent maintained pressure is a 4 digits value not exceeding 1999 KPa. Similarly, for an even first digit of the pressure setting, the equivalent maintained pressure is 3 digits, as shown in table 3.2. For example, a thumbwheel setting of 2130 (has an even first digit equal to 2)

indicates a target pressure of 130 KPa is maintained using a maximum volume change of 50 mm<sup>3</sup>/sec. A thumbwheel setting of 1130 (has an odd first digit equal to 1) indicates that a target pressure of 1130 KPa is maintained using a maximum volume change of 12.5 mm<sup>3</sup>/sec.

### 3.3 THE CONTROL UNIT

An HP-85 micro computer is used to control the GDS Triaxial Testing System. It is a versatile computing device which enables the operator to carry out a variety of useful and interesting functions and initiate and control test performance. The purpose of using the HP-85 is to achieve the following requirements:

1. Perform calculations in a simple and straightforward manner.
2. Execute and control available Basic-language programs.
3. Communicate with the three GDS pressure controllers by sending and receiving necessary information to and from the computer in accordance with the IEEE-488 communication standard.
4. Store permanently programs and data on a magnetic tape cartridge.
5. Display onto the printer all necessary information for review and and judgement of the results.
6. Display on the screen a plot of the results during execution of the test.

7. Provide the possibility of editing, correcting and modifying any statement that appears on the screen.

### 3.3.1 THE GRAPHICS PLOTTER

Various combinations of data obtained from the triaxial testing can be plotted by means of the HP7470A Graphics Plotter by using the GDSFBP plotting program. The operator should always verify the connections by running the "Communication Verification" program. If the plotter labels "COMMUNICATION OK", further drawing can be performed. If not, the operator must check the following:

1. The computer is functioning by running a known program.
2. The communications hardware and cable by making the following verifications:
  - a) None of the connectors on the computer interface, cable, or plotter interface is damaged.
  - b) The switches are set properly on the communications hardware.
  - c) The card is in the correct slot of the computer.

3. The plotter performance by checking if:
  - a) The plotter is switched on.
  - b) The correct pin setting is on.
  - c) The plotter self-test, presented at the end of this subsection, is performed.
4. The statement "plotter is 705", that defines the plotter to the computer, is provided at the beginning of the plotting program.
5. The GDS pressure controllers are switched on.
6. The correct operating system and programming language are used.

To verify the communications between the graphics plotter and the computer, the operator may run the following "COMMUNICATION VERIFICATION" program:

```
10 PLOTTER IS 705
20 PEN 1
30 MOVE 5,10
40 LABEL "COMMUNICATION OK"
50 MOVE 0,0
60 PEN 0
70 END
```

If the plotter labels "COMMUNICATION OK", the operator can start plotting.

### 3.3.2 EQUIPMENT INTERCOMMUNICATION

The GDS controller has been designed to act as "talker" and "listener". This means, it supplies information (pressure, volume change and status) directly to the computer and it receives information (target pressure and type of test) directly from the computer.

Three GDS controllers, Graphics plotter and HB-85 controlling computer are linked by means of interface bus cables. This is achieved by stacking one plug into another to form a daisy-chain configurations as shown in Fig. 3.4.

The Bishop-Wesley triaxial cell is connected to the GDS controllers by means of 4 mm plastic tubes as shown in Fig. 3.5. The controlling computer initiates and controls the test execution. The transmission of the digital information is performed in two ways via the interface bus in accordance with the IEEE-488 communication standard. Each device has an IEEE address which can be set within the range 0 to 15.

Each address has been already set up during the calibration which is the last digit of the device serial number. A

controller with a serial number of 089 would have an IEEE address of 9. As soon as this address is set properly, it becomes a part of the program unless the operator has decided to change it.

Using such protocol, the test data are transmitted rapidly, orderly, and identified by the computer. During the test, each device can talk or listen as commanded from an unaddressed state (e.g. the controlling computer).

Chapter IV  
GDS SYSTEM OPERATIONS

4.1 PRELIMINARY OPERATION

4.1.1 SOIL SAMPLE AND TRIAXIAL CELL SET UP

The sampling procedure for clay specimen must be performed as follows:

1. Unwrap sample and place in trimming device such that there is excess sample on both ends.
2. Trim the sample flush with the end of the trimming device using the wire saw. Care must be taken to prevent the sample from breaking and creating an irregular surface.
3. Remove the sample from the trimming device carefully and measure its diameter in at least three locations and take the average value. Also, measure its length and record all data.
4. Weigh sample and record data.

5. Place a saturated filter stone on the pedestal of the triaxial base and cover with an end filter and cap.
6. Wet the side drain filter and place around the outside of the sample.
7. Place the rubber membrane inside of the membrane stretcher and fold ends over the device.
8. Create a vacuum in the membrane stretcher and place over the sample.
9. Allow air to re-enter the stretcher and slide membrane off the device (The membrane should now encase the pedestal, filter stone, filter paper and end cap with all excess membrane at the top).
10. Stretch two "O" rings over the membrane stretcher. Place the stretcher over the sample and slide "O" ring off such that seal the membrane over the membrane over the pedestal.
11. With the pore water pressure controller disengaged, force water with a wash bottle into the membrane until it begins to bulge slightly, and then immediately engage the hold volume.
12. Install two more "O" rings and seal membrane against the top cap.

13. Install the cell over the sample and firmly press downward.
14. Raise the piston until the specimen top cap is at a distance of 2 mm from the load cell.
15. Fill the cell with deaired water.
16. Do the appropriate connection.

Note, for the sampling of sand specimen, it is recommended to follow the procedure presented by Bishop and Henkel (1969).

#### 4.1.2 CONNECTION STAGE

All electrical equipment must be connected to the power source at the beginning. Special form of connecting cables, called interface bus cables, are available to connect one instrument to another. This is done by plugging the cable directly to the unit, using the 24 pin Amphenol socket provided at the side of each device.

The triaxial cell is connected to the three GDS Digital Pressure Controllers by means of 4 mm plastic tubes. Two GDS controllers having a capacity of 200 mm<sup>3</sup> and one controller having a capacity of 100 mm<sup>3</sup> are available in the laboratory. One controller having a capacity of 200 mm<sup>3</sup> is connected to

the lower chamber (to control the axial pressure) and the other is connected to the cell (to control the cell pressure). The third GDS controller (100 mm<sup>3</sup>) is connected directly to the top or the bottom (or top and bottom at the same time) of the soil sample to control the pore water pressure. A detailed description of the connection is shown in Fig. 3.5.

#### 4.1.3 SET UP OF PRESSURE DATUM

Engage the HOLD VOLUME push-button switch. Then, for each pressure controller, raise the open end of the outlet tube to mid height of sample until pressure datum is set to zero by adjusting the ZERO-offset knob. Subsequently, reconnection will take place.

#### 4.1.4 SET UP GDS PRESSURE CONTROLLER

Fill the GDS controllers with deaired water at the beginning. Then, position the piston of the water pressure controller at the middle of the cylinder by means of the FORWARD push-button switch prior the connection of the triaxial cell. Drive the piston of the axial pressure controller rapidly, by means of the REVERSE push-button until it is set near the control panel. The connection of

the axial pressure controller to the lower chamber must be previously performed.

#### 4.1.5 VERIFICATION STAGE

Verify that no leakage is taking place at any of the connecting points. If everything is correct, proceed to the following stage.

#### 4.1.6 SET UP INITIAL PRESSURES

To set up the initial pressures (i.e cell and back pressures), engage first the hold volume on the lower chamber GDS controller. Then, dial in (manually) gradually and simultaneously the cell pressure and estimated back pressure on the cell pressure controller and water pressure controller, respectively. This procedure takes place until back pressure is 5 to 10 KPa smaller than the cell pressure.

## 4.2 OPERATION OF THE GDSTTS PROGRAM

Switch on the controlling HP-85 computer. Then, initiate the test by following the procedure presented below:

### 4.2.1 LOADING PROGRAM

Before inserting the Standard Pac Tape cartridge, ensure that the RECORD slide is in the right-most position (the same direction of the arrow). Then, insert the cartridge towards the computer and load the GDSTTS program by pressing the 'LOAD' Key and typing in:

"GDSTTS" and then press the Key 'ENDLINE'

The statement, LOAD"GDSTTS", will then disappear from the screen while the computer is loading and searching for the program. When the cursor returns to the screen and the amber tape drive light (located to the left of the eject bar) is gone, press the 'RUN' Key. The program checks the code for any error before making the program ready for operation.

### 4.2.2 INPUT STARTING DATE AND TIME

Assuming the GDSTTS program has been loaded, the operator is then asked to enter the date and time as follows:

ENTER DATE & TIME  
FORMAT DD,MM,YY,HH,MM

where DD= The DAY of testing.  
MM= The MONTH of testing.  
YY= The YEAR of testing .  
HH= The HOUR of testing.  
MM= The MINUTE of testing.

#### 4.2.3 CELL VALVES CHECKING

The program asks the operator to verify the opening of the cell valves for the purpose of transferring the pressures generated by the controllers to the sample as follows:

PLEASE ENSURE CELL VALVES OPEN  
THEN PRESS ENDLINE  
?

#### 4.2.4 IEEE GDS CONTROLLER ADDRESSES

The IEEE address of each GDS controller, is represented by the last digit of the controller serial number. These addresses can be changed and verified as follows:

a) If the program is used for the first time, the operator is given the opportunity to change the IEEE addresses by introducing them equal to zero as follow:

IEEE CONTROLLER ADDRESSES :-

CELL PRESSURE = 0  
PORE PRESSURE = 0  
LOWER CHAMBER = 0

DO YOU WISH TO CHANGE THEM  
(Y OR N)  
?

If the operator choose the Y option, the program request s  
the cell pressure controller address as follows:

ENTER CELL PRESSURE ADDRESS  
?

As soon as the question is replied, the address of the pore  
pressure controller is also requested as follows:

ENTER PORE PRESSURE ADDRESS  
?

The program will finally request the address of the lower  
chamber pressure controller as follows:

ENTER LOWER CHAMBER ADDRESS  
?

Furthermore, the entered addresses are displayed on the  
screen and the operator is given the option for modification  
as follows:

IEEE CONTROLLER ADDRESS :-  
CELL PRESSURE = #  
PORE PRESSURE = ##  
LOWER CHAMBER = ###

DO YOU WISH TO CHANGE THEM  
(Y OR N)  
?

Where # is equivalent to any value between 0 and 9.

If the addresses were properly entered, the operator must choose the N reply and proceed to subsection 4.5.

b) If the program was previously used, the N option must be chosen since the entered addresses have already become a part of the program.

#### 4.2.5 OPTIONAL RESULTS OBSERVATION

The test evolution can be checked any time, since the operator is given the option to follow the corresponding graph either on screen (S) or on plotter (P) as follows:

DO WISH TO HAVE RESULTS ON  
SCREEN OR PLOTTER (S OR P) ?

Note, it is more convenient to choose the S option at this stage since further plotting will be performed by means of the GDSFBP program.

#### 4.2.6 INPUT SAMPLE DIMENSIONS

The average area and volume of the specimen at the original state ( $A_0$  and  $V_0$ ) and the current average area and diameter of the specimen throughout the test ( $A_c$  and  $D$ ) are calculated by means of the following formulae:

$$A_0 = \frac{\pi (D_0)^2}{4} \quad (3.5)$$

$$V_0 = A_0 L_0 \quad (3.6)$$

$$A_c = \frac{A_0 \left(1 + \frac{\Delta V_6}{V_0}\right)}{1 - \epsilon_a} \quad (3.7)$$

$$D = \left[ \frac{4 A_c}{\pi} \right]^{\frac{1}{2}} \quad (3.8)$$

$$\epsilon_a = \frac{\Delta V_6}{a L_0} \quad (3.9)$$

where  $A_0$  = original area of the sample  
 $V_0$  = original volume of the sample  
 $D_0$  = mean original diameter of the sample  
 $L_0$  = mean original height of the sample  
 $A_c$  = current average area of the sample  
 $D$  = current average diameter of the sample  
 $a$  = effective area of the Bellofram seal which is  
equal to 2940 mm  
 $\epsilon_a$  = axial strain  
 $\Delta V_6$  = volume change increment of the pore water pressure

controller

$\Delta V_8$  = volume change increment of the lower chamber pressure  
controller

Therefore, the specimen dimensions are requested as follows:

ENTER AVERAGE DIAMETER  
OF TEST SPECIMEN ?

Note, the value of  $D_0$  must be between 20 and 60 mm.

ENTER HEIGHT  
OF TEST SPECIMEN  
?

Note, the value of  $L_0$  must be between 40 and 120 mm.

The entered dimensions are displayed on the screen for  
optional alteration as follows:

ENTERED VALUES ARE  
DIAMETER = ## MM  
HEIGHT = ### MM  
OK TO CONTINUE (Y OR N) ?

The two alternatives (Y and N) are interpreted as follows:

i) If the operator answers N, the program will ask to go  
back and enter the  $D_0$  and  $L_0$  values again.

ii) If the operator answers Y, the program will display on both screen and print out on the printer, simultaneously, the following output:

```
          GDS
          TRIAXIAL TESTING SYSTEM
          INVOKED AT HH/MM
              ON DD/MM/YY
          =====
          APPARATUS CONSTANTS ARE :-
          SPECIMEN DIAM =      ## MM
          SPECIMEN HEIGHT=     ### MM
          SPECIMEN AREA  =     #### SQ.MM
          SPECIMEN VOLUME= #####.# CU.MM
          SEAL AREA      = #####.# SQ.MM
```

The program will then continue to the next step requesting the initial conditions (Notice, the program provides the units in upper case letter).

#### 4.2.7 INITIAL TEST CONDITIONS

Enter the initial test condition (i.e the initial cell and porewater pressures dialed in the corresponding GDS

controller and shown on the four digit LED display, on the control panel) as follows:

ENTER INITIAL CELL PRESSURE ?

As soon as the initial cell pressure is entered, the program prompts:

ENTER INITIAL BACK PRESSURE  
IF ANY ?

Note, back pressure must be smaller than cell pressure.

The program will then show the entered values on the screen and give the option to alter them as the following example:

INITIAL TEST CONDITIONS  
CELL PRESSURE 300 KPA  
BACK PRESSURE 150 KPA  
  
OK TO CONTINUE (Y OR N)  
?

The two alternatives (Y and N) are interpreted as follows:

i) If the reply is N, the program will request again the initial pressures as above.

ii) If the reply is Y, the program will display on the screen the entered initial pressures and request to disengage the HOLD-VOLUME as follows:

ENSURE THAT HOLD-VOLUME IS NOT  
ENGAGED THEN PRESS ENDLINE  
?

### 4.3 FRICTION CALCULATION

In the GDS Triaxial Testing System, the axial load is transferred to the test specimen by means of a loading ram which travels up and down in a 'Rotolin' linear bearing. This movement of the 'Rotolin' bearing and unrolling and rolling up the two bellofram seals involves a certain amount of 'frictional' force which introduces some errors to the calculated axial stress.

When Bishop and Wesley (1975) introduced the new triaxial cell, they took into account the effect of the 'frictional' force. They found an axial stress difference of 3.7 KPa during the calibration with the ram moving up and with the ram moving down.

To correct the frictional effect, the program carries out automatically the following:

- a) The calculation of the frictional force value.
- b) It Uses the calculated frictional force to modify the lower chamber pressure by means of the "ZERO" knob on the control panel of the lower chamber controller.

When the operators disengages the HOLD-VOLUME and presses the 'ENDLINE' key the program prompts the following:

FRICTION CALC REQU'D (Y OR N)  
?

At this stage, the operator must have been already dialed in the initial cell and back pressures, placed the specimen top cap at a distance of 2 mm from the load cell and disengaged the HOLD-VOLUME. Then, the program will perform the friction calculation procedure if it is required:

Note, the following notations is used in the procedure:

\* For the pore pressure/back pressure controller with address equal to 6:

$$u_0 = P_6$$

\* For the cell pressure/radial stress controller with address equal to 9:

$$\sigma_r = P_9$$

\* for the lower pressure/axial stress controller with address equal to 8:

$$P = P_8$$

By answering Y, the calculation procedure is conducted as follows:

#### FRICITION CALCULATION PROCEDURE:

Step one: The initial conditions are set as follows:

a)  $P_6 = u_0$

b)  $P_g = \sigma_{r_0}$

Step two: The lower chamber pressure controller will engage a volume change of  $\Delta V_g + 500$  mm and measures the corresponding pressure, called  $P_g \text{ max}$ . Similarly, for a volume change of  $\Delta V_g - 500$  mm the corresponding pressure is measured and called  $P_g \text{ min}$ . The friction force correction ( $f$ ) is then calculated by means of the following formula:

$$f = (P_g \text{ max} - P_g \text{ min})/2 \quad (3.10)$$

As soon as the value of "f" is calculated, the following information are displayed on the screen:

```
CALCULATING FRICTION
=====
PRESSURE CORRECTION
FOR LOWER CHAMBER FRICTION
= #.# KPA
```

The operator is then requested to use the 'ZERO' knob, on the control panel of the lower chamber controller, for adjusting the lower chamber pressure as follows:

```
PLEASE USE ZERO OFFSET TO SET
LOWER CHAMBER PRESSURE EQUAL TO
CELL PRESSURE - FRICTION CORR.
THEN PRESS ENDLINE
?
```

When the friction correction "f" is calculated, the lower chamber pressure will be subsequently corrected at each stage by the following formula:

$$P_{8c} = P_8 + f.C(i) \quad (3.11)$$

Where  $C(i) = +1$  if  $\Delta V_8(i) < \Delta V_8(i-1)$

$C(i) = -1$  if  $\Delta V_8(i) > \Delta V_8(i-1)$

$C(i) = C(i-1)$  if  $\Delta V_8(i) = \Delta V_8(i-1)$

and  $i = \text{Stage}$

If the operator wishes not to perform the friction calculation stage, the program will set the initial conditions, only, as follows:

$$P_6 = u_0$$

$$P_9 = \sigma_{r0}$$

Furthermore, the program moves on to check the degree of saturation of the test specimen.

#### 4.4 PORE PRESSURE PARAMETER "B"

Under undrained conditions, the pore pressure parameter B is used to express the response of pore pressure to change in total stress. It is presented, under isotropic stress condition, in terms of the immediate increase in pore water pressure ( $\Delta U$ ) and total radial stress ( $\Delta\sigma_r$ ) by an expression similar to equation 2.3 as follows:

$$B = \frac{\Delta U}{\Delta\sigma_r} \quad (3.12)$$

The triaxial apparatus is used to calculate the value of B. The sample is subjected to an all-round pressure as soon as it is set up within the cell. Under undrained conditions, the increase in all-round pressure produces a change in pore water pressure and the value of B is calculated by using Equation 3.12.

The GDSTTS program gives the operator the option to calculate the value of pore pressure parameter, B. When the operator presses the 'ENDLINE' key after the accomplishment of the friction calculation procedure, the program will request the following

DO YOU WISH TO CHECK THE DEGREE  
OF SATURATION OF THE TEST  
SPECIMEN AND COMPRESSIBILITY OF

THE PORE WATER DUCTS BY  
EVALUATING THE PORE PRESSURE  
PARAMETER 'B'; (Y OR N)  
?

If the answer is Y, the cell pressure increment ( $\Delta\sigma_r$ ) is requested as follows:

ENTER THE REQUIRED CELL PRESSURE  
INCREMENT  
?

Note, the entered value must be positive integer between 0 and 1023 KPa.

As soon as the value of the cell pressure increment is entered and the 'ENDLINE' key is pressed, the operator is given the option to start the test execution as follows:

OK TO START (Y OR N)  
?

If Y, the program will proceed the execution by following the procedure presented below. If N, the initial pressures will be requested again.

#### EXECUTION PROCEDURE:

The execution procedure is composed of four parts as follows:

a) TEST INITIATION:

The test is initiated by setting up the following:

$$\Delta V_6 = 0$$

$$\Delta V_8 = 0$$

and

$$P_9 = \sigma_{r_0}$$

$$P_6 = u_0$$

$\Delta V_6$  and  $\Delta V_8$  are set equal to zero in order to monitor the change in pore pressure and to avoid any contact between the specimen top cap and the load cell.

b) TEST EXECUTION:

At the beginning of the test execution, the program calculates the new value of cell pressure by means of the following expression:

$$P_9 = \sigma_{r_0} + \Delta\sigma \quad (3.13)$$

Furthermore, the operation is proceeded by taking readings at 5 seconds intervals from the pore water pressure controller and values of B are calculated by the following expression:

$$B = \frac{(P_6^* - u_0)}{\Delta\sigma_r} \quad (3.14)$$

Where  $P_6^*$  = The new pore water pressure developed due to the cell increment.

c) OUTPUT VALUE OF "B":

The calculated value of B, corresponding to the new porewater pressure, is displayed on the screen as follows:

```

PORE PRESSURE PARAMETER
B =                      #.##
PORE PRESSURE PARAMETER
B =                      #.##
PORE PRESSURE PARAMETER
B =                      #.##
"                          "
"                          "
"                          "

```

d) TEST TERMINATION:

The test is terminated by pressing the function key K1 on the keyboard. The program will then give the option of printing the last value of B as follows:

```

DO YOU REQUIRE A PRINT OF THE
PORE PRESSURE PARAMETER 'B'
(Y OR N) ?

```

If Y, the last value of B is then displayed on the screen as follows:

```
=====
PORE PRESSURE PARAMETER
  B =  #.####

ACHIEVED USING CELL PRESSURE
INCREMENT      #####  KPA
```

Note, the operator must choose the value of B, as an indicator of the saturation saturation of the test specimen, as soon as the entered cell pressure increment is achieved on the cell pressure controller (usually the first, second or third value of B). Otherwise, the saturation condition is not correctly presented. In the case of an unsatisfactory result, an elevated value of back pressure must be re-entered and a new value of B is recalculated for a new cell pressure increment. The process is repeated until the desired result is obtained.

If the answer to any of the above three questions is N, the program will give the operator the option to revise the back pressure as follows:

```
REVISE BACK PRESSURE
?
```

If the reply is N, the program will move directly to the consolidation stage. Otherwise, the revised back pressure is requested as follows:

ENTER REVISED BACK PRESURE  
?

As soon as the revised back pressure is entered and the 'ENDLINE' key is pressed, the program moves on to the consolidation procedure described below.

#### 4.5 OPTIONAL CONSOLIDATION STAGE

To carry out the consolidation stage, drainage is permitted during the application of the all-round pressure. Sometimes it is impossible to get rid of air bubbles trapped between the rubber membrane and the soil sample. Therefore, it is recommended to apply an elevated value of back pressure ( $U_0$ ) during the consolidation so that any remaining air will be dissolved.

To perform the consolidation stage, the program displays the following:

```
DO YOU REQUIRE THE TEST SPECIMEN
TO BE CONSOLIDATED PRIOR TO THE
TEST (Y OR N)
?
```

If N, the calculation of the pore pressure parameter B is requested again. If Y, the program prompts the following:

```
DO YOU WISH TO CONSOLIDATE AT THE
CURRENT CELL PRESSURE (Y OR N)
?
```

If N, the appropriate cell pressure is requested as follows:

```
ENTERED REVISED CELL PRESSURE
?
```

Note, the entered value must be positive integer and fits within the range 0 to 1023.

If the reply is Y or upon entering the revised cell pressure, the maximum volume reduction, for scale setting purpose, is requested as follows:

ENTER MAX VOLUME REDUCTION ?

Once the appropriate value is entered, the program prompts:

ENTER MAX VOLUME GAIN  
?

The scale, title and frame of the plot are then set on the screen and the consolidation stage is conducted by following the procedure presented below:

a) INITIALIZATION:

At the beginning, the program set up the initial condition as follows:

$\Delta V_8$  is held equal to zero

$\Delta V_6$  is set equal to zero

$P_9$  is set equal to  $\sigma_r$

The purpose of holding the axial volume change equal to zero is to prevent the test specimen from any axial loading.

b) TEST EXECUTION:

The program starts the test execution by unlocking the pore water pressure controller. During the test, the pore water

pressure  $P_6$  is maintained equal to initial back pressure  $u_0$ . Furthermore, the computer will take readings from the pore water pressure controller at one-minute intervals. Then, the volume change  $\Delta V_6$  (in cubic mm) is plotted against the square root of time. The graph is scaled on the X axis from 0 to 20.

c) TEST TERMINATION:

Before achieving the estimated total test duration, the operator can terminate the test execution by pressing the function K1 on the keyboard. Thereafter, the program gives the option to print out the graph by asking the following:

DO YOU REQUIRE A PRINT (Y OR N)  
?

If Y, the program will print the following information:

```
=====
RESULTS OF CONSOLIDATION AT
CELL PRESSURE      #####   KPA

PORE PRESSURE      #####   KPA
```

The program moves on to the "Saving Result" stage. The operator is then given the option to save the results as follows:

d) SAVING RESULT:

To save the test results, the program asks the following:

```
DO YOU WISH TO SAVE THE
TEST RESULTS (Y OR N) ?
```

By answering Y, the program prompts:

```
INSERT RESULTS CARTRIDGE
ENTER FILNAME (6 CHARS)
?
```

When the results cartridge is inserted, the 'ENDLINE' key should not be pressed unless the operator has verified previously that the cartridge is already initialized.

If it is found that the results cartridge is used for the first time, the operator must initialize it by performing the following procedure:

1. Press the 'PAUSE' key on the keyboard.
2. Make sure the RECORD slide is in the right-most position (the same direction as the arrow).
3. Write on the screen the statement "erasetape" and then press 'ENDLINE'. The computer takes about 90 seconds to drive the cartridge and make it ready for archiving the results.
4. Press the 'CONT' key on the keyboard and then proceed to the saving result procedure.

As soon as the results cartridge is initialized, type the filename and press 'ENDLINE'. Then, the program prompts the following:

```
ENTER RESULTS DESCRIPTION
MAX 32 CHARS
?
```

Once the result description is entered, the program takes some times, depending on the number of data points to be stored, to save the results. The following is then displayed on the screen:

```
"RESULTS DESCRIPTION"
RESULTS SAVED IN "FILENAME"
```

At this stage, the test results are saved and ready for future analysis. The program continues its execution as follows:

```
DO YOU WISH TO CHECK THE 'B'
VALUE AGAIN (Y OR N)
?
```

If Y, the cell pressure increment is requested again and the program proceeds the test as before. If N, the program will request the revised back pressure as follows:

```
REVISED BACK PRESSURE (Y OR N)
?
```

For an Y reply, the above procedure is repeated as before. Otherwise, the consolidation option is proposed again as follows:

DO YOU REQUIRE THE TEST SPECIMEN  
TO BE CONSOLIDATED PRIOR TO THE  
TEST (Y OR N)  
?

By answering Y, the consolidation procedure is performed as before. Otherwise, the program moves on to check the B value again.

Note, giving the appropriate answer, further checks of the value of B and consolidation stages are available on a loop-round.

Having accomplishing the above, the operator is asked to dock as follows:

PLEASE 'DOCK' THEN PRESS ENDLINE  
?

Screw the loading cell down until it contacts with the top cap and the lower chamber pressure increases 1 Kpa above the undocked pressure.

Note, it is recommended, prior to set up the sample, to apply a thin layer of "silicon grease" to the loading ram cup in order to avoid any slip/stick between the load cell and the specimen top cap.

Immediately after the docking procedure and pressing the 'ENDLINE' key, the program sets the volume change in the lower chamber equal to zero. The initial conditions are then displayed on the screen as follows:

INITIAL TEST CONDITIONS  
CELL PRESSURE. #### KPA  
BACK PRESSURE #### KPA

OK TO CONTINUE (Y OR N)  
?

If the answer is N, the program will request the new cell pressure and back pressure and then proceed to show the menu of available tests. If the answer is Y, the test menu is displayed directly on the screen as follows:

AVAILABLE TESTS

=====

- 1 = UNCONSOLIDATED UNDRAINED
- 2 = CONSOLIDATED UNDRAINED WITH  
PORE PRESSURE MEASUREMENT
- 3 = DRAINED
- 4 = KO CONSOLIDATION & SWELLING  
TO SPEC'D OVERCONSOLIDATION RATIO
- 5 = CONTINUOUS LINEAR  
STRESS PATHS
- 6 = CYCLIC LOADING
- 9 = TERMINATE PROGRAM

=====

LOAD GDSTTS CARTRIDGE

ENTER REQUIRED TEST NUMBER ?

The entered number must be within the range 1 to 6 in order to carry out any specific test. If the entered value is 9, the program will terminate.

## 4.6 TESTS EXECUTION

### 4.6.1 UNCONSOLIDATED-UNDRAINED TEST

Entering number "1" from the test menu loads the unconsolidated undrained test subroutine and prompts the following:

```
WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS  
?
```

The program will then request the testing rate as follows:

```
PROGRAM BEING LOADED & READIED  
WHAT TESTING RATE DO YOU REQUIRE  
1 = AXIAL TOTAL STRESS KPA/HR  
5 = AXIAL DEFORMATION MM/HR  
ENTER TYPE, RATE  
?
```

Note, if the rate type 1 is chosen, the entered value must be within the range 0 to 2000 KPa/hr. If the rate type 5 is chosen, the entered value must be within the range 1 to 100 mm/hr.

As soon as the testing rate is entered and the 'ENDLINE' key is pressed, the program requests the estimated terminal axial strain as follows:

```
AT WHAT VALUE OF PERCENTAGE  
AXIAL STRAIN DO YOU WISH  
THE TEST TO BE STOPPED  
?
```

Note, the Entered value of the terminal axial strain must be within the range 0 to 30 percent.

The maximum deviator stress is requested for setting up the scale of the Y axis as follows:

ENTER MAXIMUM DEVIATOR STRESS  
?

Note, the entered value of the maximum deviator stress must be within the range 1 to 6000 KPa.

The minimum value of deviator stress is also needed for setting the Y axis scale:

ENTERED MIN DEVIATOR STRESS  
?

Note, the entered value here also must be within the range 0 to 6000 KPa.

Once the minimum deviator stress is entered, the program moves on to its final stage and gives the operator the option to start the shearing test as follows:

OK TO START (Y OR N) ?

On an N repl; , the program prompts the testing rate again and the above procedure is also repeated. Otherwise, the initial information are displayed as follows:

```
=====
TEST - UNCONSOLIDATED UNDRAINED
CELL PRESSURE   #### KPA
```

BACK PRESSURE   #### KPA  
AXIAL DEFORMATION CONTROL  
AT RATE OF       ### MM/HR  
TERMINATION % AXIAL STRAIN  
=           ##  
MAXIMUM DEVIATOR STRESS  
=           #### KPA

The program displays the scale of the graph, on the screen, and sets the test conditions prior to the test execution, by proceeding the following:

a) The initial test conditions are as follows:

$\Delta V_6$  is held equal to zero

$P_9$  is held equal to  $\sigma_{r0}$

$P_8$  is set equal to  $P_9 + \Delta P$  (due to docking)

b) The program starts the timer and proceeds with the execution by taking readings from the controllers. It calculates either  $\Delta V_8$  according to equation 6.3 or  $P$  according to equation 6.7 (in appendix A), depending on the type of rate chosen. The process is repeated until the desired axial percentage strain, entered, is achieved.

c) A graph of deviator stress ( $\sigma_a - \sigma_r$ ) versus axial strain (Ea%) is plotted during the test on the screen.

d) The operator can abort at any stage the test by pressing the 'pause' key on the keyboard. To obtain a print of the screen on the printer and save the results at the current stage type in:

"CONT 1228" and press 'ENDline'.

e) If step d) is not desired, the test will terminate when the calculated value of axial percentage strain becomes greater than or equal to the entered axial strain. Immediately after, the graph is automatically printed out on the printer. The program will then give the option to save the results as in the case of section 4.5(d). Furthermore, the program displays the following:

RESULTS SAVED IN "FILENAME"

L = ##.#####

D = ##.#####

DO YOU WISH TO CARRY ANOTHER  
TEST ON THIS SPECIMEN (Y OR N)  
?

If Y, another test will carry out. If N, the program will display the end statement on the screen as follows:

END

#### 4.6.2 CONSOLIDATED UNDRAINED TEST

The Consolidated-Undrained test is carried out by permitting the drainage of the test specimen under a specified all-round pressure until the consolidation stage (described before) is completed. The axial loading is then applied with no drainage being permitted by locking the GDS pore water controller. The pore water pressure measurements are taken during the undrained part of the test.

Entering number "2" from the test menu and pressing the 'ENDLINE' key prompts the following:

```
WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS  
?
```

As soon as the question is answered, the program requests the testing rate as follows:

```
PROGRAM BEING LOADED & READIED  
WHAT TESTING RATE DO YOU REQUIRE  
1 = AXIAL TOTAL STRESS KPA/HR  
5 = AXIAL DEFORMATION MM/HR  
ENTER TYPE, RATE  
?
```

Once the appropriate number is chosen, the program requests the terminal testing rate as follows:

```
AT WHAT VALUE OF PERCENTAGE  
AXIAL STRAIN DO YOU WISH  
THE TEST TO BE STOPPED  
?
```

Furthermore, the program will ask to choose one of the following plots:

```
DO YOU REQUIRE A PLOT OF : -  
1 = DEVIATOR STRESS & PORE PRESSURE  
2 = STRESS RATIO  
ENTER CHOICE; E.G. 1 ?
```

Note, if the entered number is neither "1" nor "2" the program will prompt the question again.

If the operator enters 1, the maximum deviator stress is then requested as follows:

```
ENTER MAX DEVIATOR STRESS  
?
```

and the minimum deviator stress as follows:

```
ENTER MIN DEVIATOR STRESS  
?
```

The operator is then given the option to start the test execution:

```
OK TO START (Y OR N) ?
```

On an N reply, the above procedure is repeated again. Otherwise, the initial information will be printed out.

At this stage, the program sets up the initial test conditions subsequently and proceeds with the test execution as in the case of section 4.5(a) and section 4.5(b) respectively.

The results are displayed throughout the test, under either of the two forms:

1) Deviator Stress and Pore Pressure vs percentage axial strain:

The deviator stress ( $\sigma_a - \sigma_r$ ) and pore pressure ( $u_0$ ), on the Y axis, are plotted versus the percentage axial strain on the X axis. The graph is scaled on the X axis from 0 to the entered terminal axial strain and on the Y axis from 0 to the maximum of either the deviator stress or the maximum of the current pore water pressure.

2) Stress ratio vs percentage axial stress:

The stress ratio ( $\sigma'_a / \sigma'_r$ ) on the Y axis is plotted versus percentage axial strain on the X axis. The graph is scaled on the Y axis from 0 to 5 and from 0 to the terminal percentage axial strain on the X axis.

The test termination and saving results procedures are performed as in the case of section 4.5(c) and section 4.5(d) respectively.

If the operator wishes to stop the test before attaining the entered percentage axial strain, the 'PAUSE' key must be pressed. To print out and save the results type in:

"CONT 2332" and press the 'ENDLINE' key.

The program will then give the option to carry out another test on the same specimen or stop. A plot of deviator stress versus percentage axial strain will be displayed on the screen during the test execution.

#### 4.6.3 DRAINED TEST

The Drained test is carried out by permitting the drainage of the specimen under a specified all-round pressure until the consolidation stage (if it is required) is completed. The axial loading is then applied, with drainage still being permitted, by unlocking the pore water controller. The rate must be slow enough in order to maintain the excess pore water pressure equal to zero.

Choosing number "3" from the test menu and pressing the 'ENDLINE' key prompts:

```
WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS  
?
```

As soon as the question is replied, the program prompts

```
PROGRAM BEING LOADED & READIED
```

Furthermore, the types of rate are requested as follows:

```
WHAT TESTING RATE DO YOU REQUIRE  
1 = AXIAL TOTAL STRESS KPA/HR  
5 = AXIAL DEFORMATION MM/HR  
ENTER TYPE, RATE  
?
```

Note, if type 1 is chosen, the entered value must be within the range 0 to 2000. If type 5 is chosen, the entered value must be within the range 1 to 100 mm/hr.

Then, the operator is asked to enter the terminal axial strain as follows:

AT WHAT VALUE OF PERCENTAGE  
AXIAL STRAIN DO YOU WISH  
THE TEST TO BE STOPPED  
?

After inserting a value between 0 and 30 percent, the operator is asked to select the required plot as follows:

DO YOU REQUIRE A PLOT OF : -  
1 = DEVIATOR STRESS & PORE PRESS  
2 = STRESS RATIO  
3 = VOLUME CHANGE  
ENTER CHOICE; E.G. 1 ?

i) If 1 is entered, two subsequent questions will be asked as follows:

ENTER MAXIMUM DEVIATOR STRESS  
?

and

ENTER MINIMUM DEVIATOR STRESS  
?

Note, the entered value must be within the rang 0 to 6000 KPa.

ii) If 3 is entered, the program will request the anticipated volume change as follows:

WHAT IS THE EXPECTED  
MAXIMUM VOLUME  
CHANGE (CU. MM) ?

