UNIVERSITY OF NOTTINGHAM

DEPARTMENT OF CIVIL ENGINEERING

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by

Robert Francis Overy, B.Sc.(Hons)

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ABSTRACT

The aim of this research was to investigate the behaviour of a clay subjected to cyclic loading of a type suitable for use in the design and understanding of wave loaded foundations. The material investigated was Keuper marl, a silty clay, found extensively in Great Britain and extending under the North Sea. A review of previous research is presented and details of new equipment developments and experimental techniques are included.

Laboratory testing of the material was carried out in a triaxial apparatus capable of applying repeated stress in both axial and radial directions. The clay was reconstituted from a slurry and was anisotropically consolidated under K_0 conditions in an attempt to simulate field conditions. The main test programme involved normally consolidated soil specimens being subjected to undrained cyclic loading interspersed with drained periods under static load.

The main conclusions drawn from this research were:

(i) The permanent response of Keuper marl under cyclic loading at 0.1 Hz was predominantly viscous in nature.

(ii) Permanent shear strain and pore pressure developed with each load cycle until failure occurred or an equilibrium state was achieved. For the stress levels applied, at least one drainage period was required for equilibrium.

(iii) The resilient response of Keuper marl was independent of viscous effects and the effective stress path was unique when the behaviour was elastic.

(iv) Upper and lower bounds to the viscous response were indicated and a unique failure envelope was found for compression tests.

The data produced was used to analyse a model prediction by Carter et al., (1979) and initiate new developments so as to model the viscous effects seen in the experimental work.

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CONTENTS

LIST OF SYMBOLS

B	pore pressure coefficient
C_c	slope of normal consolidation line in V-log p' space
D	damage potential
D.C.	direct current
G	shear modulus
G_s	specific gravity
Hz	Hertz (1/seconds)
K	bulk modulus
K	stress ratio during consolidation
K_o	stress ratio during consolidation giving no radial strain
LVDT	linear variable differential transformer
M_r	resilient modulus of elasticity
N	number of load cycles
OCR	overconsolidation ratio
S	stress ratio
V	specific volume (1 + e)
V_λ	specific volume of λ line at p'=1
V_κ	specific volume of κ line at p'=1
cs	centistokes
c_v	coefficient of consolidation
e	voids ratio
k	coefficient of permeability
m_v	coefficient of volume compressibility
u	pore pressure
w_L	liquid limit
w_P	plastic limit
Γ	specific volume of critical state line at p'=1
Δ	small increment
μ	10^{-6}

M	ratio of q/p' at failure		
γ_w	density of water		
η	ratio q/p'		
θ	parameter relating current stresses to yield stresses		
κ	slope of overconsolidated line in $V - \ln p'$ space		
λ	slope of normally consolidated line in $V - \ln p'$ space		
ν	Poisson's ratio		
τ	shear stress		
Φ'	angle of internal friction		
$\sigma_1, \sigma_2, \sigma_3$	principle stresses		
σ_a	axisymmetric axial stress - triaxial axial stress		
σ_r	axisymmetric radial stress - triaxial radial stress		
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	principle strains		
ε_a	axisymmetric axial strain - triaxial axial strain		
ε_r	axisymmetric radial strain - triaxial radial strain		
		triaxial stresses	three dimensional stress
p	normal stress	$\dfrac{\sigma_a + 2\sigma_r}{3}$	$\dfrac{\sigma_1+\sigma_2+\sigma_3}{3}$
q	deviator stress	$\sigma_a - \sigma_r$	$\dfrac{1}{\sqrt{2}}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2\right]^{\frac{1}{2}}$
ε_v	volumetric strain	$\varepsilon_a + 2\varepsilon_r$	$\varepsilon_1 + \varepsilon_2 + \varepsilon_3$
ε_s	shear strain	$\frac{2}{3}(\varepsilon_a - \varepsilon_r)$	$\dfrac{\sqrt{2}}{3}\left[(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2 + (\varepsilon_3-\varepsilon_1)^2\right]^{\frac{1}{2}}$

Superscripts

p	permanent
r	resilient

Stresses listed are total stresses. Effective stresses are denoted by the use of primes.

Compressive stresses and strains are taken as positive. Other symbols are defined and used in restricted conditions as the need arises.

LIST OF PLATES

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CHAPTER ONE

INTRODUCTION

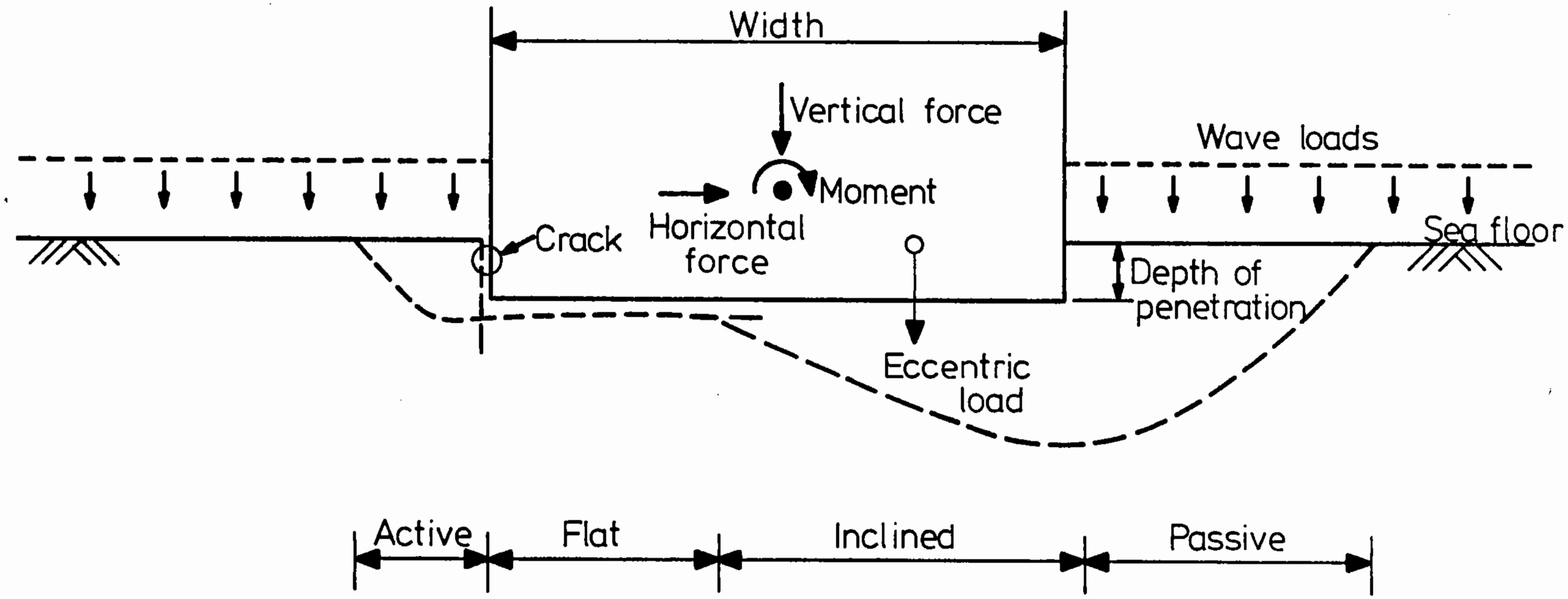
The increased world demand for oil in the last 30 years has resulted in the exploration of increasingly hostile environments. The first offshore oil rigs were constructed off the coast of Louisiana in 6-15 m of water and were held in position by six piles, one driven through each leg. No prior geotechnical site investigation was undertaken and piles were driven to refusal (McClelland, 1974). As the water depths encountered increased, attempts were made to investigate the soils that formed the sea bed. The occurrence of hurricanes caused failure of some offshore structures in the Gulf of Mexico, which emphasised the need for these investigations (Focht and Kraft, 1977).

Oil exploration in the North Sea began in the early 1970's, in water depths of 100 metres or more, following finds of gas fields in the southern North Sea. The North Sea has a complex geology consisting of quaternary deposits (Schjetne et al., 1979), the clays have been overconsolidated by repeated periods of complete or partial glaciation. Typically, the overconsolidation ratio varies from 50 or greater at the sea floor becoming normally consolidated at about 50 m penetration. Sand strata occur, interbedded with the clays and are generally very dense due to the shearing action of waves (Bjerrum, 1973). However, soft, normally consolidated clays exist interspersed with the above and it has been proposed by Schjetne et al. (1979) that these were formed by layers of permafrost which prevented the soil stress history from developing and also caused migration of water from other layers. Recent deposits have filled the sea floor depressions with mud which is normally consolidated. These normally consolidated layers can be 10-20 m thick.

Two main types of rig have been used to date; steel template structures which are supported by large pile groups and gravity structures which rest on the sea bed and derive their stability from their submerged weight. An oil rig and its foundation must be designed to withstand the environmental loading which, for design purposes, can be separated into vertical and horizontal forces and resulting overturning moments. These forces are due to the self weight of the structure, storm waves, winds and currents. The loads cause various settlements; an initial settlement on installation, consolidation settlements, secondary settlement, permanent strain during undrained loading, strain from dissipation of pore pressures, differential settlement, cyclic movements and lateral displacement (Smits, 1980). Possible failure modes for a gravity structure can be due to active or passive pressures, sliding or lack of bearing capacity as summarised in Figure 1.1. For a piled structure, inadequate skin friction or bearing capacity of the piles or differential settlement of the legs can cause failure.

The design of an offshore oil rig to withstand the above conditions was originally carried out by extrapolating practice from land based structures. As experience was gained and by using the data accumulated, safer and more economic designs were possible. To this end, the designer has certain tools available, namely:-

Geophysical surveys
Insitu tests and site investigation
Large scale tests
Sampling for laboratory tests
Laboratory investigations
Material and Finite element models



LIMITING EQUILIBRIUM FOR FOUNDATION STABILITY ANALYSIS

(after Lauritzsen and Schjetne, 1976)

Figure 1.1

Geophysical surveys are carried out by towing a streamlined body through the water. This carries an acoustic system so that echoes can be picked up from strata in the sea bed to give a vertical profile of the deposits. Other types of scanner such as the side scanner will give a horizontal profile of the sea bed surface (Andresen et al., 1979).

Insitu tests have evolved with the development of the industry and are now capable of producing more reliable data (Eide, 1974; Andresen et al., 1979). The most common test is the cone penetrometer which gives a measure of the undrained shear strength. It is also possible with some cones to measure side friction independently for use in pile design.

Retrieving samples of the sea bed deposits presents many problems. One technique is to drop a sample tube on a wire so that it partially penetrates the sea bed; it can then be hammered into the soil by a weight (Bjerrum, 1973; Eide, 1974). Another percussion method can be included in a drill string (McClelland, 1974). The major drawback of these methods is that the amount of material retrieved is often small while disturbance is large. Better quality samples have been retrieved by push sampling using the reaction of the drill string, but this is limited by the weight of the string. More modern methods use a rig which is lowered onto the sea bed. This guides the drill string and uses hydraulic rams to grip and push the sampler into the soil. This gives less disturbance and greater available force (Zuidberg, 1974; Sullivan, 1980).

Laboratory tests using site samples suffer from the drawback that no matter how carefully they are handled, some disturbance will occur. Possibly more important than this, is the stress relief caused by bringing the soil to the surface, during which irreversible changes can occur. Site samples and insitu tests are essential to obtain the quantitative data needed for today's empirical design methods. Due to the difficulties involved, qualitative tests can be satisfactorally performed on laboratory specimens where the soil is reconstituted from a slurry and has its stress history controlled. There is the added advantage that there is no shortage of specimens available. Laboratory investigations are usually element tests using the triaxial or simple shear equipment, although centrifuge tests allow site performance to be modelled because of the scale factors that can be included.

The analysis of a structure and its foundation is possible with computer finite element models. The soil and applied loads can be represented by a system of differential equations which are governed by boundary conditions and the stiffness of the elements. If good quality data is obtained from the testing programmes in a laboratory investigation, then it is possible to develop models for predicting material behaviour (Schofield and Wroth, 1968; Prevost, 1977; Mroz et al., 1979; Pender, 1980). These models provide the necessary stress-strain relationships in a form which can be used in the computer finite element programmes.

The research detailed in this dissertation was intended to form a careful laboratory investigation of a clay such that it has relevance to wave loaded soil foundations. The main objective was to obtain good quality data on the response of a normally consolidated or lightly overconsolidated fine grained soil to cyclic loading under undrained conditions, interspersed with drainage periods under static load, using a triaxial test facility. This was intended to simulate the sequence of wave loading, due to storms and quiet periods experienced by offshore structures.

The triaxial apparatus was chosen as the stress conditions within the test specimen are well defined. During the passage of a wave, elements of soil would be subjected to similar stresses to the test specimen. However, the wave would cause the directions of the principle stresses to rotate which cannot be simulated. The triaxial test is also a widely used test and results from it can be correlated to much research performed on cyclic loading. The clay used was Keuper marl, which was consolidated from a slurry so that its stress history could be controlled.

The placement of a gravity structure causes significant consolidation of the shallow sea bed deposits, tending to reduce the overconsolidation ratio. The installation of piles completely remoulds the soil locally so that all stress history is destroyed and the soil becomes normally consolidated, although the principle stress directions are changed (Randolph et al., 1979). For these reasons and because the experiments were time consuming to perform, the main test programme was confined to an investigation of normally consolidated soil. Each specimen was subjected to a single cyclic stress level, to reduce the number of variables and to provide a characteristic response for each stress level. The main programme was augmented by tests subjected to several cyclic stress levels, to simulate storm loading, and the two types of loading were compared. At the end of cyclic loading, strength tests were performed. Four supplementary programmes were carried out. The first was a preliminary test series using isotropically consolidated soil to generate basic soil parameters. The other three involved soil consolidated to the same initial stresses as the main programme. One series was lightly overconsolidated prior to applying cyclic load. Another was tested about various mean stress levels. The last was subjected to a range of total stress paths to investigate the effective stress response.

A further objective of the work was to provide data of use in checking theoretical models for cyclic loading, particularly that developed at Cambridge (Carter et al., 1979).

CHAPTER TWO

LITERATURE REVIEW

Clay is a complex material consisting of a skeleton of minute mineral platelets whose interstices are usually filled with air, water or some mixture of these. Despite much research, the way these soil components behave is not fully understood. Many factors influence soil behaviour and the aim of research is to identify which are important and to understand how they interact.

This review is concerned mostly with work performed in laboratory investigations, particularly on work using the triaxial cell, the most common laboratory soil stress-strain and strength testing apparatus in general use. In the work discussed below, where the triaxial test is used, the soils were isotropically consolidated unless otherwise stated.

2.1 CLAY BEHAVIOUR UNDER REPEATED LOADING

Early relevant work in this field was done by Bishop and Henkel (1953). Using a triaxial cell they applied slow stress pulses to undisturbed specimens of Weald clay (w_L=40, w_P=17) under undrained conditions. They found that pore pressure developed on application of load, some was recovered when the load was removed, but a residual pore pressure was observed. This residual pore pressure depended on the soil stress history and the magnitude of loading. For overconsolidated soil the residual pore pressure was negative, for normally consolidated soil it was positive. When drainage was allowed, the overconsolidated soil, therefore, inbibed water and softened and the normally consolidated soil expelled water and became stronger.

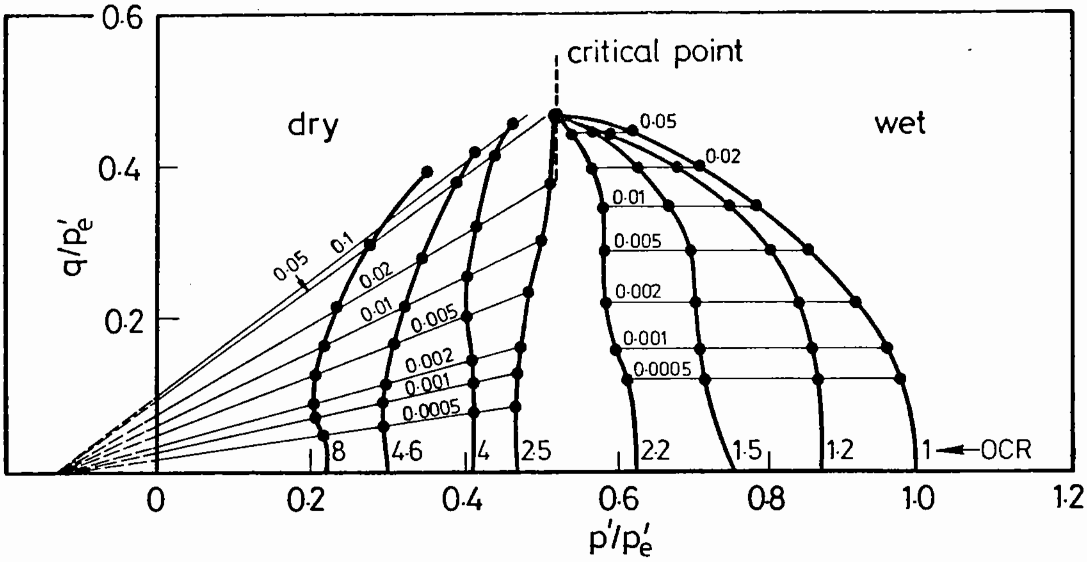
One of the largest projects on repeated loading of clay was related to offshore wave loading. It was performed by several laboratories under the direction of the Norwegian Geotechnical Institute and involved Drammen clay (w_L=55, w_P=28). Andersen (1975), in his introduction to the work, suggested that the important factors in repeated loading are the permanent components of strain and pore pressure, the elastic or cyclic components, the energy dissipated during load cycles and the strength of the soil. He also commented on the differences between short term behaviour, which is essentially undrained, and long term behaviour where drainage and consolidation can occur.