Note, the entered value must be within the range 0 to  $0.2 \cdot V_0$  CU. MM.

iii) If 2 is entered, the program will set automatically the maximum value of the stress ratio equal to 5 and the minimum equal to 0.

Once the appropriate number is chosen, the operator is given the option to start:

OK TO START (Y OR N)  
?

If N, the program will request to repeat the above procedure. If Y, the program will display the following:

=====

TEST - DRAINED

CELL PRESSURE ##### KPA

BACK PRESSURE ##### KPA

AXIAL DEFORMATION CONTROL

AT RATE OF ### MM/HR

TERMINAL % AXIAL STRAIN

= ##.#

MAXIMUM DEVIATOR STRESS

= ##### KPA if 1 is entered

MAXIMUM VOLUME CHANGE

= ##### KPA if 3 is entered

The program sets the initial test conditions as follows:

$P_9$  is set equal to  $\sigma_{r0}$  if the sample is Unconsolidated.

$P_9$  is set equal to  $\sigma_r$ , value existing at end of consolidated, if consolidation is requested.

$P_6$  held equal to  $u_0$

$P_8$  is set equal to  $P_9 + \Delta P$  (due to docking)

The graph is scaled on the screen in accordance with the option chosen by the operator.

The test is executed until the terminal axial strain is achieved. The results will then be saved as in the case of section 4.5(d).

The 'PAUSE' key must be pressed if the operator wishes to halt the test before the terminal axial strain is achieved. To obtain a print of the graph and save the test results, type in:

"CONT 3408" and then press 'ENDLINE'.

The option to carry out another test in the same specimen or stop, is also provided at this stage.

#### 4.6.4 K CONSOLIDATION AND SWELLING TEST

The purpose of this test is to load and unload the test specimen under zero radial strain by not allowing any change in the average diameter of the specimen within tolerance of 1 micrometer. The test is performed by setting the lower chamber pressure and associated volume change, and by adjusting the cell pressure needed to provide zero radial strain, by keeping the average specimen diameter constant.

The rate of consolidation is not adjusted automatically to the available algorithm. Therefore, if a very fast testing rate is used, the value of K will tend towards unity. This is due to the equivalent increase in the axial stress and the volume change which are caused by the increase of the all-round pressure. Therefore, a high testing rate is not recommended.

The testing procedure that includes the initial input and output, initial conditions, test execution, test termination, presentation of results, saving results and test abort are very well presented in Appendix E, taken from the GDS Users Handbook, and illustrated in Example 5.5 in chapter 5, of this report.

#### 4.6.5 CONTINUOUS LINEAR STRESS PATHS TEST

In the continuous linear stress paths test, the specimen is subjected to a set of total axial stress and total radial stress coordinates. This is done by moving from an initial set of total stress coordinates to a terminal set of total stress coordinates along a series of linear stress paths under drained or undrained conditions.

The operator has the option to define or not the complete stress path. If the required stress path at the terminal set is known, the operator can then define the total test by dividing the complete stress path into up to ten sets of total stress coordinates only, representing nine linear stress paths. Where each linear stress path is defined by two sets of total stress coordinates.

When the terminal set of coordinates is not known, the operator can start the test by defining two sets of coordinates only. Alternative to choose the next linear path is provided as soon as the current one is accomplished. In this way, the path can be modified as the test progresses and more than nine linear paths can be achieved.

The execution of the test is proceeded first by calculating the total axial and radial stresses. Second, by commanding the GDS controller to maintain the calculated radial stress. Third, by generating pressure in the lower chamber until the calculated axial stress is achieved. If the radial total stress changes by more than the axial total stress on a particular stress path, the radial stress control will then be chosen. Otherwise, the axial stress control will be chosen instead.

The test procedure that includes the test initialization, initial conditions, test execution, presentation of results, saving results and test abort are very well presented in Appendix B, taken from the GDS Users Handbook. The stress rate, used within the program, is limited to a maximum of 100 KPa/hr. In order that the stress path starts clearly, it is important that the test specimen is at the first set of stress co-ordinates before the test is started otherwise there is an initial disturbance while the initial co-ordinates are reached.

Note, this test is not illustrated with an example due to an unknown problem with the available software.

#### 4.6.6 CYCLIC LOADING TEST

To carry out a cyclic loading test, the lower chamber controller is set to charge the lower chamber at a constant rate of volume change. Meanwhile, the cell pressure controller is set to discharge at the same rate of volume change. By doing this, the generated axial deformation is then ramped in a triangular wave form with respect to time between axial total stress limits. The test is conducted by calculating the total axial stress from the readings that are provided by the three controllers. As soon as the upper limit of the total axial stress is reached, the cell and lower chamber controllers will reverse their mechanism and the total axial stress will decrease until the lower limit is reached. This sequence indicates that one cycle is achieved. This sequence is repeated for the required number of cycles that the operator is requesting.

Choosing number "6" from the test menu prompts the following:

```
PROGRAM BEING LOADED & READIED  
IS THE TEST TO BE : -  
1 = DRAINED  
2 = UNDRAINED  
?
```

If neither of the two numbers is entered, the program will prompt the question again.

The operator is asked to enter the required load amplitude as follows:

WHAT AMPLITUDE DO YOU REQUIRE  
IN KPA  
?

Note, the entered value must be within the range 0 to 1000 KPa, otherwise the program will prompt the question again.

To set the axial stress limits, within which the cyclic loading is proceeded, the operator is asked to enter the stress datum as follows:

WHAT AMPLITUDE IN KPA  
DO YOU REQUIRE  
?

The entered value must be higher than the previously entered amplitude. Otherwise, the operator is asked to enter the amplitude value again.

To perform the test, the program requests the estimated axial deformation rate as follows:

WHAT AXIAL DEFORMATION RATE  
DO YOU REQUIRE. THE LIMITS ARE  
100 MM/HR TO 0.1 MM/HR  
?

N.B The estimated value of the axial deformation rate should be within the range 0.1 to 100 mm/hr. If not the question is requested again.

To establish the scale, for the dynamic display during the test execution, the operator is asked to enter the axial deformation scale as follows:

WHAT AXIAL DEFORMATION SCALE  
DO YOU REQUIRE IN MM.  
?

Note, the entered value must be within the range 0.1 to 20 mm, otherwise the question is prompted again.

The program will then ask for the estimated period, which is needed to control the storage of data, as follows:

WHAT DO YOU ESTIMATE THE PERIOD  
TO BE IN SECONDS  
?

Note, the entered value must be within the range 10 to 10000 seconds otherwise, the question is prompted again.

A set of data is stored every 1/30th of the estimated period for the first cycle. Then, for the second and subsequent cycles the program stores data every 1/20th of the previous period.

The program requests the required number of cycle, to be executed during, the test as follows:

HOW MANY CYCLES DO YOU REQUIRE

TO BE EXECUTED  
?

As soon as a positive integer is entered (otherwise the question is prompted again), the program displays on the screen all entered information and gives the option to start the test as follows:

CELL PRESSURE = ##### KPA  
PORE PRESSURE = ##### KPA

SPECIMEN IS "DRAINED or UNDRAINED"

AXIAL DEFORMATION CONTROL  
AT RATE OF ### MM/HR

WAVEFORM IS TRIANGULAR  
DATUM IS ##### KPA  
AMPLITUDE IS ##### KPA  
TEST TERMINATION AFTER #####  
CYCLES

OK TO START (Y OR N)

If N, the program will go back and ask for the drainage conditions again. If Y, the program will print out the above information and then pass on to set the following initial conditions, prior to the execution process:

1.  $P_9$  is set equal to the cell pressure  $\sigma_c$  for the first cycle and then for the subsequent cycle it will take the value of the previous cycle
2.  $P_6$  is set equal to  $u_0$  if the test is drained.
3.  $\Delta V_6$  is set equal to zero if the test is undrained.  $P_8$  is set equal to  $P_9 + \Delta P$  for the first cycle, because

of the docking effect. Hence, it will take the value of the previous cycle for the subsequent cycle.

Meanwhile, the program scales the graph of the first cycle on the screen. The total axial stress in KPA on the Y axis versus the axial deformation in mm on the x axis. The program will then continue to set the execution rate of volume by using the following expression:

$$R = \frac{3.6*10}{(\text{axial deformation rate})*2950*2} \quad (3.15)$$

in milliseconds per 0.5 mm step.

The execution is performed in two repeated consecutive sequences as follows:

1. The lower chamber will be charged at the calculated rate R and the cell controller will be discharged at the same rate R . This operation is repeated until the calculated axial stress becomes higher than the datum plus the amplitude. At this stage, the upper limit is reached and the program will pass on to the reversal ramping.
2. The lower chamber will be discharged at the calculated rate R and the cell controller will be charged at the same rate R. This operation is repeated until the calculated axial stress becomes

less than the datum minus the amplitude. At this stage, the lower limit is reached and the program will move to perform the next cycle as before. This sequence is repeated for the required number of cycles.

The screen is refreshed with each successive cycle with the axes deleted.

At any stage, the operator can halt the execution by pressing the 'PAUSE' key. If a printing of the screen and saving of the results are required, type in:

"CONT 6492" and press the 'ENDLINE' key.

The results saving procedure is the same as in the case of 3.2.2.10(a). As soon as the results are saved the program prompts:

ANY MORE CYCLES (Y OR N) ?  
?

If the answer is Y, the program will go back to the drainage option and the same procedure is repeated again. If the answer is N, the new dimensions of the specimen will be displayed on the screen and the program will continue as follows:

L = ##.#####  
D = ##.#####

DO YOU WISH TO CARRY OUT ANOTHER  
TEST ON THIS SPECIMEN (Y OR N)  
?

By replying Y, the GDSTTS program is loaded again. Otherwise  
the end statement will appear on the screen:

END

#### 4.7 GDSFBP PLOTTING AND TABULATION PROGRAM

The GDSTTS program provides storage of up to 350 data points and saved on tape for subsequent tabulating and plotting. Twenty test parameters can be calculated from the saved information, which consists of information about the test specimen followed by sets of readings from the three controllers. Any one of these twenty test parameters can be plotted against another using the GDSFBP program. Scales can be enlarged so that portions of the plot may be examined in great detail. The two-pen graphics plotter provides output for direct inclusion in reports. The operation of the GDSFBP program is described as follows:

##### OPERATION OF THE GDSFBP PROGRAM

To start plotting or tabulating the results, the operator must first perform the following activities:

a) Prior to insert the Standard Pac Tape Cartridge, the operator must check that the RECORD slide is in the right-most position. The cartridge is then inserted into the computer and the GDSFBP program will be loaded by typing in:

LOAD"GDSFBP" and pressing the key 'ENDLINE'

The statement LOAD"GDSFBP" will then disappear from the screen while the computer is loading and searching for the program. When the cursor returns to the screen and the amber

tape drive light disappears, the 'RUN' key will then be pressed in order to be ready for operation. About twenty seconds of delay are required for data areas allocation and performing syntax check on the program.

b) When the program is loaded, the following is displayed:

```
DO YOU WISH TO HAVE RESULTS ON
SCREEN OR PLOTTER (S OR P)
?
```

If the answer is S, the desired plot will be displayed on the screen. It will then be printed out by pressing the 'COPY' key. If the answer is P, the results will be printed by means of the graphics plotter. By choosing either option the program will ask for membrane correction as follows:

```
DO YOU WISH TO CORRECT ?a FOR
THE EFFECT OF MEMBRANE STIFFNESS
(Y OR N)
?
```

If Y, the extension modulus of the rubber membrane is requested as follows:

```
WHAT IS THE EXTENSION MODULUS
OF THE MEMBRANE IN GRAM/MM
?
```

N.B The entered value should not be less than 1 g/mm.

If N, the program will request the following:

```
GDSFBP - VERSION 261082
INSERT RESULTS CARTRIDGE - THEN
ENTER DATA FILENAME
?
```

As soon as the data filename is entered and the 'ENDLINE' key is pressed, the program will take some times, depending on the number of data points that have been stored, to read all data into computer memory from the tape. The following will then appear on the screen:

```
=====
FILE NAME : - FILE NAME ENTERED
TYPE OF TEST

THERE ARE ### SETS OF DATA
ESTD. TEST DURATION =  ##.##  HRS
ACTUAL TEST DURATION =  ##.##  HRS
DO YOU WANT A PRINT OF OPTIONS
(Y OR N)
?
```

By replying Y, the program will display all possible parameters that the GDSFBP program can plot or tabulate as follows:

```
=====
THE GENERAL PURPOSE PLOTTING
OR TABULATION PROGRAM ALLOWS
THE FOLLOWING VARIABLES TO BE
EXAMINED :-
1 = TIME
2 = PERCENT AXIAL STRAIN
3 = AXIAL STRESS
4 = RADIAL STRESS
5 = EFFECTIVE AXIAL STRESS
6 = EFFECTIVE RADIAL STRESS
7 = DEVIATOR STRESS
8 = STRESS RATIO
9 = MEAN STRESS
10 = MEAN EFFECTIVE STRESS
11 = AVERAGE RADIAL STRAIN
12 = AVERAGE DIAMETER CHANGE
13 = PORE WATER PRESSURE
14 = VOLUME CHANGE ( V(8) )
15 = CHANGE IN LENGTH
16 = SQUARE ROOT OF TIME
17 = LOG(10) OF TIME
18 = LOG(10) OF EFFECTIVE AXIAL
19 = (DEVIATOR STRESS)/2
20 = MAX SHEAR STRAIN
```

```
THERE ARE ### SETS OF DATA
DO YOU WISH TO :-
1 = TABULATE
2 = PLOT
8 = ANOTHER FILE
9 = TERMINATE PROGRAM
ENTER YOUR CHOICE
?
```

Whereas for an N reply, the program would have displayed the following only:

```
THERE ARE ### SETS OF DATA
DO YOU WISH TO :-
1 = TABULATE
2 = PLOT
8 = ANOTHER FILE
9 = TERMINATION PROGRAM
ENTER YOUR CHOICE
?
```

i) If number 2 is chosen, the operator is asked to enter the variable numbers as follows:

```
ENTER X AND Y VARIABLE NUMBERS
FORMAT X,Y e.g 2,7
?
```

Once the question is answered, the following output will be provided for verification:

```
X = TITLE OF VARIABLE ON X AXIS
Y = TITLE OF VARIABLE ON Y AXIS
OK TO CONTINUE (Y OR N)
?
```

If N, the operator will be asked again to enter the variable numbers as above. If Y, the operator will be asked to wait a specific number of seconds as follows:

```
PLEASE WAIT   ### SECS: SCALE CALC
THE SCALE IS :-
X-MIN = #####
X-MAX = #####
Y-MIN = #####
Y-MAX = #####
DO YOU WISH TO ALTER IT (Y OR N)
?
```

Immediately after answering N, the Graphics Plotter will start plotting. Otherwise, the operator is asked to alter the scale as follows:

```
ENTER X-MIN
?
####
ENTER X-MAX
?
####
ENTER Y-MIN
?
####
ENTER Y-MAX
?
####
```

Once the graph is plotted, the operator is asked again whether tabulation, plotting, go to another file or terminate program are required.

ii) If number "1" is chosen, the program will request the variables for tabulation as follows:

```
ENTER VARIABLE # TO BE TABBED
?
##
ENTER VARIABLE # TO BE TABBED
```

```

?
##
"           "
"           "
"           "
ENTER VARIABLE # TO BE TABBED
?
99

```

The operator has the option to tabulate up to 20 variables at the same time. As soon as the variables for tabulation are chosen, the operator must type the number 99 before moving to the next option. Hence, the program gives the option to continue or not as the following example:

```

VARIABLES TO BE TABBED ARE:-
1 = T secs
2 = AXIAL STRESS KPA
OK TO CONTINUE (Y OR N)
?

```

If N, the operator is asked again to enter the variables to be tabulated. Otherwise, the output will be displayed similar to the following:

```

TABULATION FOR
TYPE OF TEST AND TESTING RATE
1 = T secs
2 = AXIAL STRESS KPA
READING NUMBER 1
1 = ##
2 = ##
READING NUMBER 2
1 = ##
2 = ##
READING NUMBER 3
1 = ##
2 = ##
"           "
"           "
"           "
"           "

```

After accomplishing the tabulation procedure, the operator is given again the option to tabulate, plot, go to another file or to terminate program.

iii) If number "8" is chosen, the operator is asked to enter the new filename as follows:

```
INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME  
?
```

By entering the new filename, the above procedure will be again applicable.

iv) Finally, a number "9" selection allows the program to display the end statement:

END

## Chapter V

### EXAMPLES

This Chapter, contains examples of representative triaxial tests undertaken to validate the correct use of the GDS.

On selected clay and sand samples, the following tests were conducted:

1. Consolidation Test.
2. Unconsolidated Undrained Test.
3. Consolidated Undrained Test.
4. Consolidated Drained Test.
5. K Consolidation and Swelling Test.
6. Cyclic Loading Test.

Due to poor resolution in the printout, the computer output examples were retyped exactly the same as they were provided by the HP-85, for clarification.

5.1 CONSOLIDATION TEST

```
=====
EXAMPLE: 5.1

Type of Test: "CONSOLIDATION"

Type of soil: Clay

Specimen original diameter (D0)= 50.7 MM

Specimen original length (L0)= 101.5 MM

=====
TEST procedure
=====
```

A typical example of the Consolidation test computer output is presented in the frame as follows:

```
LOAD"GDSTTS"
ENTER DATE & TIME
FORMAT DD,MM,YY,HH,MM
?
24,8,85,17,20
PLEASE ENSURE CELL VALVES OPEN
THEN PRESS ENDLIN
?

IEEE CONTROLLER ADDRESSES :-
CELL PRESSURE = 9
PORE PRESSURE = 6
LOWER CHAMBER = 8

DO YOU WISH TO CHANGE THEM
(Y OR N)
?
N
DO YOU WISH TO HAVE RESULTS ON
SCREEN OR PLOTTER (S OR P) ?
?
S
ENTER AVERAGE DIAMETER
OF TEST SPECIMEN?
50.7
ENTER HEIGHT
OF TEST SPECIMEN
```

?  
101.6  
ENTERED VALUES ARE  
DIAMETER = 50.7 MM  
HEIGHT = 101.6 MM  
OK TO CONTINUE (Y OR N)?  
Y

GDS  
TRIAxIAL TESTING SYSTEM  
INVOKED AT 17:21  
ON 24/08/85

=====  
APPARATUS CONSTANTS ARE :-

SPECIMEN DIAM = 50.7 MM  
SPECIMEN HEIGHT= 101.6 MM  
SPECIMEN AREA = 2018.9 SQ.MM  
SPECIMEN VOLUME= 205116.0 CU.MM  
SEAL AREA = 20587.0 SQ.MM

ENTER INITIAL CELL PRESSURE ?  
250  
ENTER INITIAL BACK PRESSURE  
IF ANY ?  
100

INITIAL TEST CONDITIONS  
CELL PRESSURE 250 KPA  
BACK PRESSURE 100 KPA

OK TO CONTINUE (Y OR N)  
?

Y  
ENSURE THAT HOLD-VOLUME IS NOT  
ENGAGED THEN PRESS ENDLINE  
?

FRICION CALC REQU'D (Y OR N) ?  
?

Y  
CALCULATING FRICTION  
=====

PRESSURE CORRECTION  
FOR LOWER CHAMBER FRICTION  
= .5 KPA

PLEASE USE ZERO OFFSET TO SET  
LOWER CHAMBER PRESSURE EQUAL TO  
CELL PRESSURE - FRICTION CORR.

THEN PRESS ENDLINE

?

DO YOU WISH TO CHECK THE DEGREE  
OF SATURATION OF THE TEST  
SPECIMEN AND COMPRESSIBILITY OF  
THE PORE WATER DUCTS BY  
EVALUATING THE PORE PRESSURE  
PARAMETER 'B'; (Y OR N)

?

Y

ENTER REQUIRED CELL PRESSURE  
INCREMENT

?

20

OK TO START (Y OR N)

?

Y

PORE PRESSURE PARAMETER

B = .9

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .95

DO YOU REQUIRE A PRINT OF THE  
PORE PRESSURE PARAMETERS 'B'  
(Y OR N) ?

Y

=====

PORE PRESSURE PARAMETER

B = .9500

ACHIEVED USING CELL PRESSURE  
INCREMENT 20 KPA

REVISE BACK PRESSURE (Y OR N)

?

N

DO YOU REQUIRE THE TEST SPECIMEN  
TO BE CONSOLIDATED PRIOR TO THE  
TEST N(Y OR N)

?

Y

DO YOU WISH TO CONSOLIDATE AT THE  
CURRENT CELL PRESSURE (Y OR N)

?

Y

ENTER MAX VOLUME REDUCTION ?

10000

ENTER MAX VOLUME GAIN

?

0

WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS

?

24

DO YOU REQUIRE A PRINT (Y OR N)

?

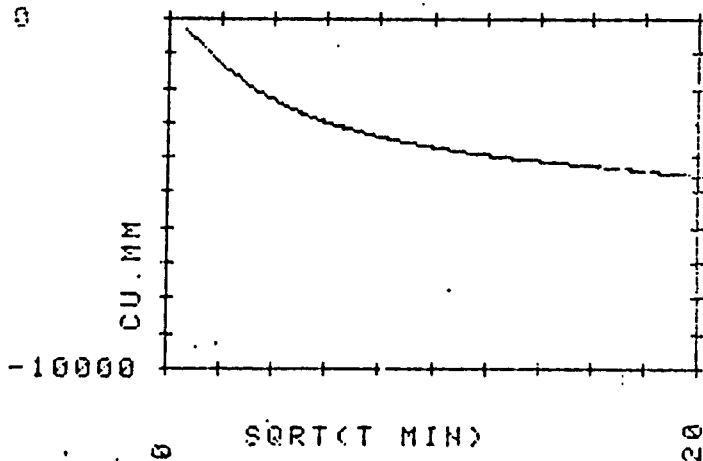
Y

=====

RESULTS OF CONSOLIDATION AT  
CELL PRESSURE 270 KPA

PORE PRESSURE 100 KPA

VOLUME CHANGE v. SQRT(TIME)



Plot of volume change  
versus square root of  
time computer output.

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N)?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

C-3

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

CONSOLIDATION

RESULTS SAVED IN C-2

DO YOU WISH TO CHECK THE 'B'  
VALUE AGAIN (Y OR N)

?  
N  
PLEASE 'DOCK' THEN PRESS ENDLINE  
?

INITIAL TEST CONDITIONS  
CELL PRESSURE 270 KPA  
BACK PRESSURE 100 KPA

OK TO CONTINUE (Y OR N)

?  
Y

AVAILABLE TESTS

- =====
- 1 = UNCONSOLIDATED UNDRAINED
  - 2 = CONSOLIDATED UNDRAINED WITH  
PORE PRESSURE MEASUREMENT
  - 3 = DRAINED
  - 4 = KO CONSOLIDATION & SWELLING  
TO SPEC'D OVERCONSOLIDATION RATIO
  - 5 = CONTINUOUS LINEAR  
STRESS PATHS
  - 6 = CYCLIC LOADING
  - 9 = TERMINATION PROGRAM
- =====

LOAD GDSTTS CARTRIDGE  
ENTER REQUIRED TEST NUMBER ?  
9  
END

\*\*\*\*\*  
\* PLOTTING STAGE \*  
\*\*\*\*\*

LOAD "GDSFBP"  
DO YOU WISH TO HAVE RESULTS ON  
SCREEN OR PLOTTER (S OR P) ?  
?  
P  
DO YOU WISH TO CORRECT ?a FOR  
THE EFFECT OF MEMBRANE STIFFNESS  
(Y OR N)  
?  
N  
GDSFBP - VERSION 261082  
INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME

?  
C-3

=====  
FILE NAME : - C-3  
CONSOLIDATION

THERE ARE 271 SETS OF DATA  
ESTD. TEST DURATION = 25.2 HRS  
ACTUAL TEST DURATION = 22.7 HRS  
DO YOU WANT A PRINT OF OPTIONS  
(Y OR N)  
?  
Y

=====  
THE GENERAL PURPOSE PLOTTING  
OR TABULATING PROGRAM ALLOWS  
THE FOLLOWING VARIABLES TO BE  
EXAMINED : -  
1 = TIME  
2 = PERCENT AXIAL STRAIN  
3 = AXIAL STRESS  
4 = RADIAL STRESS  
5 = EFFECTIVE AXIAL STRESS  
6 = EFFECTIVE RADIAL STRESS  
7 = DEVIATOR STRESS  
8 = STRESS RATIO  
9 = MEAN STRESS  
10 = MEAN EFFECTIVE STRESS  
11 = AVERAGE RADIAL STRAIN  
12 = AVERAGE DIAMETER CHANGE  
13 = PORE WATER PRESSURE  
14 = VOLUME CHANGE ( V(8) )  
15 = CHANGE IN LENGTH  
16 = SQUARE ROOT OF TIME  
17 = LOG(10) OF TIME  
18 = LOG(10) OF EFFECTIVE AXIAL  
19 = (DEVIATOR STRESS)/2  
20 = MAX SHEAR STRAIN

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
1,14  
X = TIME

Y = VOLUME CHANGE  
OK TO CONTINUE (Y OR N)  
?  
Y  
PLEASE WAIT 68 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 0.1  
X-MAX = 81637  
Y-MIN = -5440  
Y-MAX = -320  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
Y  
ENTER X-MIN  
?  
0  
ENTER X-MAX  
?  
90000  
ENTER Y-MIN  
?  
-6000  
ENTER Y-MAX  
?  
0  
  
THERE ARE 271 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
16,14  
X = SQRT(TIME)  
Y = VOLUME CHANGE  
OK TO CONTINUE (Y OR N)  
?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N  
PLEASE WAIT 92 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 0.1  
X-MAX = 285.721892756  
Y-MIN = -5440  
Y-MAX = -320

DO YOU WISH TO ALTER IT (Y OR N)

?

N

THERE ARE 24 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

9

END

## 5.2 UNCONSOLIDATED UNDRAINED TEST

```
=====
EXAMPLE: 5.2

Type of Test: "UNCONSOLIDATED UNDRAINED"
Type of soil: Clay
Specimen original diameter (Do)= 50.6 MM
Specimen original length (Lo)= 101.3 MM
=====
TEST procedure
=====
```

A typical example of the Unconsolidated Undrained Test computer output is presented in the frame as follows:

```
LOAD"G DSTTS"
ENTER DATE & TIME
FORMAT DD,MM,YY,HH,MM
?
26,8,85,15,00
PLEASE ENSURE CELL VALVES OPEN
THEN PRESS ENDLINE
?

IEEE CONTROLLER ADDRESSES :-
CELL PRESSURE = 9
PORE PRESSURE = 6
LOWER CHAMBER = 8

DO YOU WISH TO CHANGE THEM
(Y OR N)
?
N
DO YOU WISH TO HAVE RESULTS ON
SCREEN OR PLOTTER (S OR P) ?
?
S
ENTER AVERAGE DIAMETER
OF TEST SPECIMEN?
50.6
ENTER HEIGHT
```

OF TEST SPECIMEN  
?  
101.3  
ENTERED VALUES ARE  
DIAMETER = 50.6 MM  
HEIGHT = 101.3 MM  
OK TO CONTINUE (Y OR N)?  
Y

GDS  
TRIAxIAL TESTING SYSTEM  
INVOKED AT 15:12  
ON 26/08/85

=====

APPARATUS CONSTANTS ARE :-

SPECIMEN DIAM = 50.6 MM  
SPECIMEN HEIGHT= 101.3 MM  
SPECIMEN AREA = 2010.9 SQ.MM  
SPECIMEN VOLUME= 203704.4 CU.MM  
SEAL AREA = 20587.0 SQ.MM

ENTER INITIAL CELL PRESSURE ?  
110  
ENTER INITIAL BACK PRESSURE  
IF ANY ?  
50

INITIAL TEST CONDITIONS  
CELL PRESSURE 110 KPA  
BACK PRESSURE 50 KPA

OK TO CONTINUE (Y OR N)

?

Y

ENSURE THAT HOLD-VOLUME IS NOT  
ENGAGED THEN PRESS ENDLIN  
E  
?

FRICION CALC REQU'D (Y OR N) ?

?

Y

CALCULATING FRICTION

=====

PRESSURE CORRECTION  
FOR LOWER CHAMBER FRICTION  
= 0.0 KPA

PLEASE USE ZERO OFFSET TO SET  
LOWER CHAMBER PRESSURE EQUAL TO

CELL PRESSURE - FRICTION CORR.  
THEN PRESS ENDLINE  
?

DO YOU WISH TO CHECK THE DEGREE  
OF SATURATION OF THE TEST  
SPECIMEN AND COMPRESSIBILITY OF  
THE PORE WATER DUCTS BY  
EVALUATING THE PORE PRESSURE  
PARAMETER 'B'; (Y OR N)

?

Y

ENTER REQUIRED CELL PRESSURE  
INCREMENT

?

20

OK TO START (Y OR N)

?

Y

PORE PRESSURE PARAMETER

B = .85

PORE PRESSURE PARAMETER

B = .9

PORE PRESSURE PARAMETER

B = .9

PORE PRESSURE PARAMETER

DO YOU REQUIRE A PRINT OF THE  
PORE PRESSURE PARAMETERS 'B'  
(Y OR N) ?

Y

=====  
PORE PRESSURE PARAMETER

B = .9000

ACHIEVED USING CELL PRESSURE  
INCREMENT 20 KPA

REVISE BACK PRESSURE (Y OR N)

?

N

DO YOU REQUIRE THE TEST SPECIMEN  
TO BE CONSOLIDATED PRIOR TO THE  
TEST N(Y OR N)

?

N

DO YOU WISH TO CHECK THE 'B'  
VALUE AGAIN (Y OR N)

?

N

PLEASE 'DOCK' THEN PRESS ENDLINE

?

INITIAL TEST CONDITIONS  
CELL PRESSURE 130 KPA  
BACK PRESSURE 50 KPA

OK TO CONTINUE (Y OR N)  
?  
Y

AVAILABLE TESTS

=====

- 1 = UNCONSOLIDATED UNDRAINED
- 2 = CONSOLIDATED UNDRAINED WITH  
PORE PRESSURE MEASUREMENT
- 3 = DRAINED
- 4 = KO CONSOLIDATION & SWELLING  
TO SPEC'D OVERCONSOLIDATION RATIO
- 5 = CONTINUOUS LINEAR  
STRESS PATHS
- 6 = CYCLIC LOADING
- 9 = TERMINATION PROGRAM

=====

LOAD GDSTTS CARTRIDGE  
ENTER REQUIRED TEST NUMBER ?

1  
WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS

?  
10  
PROGRAM BEING LOADED & READIED  
WHAT TESTING RATE DO YOU REQUIRE

1 = AXIAL TOTAL STRESS KPA/HR  
5 = AXIAL DEFORMATION MM/HR  
ENTER TYPE, RATE

?  
5,3  
AT WHAT VALUE OF PERCENTAGE  
AXIAL STRAIN DO YOU WISH  
THE TEST TO BE STOPPED

?  
3  
DO YOU REQUIRE A PLOT OF :-  
1 = DEVIATOR STRESS  
2 = STRESS RATIO

ENTER CHOICE; E.G. 1 ?  
1  
ENTER MAX DEVIATOR STRESS

?  
400  
ENTER MIN DEVIATOR STRESS  
?

0  
OK TO START (Y OR N)?  
Y

=====

TEST - CONSOLIDATED UNDRAINED

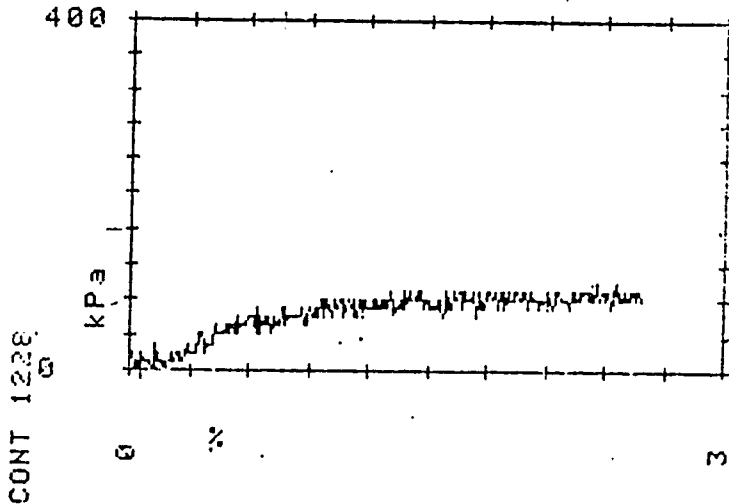
CELL PRESSURE = 130  
PORE PRESSURE = 50

AXIAL DEFORMATION CONTROL  
AT RATE OF 3 MM/HR

TERMINATION % AXIAL STRAIN  
= 3.0

MAXIMUM DEVIATOR STRESS  
= 400 KPA

DEV STRESS v. % AXIAL STRAIN



Plot of deviator stress  
versus percentage axial  
strain computer output.

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N) ?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

UU-1

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

CONSOLIDATED UNDRAINED

RESULTS SAVED IN CU-1

L= 98.6854859863

D= 51.2659013439

DO YOU WISH TO CARRY OUT ANOTHER  
TEST ON THIS SPECIMEN (Y OR N)

?

N

END

\*\*\*\*\*  
\* PLOTTING STAGE \*  
\*\*\*\*\*

LOAD"GDSFBP"  
DO YOU WISH TO HAVE RESULTS ON  
SCREEN OR PLOTTER (S OR P) ?  
?  
P  
DO YOU WISH TO CORRECT ?a FOR  
THE EFFECT OF MEMBRANESTIFFNESS  
(Y OR N)  
?  
N  
GDSFBP - VERSION 261082  
INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME  
?

UU-1

=====  
FILE NAME : - UU-1  
UNCONSOLIDATED UNDRAINED

THERE ARE 223 SETS OF DATA  
ESTD. TEST DURATION = 10.5 HRS  
ACTUAL TEST DURATION = .8 HRS  
DO YOU WANT A PRINT OF OPTIONS  
(Y OR N)  
?  
Y

=====  
THE GENERAL PURPOSE PLOTTING  
OR TABULATING PROGRAM ALLOWS  
THE FOLLOWING VARIABLES TO BE  
EXAMINED : -  
1 = TIME  
2 = PERCENT AXIAL STRAIN  
3 = AXIAL STRESS  
4 = RADIAL STRESS  
5 = EFFECTIVE AXIAL STRESS  
6 = EFFECTIVE RADIAL STRESS  
7 = DEVIATOR STRESS  
8 = STRESS RATIO  
9 = MEAN STRESS  
10 = MEAN EFFECTIVE STRESS  
11 = AVERAGE RADIAL STRAIN  
12 = AVERAGE DIAMETER CHANGE

13 = PORE WATER PRESSURE  
14 = VOLUME CHANGE ( V(8) )  
15 = CHANGE IN LENGTH  
16 = SQUARE ROOT OF TIME  
17 = LOG(10) OF TIME  
18 = LOG(10) OF EFFECTIVE AXIAL  
19 = (DEVIATOR STRESS)/2  
20 = MAX SHEAR STRAIN

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?

2,7

X = % AXIAL STRAIN  
Y = DEV STRESS

OK TO CONTINUE (Y OR N)

?

Y

PLEASE WAIT 8 SECS: SCALE CALC  
THE SCALE IS :-

X-MIN = 0

X-MAX = 2.5078626908

Y-MIN = 10.216977821

Y-MAX = 90.929552861

DO YOU WISH TO ALTER IT (Y OR N)

?

N

THERE ARE 26 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?

2,3

X = % AXIAL STRAIN  
Y = AXIAL STRESS

OK TO CONTINUE (Y OR N)

?

Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N  
PLEASE WAIT 8 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 0  
X-MAX = 2.50783626908  
Y-MIN = 140.216977821  
Y-MAX = 219.929552861  
DO YOU WISH TO ALTER IT (Y OR N)

?  
Y  
ENTER X-MIN  
?  
0  
ENTER X-MAX  
?  
3  
ENTER Y-MIN  
?  
0  
ENTER Y-MAX  
?  
250

THERE ARE 26 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2

THERE ARE 26 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
2,7

X = % AXIAL STRAIN  
Y = RADIAL STRESS  
OK TO CONTINUE (Y OR N)

?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
Y  
ENTER REQUIRED LINE TYPE (1-8)  
?  
6

THERE ARE 26 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
2,13

X = % AXIAL STRAIN  
Y = PORE PRESSURE  
OK TO CONTINUE (Y OR N)

?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
Y  
ENTER REQUIRED LINE TYPE (1-8)  
?  
7

THERE ARE 26 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
1,15

X = TIME  
Y = LENGTH CHANGE  
OK TO CONTINUE (Y OR N)

?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N  
PLEASE WAIT 7 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = .01  
X-MAX = 3055  
Y-MIN = 0  
Y-MAX = 2.54043814058  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
N

THERE ARE 24 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE.  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
2,8

X = % AXIAL STRAIN  
Y = STRESS RATIO  
OK TO CONTINUE (Y OR N)  
?

Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N

PLEASE WAIT 7 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 0  
X-MAX = 2.50783626908  
Y-MIN = 1.33024819729  
Y-MAX = 8.57746273842  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
Y  
ENTER X-MIN  
?  
0  
ENTER X-MAX  
?  
3

ENTER Y-MIN

?

0

ENTER Y-MAX

?

10

THERE ARE 24 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

9

END

### 5.3 CONSOLIDATED UNDRAINED REST

```
=====
EXAMPLE: 5.3

Type of Test: "CONSOLIDATED UNDRAINED"
Type of soil: Clay
Specimen original diameter (Do)= 50.2 MM
Specimen original length (Lo)= 100.7 MM
=====
TEST procedure
=====
```

A typical example of the Consolidated Undrained Test computer output is presented in the frame as follows:

```
LOAD"GDSTTS"
ENTER DATE & TIME
FORMAT DD,MM,YY,HH,MM
?
23,8,85,1,00
PLEASE ENSURE CELL VALVES OPEN
THEN PRESS ENDLINE
?

IEEE CONTROLLER ADDRESSES :-
CELL PRESSURE = 9
PORE PRESSURE = 6
LOWER CHAMBER = 8

DO YOU WISH TO CHANGE THEM
(Y OR N)
?
N
DO YOU WISH TO HAVE RESULTS ON
SCREEN OR PLOTTER (S OR P) ?
?
S
ENTER AVERAGE DIAMETER
OF TEST SPECIMEN?
50.2
ENTER HEIGHT
```

OF TEST SPECIMEN  
?  
100.7  
ENTERED VALUES ARE  
DIAMETER = 50.2 MM  
HEIGHT = 100.7 MM  
OK TO CONTINUE (Y OR N)?  
Y

GDS  
TRIAxIAL TESTING SYSTEM  
INVOKED AT 19:16  
ON 21/08/85

=====  
APPARATUS CONSTANTS ARE :-

SPECIMEN DIAM = 50.2 MM  
SPECIMEN HEIGHT= 100.7 MM  
SPECIMEN AREA = 1979.2 SQ.MM  
SPECIMEN VOLUME= 199308.9 CU.MM  
SEAL AREA = 20587.0 SQ.MM

ENTER INITIAL CELL PRESSURE ?  
280  
ENTER INITIAL BACK PRESSURE  
IF ANY ?  
80

INITIAL TEST CONDITIONS  
CELL PRESSURE 280 KPA  
BACK PRESSURE 80 KPA

OK TO CONTINUE (Y OR N)

?  
Y  
ENSURE THAT HOLD-VOLUME IS NOT  
ENGAGED THEN PRESS ENDLINE  
?

FRICION CALC REQU'D (Y OR N) ?

?  
Y  
CALCULATING FRICTION

=====  
PRESSURE CORRECTION  
FOR LOWER CHAMBER FRICTION  
= 0.0 KPA  
PLEASE USE ZERO OFFSET TO SET  
LOWER CHAMBER PRESSURE EQUAL TO

CELL PRESSURE - FRICTION CORR.  
THEN PRESS ENDLINE  
?

DO YOU WISH TO CHECK THE DEGREE  
OF SATURATION OF THE TEST  
SPECIMEN AND COMPRESSIBILITY OF  
THE PORE WATER DUCTS BY  
EVALUATING THE PORE PRESSURE  
PARAMETER 'B'; (Y OR N)

?

Y

ENTER REQUIRED CELL PRESSURE  
INCREMENT

?

10

OK TO START (Y OR N)

?

Y

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .9

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = 1

DO YOU REQUIRE A PRINT OF THE  
PORE PRESSURE PARAMETERS 'B'  
(Y OR N) ?

Y

=====

PORE PRESSURE PARAMETER

B = +1.0000

ACHIEVED USING CELL PRESSURE  
INCREMENT 10 KPA

REVISE BACK PRESSURE (Y OR N)

?

N

DO YOU REQUIRE THE TEST SPECIMEN  
TO BE CONSOLIDATED PRIOR TO THE  
TEST N(Y OR N)

?

Y

DO YOU WISH TO CONSOLIDATE AT THE  
CURRENT CELL PRESSURE (Y OR N)

?

Y

ENTER MAX VOLUME REDUCTION ?

5000

ENTER MAX VOLUME GAIN

?

0

WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS

?

12

DO YOU REQUIRE A PRINT (Y OR N)

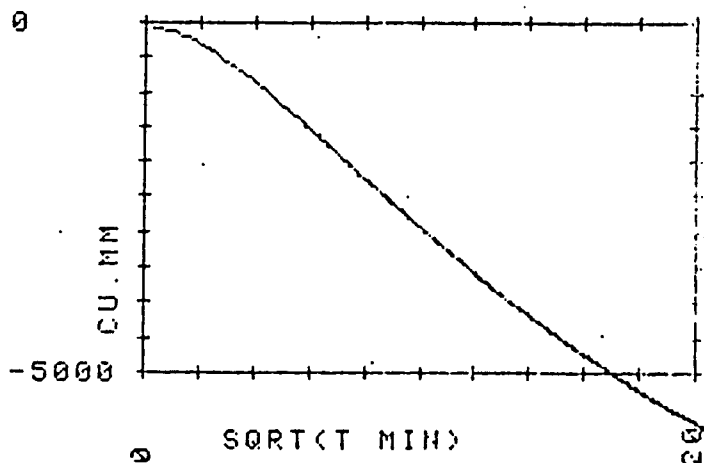
?

Y

=====  
RESULTS OF CONSOLIDATION AT  
CELL PRESSURE 290 KPA

PORE PRESSURE 80 KPA

VOLUME CHANGE v. SQRT(TIME)



Plot of volume change  
versus square root of  
time computer output.

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N)?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

C-2

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

CONSOLIDATION

RESULTS SAVED IN C-2

DO YOU WISH TO CHECK THE 'B'

VALUE AGAIN (Y OR N)

?

N

PLEASE 'DOCK' THEN PRESS ENDLINE

?

INITIAL TEST CONDITIONS

CELL PRESSURE 290 KPA

BACK PRESSURE 80 KPA

OK TO CONTINUE (Y OR N)

?

Y

AVAILABLE TESTS

=====

1 = UNCONSOLIDATED UNDRAINED

2 = CONSOLIDATED UNDRAINED WITH  
PORE PRESSURE MEASUREMENT

3 = DRAINED

4 = NO CONSOLIDATION & SWELLING  
TO SPEC'D OVERCONSOLIDATION RATIO

5 = CONTINUOUS LINEAR  
STRESS PATHS

6 = CYCLIC LOADING

9 = TERMINATION PROGRAM

=====

LOAD GDSTTS CARTRIDGE

ENTER REQUIRED TEST NUMBER ?

2

WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS

?

10

PROGRAM BEING LOADED & READIED

WHAT TESTING RATE DO YOU REQUIRE

1 = AXIAL TOTAL STRESS KPA/HR

5 = AXIAL DEFORMATION MM/HR

ENTER TYPE, RATE

?

5,4

AT WHAT VALUE OF PERCENTAGE

AXIAL STRAIN DO YOU WISH

THE TEST TO BE STOPPED

?

3

DO YOU REQUIRE A PLOT OF :-

1 = DEVIATOR STRESS

2 = STRESS RATIO

ENTER CHOICE; E.G. 1 ?

1

ENTER MAX DEVIATOR STRESS

?

400

ENTER MIN DEVIATOR STRESS

?

0

OK TO START (Y OR N)?

Y

=====

TEST - CONSOLIDATED UNDRAINED

CELL PRESSURE = 290

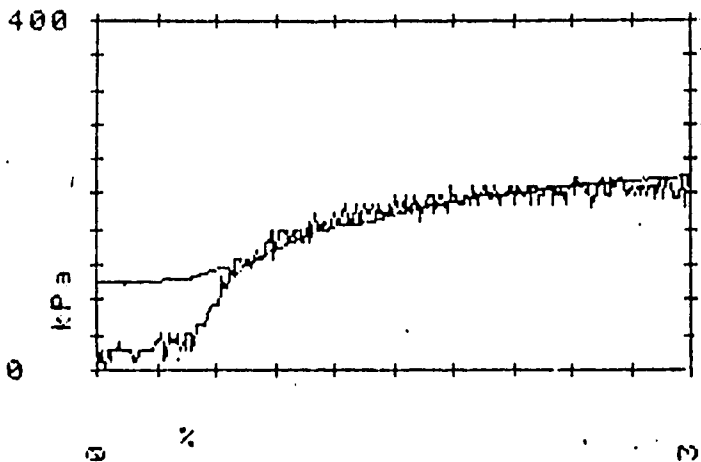
PORE PRESSURE = 80

AXIAL DEFORMATION CONTROL  
AT RATE OF 4 MM/HR

TERMINATION % AXIAL STRAIN  
= 3.0

MAXIMUM DEVIATOR STRESS  
= 400 KPA

DEV STRESS AND u v. % AX STRAIN



Plot of deviator stress  
versus percentage axial  
strain computer output.

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N) ?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

CU-1

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

CONSOLIDATED UNDRAINED

RESULTS SAVED IN CU-1  
L= 96.5691379527  
D= 50.3898087573  
DO YOU WISH TO CARRY OUT ANOTHER  
TEST ON THIS SPECIMEN (Y OR N)  
?  
N  
END

\*\*\*\*\*  
\* PLOTTING STAGE \*  
\*\*\*\*\*

LOAD"GDSFBP"  
DO YOU WISH TO HAVE RESULTS ON  
SCREEN OR PLOTTER (S OR P) ?  
?  
P  
DO YOU WISH TO CORRECT ?a FOR  
THE EFFECT OF MEMBRANESTIFFNESS  
(Y OR N)  
?  
N  
GDSFBP - VERSION 261082  
INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME  
?  
C-2  
=====

FILE NAME : - C-2  
CONSOLIDATION

THERE ARE 223 SETS OF DATA  
ESTD. TEST DURATION = 15.1 HRS  
ACTUAL TEST DURATION = 11.2 HRS  
DO YOU WANT A PRINT OF OPTIONS  
(Y OR N)  
?  
Y

=====

THE GENERAL PURPOSE PLOTTING  
OR TABULATING PROGRAM ALLOWS  
THE FOLLOWING VARIABLES TO BE  
EXAMINED : -  
1 = TIME  
2 = PERCENT AXIAL STRAIN  
3 = AXIAL STRESS

4 = RADIAL STRESS  
5 = EFFECTIVE AXIAL STRESS  
6 = EFFECTIVE RADIAL STRESS  
7 = DEVIATOR STRESS  
8 = STRESS RATIO  
9 = MEAN STRESS  
10 = MEAN EFFECTIVE STRESS  
11 = AVERAGE RADIAL STRAIN  
12 = AVERAGE DIAMETER CHANGE  
13 = PORE WATER PRESSURE  
14 = VOLUME CHANGE ( V(8) )  
15 = CHANGE IN LENGTH  
16 = SQUARE ROOT OF TIME  
17 = LOG(10) OF TIME  
18 = LOG(10) OF EFFECTIVE AXIAL  
19 = (DEVIATOR STRESS)/2  
20 = MAX SHEAR STRAIN

THERE ARE 303 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS

FORMAT X,Y e.g. 2,7

?

1,14

X = TIME

Y = VOLUME CHANGE

OK TO CONTINUE (Y OR N)

?

Y

PLEASE WAIT 68 SECS: SCALE CALC

THE SCALE IS :-

X-MIN = 0.1

X-MAX = 40280.4

Y-MIN = -6800

Y-MAX = -70

DO YOU WISH TO ALTER IT (Y OR N)

?

Y

ENTER X-MIN

?

0

ENTER X-MAX

?

40000

ENTER Y-MIN

?

-10000

ENTER Y-MAX

?

0

THERE ARE 223 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS

FORMAT X,Y e.g. 2,7

?

16,14

X = SQRT(TIME)

Y = VOLUME CHANGE

OK TO CONTINUE (Y OR N)

?

Y

DO YOU WISH TO USE THE

EXISTING SCALE (Y OR N)

?

N

PLEASE WAIT 92 SECS: SCALE CALC

THE SCALE IS :-

X-MIN = 0.1

X-MAX = 200.699775785

Y-MIN = -6800

Y-MAX = -70

DO YOU WISH TO ALTER IT (Y OR N)

?

Y

ENTER X-MIN

?

0

ENTER X-MAX

?

200

ENTER Y-MIN

?

-10000

ENTER Y-MAX

?

0

THERE ARE 303 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

8

INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME

?

CU-1

=====  
FILE NAME :- CU-1  
CONSOLIDATED UNDRAINED

THERE ARE 24 SETS OF DATA  
ESTD. TEST DURATION = 10.5 HRS  
ACTUAL TEST DURATION = .7 HRS  
DO YOU WANT A PRINT OF OPTIONS  
(Y OR N)

?

N

THERE ARE 24 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?

2,7

X = % AXIAL STRAIN

Y = DEV STRESS

OK TO CONTINUE (Y OR N)

?

Y

DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)

?

N

PLEASE WAIT 7 SECS: SCALE CALC  
THE SCALE IS :-

X-MIN = 0

X-MAX = 3.0055864244

Y-MIN = 21.226557283

Y-MAX = 216.789780324

DO YOU WISH TO ALTER IT (Y OR N)

?

N

THERE ARE 24 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE

2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
2,13

X = % AXIAL STRAIN  
Y = PORE PRESSURE  
OK TO CONTINUE (Y OR N)  
?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
Y  
ENTER REQUIRED LINE TYPE (1-8)  
?  
6

THERE ARE 24 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
2,8

X = % AXIAL STRAIN  
Y = STRESS RATIO  
OK TO CONTINUE (Y OR N)  
?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N  
PLEASE WAIT 7 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 0  
X-MAX = 3.0055864244  
Y-MIN = 1.11306686496  
Y-MAX = 4.23566836304  
DO YOU WISH TO ALTER IT (Y OR N)

?  
N

THERE ARE 24 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?  
2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?  
1,15

X = TIME  
Y = LENGTH CHANGE  
OK TO CONTINUE (Y OR N)

?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)

?  
N  
PLEASE WAIT 7 SECS: SCALE CALC

THE SCALE IS :-

X-MIN = 0.1  
X-MAX = 2699  
Y-MIN = 0  
Y-MAX = 2.99217953077

DO YOU WISH TO ALTER IT (Y OR N)

?  
N

THERE ARE 24 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?  
9  
END

#### 5.4 CONSOLIDATED DRAINED TEST

```
=====
EXAMPLE: 5.4

Type of Test: "CONSOLIDATED DRAINED"
Type of soil: Sand
Specimen original diameter (D0)= 51.3 MM
Specimen original length (L0)= 102.0 MM
=====
TEST procedure
=====
```

A typical example of the Consolidated Drained Test computer output is presented in the frame as follows:

```
LOAD "GDSTTS"
ENTER DATE & TIME
FORMAT DD,MM,YY,HH,MM
?
26,8,85,19,20
PLEASE ENSURE CELL VALVES OPEN
THEN PRESS ENDLINE
?

IEEE CONTROLLER ADDRESSES :-
CELL PRESSURE = 9
PORE PRESSURE = 6
LOWER CHAMBER = 8

DO YOU WISH TO CHANGE THEM
(Y OR N)
?
N
DO YOU WISH TO HAVE RESULTS ON
SCREEN OR PLOTTER (S OR P) ?
?
S
ENTER AVERAGE DIAMETER
OF TEST SPECIMEN?
51.3
ENTER HEIGHT
```

OF TEST SPECIMEN

?

102

ENTERED VALUES ARE

DIAMETER = 51.3 MM

HEIGHT = 102 MM

OK TO CONTINUE (Y OR N)?

Y

GDS

TRIAxIAL TESTING SYSTEM

INVOKED AT 19:22

ON 21/08/85

=====

APPARATUS CONSTANTS ARE :-

SPECIMEN DIAM = 51.3 MM

SPECIMEN HEIGHT= 102.0 MM

SPECIMEN AREA = 2066.9 SQ.MM

SPECIMEN VOLUME= 210826.3 CU.MM

SEAL AREA = 20587.0 SQ.MM

ENTER INITIAL CELL PRESSURE ?

400

ENTER INITIAL BACK PRESSURE

IF ANY ?

300

INITIAL TEST CONDITIONS

CELL PRESSURE 400 KPA

BACK PRESSURE 300 KPA

OK TO CONTINUE (Y OR N)

?

Y

ENSURE THAT HOLD-VOLUME IS NOT

ENGAGED THEN PRESS ENDLIN

?

FRICION CALC REQU'D (Y OR N) ?

?

Y

CALCULATING FRICTION

=====

PRESSURE CORRECTION

FOR LOWER CHAMBER FRICTION

= 0.0 KPA

PLEASE USE ZERO OFFSET TO SET

LOWER CHAMBER PRESSURE EQUAL TO

CELL PRESSURE - FRICTION CORR.  
THEN PRESS ENDLINE  
?

DO YOU WISH TO CHECK THE DEGREE  
OF SATURATION OF THE TEST  
SPECIMEN AND COMPRESSIBILITY OF  
THE PORE WATER DUCTS BY  
EVALUATING THE PORE PRESSURE  
PARAMETER 'B'; (Y OR N)

?

Y

ENTER REQUIRED CELL PRESSURE  
INCREMENT

?

30

OK TO START (Y OR N)

?

Y

PORE PRESSURE PARAMETER

B = .8

PORE PRESSURE PARAMETER

B = .8

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8666

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8333

PORE PRESSURE PARAMETER

B = .8

DO YOU REQUIRE A PRINT OF THE  
PORE PRESSURE PARAMETERS 'B'  
(Y OR N) ?

Y

=====

PORE PRESSURE PARAMETER

B = +.8000

ACHIEVED USING CELL PRESSURE

INCREMENT 30 KPA

REVISE BACK PRESSURE (Y OR N)

?

N

DO YOU REQUIRE THE TEST SPECIMEN  
TO BE CONSOLIDATED PRIOR TO THE  
TEST N(Y OR N)

?

Y

DO YOU WISH TO CONSOLIDATE AT THE  
CURRENT CELL PRESSURE (Y OR N)

?

Y

ENTER MAX VOLUME REDUCTION ?

300

ENTER MAX VOLUME GAIN

?

300

WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS

?

10

DO YOU REQUIRE A PRINT (Y OR N)

?

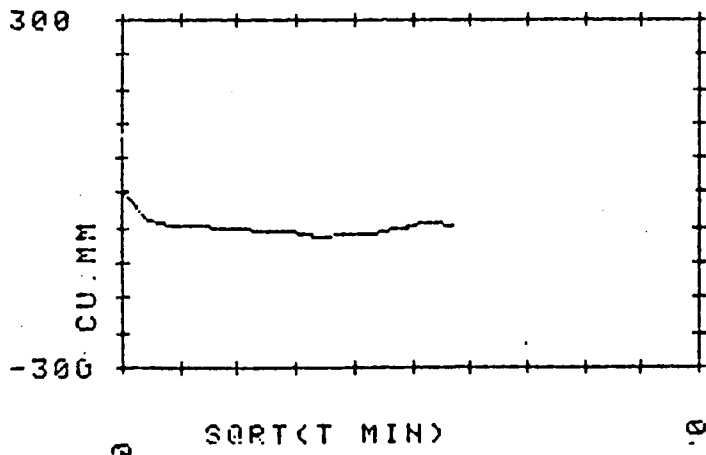
Y

=====

RESULTS OF CONSOLIDATION AT  
CELL PRESSURE 430 KPA

PORE PRESSURE 300 KPA

VOLUME CHANGE v. SQRT(TIME)



Plot of volume change  
versus square root of  
time computer output.

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N)?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

C-4

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

CONSOLIDATION

RESULTS SAVED IN C-4

DO YOU WISH TO CHECK THE 'B'  
VALUE AGAIN (Y OR N)

?

N

PLEASE 'DOCK' THEN PRESS ENDLINE

?

INITIAL TEST CONDITIONS

CELL PRESSURE 430 KPA

BACK PRESSURE 300 KPA

OK TO CONTINUE (Y OR N)

?

Y

AVAILABLE TESTS

=====

1 = UNCONSOLIDATED UNDRAINED

2 = CONSOLIDATED UNDRAINED WITH  
PORE PRESSURE MEASUREMENT

3 = DRAINED

4 = KO CONSOLIDATION & SWELLING  
TO SPEC'D OVERCONSOLIDATION RATIO

5 = CONTINUOUS LINEAR  
STRESS PATHS

6 = CYCLIC LOADING

9 = TERMINATION PROGRAM

=====

LOAD GDSTTS CARTRIDGE

ENTER REQUIRED TEST NUMBER ?

3

WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS

?

5

PROGRAM BEING LOADED & READIED

WHAT TESTING RATE DO YOU REQUIRE

1 = AXIAL TOTAL STRESS KPA/HR

5 = AXIAL DEFORMATION MM/HR

ENTER TYPE, RATE

?

5,3

AT WHAT VALUE OF PERCENTAGE

AXIAL STRAIN DO YOU WISH

THE TEST TO BE STOPPED

?

20

DO YOU REQUIRE A PLOT OF :-

1 = DEVIATOR STRESS & PORE PRESS

2 = STRESS RATIO

3 = VOLUME CHANGE

ENTER CHOICE; E.G. 1 ?

1

ENTER MAX DEVIATOR STRESS

?

400

ENTER MIN DEVIATOR STRESS

?

0

OK TO START (Y OR N)?

Y

=====

TEST - CONSOLIDATED UNDRAINED

CELL PRESSURE = 430

PORE PRESSURE = 300

AXIAL DEFORMATION CONTROL

AT RATE OF 3.00 MM/HR

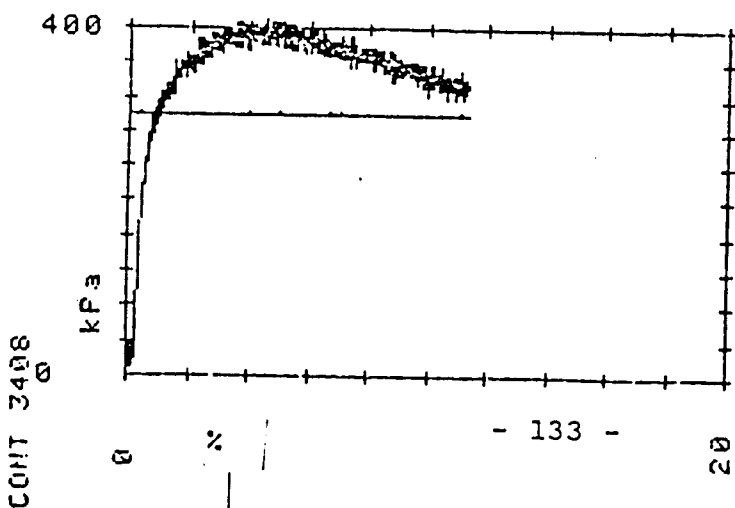
TERMINATION % AXIAL STRAIN

= 20.0

MAXIMUM DEVIATOR STRESS

= 400 KPA

STRESS CONTROL



Plot of deviator stress and pore pressure versus percentage axial strain computer output.

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N) ?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

CD-1

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

CONSOLIDATED DRAINED  
FILENAME ALREADY IN-USE  
CORRECT FAULT THEN PRESS ENDLINE

?

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N) ?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

D-1

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

DRAINED

RESULTS SAVED IN D-1

L= 90.4505402225

D= 56.0786055016

DO YOU WISH TO CARRY OUT ANOTHER  
TEST ON THIS SPECIMEN (Y OR N)

?

N

END

```
*****  
*                PLOTTING STAGE                *  
*****
```

LOAD"GDSFBP"

DO YOU WISH TO HAVE RESULTS ON  
SCREEN OR PLOTTER (S OR P) ?

?

P

DO YOU WISH TO CORRECT ?a FOR  
THE EFFECT OF MEMBRANESTIFFNESS  
(Y OR N)

?

N

GDSFBP - VERSION 261082  
INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME

?

D-1

=====  
FILE NAME : - D-1  
DRAINED

THERE ARE 209 SETS OF DATA  
ESTD. TEST DURATION = 5.0 HRS  
ACTUAL TEST DURATION = 3.8 HRS  
DO YOU WANT A PRINT OF OPTIONS  
(Y OR N)

?

Y

=====  
THE GENERAL PURPOSE PLOTTING  
OR TABULATING PROGRAM ALLOWS  
THE FOLLOWING VARIABLES TO BE  
EXAMINED : -  
1 = TIME  
2 = PERCENT AXIAL STRAIN  
3 = AXIAL STRESS  
4 = RADIAL STRESS  
5 = EFFECTIVE AXIAL STRESS  
6 = EFFECTIVE RADIAL STRESS  
7 = DEVIATOR STRESS  
8 = STRESS RATIO  
9 = MEAN STRESS  
10 = MEAN EFFECTIVE STRESS  
11 = AVERAGE RADIAL STRAIN  
12 = AVERAGE DIAMETER CHANGE  
13 = PORE WATER PRESSURE  
14 = VOLUME CHANGE ( V(8) )  
15 = CHANGE IN LENGTH  
16 = SQUARE ROOT OF TIME  
17 = LOG(10) OF TIME  
18 = LOG(10) OF EFFECTIVE AXIAL  
19 = (DEVIATOR STRESS)/2  
20 = MAX SHEAR STRAIN

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
2,7  
X = % AXIAL STRAIN  
Y = DEV STRESS  
OK TO CONTINUE (Y OR N)  
?  
Y  
PLEASE WAIT 64 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 0  
X-MAX = 11.2795011969  
Y-MIN = 9.949640843  
Y-MAX = 408.712098184  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
Y  
ENTER X-MIN  
?  
0  
ENTER X-MAX  
?  
20  
ENTER Y-MIN  
?  
0  
ENTER Y-MAX  
?  
500  
  
THERE ARE 223 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
2,13  
X = % AXIAL STRAIN  
Y = PORE PRESSURE  
OK TO CONTINUE (Y OR N)  
?  
Y

DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)

?

Y

ENTER REQUIRED LINE TYPE (1-8)

?

6

THERE ARE 209 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS

FORMAT X,Y e.g. 2,7

?

2,8

X = % AXIAL STRAIN

Y = STRESS RATIO

OK TO CONTINUE (Y OR N)

?

Y

DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)

?

N

PLEASE WAIT 64 SECS: SCALE CALC

THE SCALE IS :-

X-MIN = 0

X-MAX = 11.2795011969

Y-MIN = 1.07595145682

Y-MAX = 4.1439392168

DO YOU WISH TO ALTER IT (Y OR N)

?

Y

ENTER X-MIN

?

0

ENTER X-MAX

?

20

ENTER Y-MIN

?

0

ENTER Y-MAX

?

5

THERE ARE 209 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS

FORMAT X,Y e.g. 2,7

?

2,14

X = % AXIAL STRAIN

Y = VOLUME CHANGE

OK TO CONTINUE (Y OR N)

?

Y

DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)

?

N

PLEASE WAIT 64 SECS: SCALE CALC

THE SCALE IS :-

X-MIN = 0

X-MAX = 11.2795011969

Y-MIN = -80

Y-MAX = 12680

DO YOU WISH TO ALTER IT (Y OR N)

?

N

THERE ARE 209 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

9

END

## 5.5 K CONSOLIDATION AND SWELLING TEST

```
=====
EXAMPLE: 5.5

Type of Test: " K CONSOLIDATED AND SWELLING
Type of soil: Clay
Specimen original diameter (Do)= 50.5 MM
Specimen original length (Lo)= 101.6 MM
=====
TEST procedure
=====
```

A typical example of K Consolidation and Swelling Test computer output is presented in the frame as follows:

```
LOAD"GDSTTS"
ENTER DATE & TIME
FORMAT DD,MM,YY,HH,MM
?
15,9,85,22,20
PLEASE ENSURE CELL VALVES OPEN
THEN PRESS ENDLINE
?

IEEE CONTROLLER ADDRESSES :-
CELL PRESSURE = 9
PORE PRESSURE = 6
LOWER CHAMBER = 8

DO YOU WISH TO CHANGE THEM
(Y OR N)
?
N
DO YOU WISH TO HAVE RESULTS ON
SCREEN OR PLOTTER (S OR P) ?
?
S
ENTER AVERAGE DIAMETER
OF TEST SPECIMEN?
50.5
ENTER HEIGHT
```

OF TEST SPECIMEN

?

101.6

ENTERED VALUES ARE

DIAMETER = 50.5 MM

HEIGHT = 101.6 MM

OK TO CONTINUE (Y OR N)?

Y

GDS

TRIAxIAL TESTING SYSTEM

INVOKED AT 22:20

ON 15/09/85

=====

APPARATUS CONSTANTS ARE :-

SPECIMEN DIAM = 50.5 MM

SPECIMEN HEIGHT= 101.6 MM

SPECIMEN AREA = 2003.0 SQ.MM

SPECIMEN VOLUME= 203500.9 CU.MM

SEAL AREA = 20587.0 SQ.MM

ENTER INITIAL CELL PRESSURE ?

150

ENTER INITIAL BACK PRESSURE

IF ANY ?

145

INITIAL TEST CONDITIONS

CELL PRESSURE 150 KPA

BACK PRESSURE 145 KPA

OK TO CONTINUE (Y OR N)

?

Y

ENSURE THAT HOLD-VOLUME IS NOT

ENGAGED THEN PRESS ENDLINE

?

FRICITION CALC REQU'D (Y OR N) ?

?

Y

CALCULATING FRICTION

=====

PRESSURE CORRECTION

FOR LOWER CHAMBER FRICTION

= 0.5 KPA

PLEASE USE ZERO OFFSET TO SET

LOWER CHAMBER PRESSURE EQUAL TO

CELL PRESSURE - FRICTION CORR.  
THEN PRESS ENDLINE

?

DO YOU WISH TO CHECK THE DEGREE  
OF SATURATION OF THE TEST  
SPECIMEN AND COMPRESSIBILITY OF  
THE PORE WATER DUCTS BY  
EVALUATING THE PORE PRESSURE  
PARAMETER 'B'; (Y OR N)

?

Y  
ENTER REQUIRED CELL PRESSURE  
INCREMENT

?

20  
OK TO START (Y OR N)

?

Y

PORE PRESSURE PARAMETER  
B = .85  
PORE PRESSURE PARAMETER  
B = .9  
PORE PRESSURE PARAMETER  
B = .95

DO YOU REQUIRE A PRINT OF THE  
PORE PRESSURE PARAMETERS 'B'  
(Y OR N) ?

Y

=====  
PORE PRESSURE PARAMETER  
B = +.9500

ACHIEVED USING CELL PRESSURE  
INCREMENT 20 KPA

REVISE BACK PRESSURE (Y OR N)

?

Y  
ENTER REVISED BACK PRESSURE

?

160

DO YOU REQUIRE THE TEST SPECIMEN  
TO BE CONSOLIDATED PRIOR TO THE  
TEST N(Y OR N)

?

N  
DO YOU WISH TO CHECK THE 'B'  
VALUE AGAIN (Y OR N)

?

N

PLEASE 'DOCK' THEN PRESS ENDLINE  
?

INITIAL TEST CONDITIONS  
CELL PRESSURE 170 KPA  
BACK PRESSURE 160 KPA

OK TO CONTINUE (Y OR N)  
?  
Y

AVAILABLE TESTS

- =====
- 1 = UNCONSOLIDATED UNDRAINED
  - 2 = CONSOLIDATED UNDRAINED WITH  
PORE PRESSURE MEASUREMENT
  - 3 = DRAINED
  - 4 = KO CONSOLIDATION & SWELLING  
TO SPECD OVERCONSOLIDATION RATIO
  - 5 = CONTINUOUS LINEAR  
STRESS PATHS
  - 6 = CYCLIC LOADING
  - 9 = TERMINATION PROGRAM
- =====

LOAD GDSTTS CARTRIDGE  
ENTER REQUIRED TEST NUMBER ?  
4

WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS  
?  
80

PROGRAM BEING LOADED & READIED  
ENTER TARGET RATE IN MM/HR  
?  
3

WHAT IS THE VALUE OF AXIAL  
EFFECTIVE STRESS REQUIRED AT THE  
END OF CONSOLIDATION?  
410

DO YOU REQUIRED THE TEST SPECIMEN  
TO SWELL BACK AT THE END OF  
CONSOLIDATION (Y OR N)  
?  
Y

WHAT IS THE VALUE OF AXIAL  
EFFECTIVE STRESS REQUIRED AT THE  
END OF SWELLING  
?  
205

DO YOU REQUIRED A PLOT OF  
1 = VOLUME CHANGE  
2 = EFF.AXIAL V EFF RADIAL  
ENTER CHOICE, E.G. 1  
?

2  
OK TO START (Y OR N)  
?  
Y

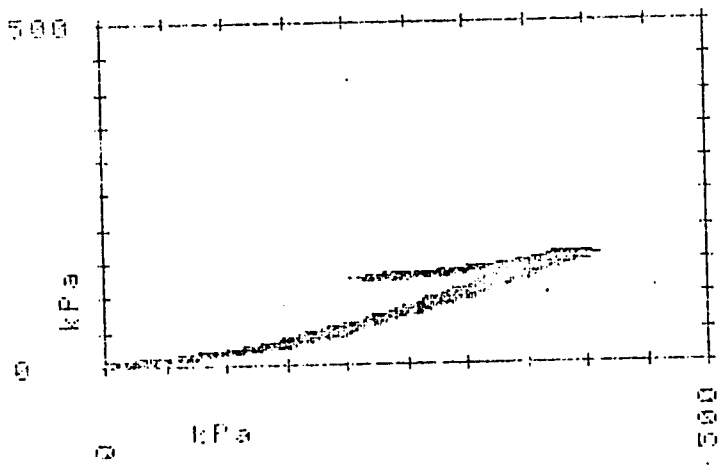
=====

TEST - KO CONSOLIDATION/SWELLING

CELL PRESSURE 170 KPA  
BACK PRESSURE 160 KPA

AXIAL DEFORMATION CONTROL  
AT RATE OF 3.000 MM/HR  
TERMINAL EFFECTIVE AXIAL STRESS  
FOR CONSOLIDATION = 410 KPA  
FOR SWELLING = 205 KPA

EFF RAD STRESS v. EFF AX STRESS



Plot of effective radial stress versus effective axial stress computer output.

DO YOU WISH TO SAVE THE TEST RESULTS (Y OR N) ?  
Y  
INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)  
?  
KO-3  
ENTER RESULTS DESCRIPTION  
MAX 32 CHARS  
?  
KO SWELLING CONSOLIDATION  
RESULTS SAVED IN KO-3  
L= 97.8283965609  
D= 50.4999197331  
DO YOU WISH TO CARRY OUT ANOTHER TEST ON THIS SPECIMEN (Y OR N)  
?  
N

END

```
*****  
*                               *  
*           PLOTTING STAGE     *  
*                               *  
*****
```

LOAD"GDSFBP"  
DO YOU WISH TO HAVE RESULTS ON  
SCREEN OR PLOTTER (S OR P) ?

?

P

DO YOU WISH TO CORRECT ?a FOR  
THE EFFECT OF MEMBRANESTIFFNESS  
(Y OR N)

?

N

GDSFBP - VERSION 261082  
INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME

?

KO-3

=====

FILE NAME : - KO-3  
KO SWELLING CONSOLIDATION

THERE ARE 132 SETS OF DATA  
ESTD. TEST DURATION = 80.8 HRS  
ACTUAL TEST DURATION = 34.8 HRS  
DO YOU WANT A PRINT OF OPTIONS  
(Y OR N)

?

Y

=====

THE GENERAL PURPOSE PLOTTING  
OR TABULATING PROGRAM ALLOWS  
THE FOLLOWING VARIABLES TO BE  
EXAMINED : -

- 1 = TIME
- 2 = PERCENT AXIAL STRAIN
- 3 = AXIAL STRESS
- 4 = RADIAL STRESS
- 5 = EFFECTIVE AXIAL STRESS
- 6 = EFFECTIVE RADIAL STRESS
- 7 = DEVIATOR STRESS
- 8 = STRESS RATIO
- 9 = MEAN STRESS
- 10 = MEAN EFFECTIVE STRESS

11 = AVERAGE RADIAL STRAIN  
12 = AVERAGE DIAMETER CHANGE  
13 = PORE WATER PRESSURE  
14 = VOLUME CHANGE ( V(8) )  
15 = CHANGE IN LENGTH  
16 = SQUARE ROOT OF TIME  
17 = LOG(10) OF TIME  
18 = LOG(10) OF EFFECTIVE AXIAL  
19 = (DEVIATOR STRESS)/2  
20 = MAX SHEAR STRAIN

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?

5,12

X = EFF AX STRESSN

Y = AV DIA CHANGE

OK TO CONTINUE (Y OR N)

?

Y

PLEASE WAIT 40 SECS: SCALE CALC  
THE SCALE IS :-

X-MIN = 16.278727489

X-MAX = 416.970513064

Y-MIN = -.300326530001

Y-MAX = 6.20428466101

DO YOU WISH TO ALTER IT (Y OR N)

?