2.1.1 Permanent Deformation

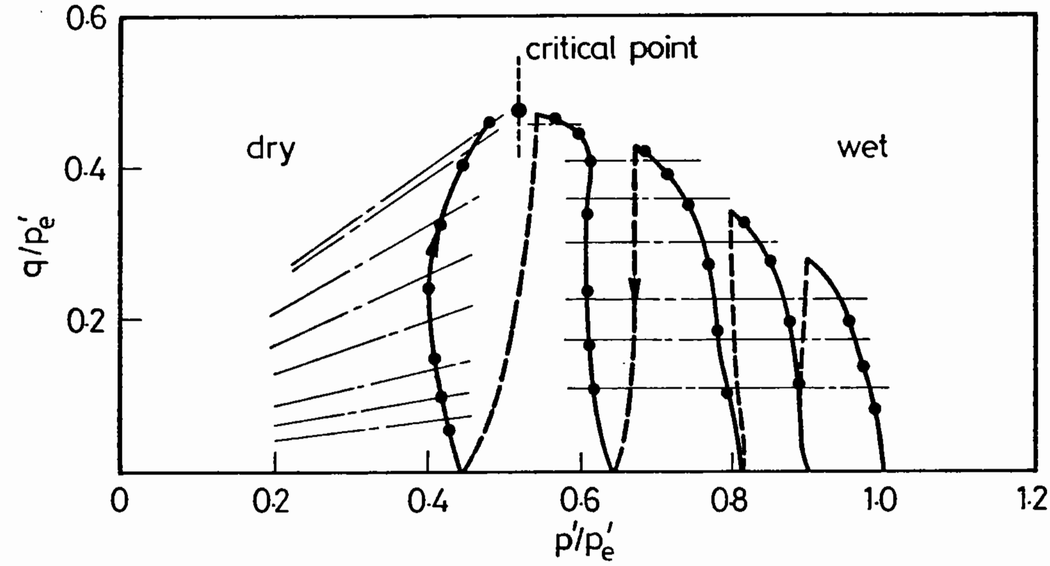
Under repeated load, soil undergoes an irrecoverable strain which accumulates until either failure or equilibrium is achieved. Sangrey et al., (1969) applied cyclic loads to triaxial specimens of Newfield clay (w_L=28, w_P=18). It was found that, regardless of the stress history and provided failure did not occur, the soil developed strain with each cycle until an equilibrium condition occurred. Seed et al., (1955) found that for a compacted clay, the stress required to reach a given strain was lower under repeated loading than under normal static loading. It was also observed that strain increased with number of cycles and repeated stress level. Lashine (1971) testing Keuper marl (w_L=30, w_P=17), found that the permanent strain at failure in repeated loading (defined using a strain rate criterion) was less than that measured at failure in monotonic tests.

Austin (1979) performed isotropically consolidated creep and repeated load triaxial tests on normally consolidated and lightly overconsolidated Keuper marl. He found that, for specimens which did not fail under the applied loads, the additional strain to failure regardless of the stress history was about 0.5% in all cases. His results also showed that, prior to failure, about a half of the total strain developed during repeated load tests developed in the first cycle and a similar proportion occurred in creep tests on initial application of load.

Wroth and Loudon (1967) tested Kaolin at different overconsolidation ratios, under slow cyclic load and strain controlled monotonic load. The results were plotted in stress space using axes of deviator stress, $q(\sigma_1' - \sigma_3')$, and effective normal stress, $p'(\frac{\sigma_1' + 2\sigma_3'}{3})$, normalised by the equivalent pressure (p_e'). This p_e' is the mean normal stress on the virgin consolidation line, at the same specific volume as the specimen. They found the behaviour of the soil to be similar under both loading regimes. Figure 2.1 shows the results where successive cycles of load produce loading paths similar in shape to samples of increasing overconsolidation ratio implying that the cyclic loading gave the soil an apparent overconsolidation. In addition, as shown in Figure 2.1, the stress paths tended to a critical state point such that strain contours could be drawn parallel to the p'/p_e' axis, for specimens wet of critical, and in a fan shape for specimens dry of critical. The wet and dry conditions and the critical state point are defined by Schofield and Wroth (1968). Parry and Nadarajah (1973), also testing Kaolin, showed the same contour effect for monotonic tests on both isotropic and anisotropic consolidated specimens. The contours for anisotropic consolidated soil were shown parallel to the K_0 line until failure was approached. Hyde (1974) found this effect for isotropic Keuper marl. However, Brown et al., (1975) found the contours to be badly defined.



(a) Stress paths and strain contours for undrained triaxial tests on Kaolin



(b) Stress path for cyclic undrained triaxial test on normally consolidated Kaolin

STRESS PATHS FOR KAOLIN

(after Wroth and Loudon, 1967)

Figure 2.1

2.1.2 Resilient Deformation

During each cycle of load, soil undergoes a deformation which is recovered as the load is removed. Seed et al., (1955) defined a resilient modulus (M_r), applicable to triaxial testing (with constant σ_r), as the ratio of repeated deviator stress to the recoverable axial strain. The modulus decreased rapidly with increasing deviator stress. This has been used to describe the pattern of resilient response by Hyde et al., (1974). Triaxial tests were performed on specimens of Keuper marl with low over-consolidation ratios, which reached a non failure equilibrium after about 10^5 cycles. It was observed that under a constant deviator stress level, the modulus decreased as the number of cycles increased. This suggests that the modulus varied with the ratio of q and p'. Andersen (1975) and Brown et al., (1975) supported this finding. The latter showed that the decrease was large for specimens normally or lightly overconsolidated, with a reduced effect at higher overconsolidations. They also found that the modulus was stress dependent and that results from triaxial tests performed under different applied stresses and with different stress histories could be correlated by use of the stress function q_r/σ_3', obtaining a relationship of the form:

$$M_r = \frac{k}{(q_r/\sigma_3')^n}$$

where q_r = cyclic deviator stress

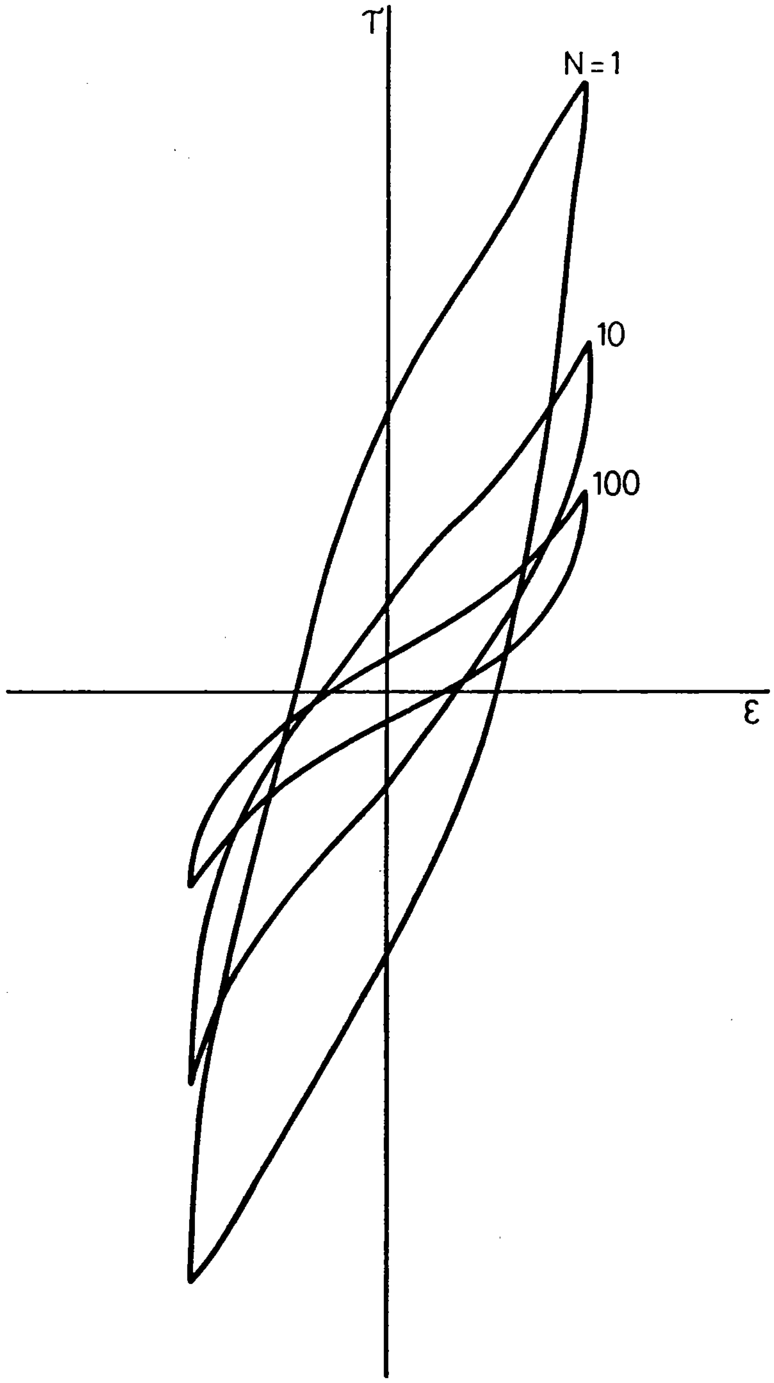
σ_3' = initial effective confining stress