N

THERE ARE 132 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?

18,14

X = LOG AX STRESS

Y = VOLUME CHANGE

DO YOU WISH TO USE THE)

EXISTING SCALE (Y OR N)  
?  
PLEASE WAIT 40 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 1.211620453  
X-MAX = 2.62010534402  
Y-MIN = -8070  
Y-MAX = -40  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
N  
THERE ARE 132 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
5,6  
X = EFF AX STRESS  
Y = EFF RAD STRESS  
OK TO CONTINUE (Y OR N)  
?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N  
PLEASE WAIT 64 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 16.278727489  
X-MAX = 416.970513064  
Y-MIN = 6  
Y-MAX = 160  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
N  
THERE ARE 132 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g 2,7

```
?  
5,12  
X = EFF AX STRESS  
Y = AV DIA CHANGE  
OK TO CONTINUE (Y OR N)  
?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N  
PLEASE WAIT 40 SECS: SACLE CALC  
THE SCALE IS :-  
X-MIN = 16.278727489  
X-MAX = 416.970513064  
Y-MIN = -.300326530001  
Y-MAX = 6.20428466101  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
Y  
ENTER X-MIN  
?  
Y  
ENTER X-MAX  
?  
500  
ENTER Y-MIN  
?  
-3  
ENTER Y-MAX  
?  
5  
THERE ARE 132 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TEREminate PROGRAM  
ENTER YOU$ CHOICE  
?  
9  
END
```

5.6 CYCLIC LOADING TEST

```
=====
EXAMPLE: 5.6

Type of Test: " CYCLIC LOADING"
Type of soil: Clay
Specimen original diameter (Do)= 50.5 MM
Specimen original length (Lo)= 101.7 MM
=====
TEST procedure
=====
```

A typical example of the Cyclic Loading Test computer output is presented in the frame as follows:

```
LOAD"G DSTTS"
ENTER DATE & TIME
FORMAT DD,MM,YY,HH,MM
?
21,8,85,19,10
PLEASE ENSURE CELL VALVES OPEN
THEN PRESS ENDLINE
?

IEEE CONTROLLER ADDRESSES :-
CELL PRESSURE = 9
PORE PRESSURE = 6
LOWER CHAMBER = 8

DO YOU WISH TO CHANGE THEM
(Y OR N)
?
N
DO YOU WISH TO HAVE RESULTS ON
SCREEN OR PLOTTER (S OR P) ?
?
S
ENTER AVERAGE DIAMETER
OF TEST SPECIMEN?
50.5
ENTER HEIGHT
```

OF TEST SPECIMEN

?

101.7

ENTERED VALUES ARE

DIAMETER = 50.5 MM

HEIGHT = 101.7 MM

OK TO CONTINUE (Y OR N)?

Y

GDS

TRIAxIAL TESTING SYSTEM

INVOKED AT 19:16

ON 21/08/85

=====

APPARATUS CONSTANTS ARE :-

SPECIMEN DIAM = 50.6 MM

SPECIMEN HEIGHT= 101.7 MM

SPECIMEN AREA = 2010.9 SQ.MM

SPECIMEN VOLUME= 204508.7 CU.MM

SEAL AREA = 20587.0 SQ.MM

ENTER INITIAL CELL PRESSURE ?

200

ENTER INITIAL BACK PRESSURE

IF ANY ?

100

INITIAL TEST CONDITIONS

CELL PRESSURE 200 KPA

BACK PRESSURE 100 KPA

OK TO CONTINUE (Y OR N)

?

Y

ENSURE THAT HOLD-VOLUME IS NOT

ENGAGED THEN PRESS ENDLIN

?

FRICION CALC REQU'D (Y OR N) ?

?

Y

CALCULATING FRICTION

=====

PRESSURE CORRECTION

FOR LOWER CHAMBER FRICTION

= 1.0 KPA

PLEASE USE ZERO OFFSET TO SET

LOWER CHAMBER PRESSURE EQUAL TO

CELL PRESSURE - FRICTION CORR.  
THEN PRESS ENDLINE  
?

DO YOU WISH TO CHECK THE DEGREE  
OF SATURATION OF THE TEST  
SPECIMEN AND COMPRESSIBILITY OF  
THE PORE WATER DUCTS BY  
EVALUATING THE PORE PRESSURE  
PARAMETER 'B'; (Y OR N)

?

Y

ENTER REQUIRED CELL PRESSURE  
INCREMENT

?

20

OK TO START (Y OR N)

?

Y

PORE PRESSURE PARAMETER

B = .9

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .9

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = .95

PORE PRESSURE PARAMETER

B = 1

DO YOU REQUIRE A PRINT OF THE  
PORE PRESSURE PARAMETERS 'B'  
(Y OR N) ?

Y

=====

PORE PRESSURE PARAMETER

B = +1.0000

ACHIEVED USING CELL PRESSURE  
INCREMENT 20 KPA

REVISE BACK PRESSURE (Y OR N)

?

N  
DO YOU REQUIRE THE TEST SPECIMEN  
TO BE CONSOLIDATED PRIOR TO THE  
TEST N(Y OR N)

?

Y

DO YOU WISH TO CONSOLIDATE AT THE  
CURRENT CELL PRESSURE (Y OR N)

?

Y

ENTER MAX VOLUME REDUCTION ?

5000

ENTER MAX VOLUME GAIN

?

0

WHAT IS YOUR ESTIMATE OF TOTAL  
TEST DURATION IN HOURS

?

10

DO YOU REQUIRE A PRINT (Y OR N)

?

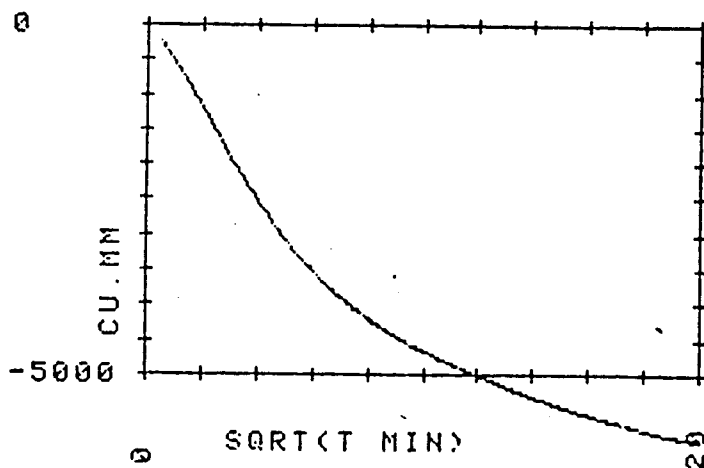
Y

=====

RESULTS OF CONSOLIDATION AT  
CELL PRESSURE 220 KPA

PORE PRESSURE 100 KPA

VOLUME CHANGE v. SQRT(TIME)



Plot of volume change  
versus square root of  
time computer output.

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N)?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

C-15

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

CONSOLIDATION

RESULTS SAVED IN C-15  
DO YOU WISH TO CHECK THE 'B'  
VALUE AGAIN (Y OR N)

?

N

PLEASE 'DOCK' THEN PRESS ENDLINE

?

INITIAL TEST CONDITIONS  
CELL PRESSURE 220 KPA  
BACK PRESSURE 100 KPA

OK TO CONTINUE (Y OR N)

?

Y

AVAILABLE TESTS

=====

- 1 = UNCONSOLIDATED UNDRAINED
- 2 = CONSOLIDATED UNDRAINED WITH  
PORE PRESSURE MEASUREMENT
- 3 = DRAINED
- 4 = KO CONSOLIDATION & SWELLING  
TO SPEC'D OVERCONSOLIDATION RATIO
- 5 = CONTINUOUS LINEAR  
STRESS PATHS
- 6 = CYCLIC LOADING
- 9 = TERMINATION PROGRAM

=====

LOAD GDSTTS CARTRIDGE  
ENTER REQUIRED TEST NUMBER ?

6

PROGRAM BEING LOADED & READIED  
IS THE TEST TO BE :-

1 = DRAINED

2 = UNDRAINED

?

2

WHAT AMPLITUDE DO YOU REQUIRE  
IN KPA

?

50

WHAT DATUM IN KPA  
DO YOU REQUIRE

?

250

WHAT AXIAL DEFORMATION RATE  
DO YOU REQUIRE. THE LIMITS ARE  
100 MM/HR TO 0.1 MM/HR

?

50

WHAT AXIAL DEFORMATION SCALE  
DO YOU REQUIRE IN MM.

?

1

WHAT DO YOU ESTIMATE THE PERIOD  
TO BE IN SECONDS

?

100

HOW MANY CYCLES DO YOU REQUIRE  
TO BE EXECUTED

?

9

=====  
TEST - CYCLIC LOADING

CELL PRESSURE = 200  
PORE PRESSURE = 100

SPECIMEN IS UNDRAINED

AXIAL DEFORMATION CONTROL  
AT RATE OF 50 MM/HR

WAVEFORM IS TRIANGULAR  
DATUM IS 250 KPA  
AMPLITUDE IS 50 KPA  
TEST TERMINATION AFTER 9  
CYCLES

OK TO START (Y OR N)

?

Y

=====  
TEST - CYCLIC LOADING

CELL PRESSURE = 220  
PORE PRESSURE = 100

SPECIMEN IS UNDRAINED

AXIAL DEFORMATION CONTROL  
AT RATE OF 50 MM/HR

WAVEFORM IS TRIANGULAR  
DATUM IS 250 KPA  
AMPLITUDE IS 50 KPA  
TEST TERMINATION AFTER 9  
CYCLES

DO YOU WISH TO SAVE THE  
TEST RESULTS (Y OR N) ?

Y

INSERT RESULTS CARTRIDGE  
ENTER FILENAME (6 CHARS)

?

CL-2

ENTER RESULTS DESCRIPTION  
MAX 32 CHARS

?

CYCLIC LOADING

RESULTS SAVED IN CL-2  
ANY MORE CYCLES (Y OR N)

?

N

L= 100.659328703

D= 50.2350649751

DO YOU WISH TO CARRY OUT ANOTHER  
TEST ON THIS SPECIMEN (Y OR N)

?

N

END

```
*****  
*                PLOTTING STAGE                *  
*****
```

LOAD"GDSFBP"

DO YOU WISH TO HAVE RESULTS ON  
SCREEN OR PLOTTER (S OR P) ?

?

P

DO YOU WISH TO CORRECT ?a FOR  
THE EFFECT OF MEMBRANESTIFFNESS  
(Y OR N)

?

N

GDSFBP - VERSION 261082

INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME

?

CL-2

=====  
FILE NAME : - CL-2  
CYCLIC LOADING

THERE ARE 303 SETS OF DATA  
ACTUAL TEST DURATION = .8 HRS  
DO YOU WANT A PRINT OF OPTIONS  
(Y OR N)  
?  
Y

=====

THE GENERAL PURPOSE PLOTTING  
OR TABULATING PROGRAM ALLOWS  
THE FOLLOWING VARIABLES TO BE  
EXAMINED : -

- 1 = TIME
- 2 = PERCENT AXIAL STRAIN
- 3 = AXIAL STRESS
- 4 = RADIAL STRESS
- 5 = EFFECTIVE AXIAL STRESS
- 6 = EFFECTIVE RADIAL STRESS
- 7 = DEVIATOR STRESS
- 8 = STRESS RATIO
- 9 = MEAN STRESS
- 10 = MEAN EFFECTIVE STRESS
- 11 = AVERAGE RADIAL STRAIN
- 12 = AVERAGE DIAMETER CHANGE
- 13 = PORE WATER PRESSURE
- 14 = VOLUME CHANGE ( V(8) )
- 15 = CHANGE IN LENGTH
- 16 = SQUARE ROOT OF TIME
- 17 = LOG(10) OF TIME
- 18 = LOG(10) OF EFFECTIVE AXIAL
- 19 = (DEVIATOR STRESS)/2
- 20 = MAX SHEAR STRAIN

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-

- 1 = TABULATE
- 2 = PLOT
- 8 = ANOTHER FILE
- 9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?

1,15

X = TIME

Y = LENGTH CHANGE

OK TO CONTINUE (Y OR N)

?

Y

PLEASE WAIT 92 SECS: SCALE CALC

THE SCALE IS :-

X-MIN = 0.1

X-MAX = 2934  
Y-MIN = 0  
Y-MAX = 0.396852382572  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
Y  
ENTER X-MIN  
?  
0  
ENTER X-MAX  
?  
3000  
ENTER Y-MIN  
?  
0  
ENTER Y-MAX  
?  
0.4

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?

1,3

X = TIME

Y = AXIAL STRESS

OK TO CONTINUE (Y OR N)

?

Y

DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)

?

N

PLEASE WAIT 92 SECS: SCALE CALC  
THE SCALE IS :-

X-MIN = 0.1

X-MAX = 2934

Y-MIN = 197.225180212

Y-MAX = 310.262486235

DO YOU WISH TO ALTER IT (Y OR N)

?

N

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE

2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
1,13  
  
X = TIME  
Y = PORE PRESSURE  
OK TO CONTINUE (Y OR N)  
?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N  
PLEASE WAIT 92 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 0.1  
X-MAX = 2934  
Y-MIN = 150  
Y-MAX = 170  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
N  
  
THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
1,7  
  
X = TIME  
Y = DEV STRESS  
OK TO CONTINUE (Y OR N)  
?  
Y  
DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N  
PLEASE WAIT 92 SECS: SCALE CALC

THE SCALE IS :-  
X-MIN = 0.1  
X-MAX = 2934  
Y-MIN = -20.802989244  
Y-MAX = 93.264290684  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
N

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
1,8

X = TIME  
Y = STRESS RATIO  
OK TO CONTINUE (Y OR N)  
?  
Y

DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)  
?  
N

PLEASE WAIT 92 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = 0.1  
X-MAX = 2934  
Y-MIN = .675393440813  
Y-MAX = 2.98430821777  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
N

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE

?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?

2,3

X = % AXIAL STRAIN

Y = AXIAL STRESS

OK TO CONTINUE (Y OR N)

?

Y

DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)

?

N

PLEASE WAIT 92 SECS: SCALE CALC  
THE SCALE IS :-

X-MIN = 0

X-MAX = .393702760488

Y-MIN = 197.225180212

Y-MAX = 310.262486235

DO YOU WISH TO ALTER IT (Y OR N)

?

N

THERE ARE 303 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS

FORMAT X,Y e.g. 2,7

?

1,3

X = TIME

Y = AXIAL STRESS

OK TO CONTINUE (Y OR N)

?

Y

DO YOU WISH TO USE THE  
EXISTING SCALE (Y OR N)

?

N

PLEASE WAIT 92 SECS: SCALE CALC  
THE SCALE IS :-

X-MIN = 0.1

X-MAX = 2934

Y-MIN = 197.225180212

Y-MAX = 310.262486235

DO YOU WISH TO ALTER IT (Y OR N)

?

Y

ENTER X-MIN

?  
0  
ENTER X-MAX  
?  
800  
ENTER Y-MIN  
?  
0  
ENTER Y-MAX  
?  
400

THERE ARE 303 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

8

INSERT RESULTS CARTRIDGE - THEN  
ENTER DATA FILENAME

?

C-15

=====

FILE NAME :- C-15  
CONSOLIDATION

THERE ARE 197 SETS OF DATA  
ESTD. TEST DURATION = 10.1 HRS  
ACTUAL TEST DURATION = 6.6 HRS  
DO YOU WANT A PRINT OF OPTIONS  
(Y OR N)

?

N

THERE ARE 197 SETS OF DATA  
DO YOU WISH TO :-

1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

2

ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7

?

1,14

X = TIME

Y = VOLUME CHANGE

OK TO CONTINUE (Y OR N)

?

Y  
PLEASE WAIT 60 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = .01  
X-MAX = 23716  
Y-MIN = -5950  
Y-MAX = -250  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
Y  
ENTER X-MIN  
?  
0  
ENTER X-MAX  
?  
25000  
ENTER Y-MIN  
?  
-7000  
ENTER Y-MAX  
?  
0

THERE ARE 197 SETS OF DATA  
DO YOU WISH TO :-  
1 = TABULATE  
2 = PLOT  
8 = ANOTHER FILE  
9 = TERMINATE PROGRAM  
ENTER YOUR CHOICE  
?  
2  
ENTER X AND Y VARIABLE NUMBERS  
FORMAT X,Y e.g. 2,7  
?  
16,1h

X = SQRT(YIME)  
Y = VOLUME CHANGE  
OK TO CONTINUE (Y OR N)  
?  
Y  
PLEASE WAIT 60 SECS: SCALE CALC  
THE SCALE IS :-  
X-MIN = .01  
X-MAX = 154  
Y-MIN = -5950  
Y-MAX = -250  
DO YOU WISH TO ALTER IT (Y OR N)  
?  
Y  
ENTER X-MIN  
?  
0

ENTER X-MAX

?

160

ENTER Y-MIN

?

-7000

ENTER Y-MAX

?

0

THERE ARE 197 SETS OF DATA

DO YOU WISH TO :-

1 = TABULATE

2 = PLOT

8 = ANOTHER FILE

9 = TERMINATE PROGRAM

ENTER YOUR CHOICE

?

9

END

## Chapter VI

### CONCLUSIONS

From the investigation performed, it is concluded that the GDS Triaxial Digital System meets the needs of both research scientists and practicing engineers.

The controllers replaced efficiently conventional equipment and generated target pressure at a flexible rate of volume change. Each controller acted as an automated constant pressure source and volume change gauge accurate to 1 KPa and 1 mm respectively.

Controllers-computer intercommunication was conducted by transmitting digital information in two ways via the interface bus in accordance with the IEEE-488 communication standard.

Under total automatic control, the GDSTTS program executed most of the available tests (such as the Unconsolidated Undrained, Consolidated Undrained, Drained,  $K_0$  Consolidation and Swelling and Cyclic Loading) except the Linear Stress Paths Test (due to a problem with the available software).

As soon as the the Geotechnical Digital System LMT provides more clarification about the Linear Stress Paths Test, more

readily simulation for stress paths designated in the field can be performed. Controlled-stress and controlled-strain can be carried out by following a wide range of stress paths in both axial compression and axial extension.

Optional consolidation stage and checking for the pore pressure parameter, B, were always available in a loop-round prior to the tests execution.

Up to 350 data points could be stored in the computer memory, displayed on the screen during the test execution, and then saved on a tape for tabulation, plotting, and future analysis. Anyone of the 20 test parameters could be plotted against another using the GDSFBP plotting program.

The GDS system operated continuously in unmanned use 24 hours a day, several days a week.

## Chapter VII

### REFERENCES

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2. BISHOP, A. W., and HENKEL, D. J., 1969. The measurement of soil properties in the triaxial test. Edward Arnold Publishers, London, second Edition, 227 p.
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5. BOWLES, J. E., 1970. Engineering properties of soils and their measurement. McGraw-Hill Book Company, New York, pp. 131-159.
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9. HOLTZ, R. D., and KOVACS, W. D., 1981. An introduction to geotechnical Engineering. Prentice-Hall Inc., New Jersey, pp. 431-664.
10. HEWLETT-PACKARD, 1981. Owner's Manual and Programming Guide. Hewlett Packard Company, U.S.A, 342 p.
11. HEWLETT-PACKARD, 1981. Plotter/Printer ROM owner's manual. Hewlett Packard company, U.S.A, 120 p.
12. GEOTECHNICAL DIGITAL SYSTEMS LIMITED. The GDS User's Handbook. Geotechnical Digital System Limited, Walton-on-Thames, England, 145 p.
13. SINGER, F. L., and PYTEL, A., 1980. Strength of materials, third Edition, Harper and Row Publishers, New York, pp. 376-384.
14. SKEMPTON, A. W., 1954. The pore pressure coefficients A and B. Geotechnique, Vol. 4, No. 4, pp. 143-147.
15. University of Ottawa, 1984. Manual for the measurement of soil properties in the laboratory. The Civil Engineering department, Ottawa, Ontario, pp. 50- 64.

TABLES

TABLE 3.1

Interpretation of the Thumbwheel switch setting

First digit setting =====	First digit of equivalent pressure =====	Maximum volume change rate (mm <sup>3</sup> /s) =====
0	0	12.5
1	1	12.5
2	0	50
3	1	50
4	0	100
5	1	100
6	0	100
7	1	100
8	0	200
9	1	200

=====

TABLE 3.2

Typical examples of the thumbwheel switch setting.

Pressure setting value =====	Equivalent maintained pressure (KPa) =====	Maximum volume change rate (mm <sup>3</sup> /s) =====
0215	215	12.5
1160	1160	12.5
2200	200	50
3230	1230	50
4340	340	100
5610	1610	100
6880	880	100
7400	1400	100
8130	130	200
9000	1000	200

=====

FIGURES

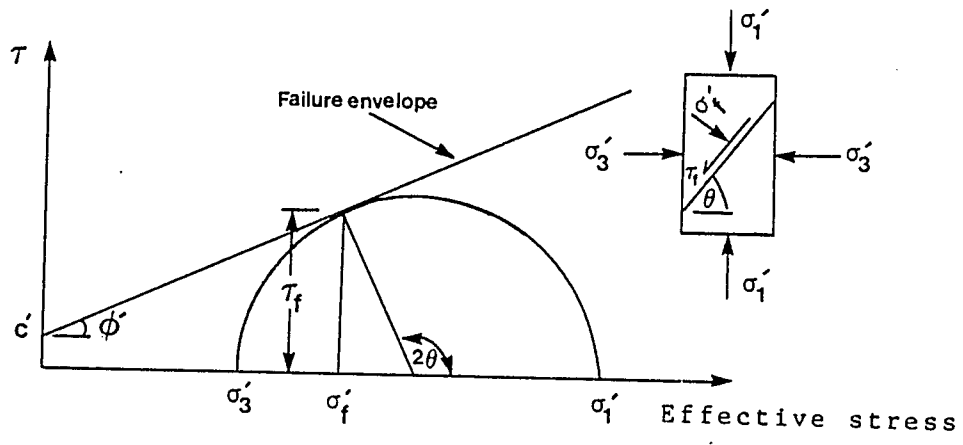


Fig. 2.1: Stress conditions at failure (after Craig, 1983).

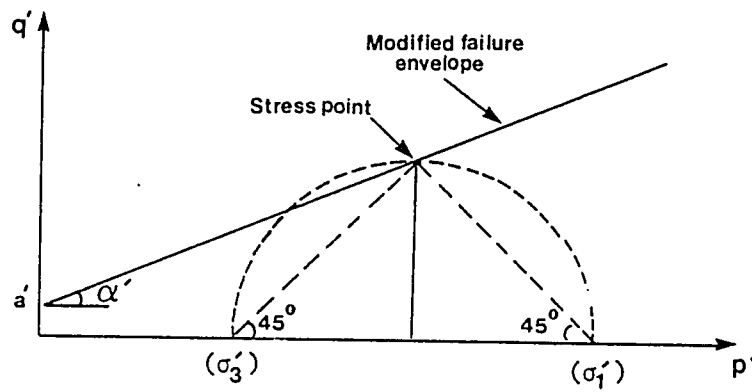


Fig. 2.2: Alternative representation of stress conditions (after Craig, 1983).

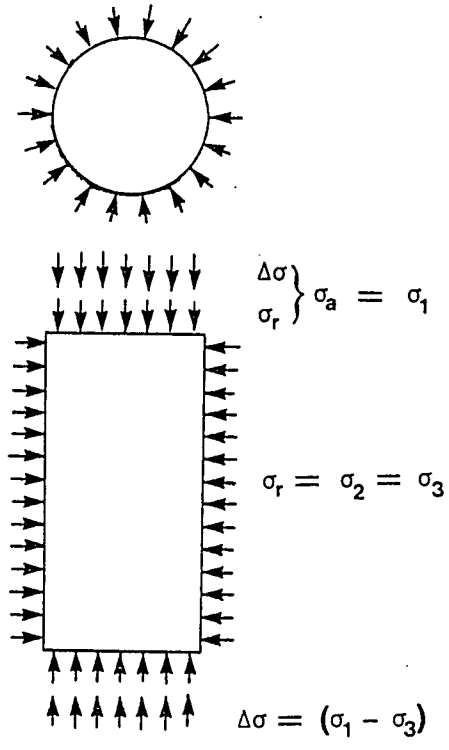


Fig. 2.3: Stress system in triaxial test (after Holtz and Kovacs, 1981).

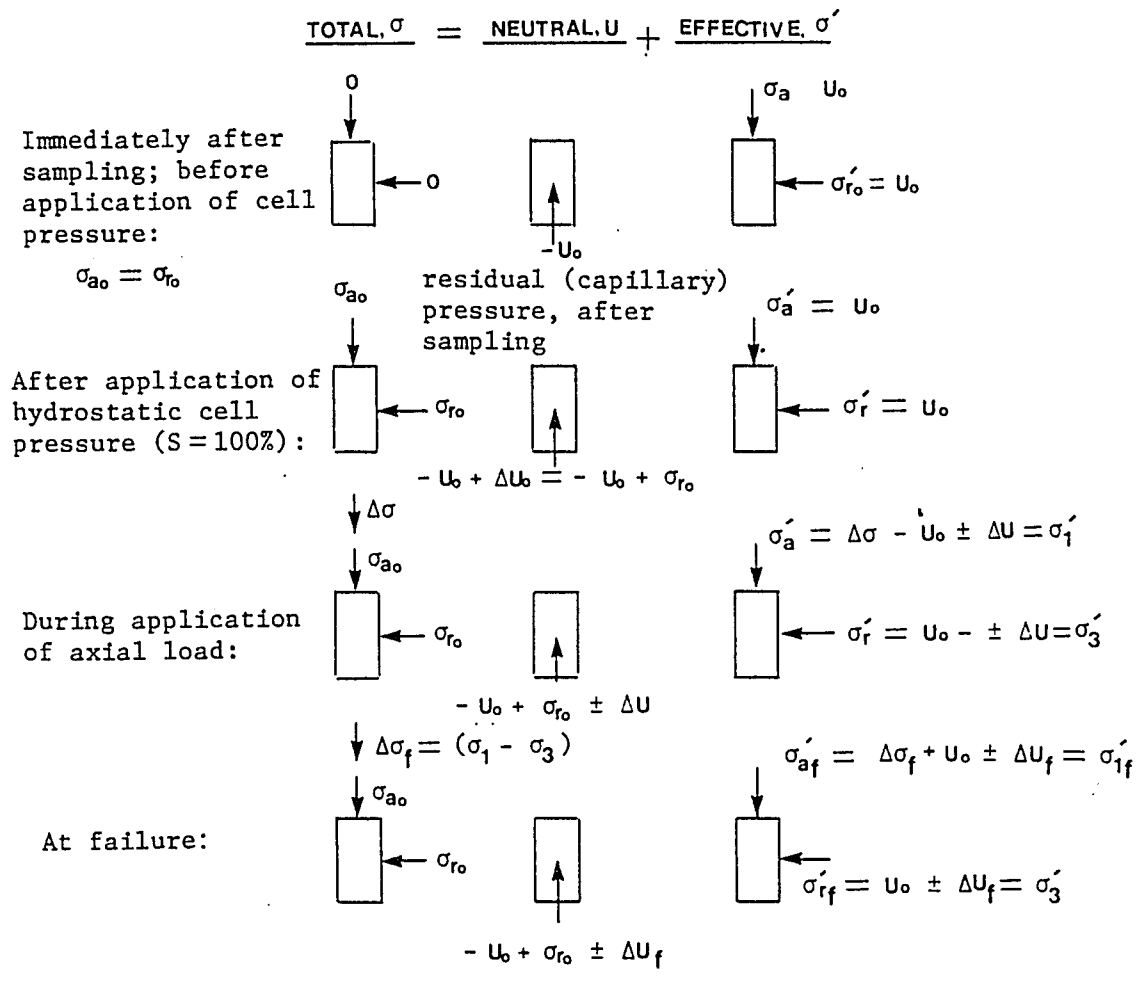


Fig. 2.4: Condition in specimen during Unconsolidated Undrained compression test (after Holtz and Kovacs, 1981).

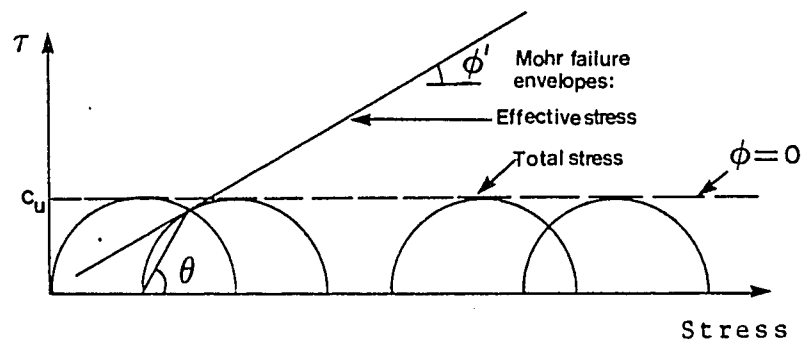
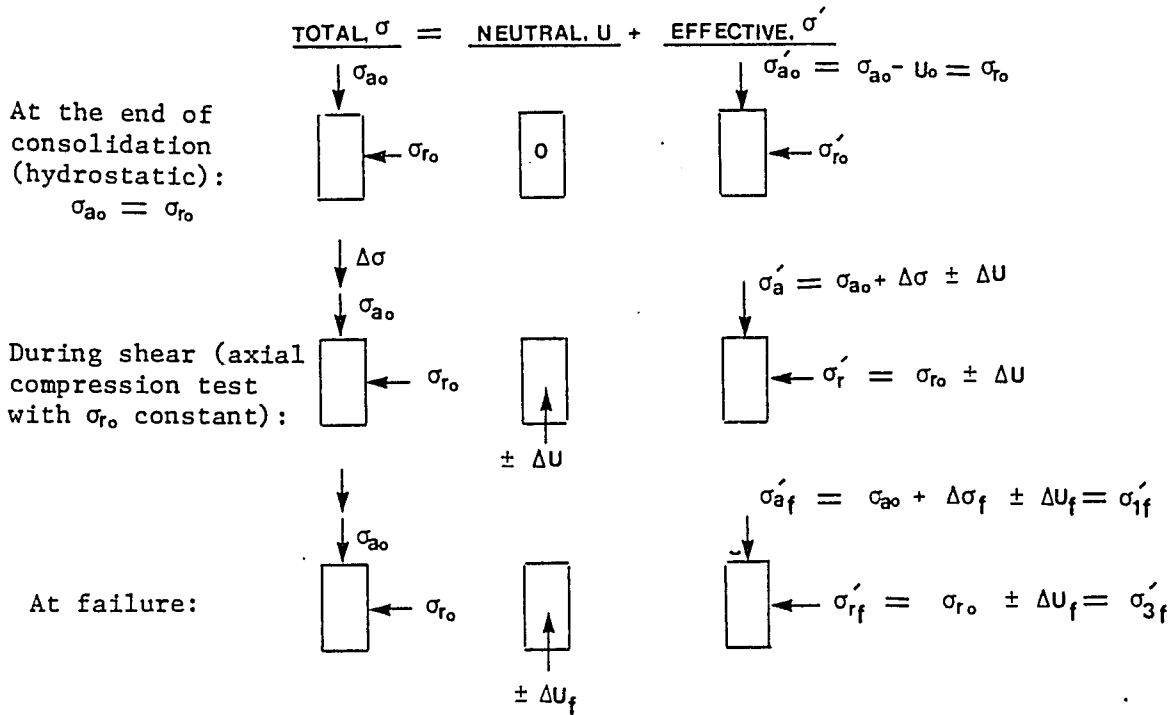


Fig. 2.5: The unique effective-stress Mohr circle at failure from the Unconsolidated Undrained test (after Holtz and Kovacs, 1981).



It is necessary to apply a back pressure to ensure 100% saturation for good measurements of the pore water pressure. The total stresses have to be increased by the same amount to keep the effective consolidation stresses constant.

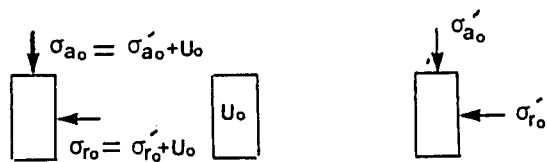


Fig. 2.6: Condition in specimen during Unconsolidated Undrained axial compression test (after Holtz and Kovacs, 1981).

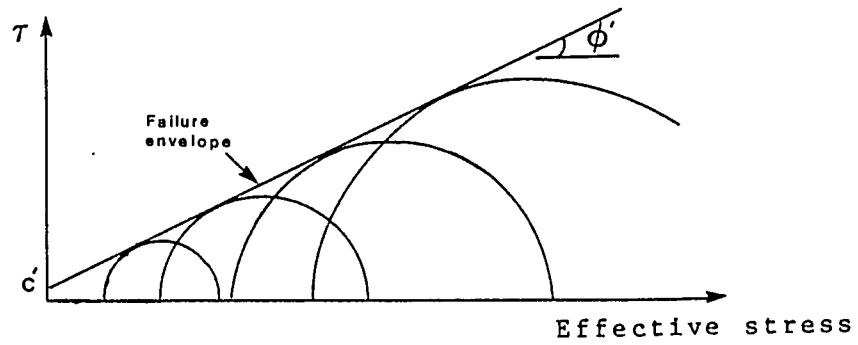


Fig. 2.7: Mohr circle at failure for a Consolidated Undrained and Drained tests (after Craig, 1983).

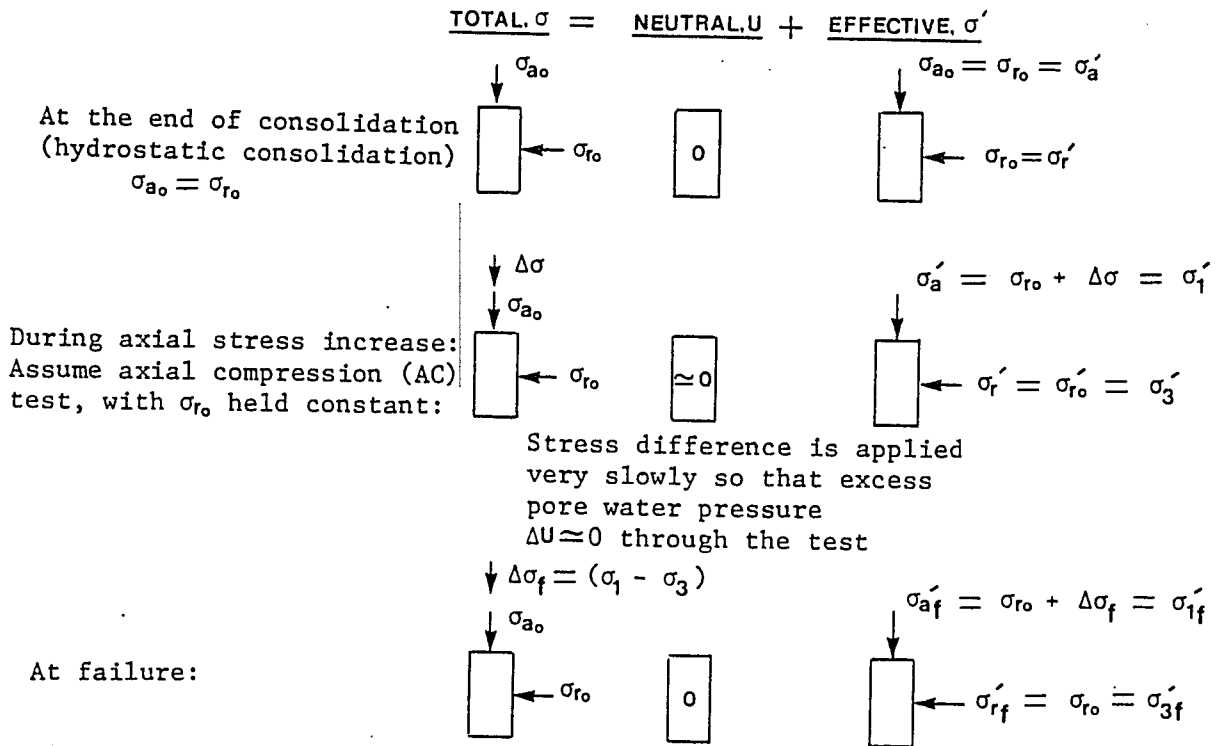


Fig. 2.8: Stress conditions in the Consolidated Drained Axial compression triaxial test (after Holtz and Kovacs, 1981).

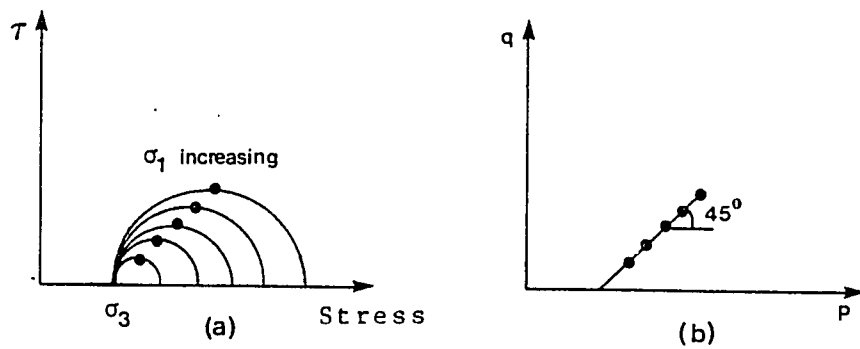


Fig. 2.9: (a) Successive Mohr circles, (b) stress path for constant ( $\sigma_3$ ) and increasing ( $\sigma_1$ ) (after Lambe and Whitman, 1969).

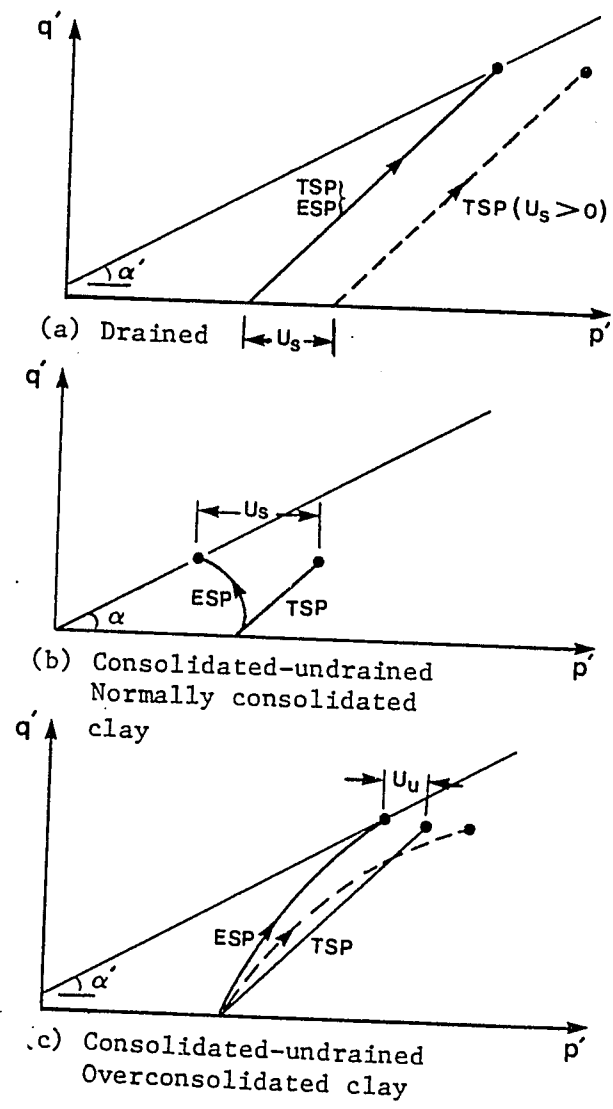
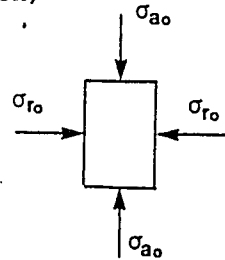
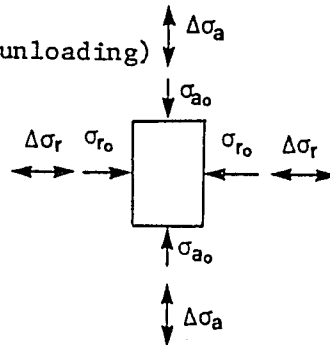


Fig. 2.10: Stress Paths for triaxial tests (after Craig, 1983)

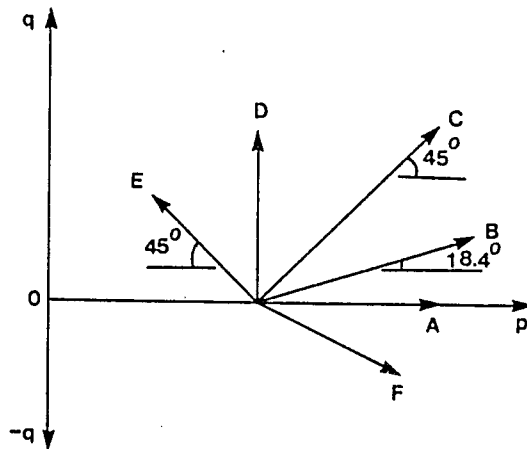
1. Initial conditions:  
 $\sigma_{a0} = \sigma_{r0}$  (hydrostatic compression)



2. During loading (or unloading)



3. Stress paths



- Path A:  $\Delta\sigma_r = \Delta\sigma_a$   
 B:  $\Delta\sigma_r = \frac{1}{2}\Delta\sigma_a$   
 C:  $\Delta\sigma_r = 0$ ,  $\Delta\sigma_a$  increases  
 D:  $\Delta\sigma_r = -\Delta\sigma_a$   
 E:  $\Delta\sigma_r$  decreases,  $\Delta\sigma_a = 0$   
 F:  $\Delta\sigma_r$  increases,  $\Delta\sigma_a$  decreases

Fig. 2.11: Different Stress Paths for initial hydrostatic stress condition (after Lambe and Whitman, 1969 ).

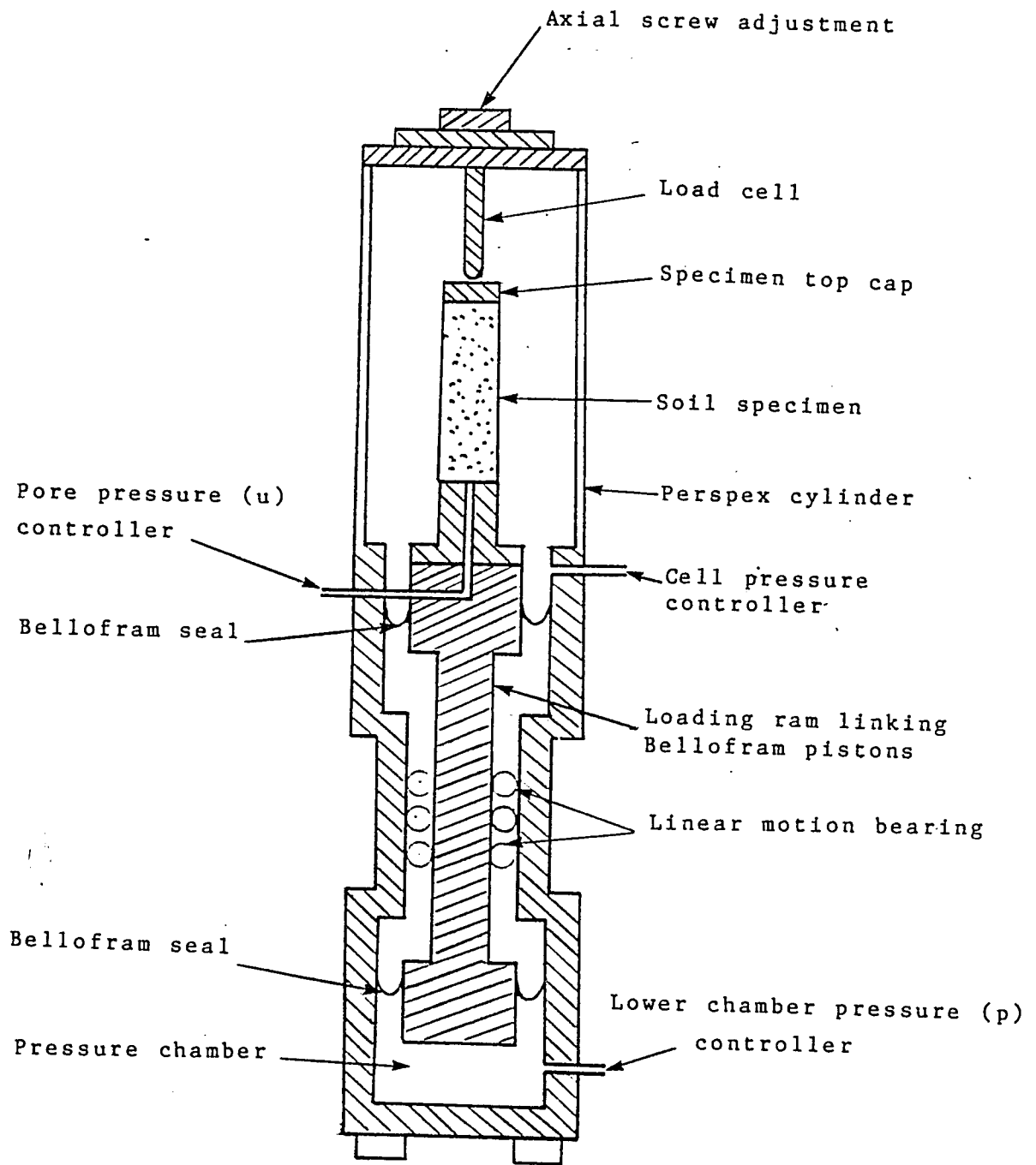


Fig. 3.1: Diagrammatic layout of the triaxial apparatus.

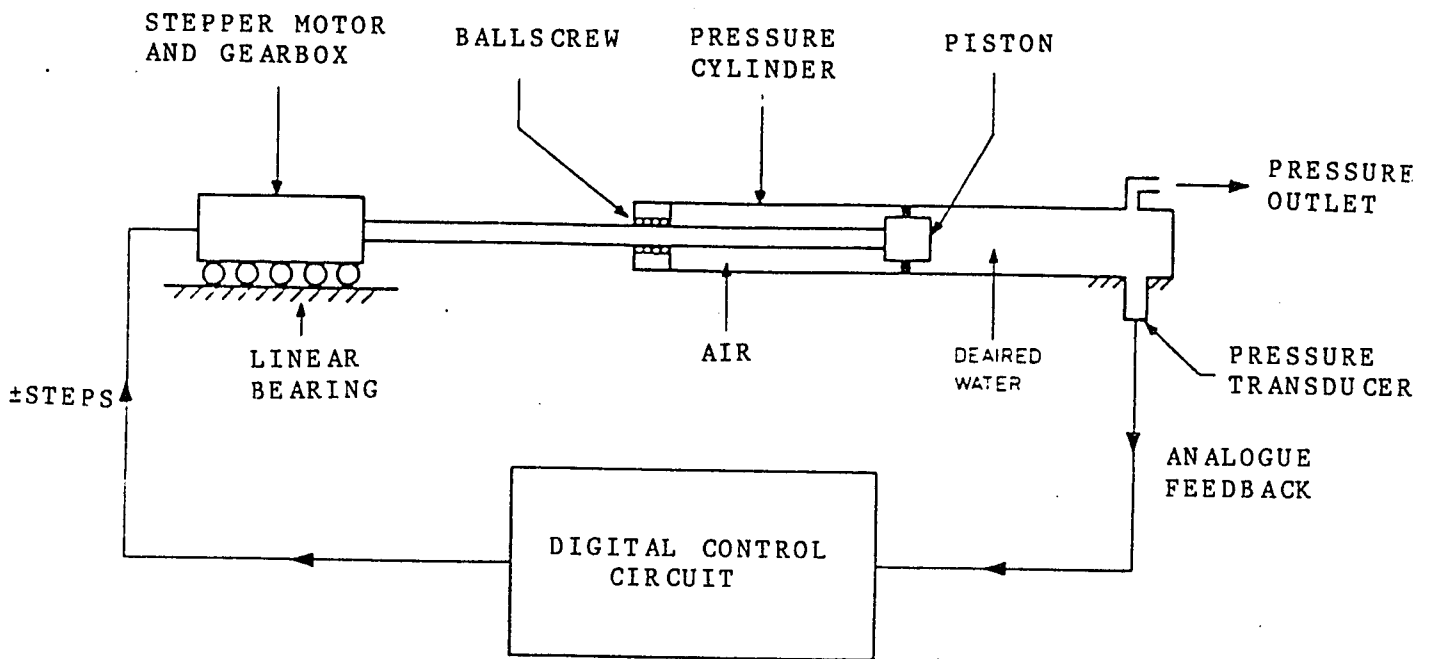


Fig. 3.2: Schematic view of the controller operation.

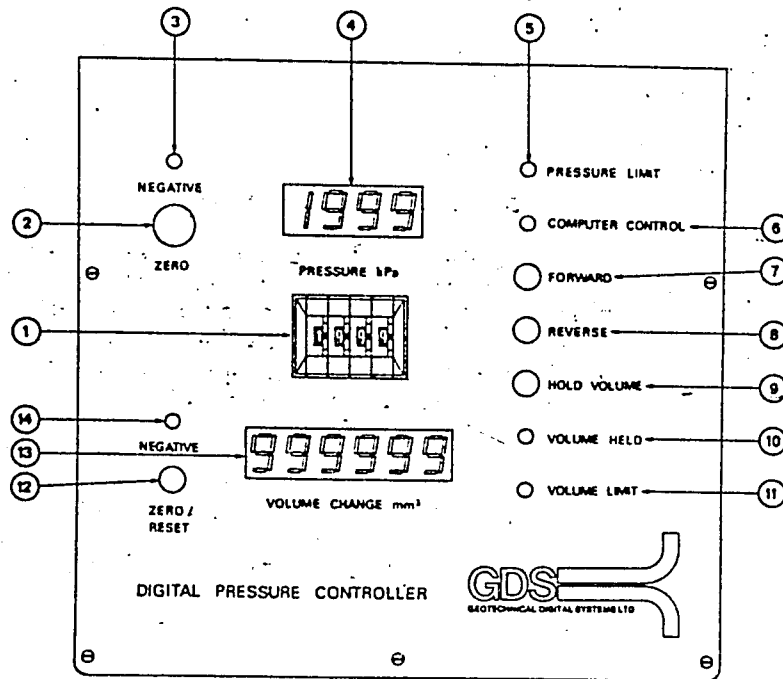


Figure 2 Control Panel Layout

- Key:
- (1) Thumbwheel switch for dialling pressure
  - (2) Zero offset for pressure
  - (3) LED to indicate negative pressure
  - (4) 4-figure LED display of pressure (kPa)
  - (5) LED to indicate pressure limit
  - (6) LED to indicate computer control
  - (7) Momentary push button for fast forward override
  - (8) Momentary push button for fast reverse override
  - (9) Latching push button for hold volume
  - (10) LED to indicate volume held
  - (11) LED to indicate volume limit
  - (12) Momentary push button for zeroing volume change and for disengaging computer control
  - (13) 6-figure LED display of volume change (mm<sup>3</sup>)
  - (14) LED to indicate volume negative.

Fig. 3.3: Control panel layout.

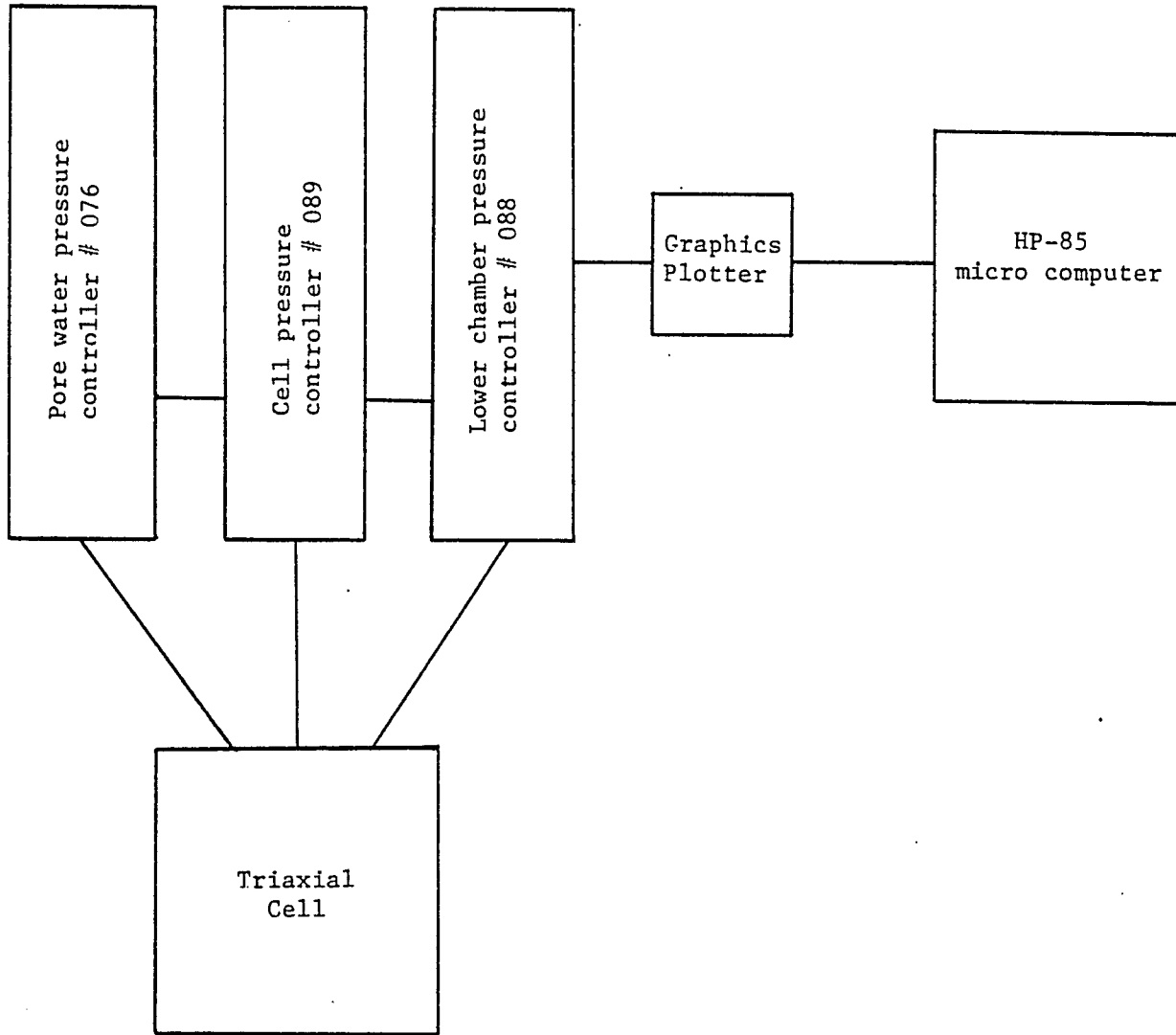


Fig. 3.4: Daisy-chain configuration.

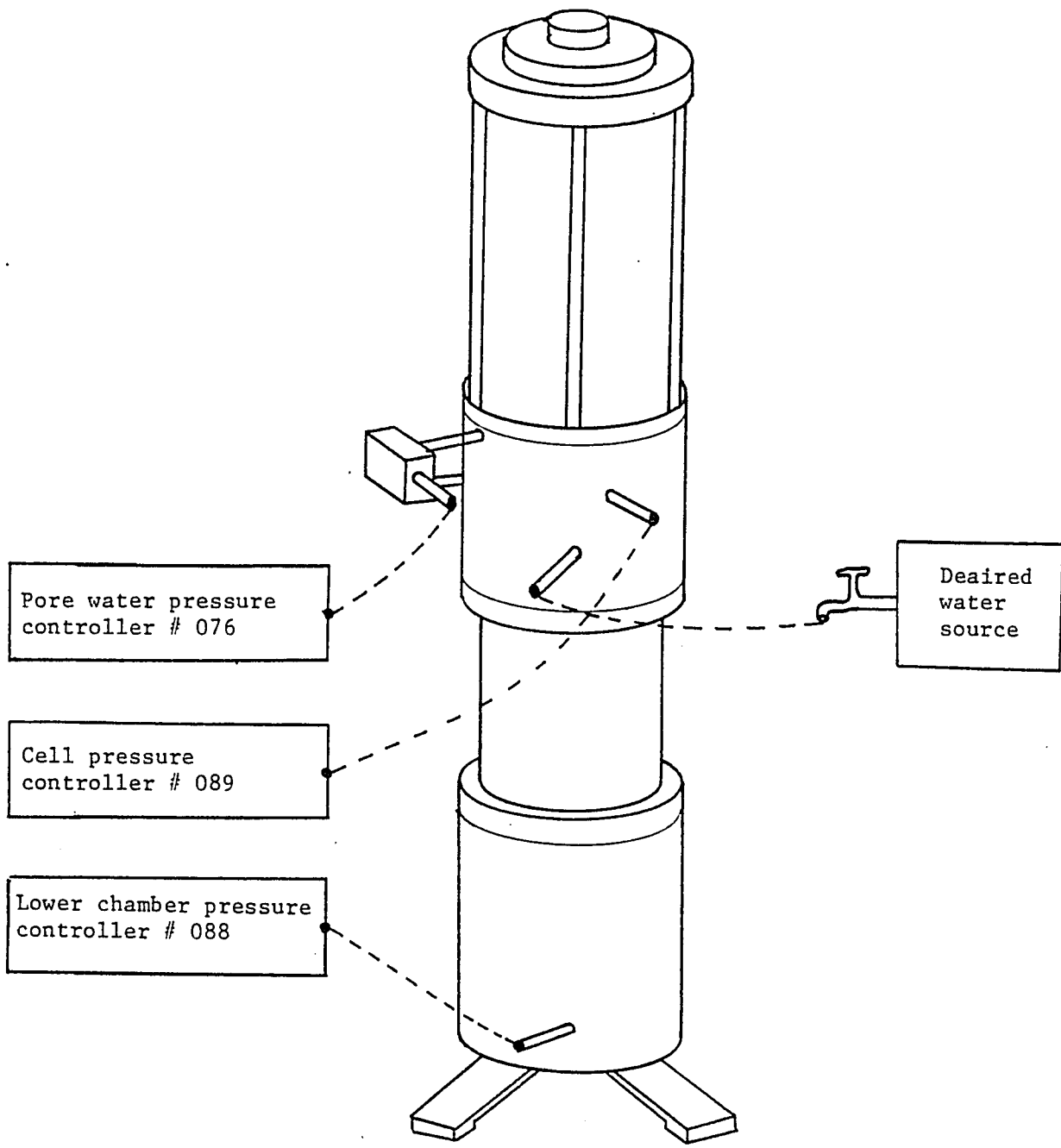
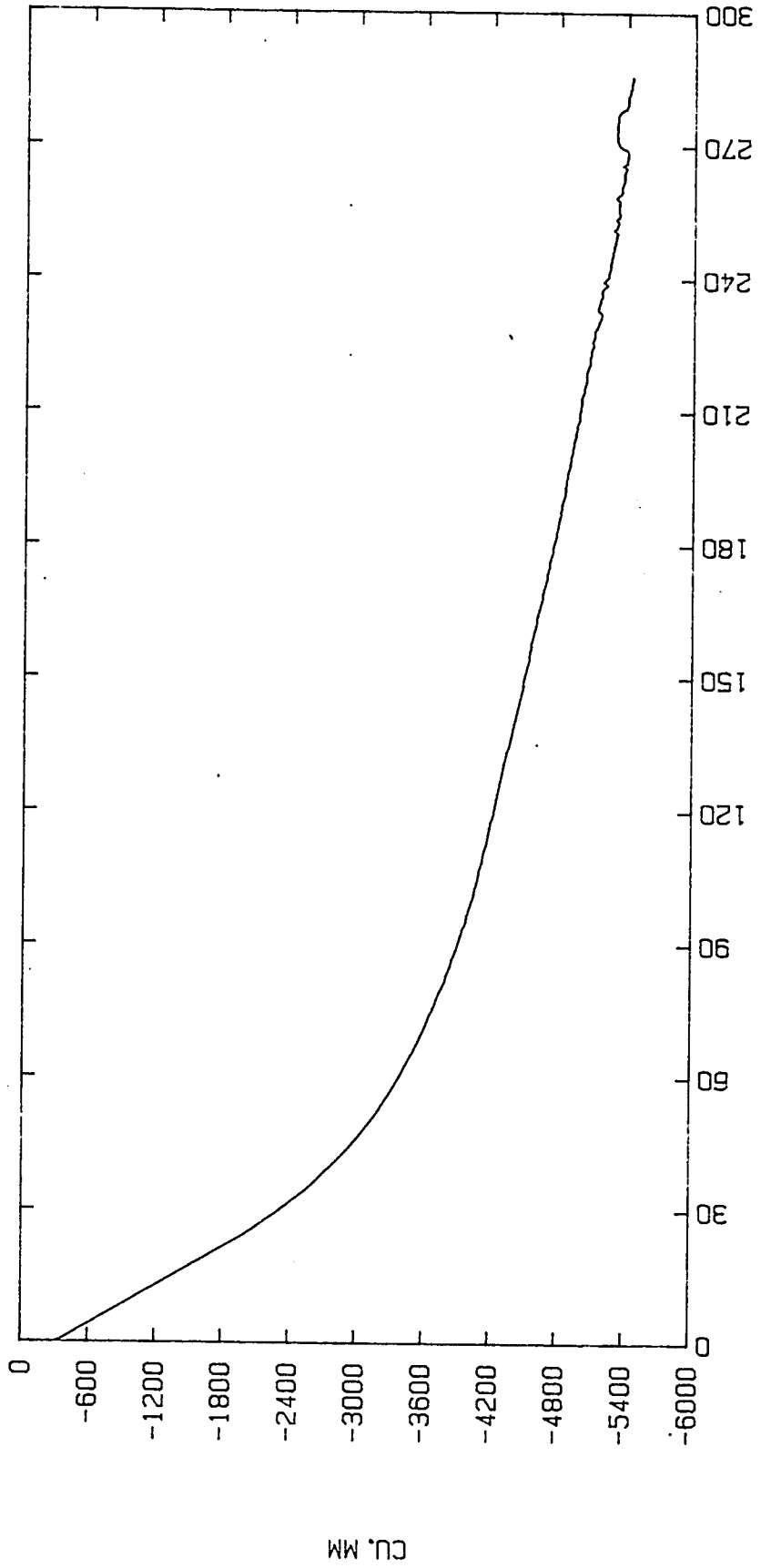


Fig. 3.5: Triaxial cell and GDS controllers connections.

CONSOLIDATION (C-3)  
VOLUME CHANGE v. SQRT(TIME)



SQRT (SECS)

Fig. 5.1.1.1: Volume change versus square route of time (obtained from the GDS).

: CONSOLIDATION (C-3)  
—— VOLUME CHANGE v. TIME

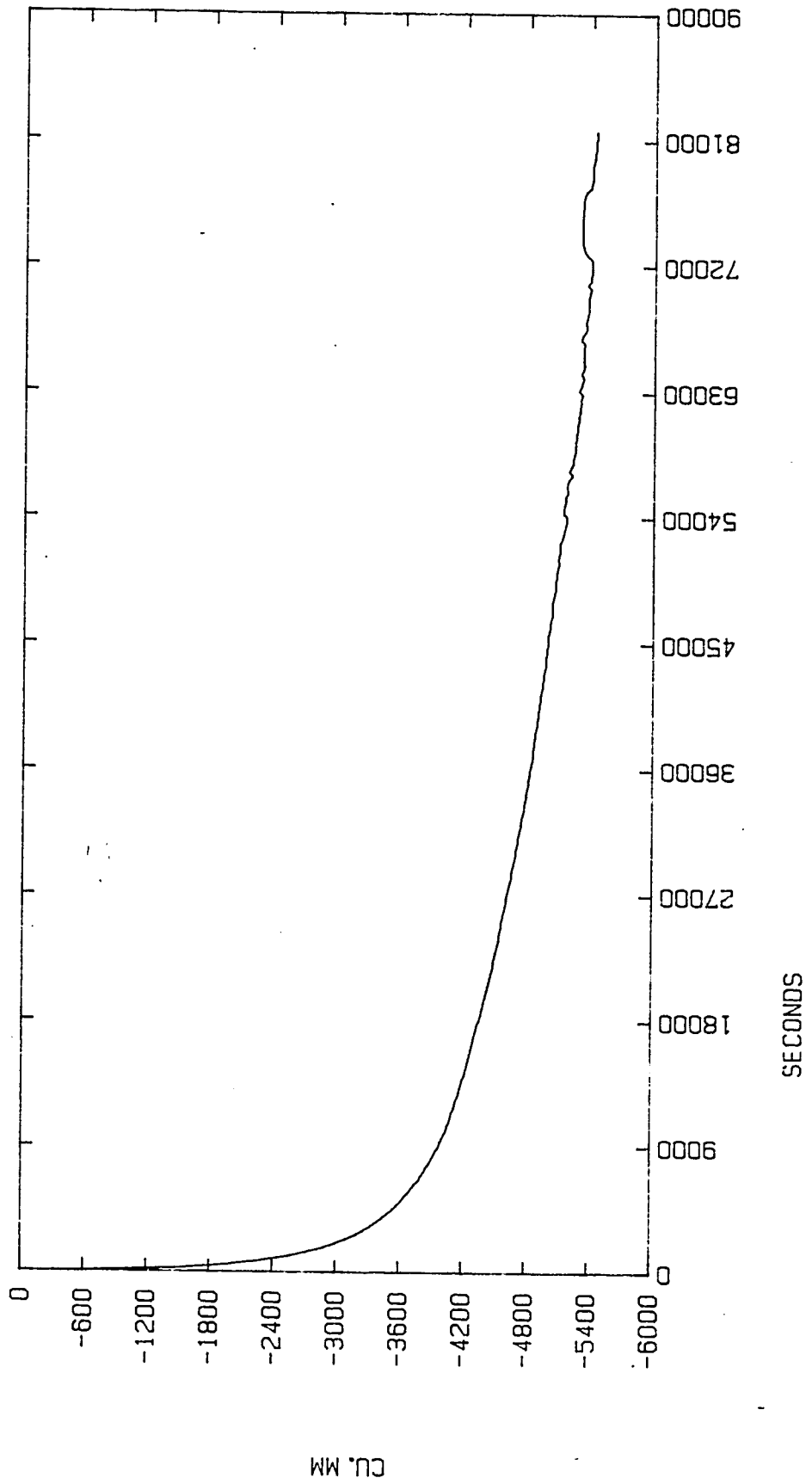
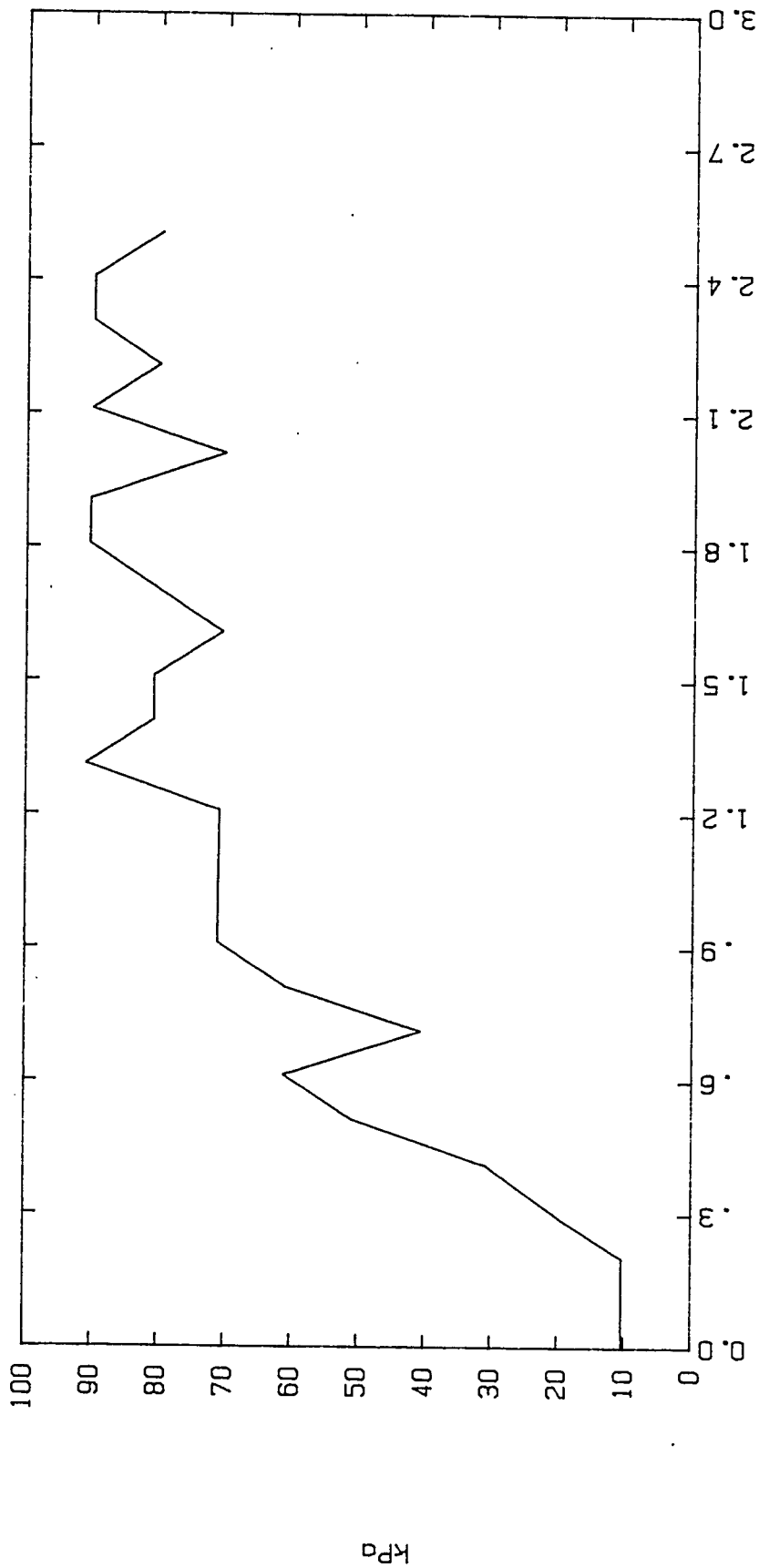


Fig. 5.1.2: Volume change versus time (obtained from the GDS)

UNDRAINED UNCONSOLIDATED (UU-1)  
 ——— DEV STRESS v. % AXIAL STRAIN



%

Fig. 5.2.1.1: Deviator stress versus percentage axial strain (obtained from the GDS).