k, n = constants

Wilson and Greenwood (1974) found that the resilient strains for normally consolidated Lacustrine clay (w_L=34, w_P=14) remained constant throughout their repeated load tests regardless of the change in permanent strain, provided that the deviator stress was less than about 37% of the failure stress.

Taylor and Bacchus (1969) presented results of tests on normally consolidated halloysite clay specimens (w_L=62, w_P=36) subjected to strain controlled cyclic tests. The tests covered both compression and triaxial extension regions of stress space. Examples of the resulting stress-strain loops are reproduced in Figure 2.2. After many cycles, the soil showed an overall reduced stiffness, which increased at each end of the loop. This represented an increase in stiffness immediately before and after reversal of the direction of shear. When the soil was subsequently tested to failure, it showed an initial low stiffness modulus which increased with strain before reducing again as the peak strength was approached. Andersen (1975) showed hysteresis loops of the same shape for strain controlled simple shear tests at high strains. He attributed the increase in modulus to the fact that the soil reached failure at either end of the loop. This forced a decrease in pore pressure with increase in deviator stress as the soil moved along the failure envelope.

The above behaviour has not been reported in stress controlled work where most researchers have shown that under similar stress conditions, the stiffness modulus is a minimum just before the reversal of shear and a maximum just after (Seed and Chan, 1966; Andersen, 1975). Andersen (1975) found that the resilient strain was proportional to repeated deviator stress provided failure was not approached. He also reported that the shear modulus for cycle 1 was greater than the modulus obtained from a static test.



STRESS-STRAIN LOOPS

(after Taylor and Bacchus, 1969)

Figure 2.2

2.1.3 Energy

During each load cycle energy is dissipated, the amount being equal to the area of the hysteresis loop obtained from a stress-strain plot. This is normally investigated by use of a damping ratio which compares the energy lost with the strain energy stored in a cycle.

Taylor and Bacchus (1969) showed a plot of energy dissipated at different stages of repeated load tests, for different stress amplitudes. They pointed out that the energy loss for large amplitudes was initially large, but reduced rapidly, whilst for small stress amplitudes the energy loss was relatively constant. Their hysteresis loops also developed into S-shape curves parallel to the stress axis, (Figure 2.2). Wood (1980) suggested that soil response can be considered independent of number of cycles only for small strains, where the hysteresis loops are elliptical and the soil behaviour visco-elastic. He further stated that modulus and damping ratio were not enough to fully describe the material behaviour when the loops change to S-shapes. Andersen (1975) reported that Drammen clay tested in simple shear and triaxial devices, had a secant shear modulus that depended on stress level and number of load cycles. When this was normalised by the undrained shear strength and plotted against the initial cyclic stress level it was independent of overconsolidation ratio.
The damping ratio was found to be independent of the cyclic shear strain over the range tested (1-3%) but increased with cyclic stress level.
Seed and Idriss (1970), in a review of work on soil moduli and damping, presented graphs of shear modulus versus shear strain which showed a large fall in modulus with increase in strain. They also reported that damping ratio increased with shear strains greater than 0.1%.

Thiers and Seed (1968) suggested modelling resilient response with a bilinear model, using two shear moduli which varied with the development of pore pressure and number of load cycles. The model reflected the hysteresis shape seen in stress controlled loading. Smith and Molenkamp (1980) used a bilinear model to study fatigue and resonance problems of a structure subjected to wave loading. They noted that materials with internal viscosity exhibit particularly complex behaviour in that they apparently grow stiffer and stronger with increased rate of loading.

2.1.4 Permanent pore water pressure

Pore water pressures result from compression of the soil skeleton causing the relatively incompressible water to carry load. Knight and Blight (1965) applied quasistatic loads to a soil by slowly loading it, unloading it and then allowing drainage before applying further load. They noticed that the residual pore pressure at the end of each cycle of load decreased as the number of cycles increased, that is, the soil tended to equilibrium. France and Sangrey (1977) tested an illite clay (w_L=57, w_P=26) at a slow cyclic rate with drainage between cycles and also reported a drop in the residual pore pressures. A subsequent undrained, monotonic test to failure then produced much lower pore pressures than a specimen that had experienced no cyclic load. They also noted that failure in overconsolidated specimens occurred because any negative pore pressure produced during a cycle was dissipated as the soil inbibed water and softened.

Andersen (1975) reported that pore pressure in Drammen clay increased with the number of cycles if no drainage was allowed. Van Eekelen and Potts (1978) when analysing the same work, used a linear relationship between pore pressure and number of cycles of load as the parameter to predict clay behaviour. Hyde (1974) testing Keuper marl at 10 Hz found that if failure was avoided, the pore pressure reached equilibrium values after 10^5-10^6 cycles. Austin (1979) testing the same soil showed that, unlike the strains which (before failure) developed half in cycle 1 and the rest with number of load cycles, most of the pore pressure developed in cycle 1 and was then fairly constant until failure although there was some variation between tests. He also found that the normally consolidated soil, when monotonically loaded after cyclic loading, developed little pore pressure and behaved as an overconsolidated specimen.

2.1.5 Cyclic pore water pressure

During each cycle of load a small pore pressure is generated and lost again. This effect has been difficult to measure accurately because of the siting and response of the necessary instrumentation. Taylor and Bacchus (1969) and Sangrey et al., (1969), found that the cyclic pore pressures varied in phase with stress and, if equilibrium was reached, then the change of pore pressure was one third of the deviator stress (q) (under constant confining stress conditions). This indicates that the effective normal stress (p') remains unchanged during a cycle, as $p' = q/_3 + \sigma_3'$. Wilson and Greenwood (1974) noted that the recoverable component of pore pressure was proportional to the recoverable component of strain as were the irrecoverable components provided the applied stress level was below 0.37 of the failure stress (q_f).

2.2 RATE EFFECTS

Soil behaviour is affected by the rate at which it is loaded. The rate effects are evident as several phenomena; secondary consolidation, creep and viscosity. Historically, research in this area has mostly concerned soil response to sustained loading. With the advent of large offshore structures subjected to transient loads that are a significant proportion of the required resistance, research has been needed on the effect of large loads applied for short periods.