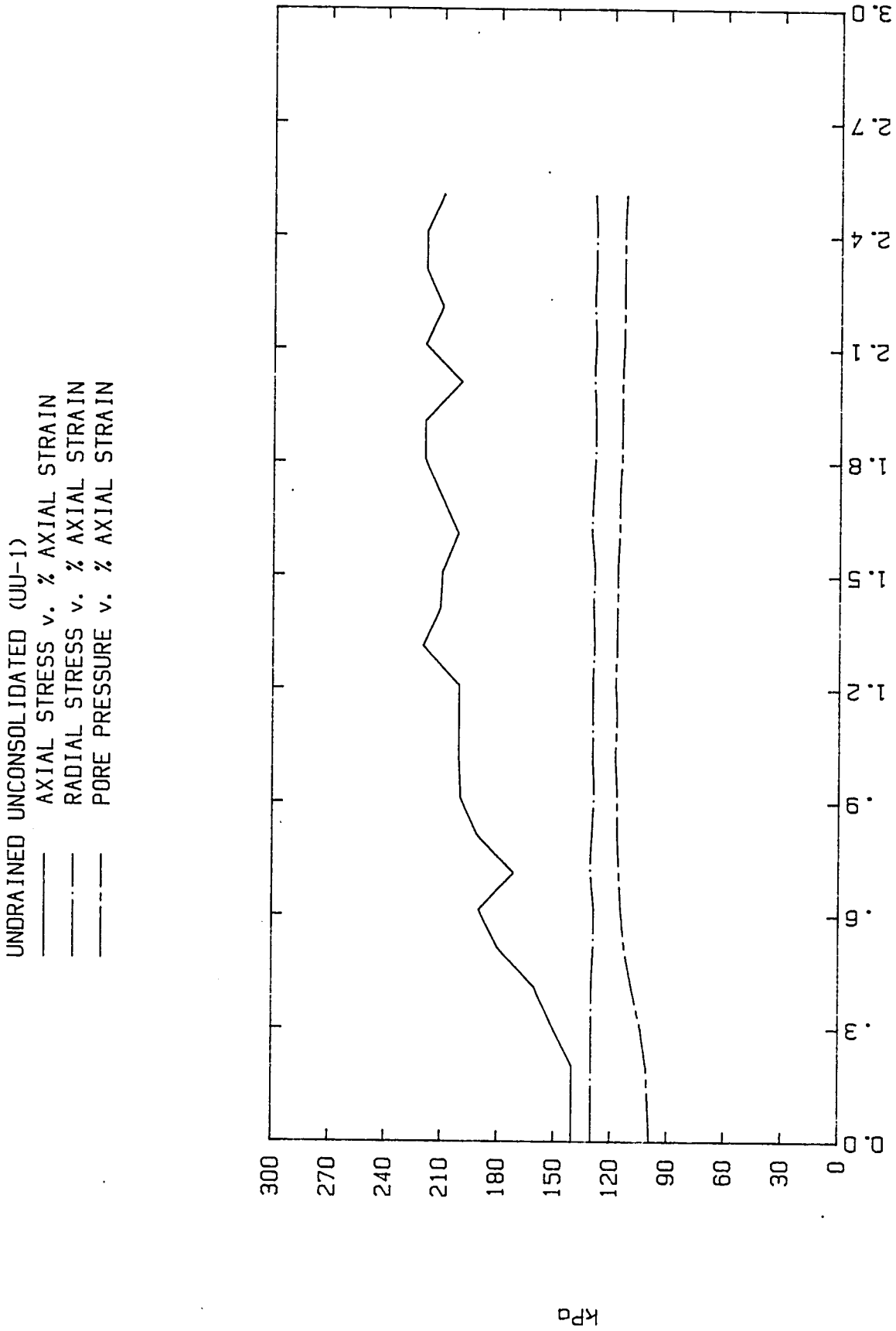
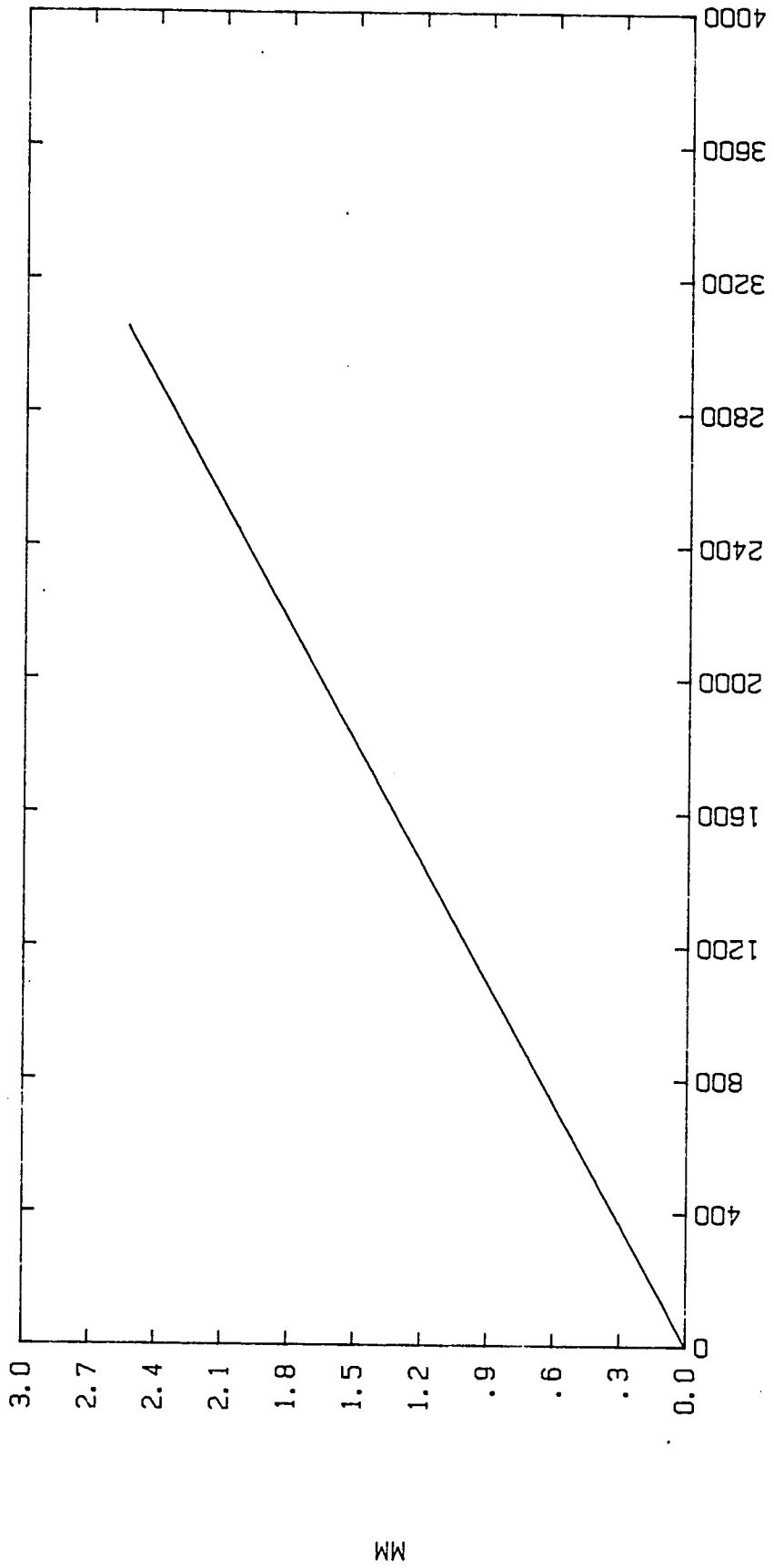


Fig. 5.2.2: Axial stress, radial stress, and pore pressure versus percentage axial strain (obtained from the GDS)

UNDRAINED UNCONSOLIDATED (UU-1)  
LENGTH CHANGE v. TIME



SECONDS

Fig. 5.2.3: Length change versus time (obtained from the GDS)

UNDRAINED UNCONSOLIDATED (UU-1)  
STRESS RATIO v. % AXIAL STRAIN

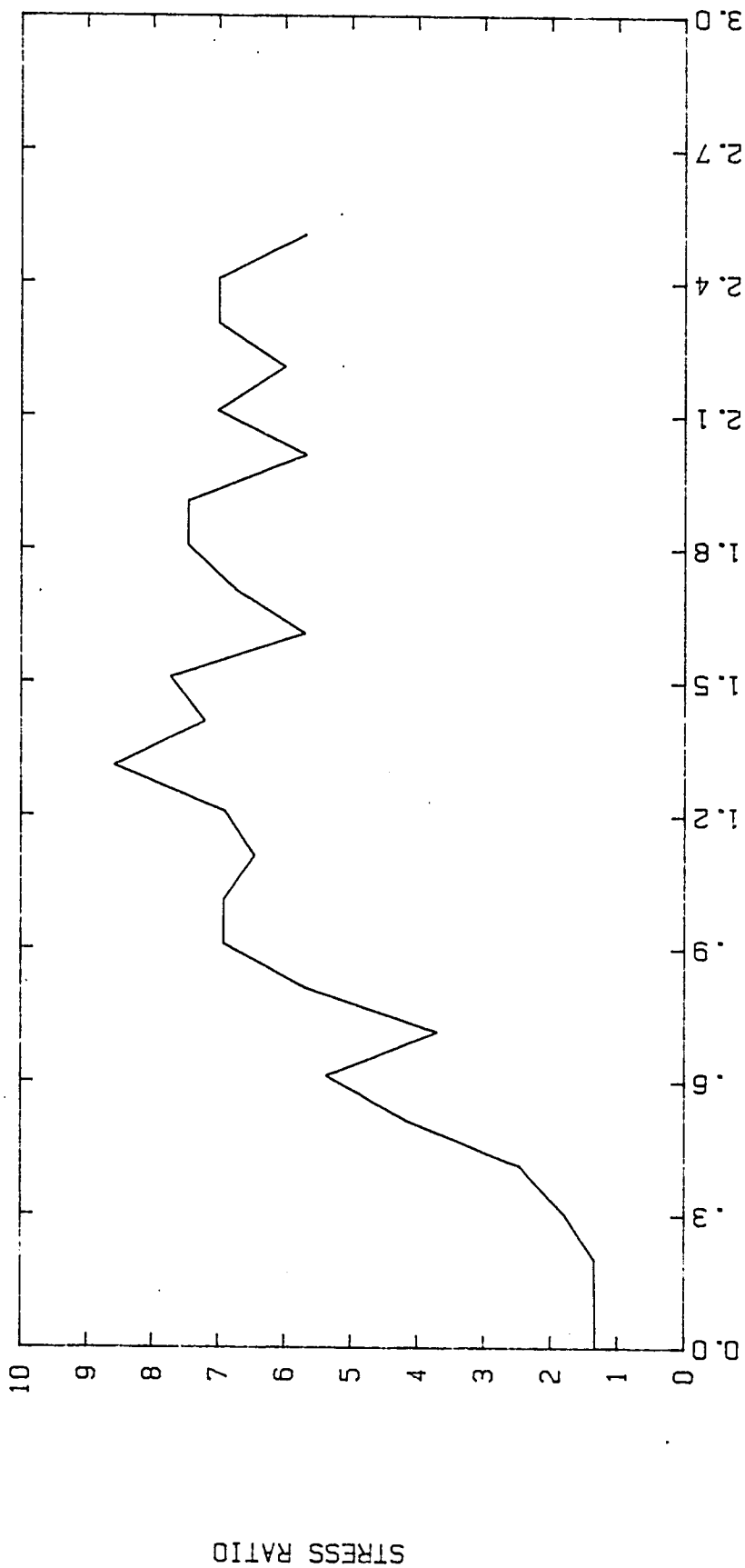


Fig. 5.2.4: Stress ratio versus percentage axial strain (obtained from the GDS).

CONSOLIDATION (C-2)  
VOLUME CHANGE v. TIME

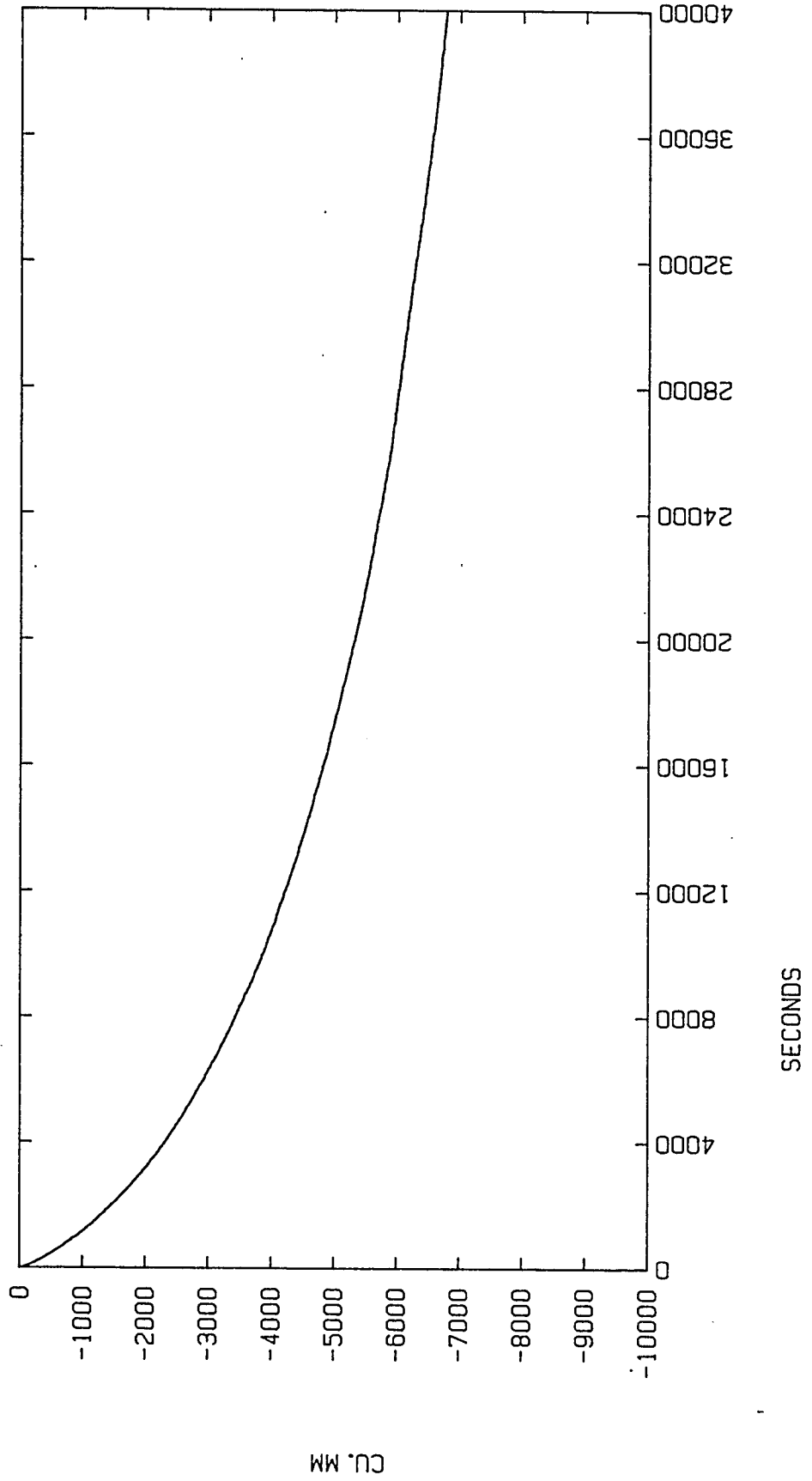
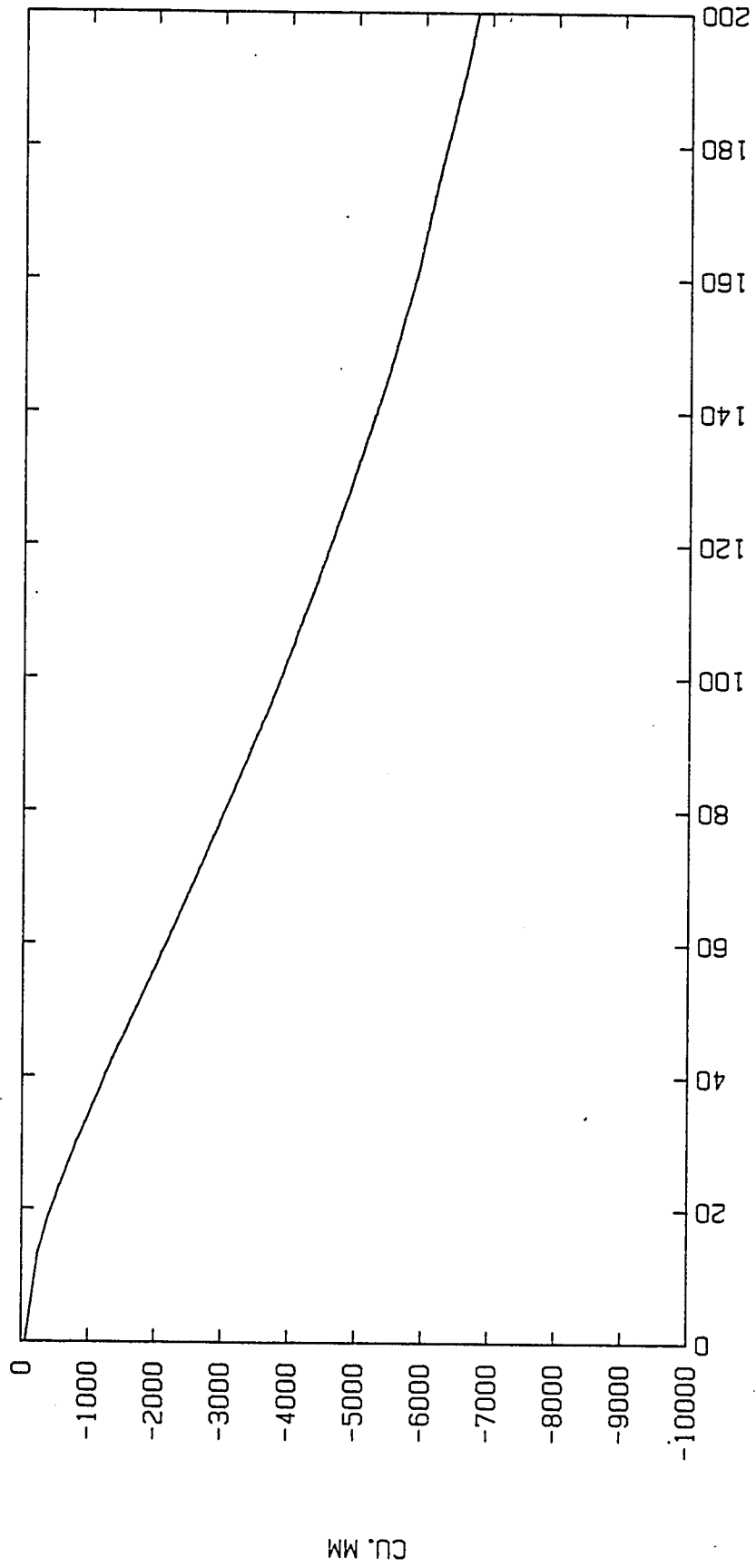


Fig. 5.3.1: Volume change versus time (obtained from the GDS)

CONSOLIDATION (C-2)  
\_\_\_\_\_ VOLUME CHANGE v. SQRT(TIME)



SQRT(SECS)

Fig. 5.3.2: Volume change versus square route of time (obtained from the GDS).

CONSOLIDATED UNDRAINED (CU-1)  
— DEV STRESS v. % AXIAL STRAIN  
- - - PORE PRESSURE v. % AXIAL STRAIN

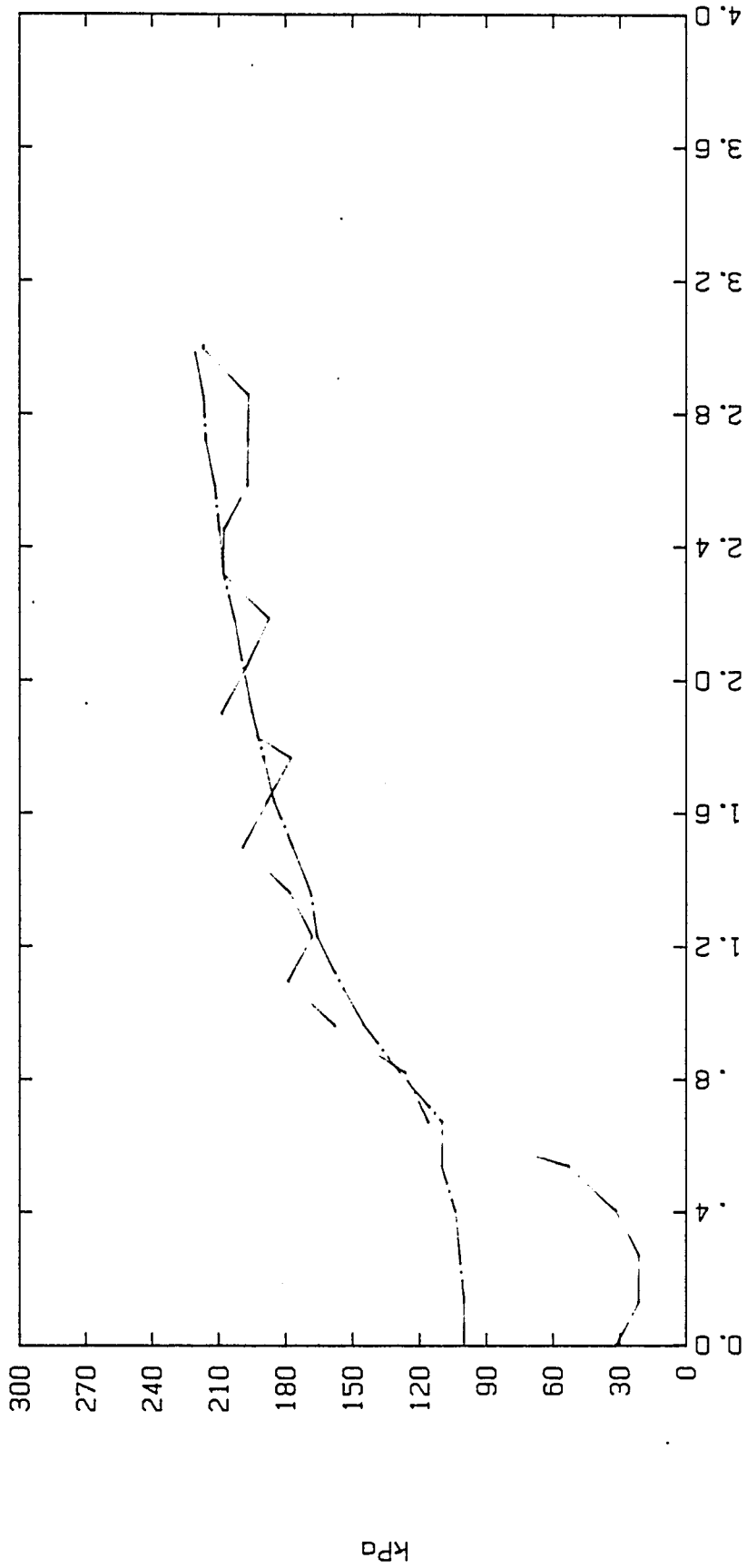
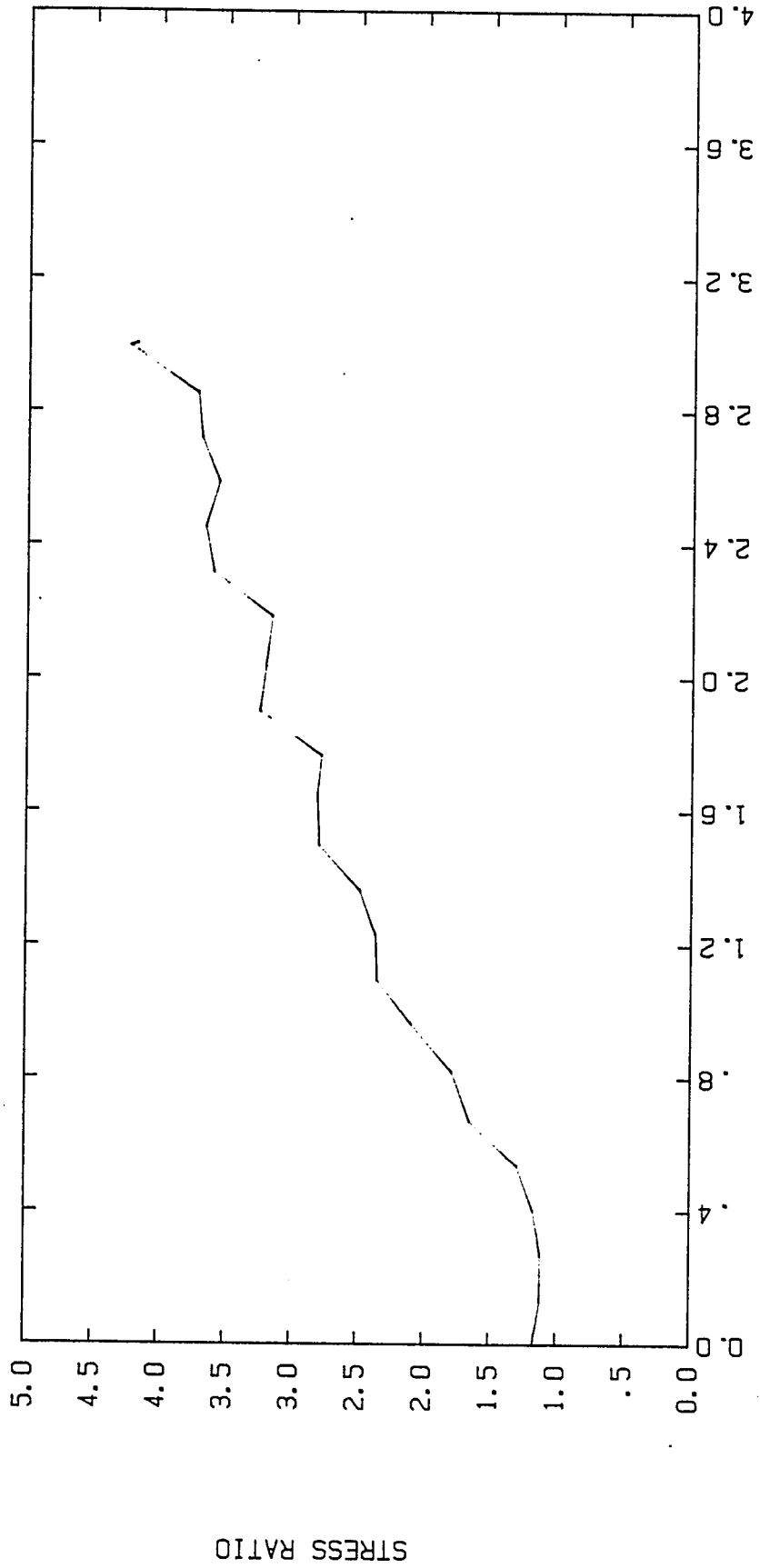


Fig. 5.3.3: Deviator stress and pore pressure versus  
(obtained from the GDS)

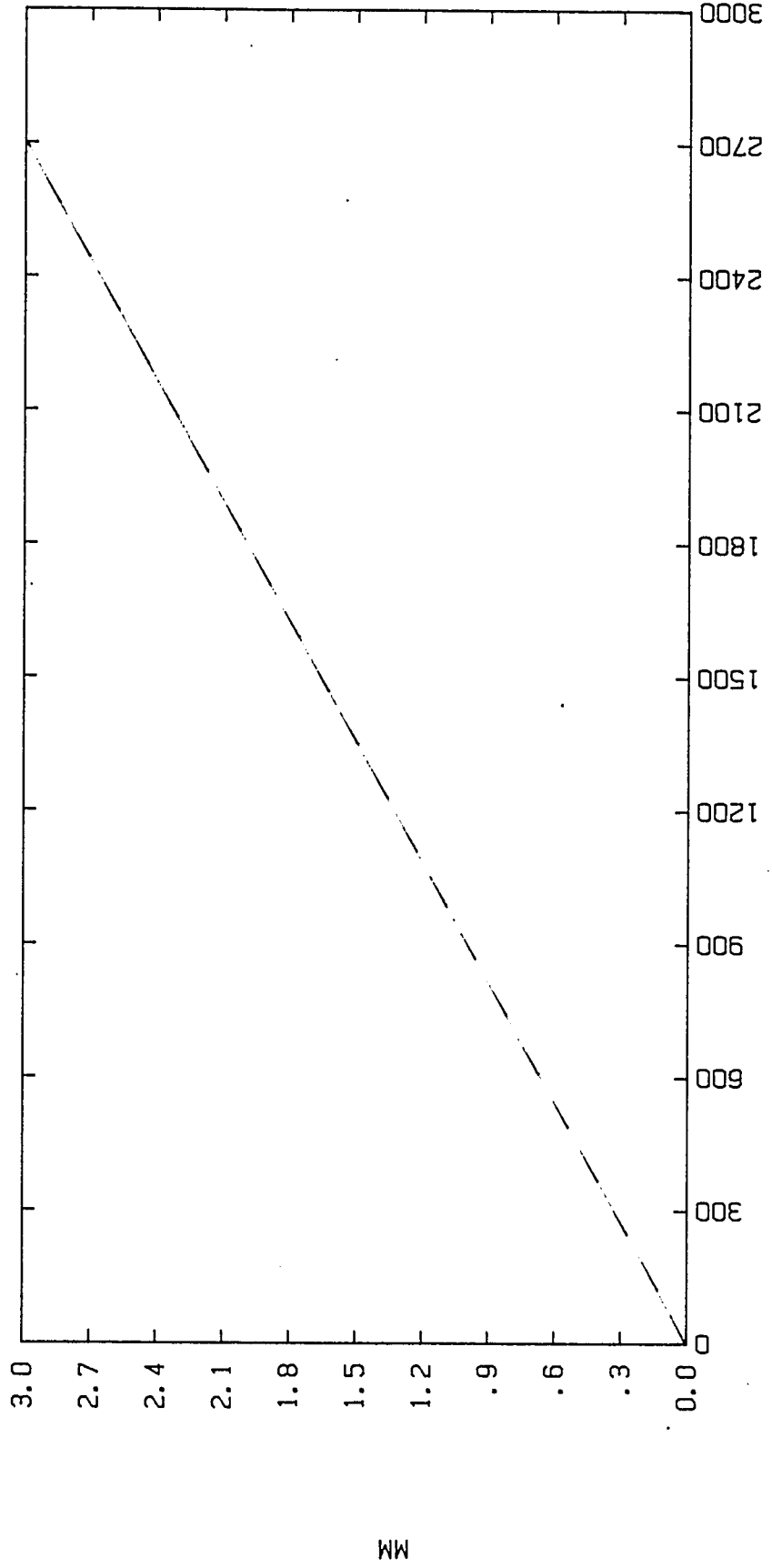
CONSOLIDATED UNDRAINED (CU-1)  
STRESS RATIO v. % AXIAL STRAIN



%

Fig.5.3.4: Stress ratio versus percentage axial strain (obtained from the GDS).

CONSOLIDATED UNDRAINED (CU-1)  
LENGTH CHANGE v. TIME



SECONDS

Fig. 5.3.5: Length change versus time (obtained from the GDS)

MM

DRAINED (D-1)  
—— DEV STRESS v. % AXIAL STRAIN  
- - - PORE PRESSURE v. % AXIAL STRAIN

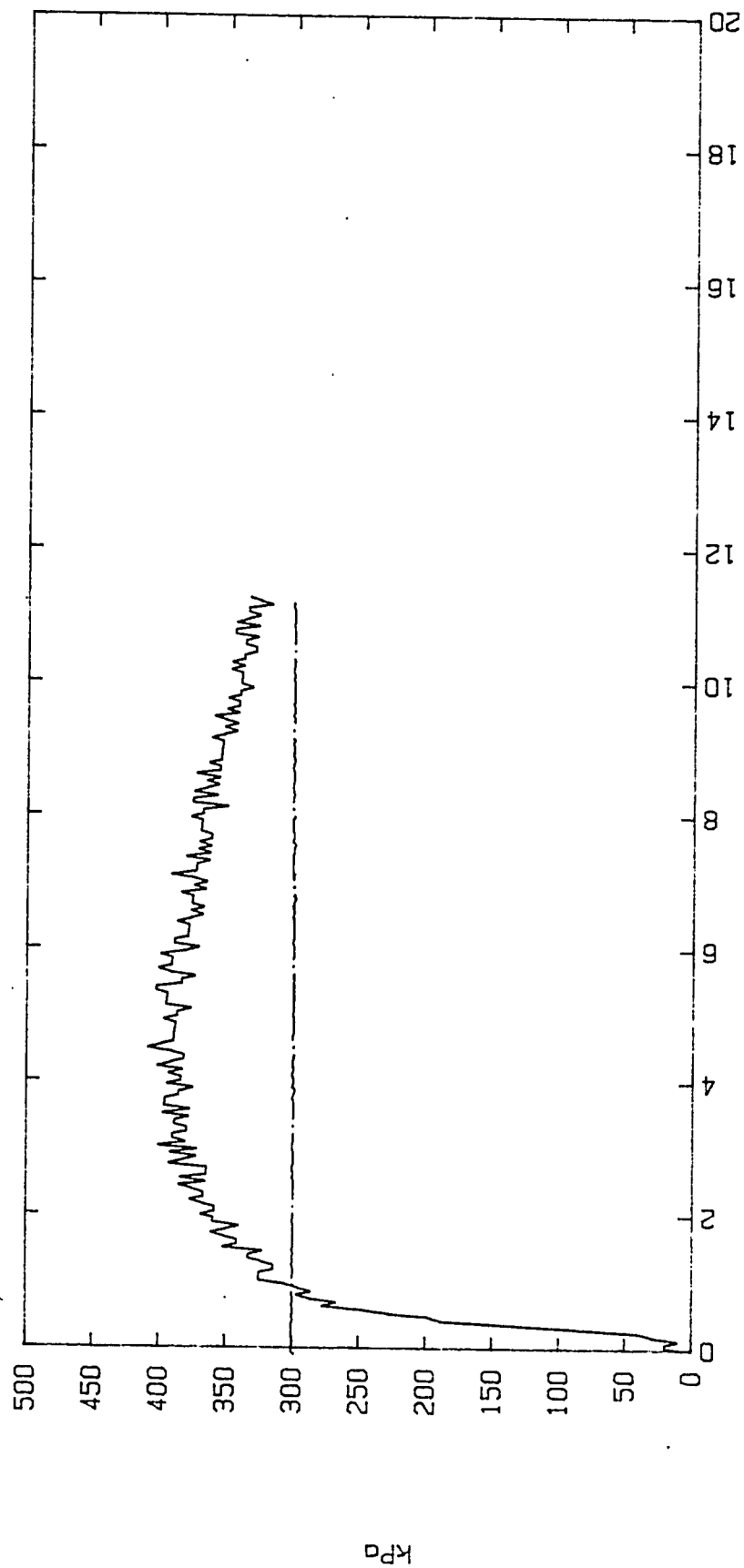


Fig. 5.4.1: Deviator stress and pore pressure versus percentage axial strain (obtained from the GDS)

DRAINED (0-1)  
STRESS RATIO v. % AXIAL STRAIN

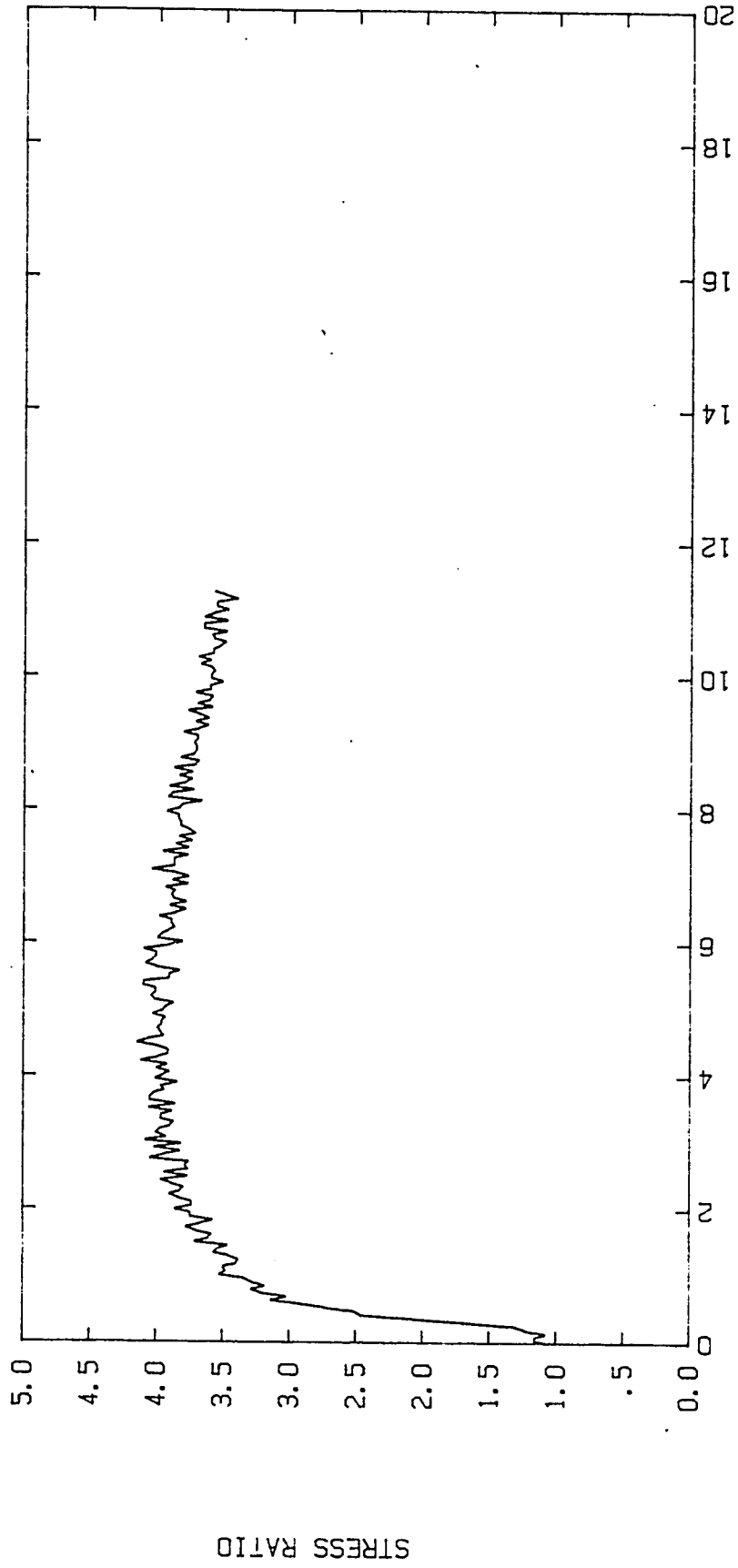


Fig. 5.4.2: Stress ratio versus percentage axial strain (obtained from the GDS).

DRAINED (D-1)  
—— VOLUME CHANGE v. % AXIAL STRAIN

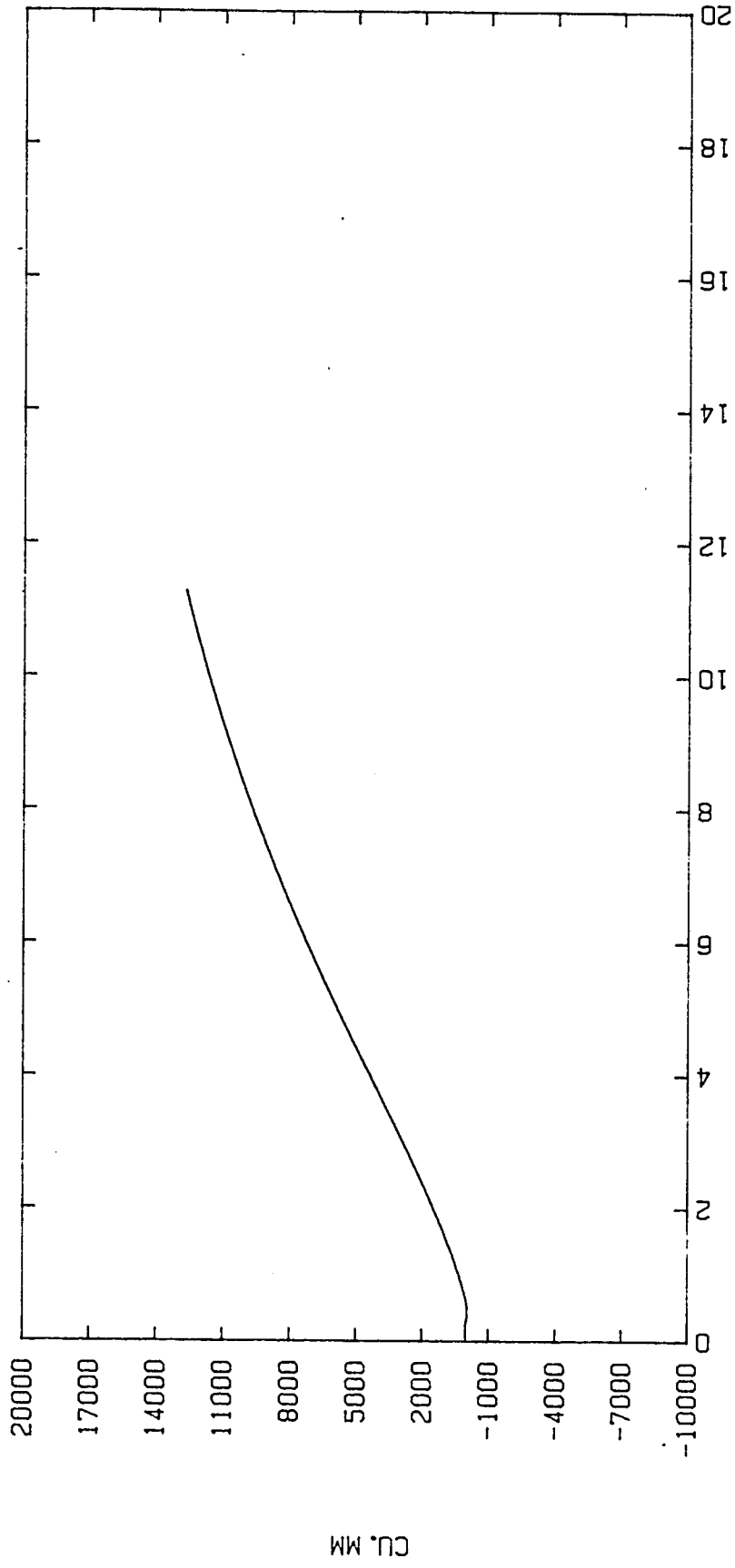
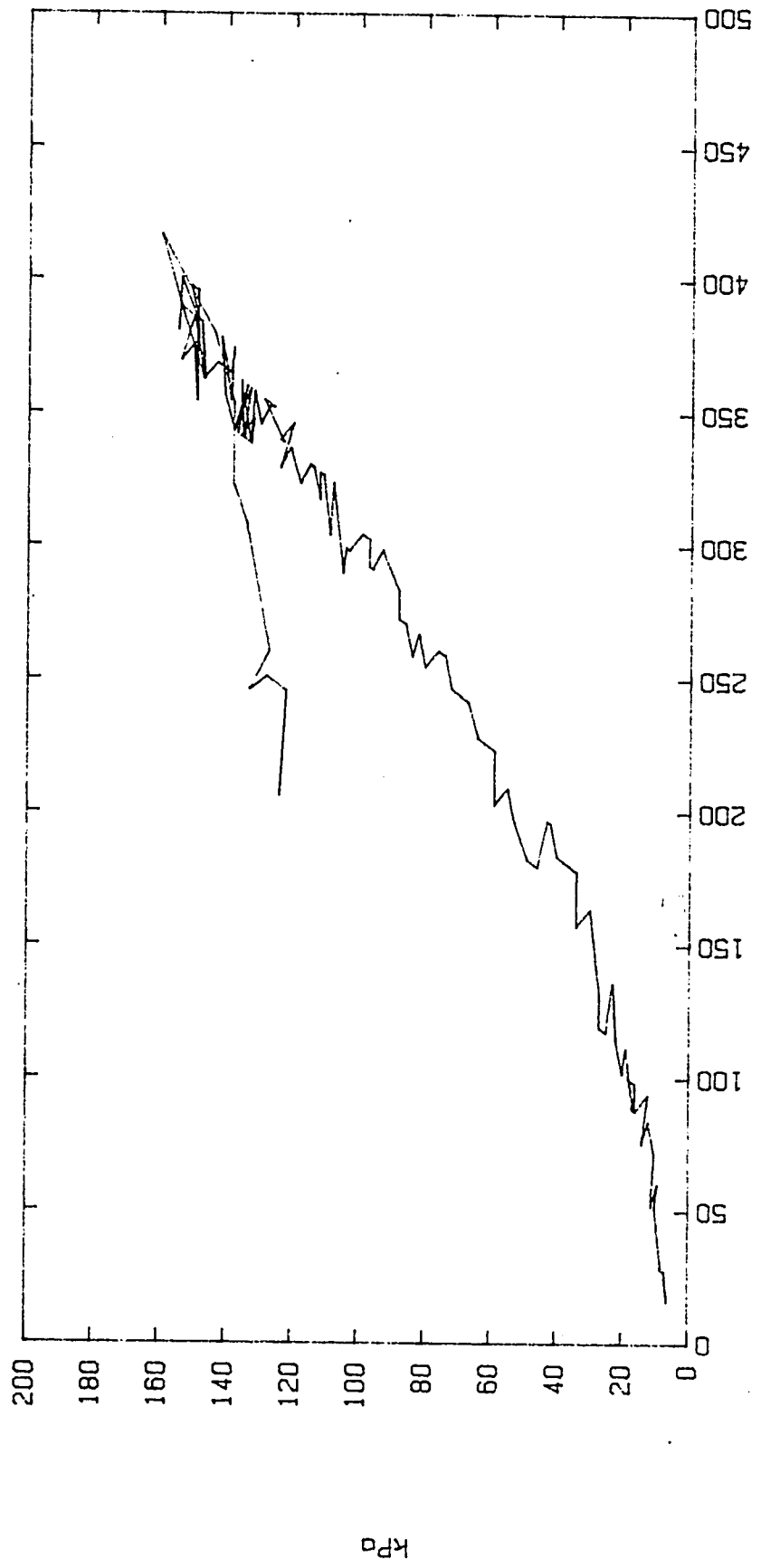


Fig. 5.4.3: Volume change versus percentage axial strain (obtained from the GDS).

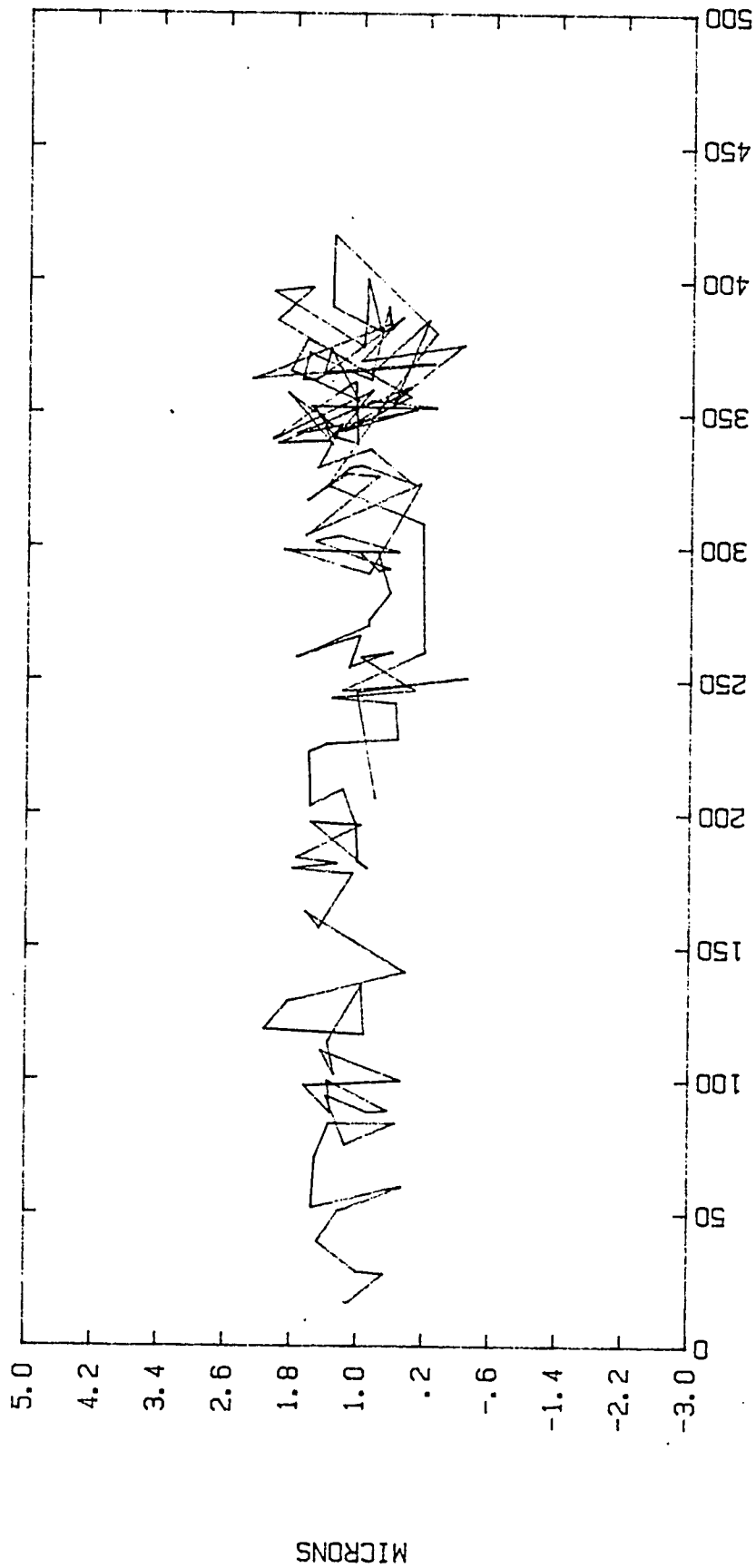
KO SWELLING CONSOLIDATION (KO-3)  
----- EFF RAD STRESS v. EFF AX STRESS



kPa

Fig. 5.5.1: Effective radial stress versus effective axial stress (obtained from the GDS)

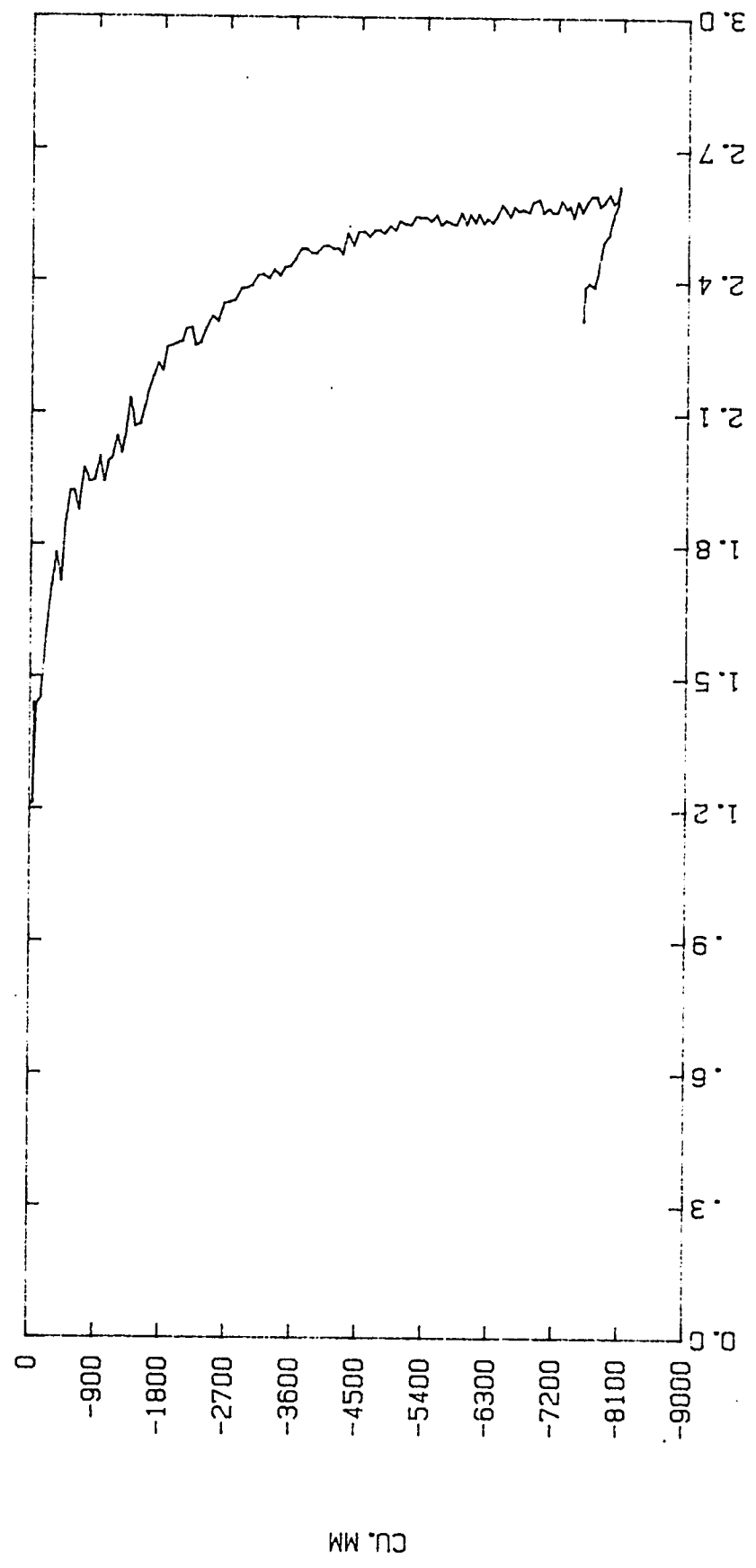
K0 SWELLING CONSOLIDATION (K0-3)  
----- AV DIA CHANGE v. EFF AX STRESS



kPa

Fig. 5.5.2: Average diameter change versus effective axial stress (obtained from the GDS)

KO SWELLING CONSOLIDATION (KO-3)  
—— VOLUME CHANGE v. LOG AX STRESS



LOG(10) kPa

Fig. 5.5.3: Volume change versus LOG axial stress (obtained from the GDS).

CYCLIC LOADING (CL-2)  
AXIAL STRESS v. TIME

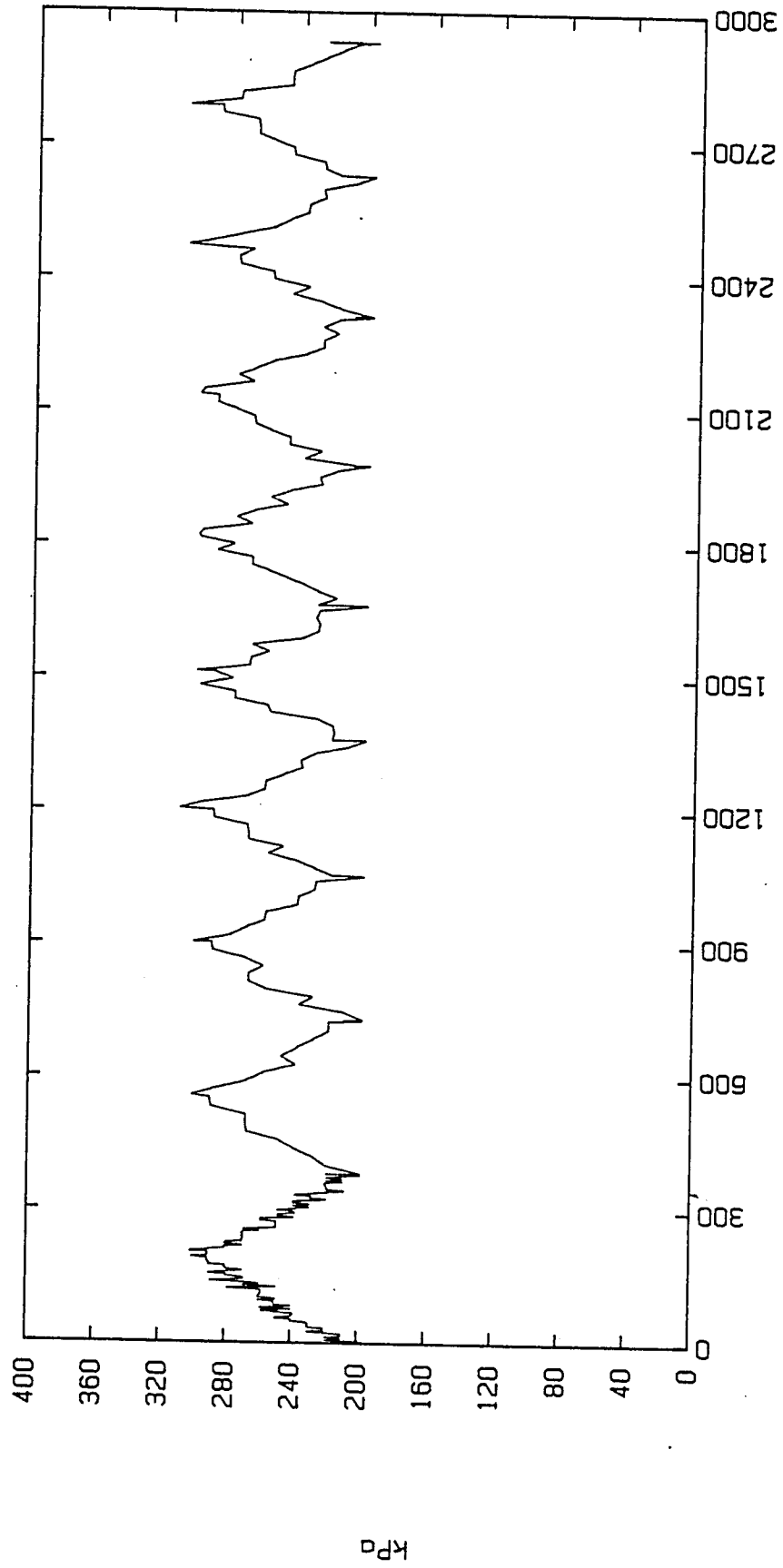
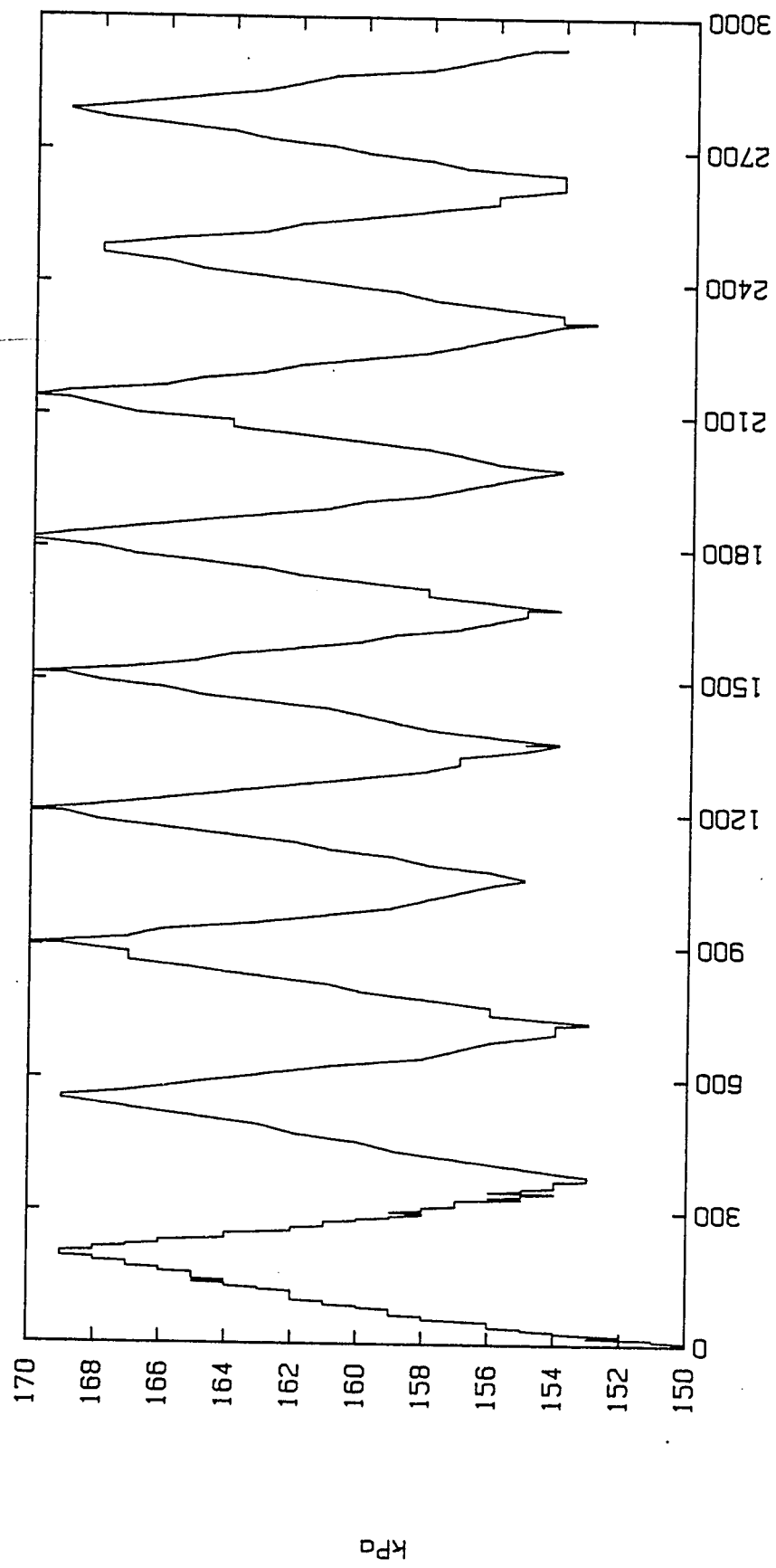


Fig. 5.6.1: Axial stress versus time (obtained from the GDS)

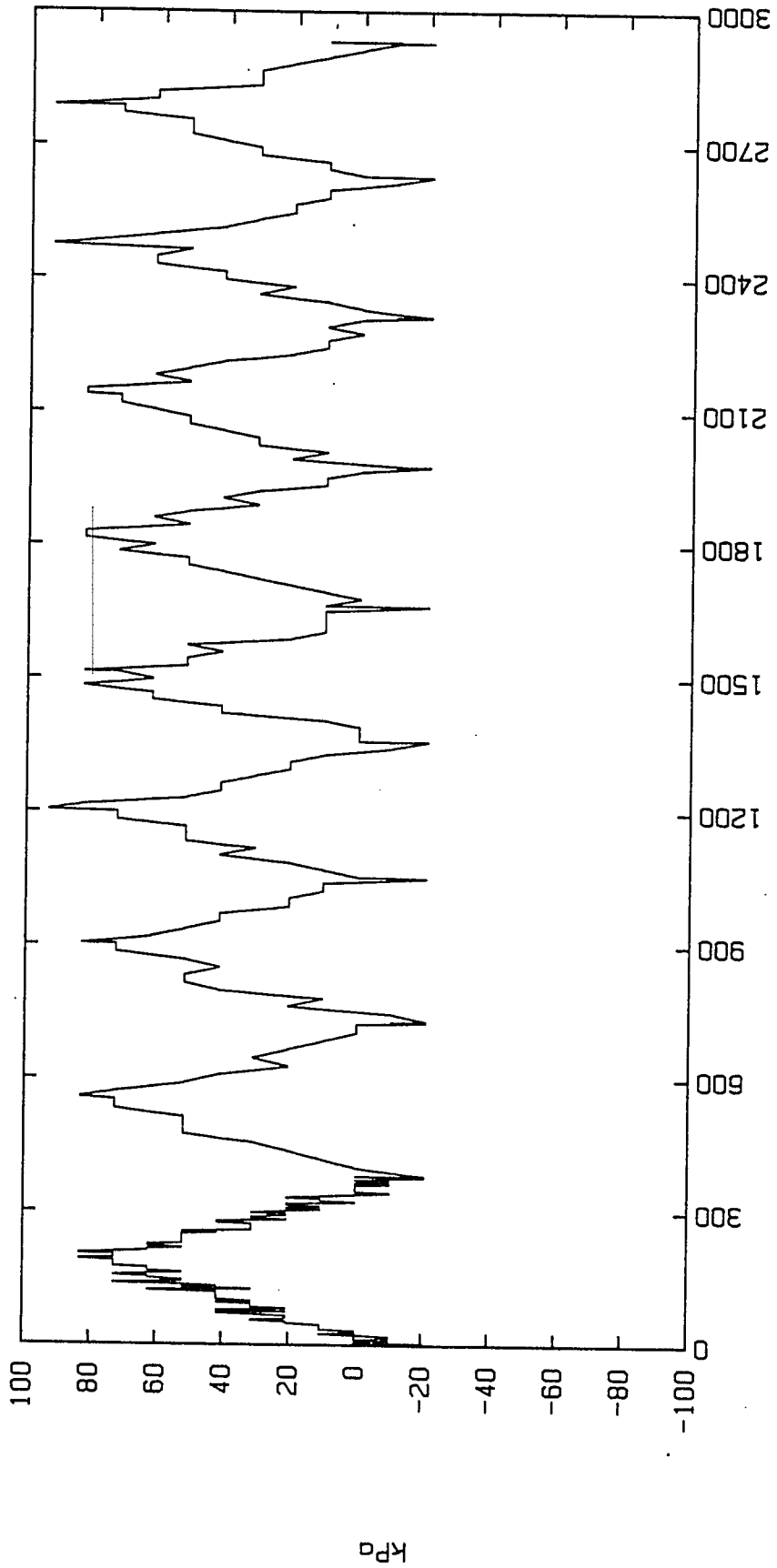
CYCLIC LOADING (CL-2)  
—— PORE PRESSURE v. TIME



SECONDS

Fig. 5.6.2 Pore pressure versus time (obtained from the GDS)

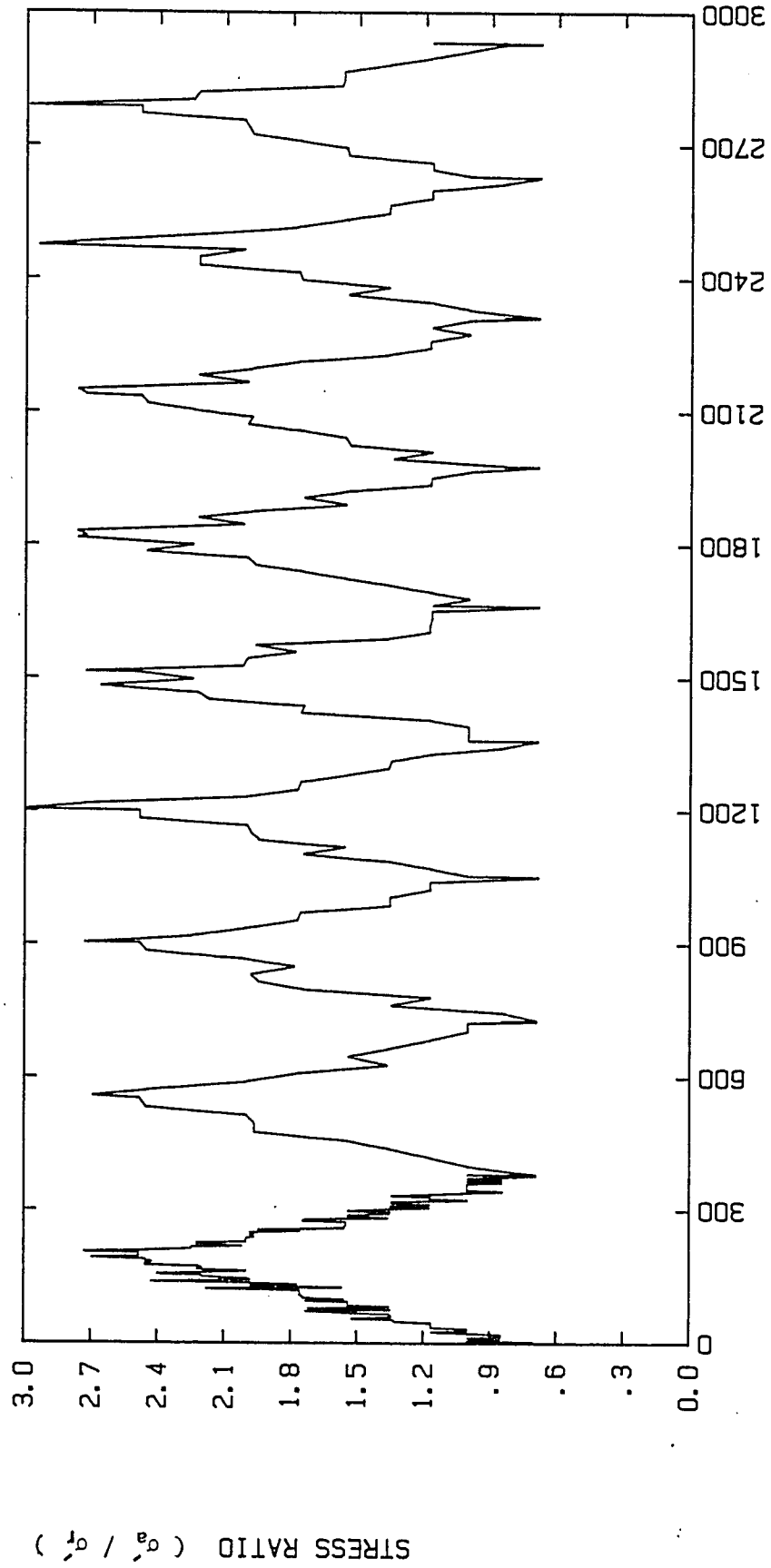
CYCLIC LOADING (CL-2)  
DEV STRESS v. TIME



SECONDS

Fig. 5.6.3: Deviator stress versus time (obtained from the GDS)

CYCLIC LOADING (CL-2)  
STRESS RATIO v. TIME



SECONDS

Fig. 5.6.4: Stress ratio versus time (obtained from the GDS)

CYCLIC LOADING (CL-2)  
----- AXIAL STRESS v. % AXIAL STRAIN

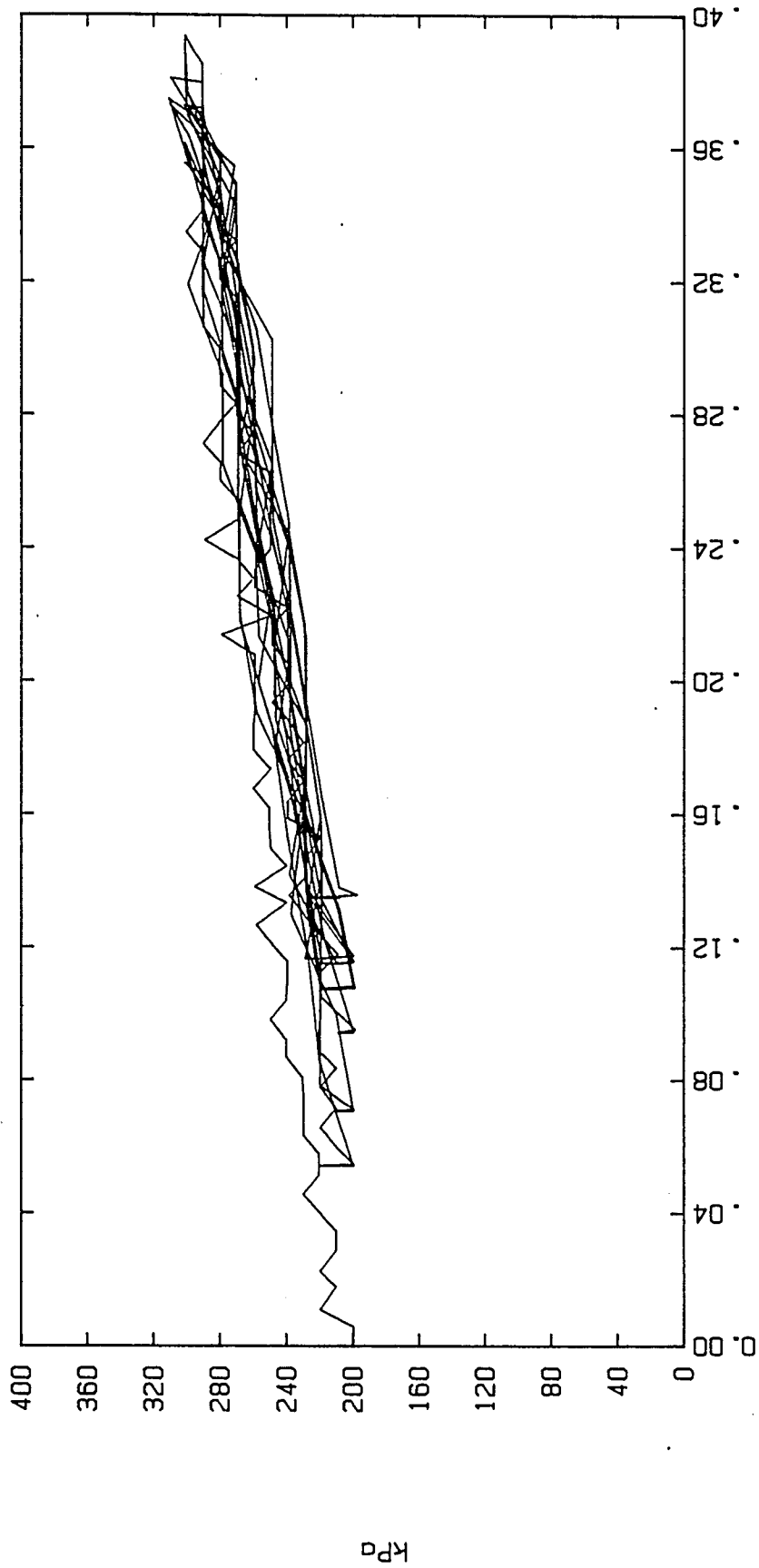
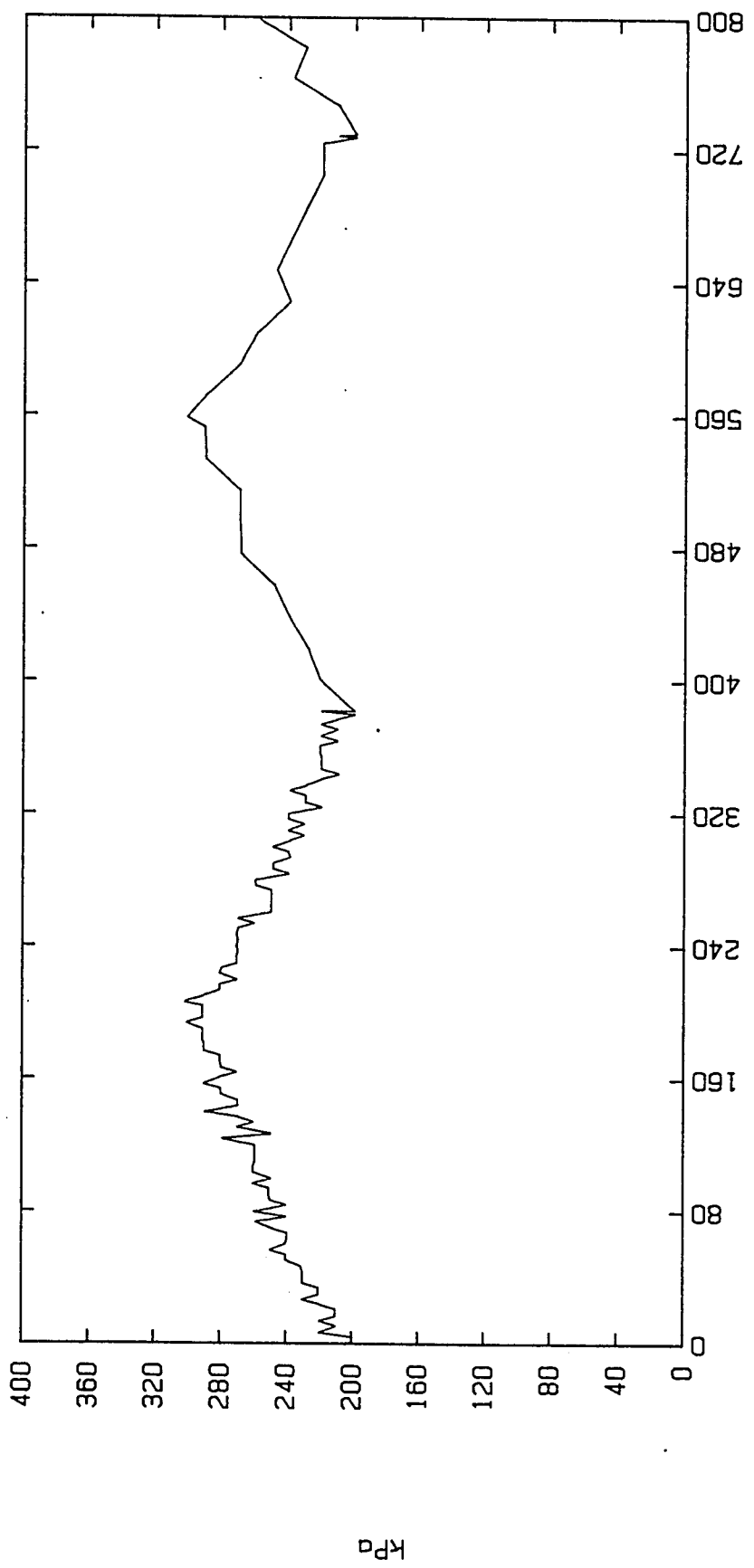