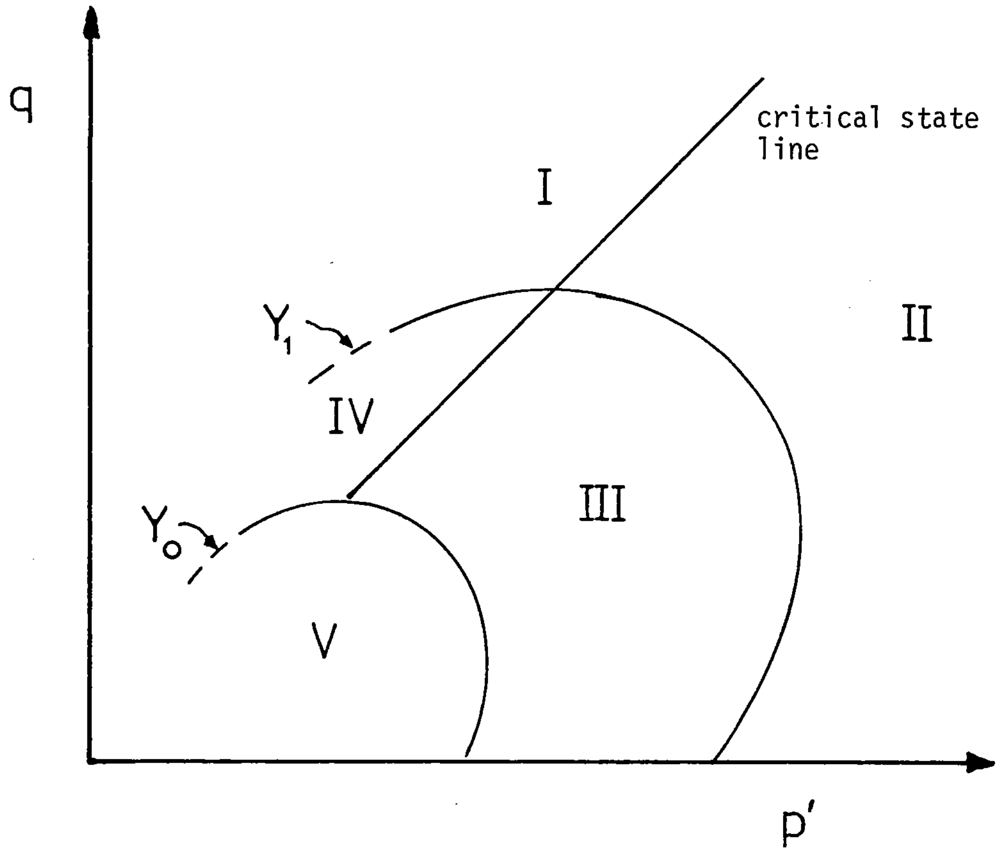
2.2.1 Secondary Consolidation

During secondary consolidation, soil undergoes a decrease in voids ratio under a constant effective stress, this is also known as ageing. The result is to give the soil a small overconsolidation ratio which increases with time. Crooks and Graham (Unpub.) analysed several one-dimensional consolidation tests and found that the preconsolidation pressure varied with the vertical strain rate. They found that above the pre-consolidation pressure where large plastic strains occur, the plots of void ratio against stress for different strain rates ran parallel to each other. Below the preconsolidation pressure where soil behaviour is predominantly elastic, there was little variation with strain rate.

Tavenas et al., (1979) suggested that creep and secondary consolidation were really manifestations of the same effect, while Tavenas and Leroueil (1977) suggested that clay behaviour can be classified by five zones as shown in Figure 2.3. The suggested soil behaviour means that rate effects depend on the current stresses and stress history. Much laboratory work on supposedly normally consolidated soil has included a period of secondary consolidation before shear testing such as reported by France and Sangrey (1977) and Donaghe and Townsend (1978). This can lead to errors when attempting to predict plastic strain behaviour of normally consolidated clays if it is not taken into consideration.

2.2.2 Creep

Work on the creep of soil under sustained load has continued for many years and much attention has been given to the behaviour of soil over long periods of time. Barden (1969) gave a useful list of the various mechanisms which have been suggested to explain creep. The main theories



Y_o - Yield surface due to consolidation

Y_1 - Yield surface due to ageing

Zone I - Failure

II - Consolidation i.e. $p' > p'_c$

III - Secondary consolidation

IV - Creep, initially stable but Y_1 moves towards Y_o eventually causing failure

V - No failure

POSSIBLE SOIL STATES

(after Tavenas and Leroueil, 1977)

Figure 2.3

include structural viscosity or thixotropic effects, which depend on adsorbed water bonds. Jumping of bonds, which includes slip from one rough spot to another on a particle, slip from particle to particle and the movement of "units" (atoms or molecules) which is known as a rate process. Barden (1969) also suggested that creep could be dependent on macropores and micropores in the soil, where primary consolidation involved the loss of water from the macropores. Creep or secondary consolidation involved water moving from the micropores to the macropores.

Matsu et al., (1980) suggested that the type of bonds in soil depend on the particle sizes involved, such that in sand the contacts are solid-solid whilst adsorbed water forms the bond in clays. They did, however, point out the importance of asperities in clay particles if contact forces are large enough to disrupt the water film locally.

Mitchell and Campanella (1963) found that creep could be initiated by temperature changes and they performed a series of experiments where it could be controlled. Variation in temperature was found to change the effective stresses and, therefore, the strain rate; the higher the temperature the lower the effective stress. Austin (1979) reported a test where a sudden rise in temperature caused failure in a creep test.

Many researchers have reported that, provided failure is avoided, the logarithm of strain rate under sustained load is linear with the logarithm of time (Austin, 1979; Mitchell et al., 1968). However, Bishop and Lovenbury (1969) performed tests on London clay and Pancone clay (both with w_L=76, w_P=29) lasting up to 3½ years and concluded that the applicability of logarithmic or power laws relating time and strain was limited.

2.2.3 Viscosity

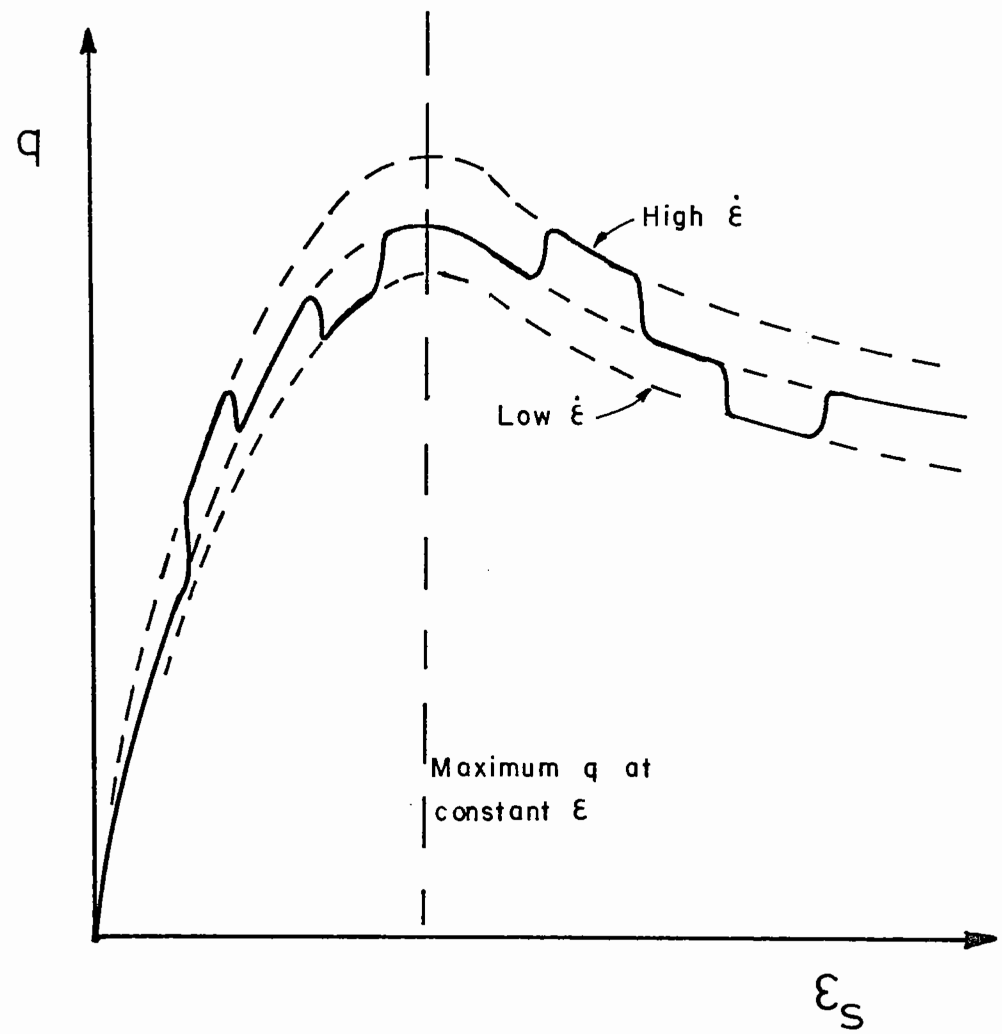
Much of the work in which rate effects or frequency of load have been investigated seem to be in agreement that soil can be described as an elastic, visco-plastic material. That is, the elastic response can be considered constant regardless of the rate of loading. Crooks and Graham (Unpub.) showed that soil behaviour at stresses less than the pre-consolidation pressure did not vary with strain rate. Sowers (1963) noted that repeated load behaviour was different from monotonic and that the cohesion of a soil decreased with an increase in time to failure as did the strength. Tavenas et al., (1978) agreed and pointed out that in their tests, the cohesion reduced to the size of the triaxial test membrane correction.

During repeated load tests, Brown et al., (1975) found that frequency of load over the range 0.01 to 10 Hz, had no effect on their measured resilient strains. Thiers and Seed (1969) reported that doubling the frequency of load from 1 Hz to 2 Hz increased the number of cycles to failure. Olszak and Perzyna (1964) noted the sensitivity of soil to the change in strain rate. They stated that, especially for dynamic loading, soil can be considered as elastic visco-plastic. Schjetne et al., (1979) reported that, for Drammen clay, the shear modulus for cycle one in a test loaded at 0.1-0.2 Hz was greater than that obtained from a static test.

Seed and Chan (1966) compared the strength of a soil when tested slowly, to the strength under a transient pulse at 0.1 Hz. They found that the transient load required to cause failure was almost double the maximum, slowly applied load. Hyde (1974) testing overconsolidated specimens of Keuper marl found he could apply transient loads at 10 Hz well above the static failure envelope without failure occurring. The failures he did get, he found were due to high pore pressures generated locally which did not have time to dissipate.

Rate effects during monotonic tests have been reported by Cooper (1970). Using strain rates between 0.024 and 0.08 millimetres per minute he found that, over the whole range, the soil had a viscous component in its response. Schmertmann (1963), Vaid and Campanella (1977) and Crooks and Graham (Unpub.) show failure tests in which the strain rate was varied both before and after failure. They found that the stress-strain plot "curve hopped" as shown in Figure 2.4. That is, if the strain rate was high, the soil supported greater load than if the strain rate was low. However, the strain at which the maximum stress occurred did not vary.

Hight (1981) testing a glacial till (w_L=25, w_P=12), in the triaxial test also found the rate of loading to be important. He tested both isotropic and anisotropic normally consolidated samples and used both failure tests and repeated load tests. For anisotropic tests, the stress paths to failure were very different from the isotropic and varied greatly with the rate of loading. In a twenty minute test, a large deviator stress was resisted by the soil with little pore pressure and strain developing before failure. In a one-day test only a small deviator stress was resisted with strain and pore pressure developing more evenly. Under cyclic load, using frequencies less than 0.002 Hz, he found he could measure significant cyclic pore pressures for isotropic specimens with shear strain continuously developing. For anisotropic specimens, using frequencies of between 0.01 and 0.001 Hz, pore pressure variation was small during any one cycle and the shear strain did not develop until failure was reached. However, he found that the same failure envelope at large strains was applicable to the soil regardless of the type of consolidation.

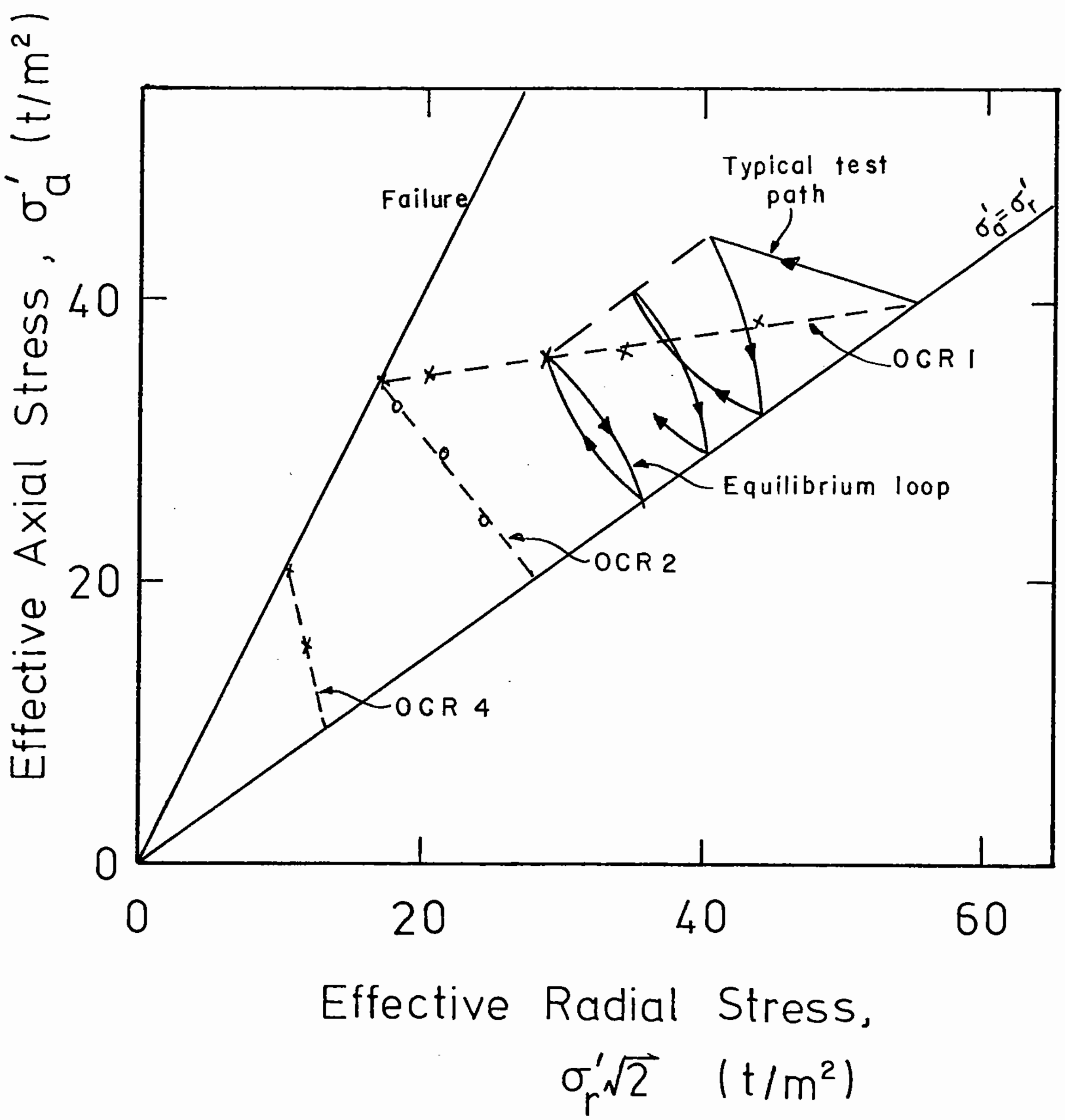


TYPICAL VARIATION OF DEVIATOR STRESS WITH STRAIN RATE

Figure 2.4

2.3 SOIL STRENGTH

Many researchers have looked for thresholds to the soil behaviour under repeated load, though they almost exclusively used isotropically consolidated specimens. Henkel (1954) found that the soil reached equilibrium if the applied deviator stress was less than some critical or threshold stress for the effective cell pressure applied. Andersen (1976) also reported a lower bound on the effect of cyclic stress level as did Wilson and Greenwood (1974), suggesting 0.37 q_f as the bound. Parr (1972), working on London clay, defined S as a ratio of cyclic shear stress to predicted single load strength and found that if $S < 0.55$, all samples reached an equilibrium state, for $0.55 < S < 0.85$, the samples would either fail or come to equilibrium, whilst with $S > 0.85$, all samples reached failure. Lashine (1971) also suggested an upper bound of 0.75-0.8 q_f for normally consolidated samples. Sangrey et al., (1969) found that if soil specimens with identical stress histories were loaded at different cyclic stress levels, such that each specimen came to equilibrium (no further development of permanent strain or pore pressure), then the peak points of the equilibrium stress loops on a p' - q plot lay on a straight line drawn between the failure envelope and the initial value of mean normal stress for the samples as shown in Figure 2.5. Motherwell and Wright (1978) tested Kaolinite specimens (w_L=82, w_P=42) to failure in either ten minutes or ten seconds, they found a 35% difference in undrained strengths. They then tested specimens under cyclic load at 0.1 Hz and found that failure only occurred if they used a cyclic stress level greater than 55% of the strength from the fast failure test. This corresponds to about 75% of the more normal measure of strength which they suggest agreed with the findings of Lashine (1971) and France and Sangrey (1977).