Fig. 5.6.5: Axial stress versus percentage axial strain  
(obtained from the GDS)

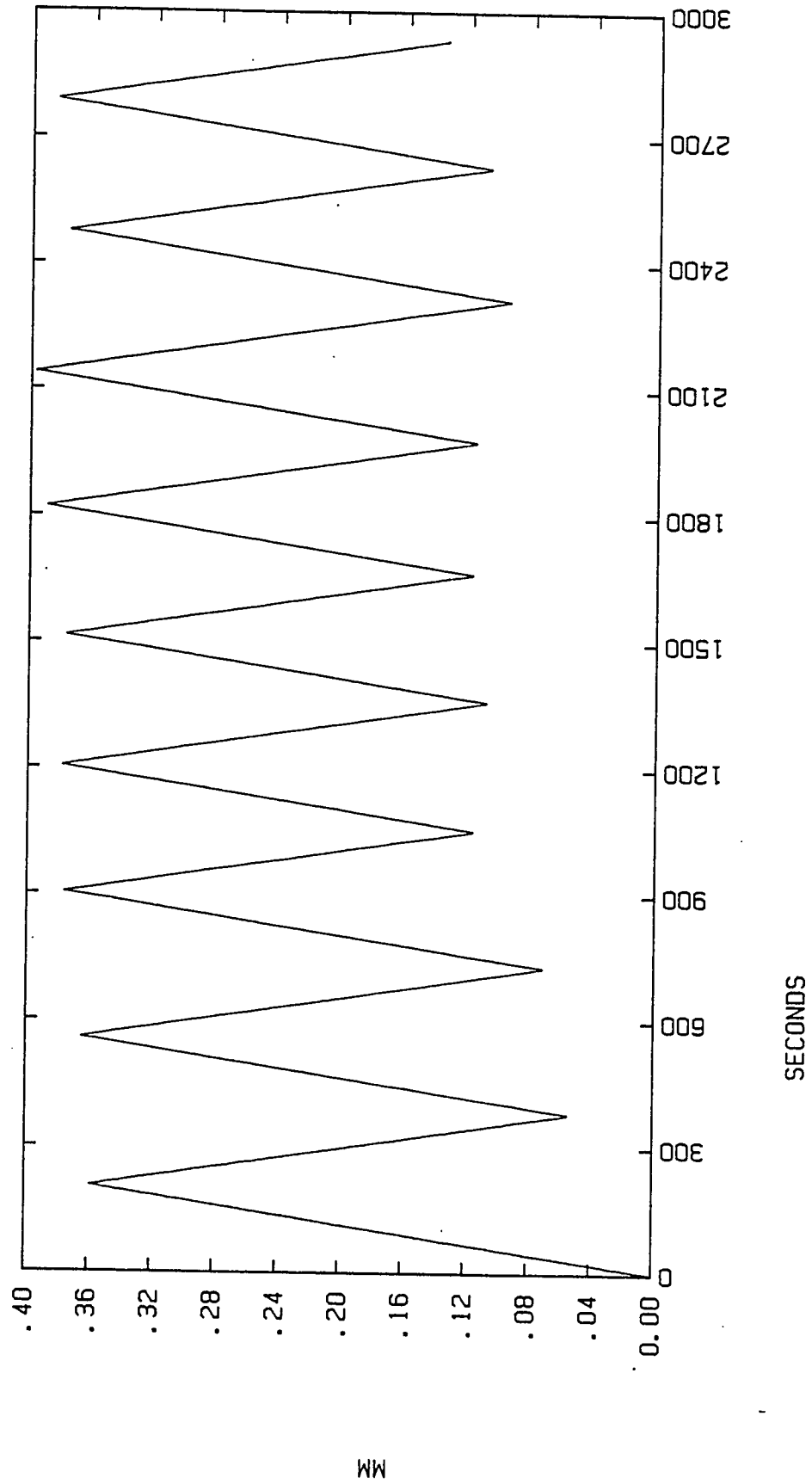
CYCLIC LOADING (CL-2)  
AXIAL STRESS v. TIME



SECONDS

Fig. 5.6.6: Axial stress versus time (obtained from the GDS)

CYCLIC LOADING (CL-2)  
LENGTH CHANGE V. TIME



• Fig. 5.6.7: Length change versus time (obtained from the GDS)

Fig. 4.7.8 CONSOLIDATION (C-15)  
VOLUME CHANGE v. TIME

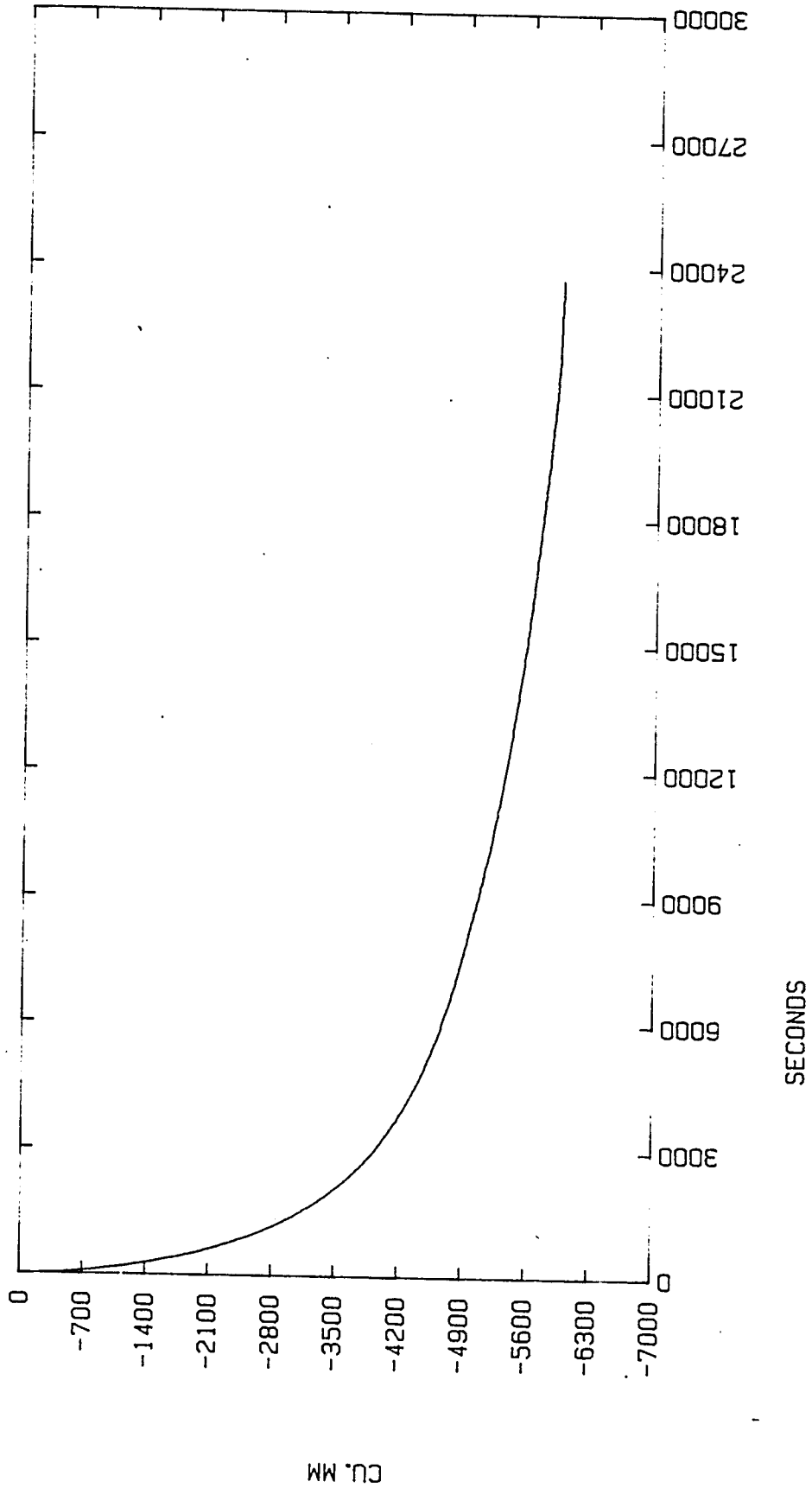
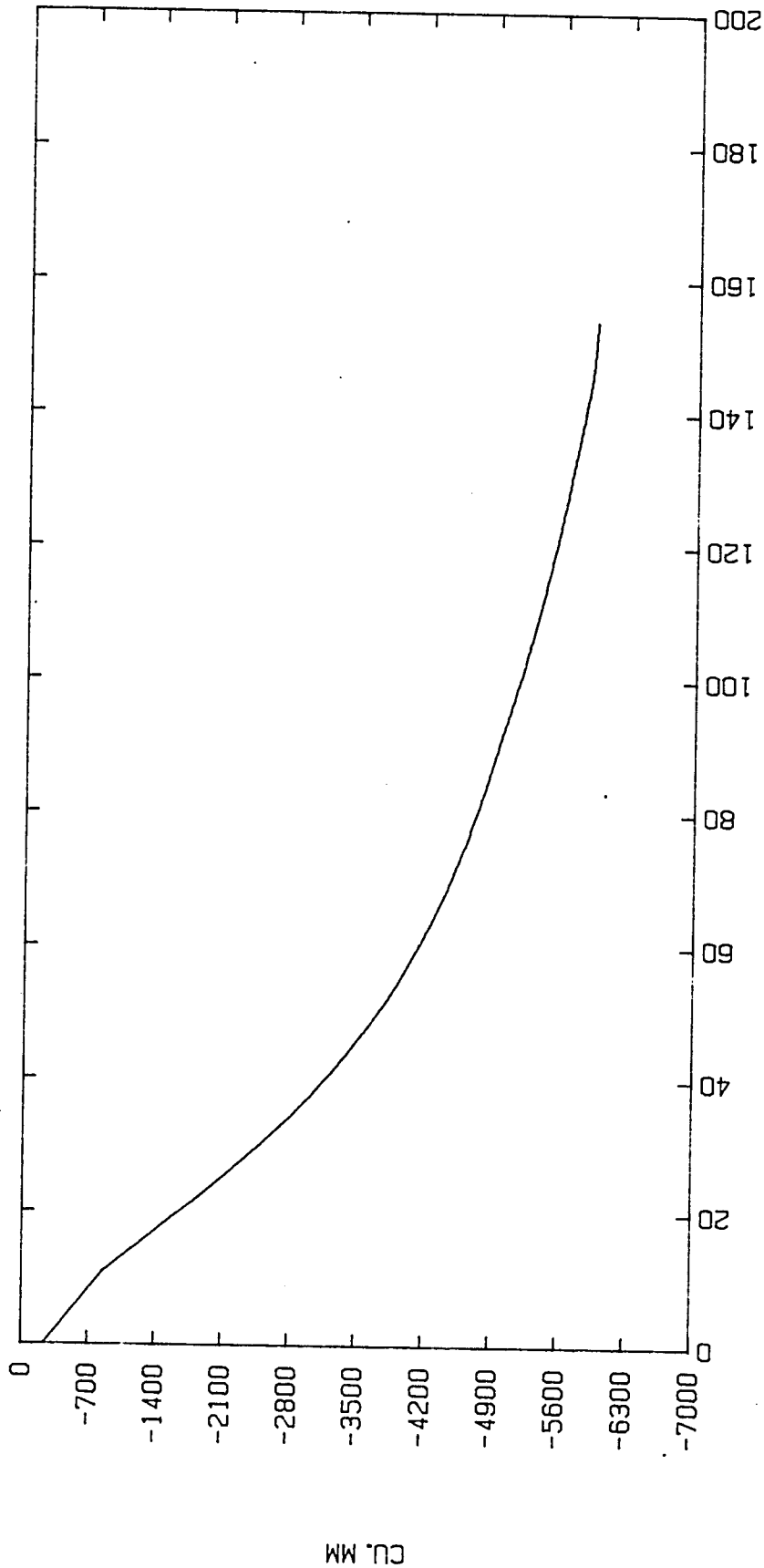


Fig. 5.6.8: Volume change versus time (obtained from the GDS)

CONSOLIDATION (C-15)  
VOLUME CHANGE v. SQRT(TIME)



SQRT (SECS)

Fig. 5.6.9: Volume change versus square route of time (obtained from the GDS).

C.U. MM

APPENDIX A

## 6. Testing Rates

### 6.1 Introduction

For most of the tests in the package the operator has the choice of rate at which the test will proceed.

There are three rate modes to choose from, these are:

1. Axial total stress control (kPa/hour)
3. Radial total stress control (kPa/hour)
5. Axial deformation control (mm/hour)

Axial deformation control is the most common mode of control. Axial total stress control is also available. Radial total stress control is required for stress paths where axial stress is not changing or changing by a small amount only.

For cyclic loading the rate is defined by the period and the amplitude and hence the rate of change is variable.

**NOTE:** System control is carried out incrementally by the computer sending out instructions on the interface bus to cause the controllers to transmit their data (pressure, volume change, status). This information is processed by the computer which then sets the current target by reference to the real time clock. Accordingly, at fast testing rates the incremental nature of the control adjustments may become apparent with, for example, a linear ramp of axial deformation versus time being approximated to by a "staircase".

The minimum changes possible are 1 kPa in pressure or 0.5 mm<sup>3</sup> in volume. Given a "staircase" rising or falling by these amounts, there is no minimum testing rate.

In the following subsections (6.2-6.4) the equations for test rate control are developed. The following values can be defined:

$t_0$  = time of test initiation

$t$  = current time

$R$  = required rate at which test is to proceed.

### 6.2 Axial Deformation Control

Axial deformation is computed from the volume change measured by the lower chamber pressure controller. This volume change measurement will include expansion in the coiled metal tube connection between the controller and the cell, and expansion caused by stretching of the Bellofram rolling diaphragm. In common with conventional dial gauge measurement, this method

of assessing axial deformation makes no allowance for compression of the internal load cell if present. By inserting a solid brass "test specimen", the axial deformation (displacement of the base pedestal) based on volume change into the lower chamber was compared with the displacement indicated by a sensitive dial gauge mounted in the usual way. For a pressure variation of 2000 kPa in the lower chamber, the volume change owing to expansion of the metal tubing (in this case, copper) and stretching of the Bellofram seal amounted to approximately 0.5% of apparent axial strain.

The required value of axial deformation ( $\Delta L$ ) at any time can be calculated as:

$$\Delta L = R(t - t_0) \quad \dots (6.1)$$

but

$$\Delta V_0 = a\Delta L \quad \dots (6.2)$$

therefore the volume change in the lower chamber required to cause an axial deformation of  $\Delta L$  is:

$$\Delta V_0 = a R (t - t_0) \quad \dots (6.3)$$

The maximum rate is 100 mm/hour.

### 6.3 Axial Total Stress Control

if  $\sigma_{a0}$  is the initial value of axial stress, then the required value of axial stress  $\sigma_a$  at any time can be calculated as:

$$\sigma_a = \sigma_{a0} + R (t - t_0) \quad \dots (6.4)$$

Given the values  $\Delta V_0^*$  and  $p_r^*$  ( $=\sigma_r^*$ ) which existed at the time  $t$  (i.e. the last set of readings), then the required value of  $p$  can be calculated as follows:

from equation (2.3):

$$\varepsilon_a = \Delta V_0^* / (aL_0) \quad \dots (6.5)$$

from equation (2.4):

$$A = A_0 (1 + \Delta V_0^* / V_0) / (1 - \varepsilon_a) \quad \dots (6.6)$$

from equation (2.8):

$$p = (\sigma_a - \sigma_r^*) A/a + \sigma_r^* \quad \dots (6.7)$$

In the following tests: 1 - Unconsolidated Undrained  
2 - Consolidated Undrained  
3 - Drained

the cell pressure is held constant by commanding the cell

pressure controller to maintain a pressure of  $\sigma_{r0}$ . The initial approach to axial total stress control was to calculate  $p$  according to equation 6.7 and set that value on the lower chamber pressure controller. However, because the pressure controllers strive to maintain a digital value of pressure, and because the lower chamber and the cell are effectively the same fluid reservoir, there is not a unique solution to the stability of the cell. The net effect of this is that marginal pressure differences between the cell and lower chamber cause large fluid displacements between the cell and lower chamber - hence an oscillatory system.

To remove oscillation in tests 1,2 and 3 the following approach is taken:

- (i) The cell is maintained under pressure control.
- (ii) The lower chamber is maintained under volume control. This is achieved by calculating the Pressure/Volume-change relationship at the outset of the test by means of a small excursion in the lower chamber. A difference between target pressure in the lower chamber and actual pressure can then be converted into a volume change which will correct that pressure difference. Once the test is under way the lower chamber P/V relationship is calculated dynamically.
- (iii) In order to allow the cell pressure controller to respond rapidly to volume changes in the lower chamber, advantage is taken of the fact that the lower chamber and cell are almost a constant volume system. The cell pressure controller is therefore synchronised to volume change in the lower chamber as follows:
  - a) Put volume change  $\Delta V$  into lower chamber
  - b) Put volume change  $-0.95 \Delta V$  into cell
  - c) Command cell pressure controller to maintain  $\sigma_{r0}$  to allow for marginal differences and possible drainage.

#### 6.4 Radial Total Stress Control

If  $\sigma_{r0}$  is the initial value of radial stress, then the required value of radial stress  $\sigma_r$  at any time can be calculated as:

$$\sigma_r = \sigma_{r0} + R (t - t_0) \quad \dots (6.8)$$

APPENDIX B

## 11. Test: Continuous Linear Stress Paths

### 11.1 Introduction

The continuous linear stress path test allows a test specimen to be taken from a starting set of stress co-ordinates to a terminal set of stress co-ordinates in a series of connecting linear steps.

The stress co-ordinates are specified in terms of total stress. The test can be carried out in a drained or undrained mode.

If the operator knows the required stress path at the outset, then the total test can be defined by specifying up to ten sets of stress co-ordinates in the correct time sequence.

As an alternative the operator may elect to choose the next linear path on completion of the current one. In this way the operator may modify the path of the test as it progresses or may carry out tests exceeding nine linear paths.

The basic control algorithm for maintaining the stress path is as follows:

- (i) Calculate required stress co-ordinates  $\sigma_a, \sigma_r$
- (ii) Command cell pressure controller to maintain pressure  $\sigma_r$ .
- (iii) Amend  $\Delta V$ , until  $\sigma_a$  has been achieved.

### 11.2 Test Control

#### 11.2.1 Introduction

The operator defines the stress path in terms of total axial stress and total radial stress. The stress path is plotted during the test in the total stress space in which it was defined.

#### 11.2.2 Relationships Between $\sigma_a$ and $\sigma_r$ on Stress Path

Consider the general linear stress path defined by the coordinates  $(\sigma_{am}, \sigma_{rm}), (\sigma_{an}, \sigma_{rn})$ . The relationship between  $\sigma_a$  and  $\sigma_r$  on this stress path is as follows:

$$\Delta\sigma_r = K \Delta\sigma_a \quad \dots (11.1)$$

$$\text{where } K = (\sigma_{rn} - \sigma_{rm}) / (\sigma_{an} - \sigma_{am}) \quad \dots (11.2)$$

Or in absolute terms

$$\sigma_r = \sigma_{rm} + K\Delta\sigma_a \quad \dots (11.3)$$

Alternatively:

$$\sigma_a = \sigma_{am} + \Delta\sigma_r / K \quad \dots (11.4)$$

#### 11.2.3 Axial Stress Controlled Path

At any time the required value of  $\sigma_a$  can be calculated as

described in section 6.3, and hence  $p_s$  can be calculated and applied.

Equation (11.3) can then be applied to give  $\sigma_r$ .

#### 11.2.4 Radial Stress Controlled Path

At any time the required value of  $\sigma_r$  can be calculated using equation (6.8),  $\sigma_a$  can be found from equation (11.4), and hence  $p_s$  can be calculated using equation (6.7).

#### 11.2.5 Choice of Control

The system automatically chooses whether to use axial stress control or radial stress control. If axial total stress changes by more than radial total stress on a particular path then axial stress control is chosen, otherwise radial stress control is chosen.

### 11.3 Test Initialisation

#### 11.3.1 Drainage Conditions

IS THE TEST TO BE:-

- 1 = DRAINED
- 2 = UNDRAINED
- ?

If the reply is not equal to 1 or 2, then the question is prompted again.

#### 11.3.2 Stress Path Definition

IS THE COMPLETE STRESS PATH TO BE DEFINED NOW (Y OR N)?

If the reply is not "Y" OR "N", then the question is prompted again.

If "N", then enter 2 sets of co-ordinates (i.e. first path).

If the reply is equal to "Y", then the operator is asked to enter up to 10 sets of co-ordinates as follows:-

HOW MANY SETS OF CO-ORDINATES DO YOU WISH TO ENTER (MAX =10)?

If the reply is not in the range 2-10, then the question is prompted again.

When the required number of co-ordinates have been entered as described in 11.3.4, then the test continues.

### 11.3.3 Stress Co-ordinate Definition

ENTER CO-ORDINATES (n)

AXIAL, RADIAL E.G. 103, 85? The entered values are validated to be in the range 0-6000 axial, 0-1000 radial.

### 11.3.4 Check Entered Values

The entered information is displayed back to the operator as follows:

=====

LINEAR STRESS PATHS  
CO-ORDINATE SPACE IS TOTAL STRESS

SPECIMEN IS (DRAINED-  
(UNDRAINED)

STRESS PATH IS

1ST CO-ORD. 2ND CO-ORD RATE VALUE  
(9999,9999), (9999,9999), 9 9999 - repeated for  
each linear path

OK TO START (Y OR N)?

If the answer is "N",  
then continue at 11.3

Rate 1 is axial stress control, Rate 3 is radial stress control.

### 11.4 Print of Initial Conditions

The information described in section 11.3.4 is output on the printer.

### 11.5 Initial Conditions

$p_s = u_s$ , then if undrained  $\Delta V_s = 0$   
 $p_r$  and  $p_s$  are calculated as described in section 11.2 using  
target time = 0.

### 11.6 Test Execution

#### 11.6.1 Start

The timer is started.

#### 11.6.2 Controller Poll

A set of readings is taken from each controller.

### 11.6.3 Control Calculations and Adjustments

The control calculations are evaluated as described in section 11.2, and new values of  $p$ , and  $p$ , or  $\Delta V$ , are set.

### 11.7 Presentation of Results

A plot of total radial stress versus total axial stress is given on the screen and is automatically transferred to the printer at the termination of the test. An example of the graph plotted from test data is shown below:

=====

LINEAR STRESS PATHS  
CO-ORDINATE SPACE IS TOTAL  
SPECIMEN IS UNDRAINED  
STRESS PATH IS

1ST CO-ORD	2ND CO-ORD	RATE	VALUE
(100,100)	(200,100)	1	60
(200,100)	(200,180)	3	60
(200,180)	(400,300)	1	60
(400,300)	(400,380)	3	60
(400,380)	(500,300)	1	60
(500,300)	(600,400)	3	60
(600,400)	(500,500)	3	60

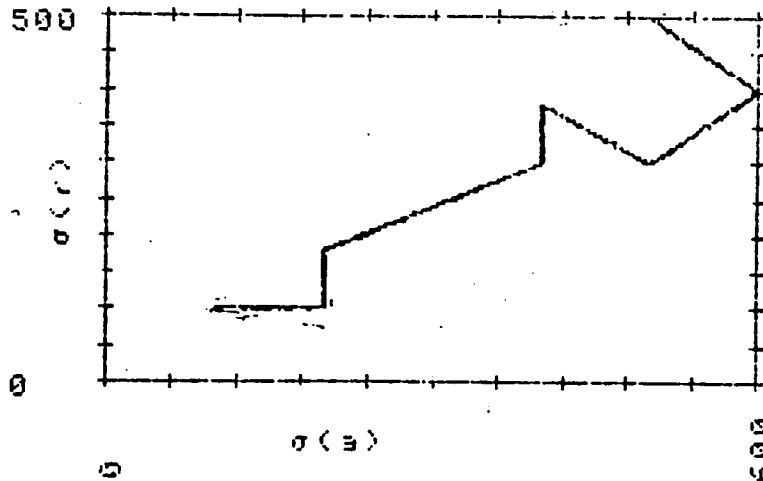


Figure 6. Computer plot of total radial stress against total axial stress for continuous linear stress paths.

### 11.8 Saving Results

As described in section 7.7.

### 11.9 Tabulating and Further Plotting of Results

See Chapter 13. An example of the stress path referred to above is plotted from test data in  $p, q$  space as shown below.

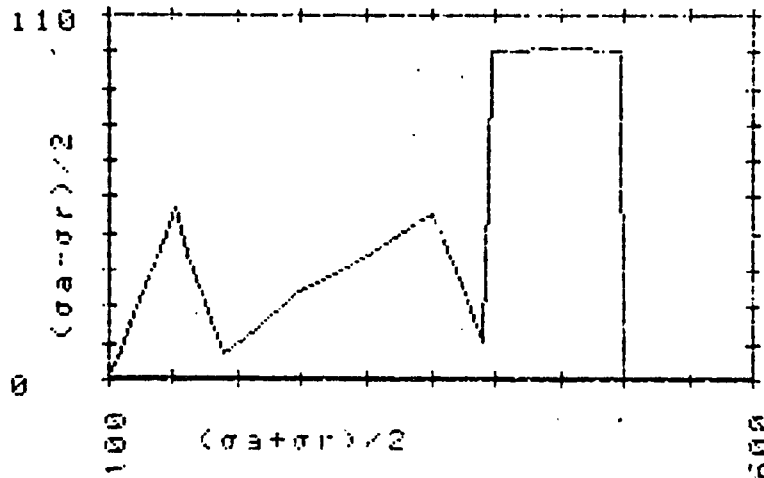


Figure 7. Computer plot of maximum shear stress ( $q$ ) against mean total stress ( $p$ ) for continuous linear stress paths defined in  $(\sigma_a, \sigma_r)$  space.

### 11.10 Test Abort

The test may be aborted at any stage by pressing the "PAUSE" key on the computer keyboard.

To obtain a print of the screen and to save the results, key in: CONT 5368, "endline".

APPENDIX C

## 10. Test: $K_0$ Consolidation/Swelling

### 10.1 Introduction

This test carries out consolidation and swelling of the test specimen at "zero" radial strain by keeping the computed mean diameter of the test specimen constant to  $\pm 1$  micrometre (micron).

The algorithm needed to control the  $K_0$  test is in two steps:

- (i) Set the lower chamber pressure and associated volume change.
- (ii) Adjust the cell pressure in such a way as to cause the volume change in the specimen ( $\Delta V_s$ ) to keep the test specimen average diameter constant.

The algorithm described above does not adjust itself automatically to the consolidation rate of the specimen. It is therefore most important that the operator use a testing rate that is not too fast for the permeability of the test specimen.

The visible effect of a testing rate that is too fast is that the apparent  $K_0$  value is too high, and for very fast rates the value of  $K_0$  approaches unity. This is due to the following causes:

- \* The system will force consolidation by increasing the cell pressure and eventually compressing the test specimen sufficiently to force a volume change by compression.
- \* The increase in cell pressure causes an equivalent increase in the axial stress, hence  $K_0 = \sigma_r' / \sigma_a'$  will tend towards unity.

The operator is asked the following sequence of questions:

#### 10.1.1 Testing Rate

Testing rate as per 7.1.1.

**NOTE:** The recommended testing rate mode is axial total stress control. A suitable rate for a fine sand is 60 kPa/h. The rate of cell pressure adjustment is geared to the testing rate.

#### 10.1.2 Terminal Consolidation Stress

WHAT IS THE VALUE OF AXIAL  
EFFECTIVE STRESS REQUIRED  
AT THE END OF  
CONSOLIDATION?

The value entered is validated  
to be in the range 1-2000.

**10.1.3 Swelling Request**

DO YOU REQUIRE THE TEST SPECIMEN TO SWELL BACK AT THE END OF CONSOLIDATION (Y OR N)?

**10.1.4 Overconsolidation Ratio**

If the answer to 10.1.3 is "Y", then:-

WHAT IS THE REQUIRED OVERCONSOLIDATION RATIO?

The value entered is validated to be in the range 1-100.

**10.1.5 Plot Selection**

DO YOU REQUIRE A PLOT OF:-

1 = LOG AXIAL EFFECTIVE STRESS V. VOLUME CHANGE  
2 = EFF. RADIAL STRESS V. EFF. AXIAL STRESS

?

If the reply is not 1 or 2, then the question is prompted again.

**10.1.6 Volume Change**

If the answer to question 10.1.5 is "1", then:

WHAT IS THE ANTICIPATED VOLUME CHANGE?

The value input is validated to be in the range 0 to  $-(0.2V_v)$

**10.1.7 Start Request**

OK TO START (Y OR N)?

If the answer is "N", then continue at 10.1.2.

**10.2 Initial Output**

The following information is output on the printer.

=====

TEST - K0 CONSOLIDATION/SWELLING

CELL PRESSURE = 9999 kPa

PORE PRESSURE = 9999 kPa

(AXIAL TOTAL STRESS CONTROL)

(AXIAL DEFORMATION CONTROL)

AT RATE OF 9999 MM/HR  
KPA/HR

TERMINAL EFFECTIVE AXIAL STRESS  
= 9999 KPA

OVERCONSOLIDATION RATIO = 99

### 10.3 Initial Conditions

$$p_1 = \sigma_{ro}$$

$$p_s = u_0$$

$$p_2 = p_1 + \Delta p \text{ (as result of docking procedure)}$$

### 10.4 Test Execution (Consolidation)

#### 10.4.1 Start

The timer is started.

#### 10.4.2 Controller Poll

A set of readings is taken from the controllers.

#### 10.4.3 Volume Change

If the rate type is 5, then  $\Delta V_0$  is calculated according to the equations in section 6.2 and the new value of  $\Delta V_0$  applied.

#### 10.4.4 Pressure Change

If the rate type is 1, then  $p$  is calculated as described in section 6.2, and the new value of  $p$  applied.

#### 10.4.5 Diameter Control

The current average diameter of the test specimen is calculated as

$$D = (4A/\pi)^{1/2} \quad \dots (10.1)$$

The difference between the original diameter  $D_0$  and the current mean diameter  $D$  is computed and held within a tolerance by operating the cell pressure controller.

#### 10.4.6 Repeat

Continue at 10.4.2.

### 10.5 Test Termination (Consolidation)

The consolidation phase is terminated when the value of axial effective stress entered at 10.1.2 is reached.

## 10.6 Test Execution (Swelling)

### 10.6.1 Swelling Bypass

If the answer to question 10.1.3. was "N"; then the swelling phase is bypassed.

### 10.6.2 Loading Reversal

To set the initial conditions correctly, the computer carries out the following:

- \* Change the sign of the rate entered at 10.1.1 to indicate the swelling phase.
- \* If rate type = 1, then set  $\sigma_{a0}$  = current value of  $\sigma_a$
- \* Set  $t_0$  = current time.

The test now continues as described in 10.4.

## 10.7 Test Termination (Swelling)

The swelling phase is terminated when (value of axial effective stress at end of consolidation entered at 10.1.2)/(current axial effective stress) is greater than or equal to the overconsolidation ratio entered at 10.1.4.

## 10.8 Presentation of Results

### 10.8.1 Volume Change

The volume change from the back pressure controller ( $\Delta V_v^*$ ) is plotted on the Y axis, against  $\log_{10} \sigma_a'$  on the X axis. The graph is scaled from 0 to  $\log_{10} \sigma_{a' \max}$  on the X axis; and 0 to  $-(0.2 V_v)$  on the Y axis.

The axial effective stress is calculated using equations 2.5. and 2.6. The volume change  $\Delta V_v^*$  is the reading from the back-pressure controller.

### 10.8.2 Axial v Radial Effective Stress

The effective radial stress  $\sigma_r'$  is plotted on the Y axis, against effective axial stress  $\sigma_a'$  on the X axis. The graph is scaled from 0 to  $\sigma_{a' \max}$  on both axes (NB  $\sigma_{a' \max}$  entered at 10.1.2 above).

Axial effective stress is calculated using (2.6). Radial effective stress is calculated using (2.7).

An example of the graph plotted from test data is shown below.

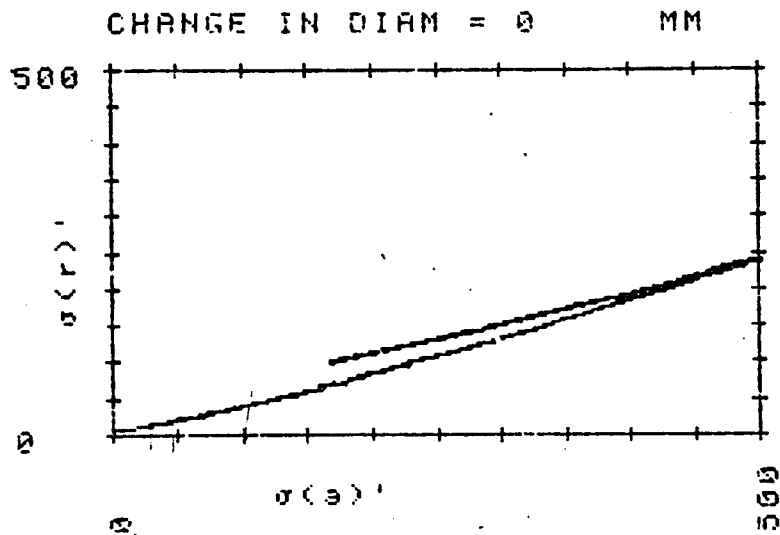


Figure 4. Computer plot of effective radial stress against effective axial stress for  $K_0$  consolidation and swelling.

#### 10.9. Saving Results

As described in 7.7.

#### 10.10 Tabulating and Further Plotting of Results

See Chapter 13. An example of the graph of average diameter change with axial effective stress plotted from test data is shown below.

---

#### TEST - $K_0$ CONSOLIDATION/SWELLING

CELL PRESSURE 500 KPA  
BACK PRESSURE 490 KPA

AXIAL TOTAL STRESS CONTROL  
AT RATE OF 60 KPA/HR

TERMINAL EFFECTIVE AXIAL STRESS  
= 500 KPA

OVERCONSOLIDATION RATIO = 3

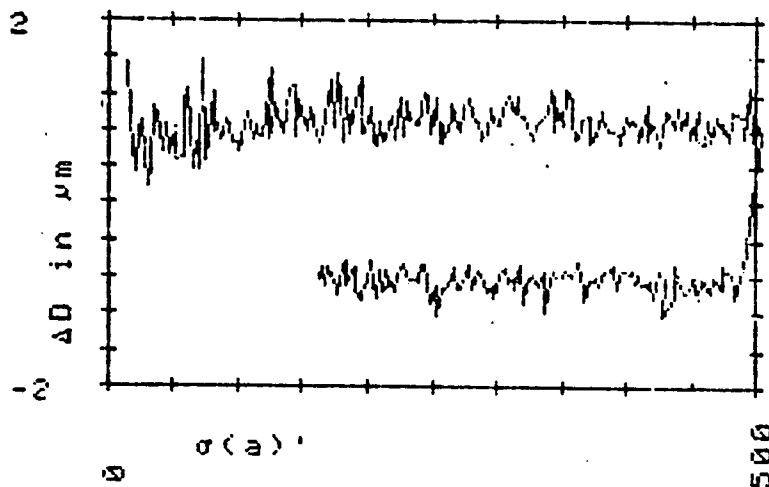


Figure 5. Computer plot of change in test specimen diameter against effective axial stress for  $K_0$  consolidation and swelling.

#### 10.11 Test Abort

The test may be aborted at any stage by pressing the "PAUSE" key on the computer keyboard.

If the operator wishes to obtain a print of the screen and to save the results the following should be keyed in:

CONT 4392, "endline".