EQUILIBRIUM LINES FOR TRIAXIAL SPECIMENS OF NEWFIELD CLAY AFTER CYCLIC LOADING

(after Sangrey, Henkel and Esrig, 1969)

Figure 2.5

When drainage is allowed, Brown et al., (1977) found that normally consolidated samples increase in strength and harden but they found little change in overconsolidated specimens of Drammen clay. They suggested that this was due to the very flat swell back line of the clay which they used. France and Sangrey (1977) found that after drainage, their normally consolidated specimens gave a 30% higher strength in monotonic tests. They reported that the overconsolidated specimens failed even after peak and residual pore pressures stabilised, as the strain continued to accrue due to the soil taking in water and softening.

Lee and Focht (1975) tested dense sand for the Ekofisk oil storage tank. They found that if drainage was allowed between periods of undrained loading, there was a ten fold increase in the number of cycles of a stress level to cause liquefaction. Further drainage gave an increase in strength provided pore pressures existed in the soil. The magnitude of each strength gain progressively decreased as the soil came to equilibrium.

2.4 ANISOTROPIC CONSOLIDATION

Soils are deposited under anisotropic conditions where the vertical stress is larger than the horizontal stresses and radial strains are zero (K_0 conditions). The soil may become overconsolidated due to many factors such as removal of overburden pressure, dessication, frost action or a change in water table. When this occurs, the stress ratio changes. For normally consolidated clay, K_0 is about 0.5, whilst for lightly overconsolidated clay, K_0 is often nearer 1.0. However, much research work has been carried out with isotropic normally consolidated soil (K_0 = 1.0). Experimental evidence suggests that soil when consolidated anisotropically behaves very differently.

Henkel and Sowa (1963), tested both anisotropic and isotropic specimens of Weald clay at 0.1%/hr. They found the stress paths of the two types of normally consolidated soil very different but the over-consolidated ones similar. They attempted to explain this by the development of microstructure during K_0 consolidation. Rowe (1959), considers that the difference could be due to the size of the increments of load, as in laboratory triaxial tests anisotropic increments of load are small while isotropic increments are large. He observed that in oedometer tests, clay structure varied greatly depending on the size of load increment. He further suggested that the small increments of load allowed more time for secondary consolidation.

The undrained stress-strain curves of anisotropic normally consolidated specimens are very different from isotropically consolidated ones. This has been noted by many workers and reported by Broms and Ratnam (1963), Ladd and Varallyay (1965), Lee and Morrison (1970), Vaid and Campanella (1974), Donaghe and Townsend (1978) and Hight (1981). Whereas the anisotropic stress-strain path shows a definite peak at low strain followed by a drop to a residual value, the isotropic path shows strain developing evenly as the soil strength reaches a maximum. For comparable stress conditions, the maximum isotropic deviator stress is close to the residual value of the anisotropic.

The phenomenon of a peak strength followed by a drop to a residual value is most noticeable in anisotropically consolidated soil. The ratio between the peak and residual values is usually called the soil sensitivity and values range typically from one (insensitive) to a maximum of about ten. Randolph et al., (1979) stated that sensitivity is due to structure in the clay particles, it being most noticeable in normally consolidated or lightly overconsolidated soils. They explained the behaviour as occurring when the soil reached equilibrium, under a particular load in one-dimensional consolidation, at a higher void ratio than would occur under isotropic conditions. If the soil is then sheared, such that it remains undrained, it reaches a peak strength before its structure collapses and the strength falls to a residual value.

Tavenas et al., (1978) and Crooks and Graham (Unpub.) stress the fact that the yield surface is fairly symmetrical about the line of whichever stress ratio (K value) is used in consolidation, although the results of Parry and Nadarajah (1973) do not show this. Parry and Nadarajah (1973) also show the failure envelope for anisotropic specimens rotated clockwise from the isotropic failure envelope by a few degrees. Donaghe and Townsend (1978) show the same effect but state clearly that the failure line was obtained from the peak strengths measured. When they plotted the residual values they found no difference in failure angle.

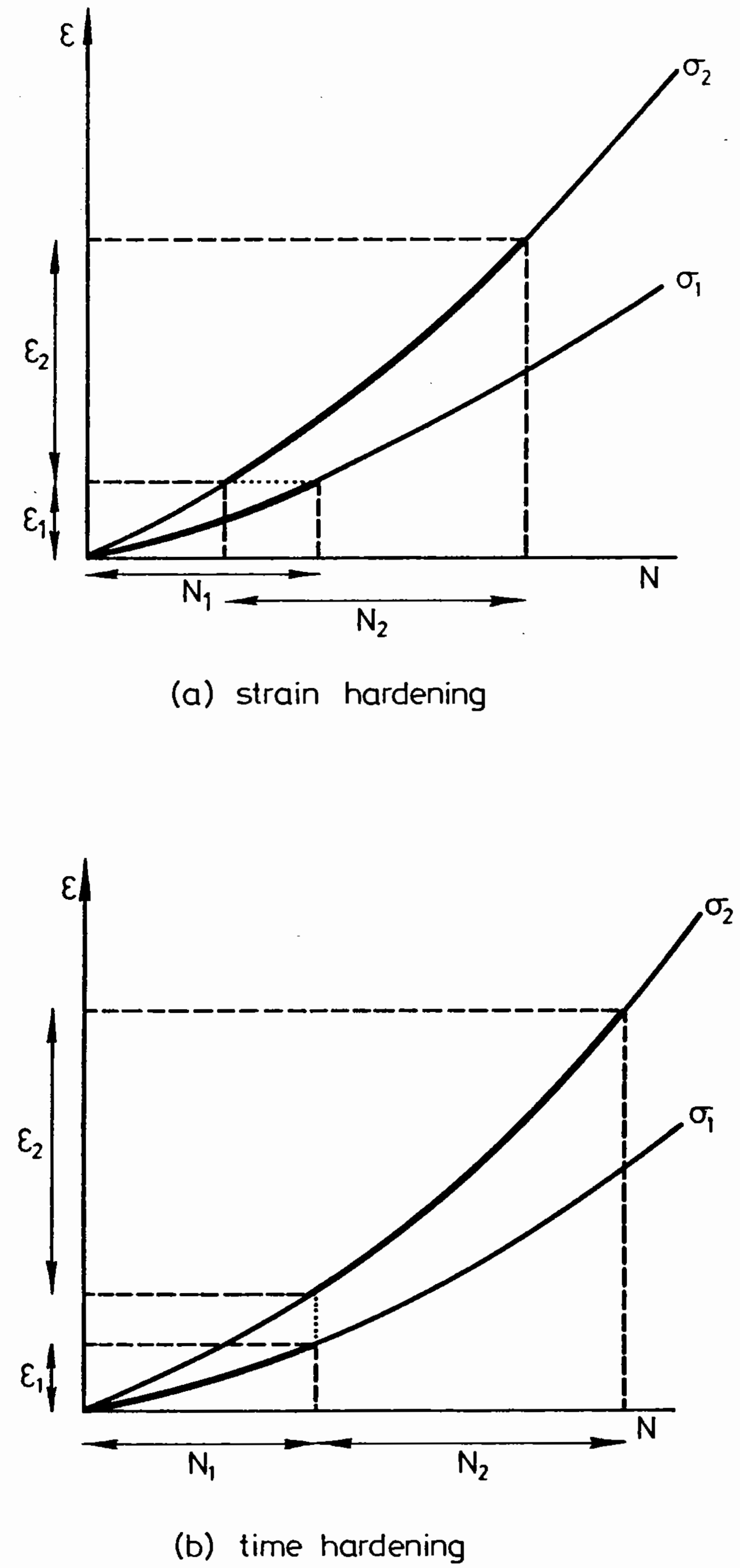
2.5 STORM LOAD PREDICTIONS

Laboratory testing of soils generally uses cycles of load all of the same size. A real storm, however, has an essentially random loading pattern over a whole spectrum of wave heights and periods. Several methods have been proposed to link the laboratory and field loadings; three are given below.

Lee and Focht (1975) suggested the use of a damage potential originally used for fatigue in metals. This approach assumes a strain criterion as comparison and that superposition of permanent shear strains is applicable. The laboratory stress levels are obtained from an actual storm load pattern. A term called the damage potential (D) is used such that if D = 1, then failure occurs. The method uses data from an actual storm of many different stress levels to give an equivalent number of stress applications at a single stress level. This equivalent number will then give the same strain in the soil as the storm.

Monismith et al., (1975), suggested two methods of prediction; strain hardening and time hardening as shown in Figure 2.6. For strain hardening, if the soil under goes N_1 cycles at σ_1 resulting in strain ε_1 and then N_2 cycles at σ_2 giving strain ε_2, it remembers the strains giving a total of $\varepsilon_1 + \varepsilon_2$. For time hardening, with the same loading, the soil remembers the number of cycles, N_1 and the effect of N_2 cycles of σ_2 is added from this point. They concluded that strain hardening is a better prediction for increasing stress levels ($\sigma_2 > \sigma_1$) whilst time hardening is a better prediction for decreasing stress levels ($\sigma_2 < \sigma_1$).

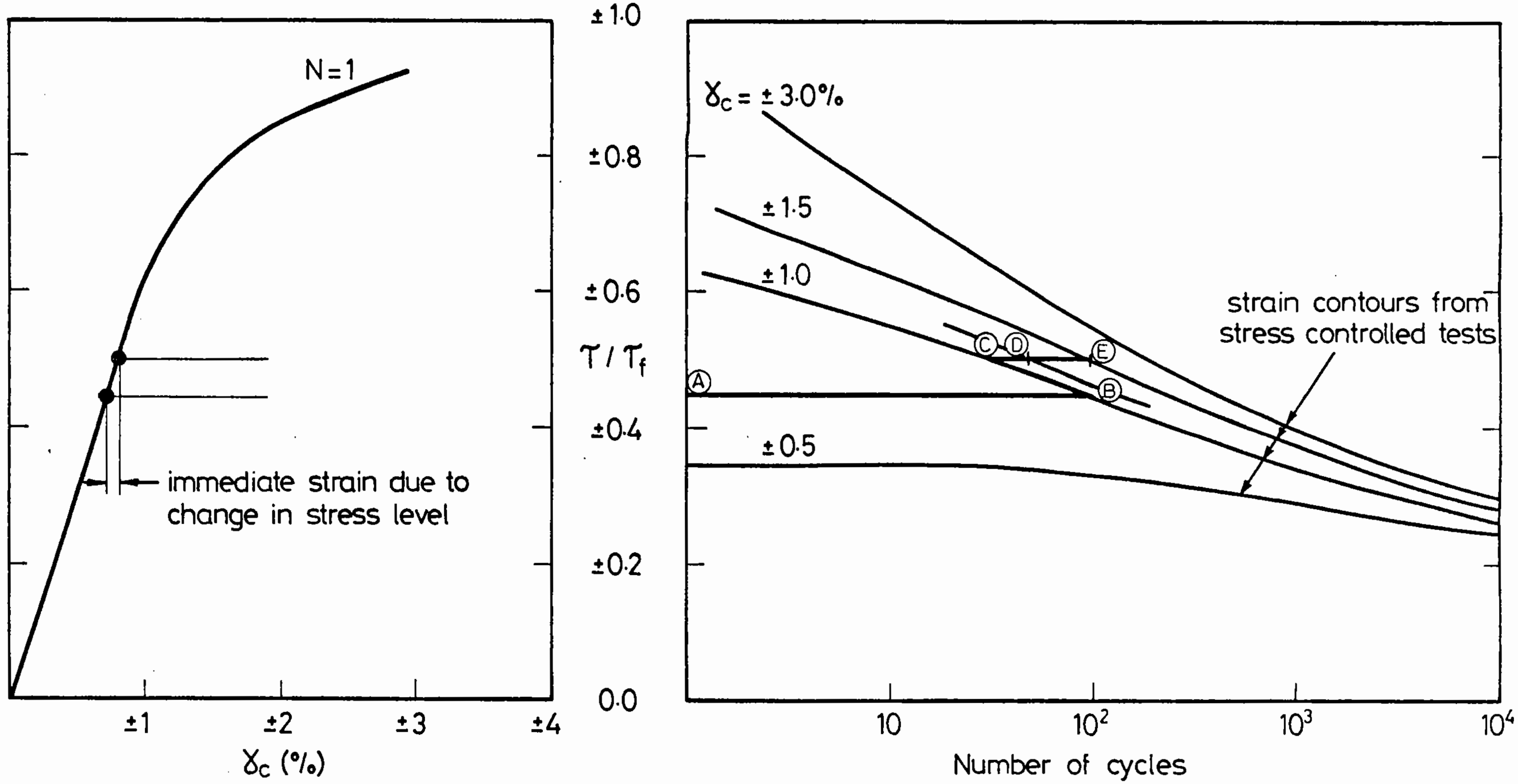
Andersen (1975, 1976) proposed a method based on shear strains. For N cycles of stress τ_N and ΔN cycles at τ_{N+1}, the total shear strain could be expressed as the sum of the shear strain after N cycles at shear stress τ_N plus the immediate change in shear strain due to change in stress level from τ_N to τ_{N+1} plus the increment in shear strain due to ΔN cycles with shear stress τ_{N+1}. Using the results of the Drammen clay work, Andersen obtained a graph of stress level against the number of cycles on which curves for various shear strains could be plotted as shown in Figure 2.7. The strain caused by a storm can then be predicted by first dividing the storm into the number of applications of various stress levels, then plotting the path of N cycles at a stress level (A-B). To plot the effect of a new stress level the storm plot moves along a strain contour to the correct stress level (B-C). The immediate strain at this new level can be obtained from a monotonic load curve. This moves the plot to another strain contour (C-D). Then, adding the effect of N cycles of the new stress level (D-E) will give the accumulated strain. This process can be continued to obtain the strain for a complete storm.



SOIL HARDENING CRITERIA

(after Monismith, Ogawa and Freeme, 1975)

Figure 2.6



PREDICTION OF STRAIN
(after Andersen, 1976)

Figure 2.7

2.6 SOIL MODELS

Many models have been postulated to try and describe the soil behaviour and they generally fit into one of the following categories. Mathematical models, which normally involve computer programs and use finite element analyses, empirical models, which are mainly curve fitting exercises and descriptive material models, which use simple mathematical equations with the use of some measured properties of the soil.

Perhaps the best known material model is based on the concepts of critical state soil mechanics which were developed at Cambridge University and set out by Schofield and Wroth (1968). This work has been developed in particular by Roscoe and Burland (1968) and Carter et al., (1979). The model has also been taken by other researchers and used in their model developments some of which are discussed below.

The critical state model for soils is known as Cam Clay. A good introduction to the concepts can be obtained from Atkinson and Bransby (1978). Only a short outline of the model is given here and greater detail may be found in the referenced texts.

The model requires the measurement of five basic parameters which are:

λ the gradient of the virgin consolidation line in $V - \ln p'$ space

κ the mean gradient of the swelling and recompression line in $V - \ln p'$ space

Γ the value of V at unit p' on the critical state line in $V - \ln p'$ space

M the value of the stress ratio q/p' at the critical state position

G the elastic shear modulus

In the previous descriptions, V is the soil specific volume and p' and q are stress invarients.

$$p' = \left(\frac{\sigma_1' + \sigma_2' + \sigma_3'}{3}\right) = \sigma_{oct}'$$

$$|q| = \frac{1}{\sqrt{2}}\left[(\sigma_1' - \sigma_2')^2 + (\sigma_2' - \sigma_3')^2 + (\sigma_3' - \sigma_1')^2\right]^{\frac{1}{2}}$$

$$= \frac{3}{\sqrt{2}}\tau_{oct}$$

When the soil behaviour is elastic, the response is governed by the shear modulus G and the bulk modulus K. Where, for the model:

$$K = \left(\frac{1 + e}{\kappa}\right) p'$$

$$G = \text{constant}$$

When the soil behaviour is plastic, a yield surface, a flow rule and a hardening rule are necessary. For Cam Clay, yielding occurs when

$$\frac{q}{Mp'} + \ln\frac{p'}{p_x'} = 1$$

p_x' = value of p' at intersection of the current yield locus and the line $q = Mp'$.

The model has an associated flow rule where the vector of plastic strain increment is normal to the yield surface:

$$\frac{d\,\varepsilon_v^p}{d\,\varepsilon_s^p} = M - \frac{q}{p'}$$

The hardening rule relates the plastic volume strain to the change in specific volume of the material.

The major modifications to the Cam Clay model were reported by Roscoe and Burland (1968) where the model was adjusted to better fit the experimental data and by Carter et al., (1979) where the model was modified to allow plastic strains to occur with successive cycles of repeated loading. This latter paper is of particular importance to this work and is discussed in Chapter Ten with the results of this research.

Other researchers have developed models using Cam Clay as their base. They include Van Eekelen and Potts (1978), who analysed the Drammen Clay work reported by Andersen (1975). They modified the associated flow rule and used a one parameter model based on a linear increase in pore pressure with number of load cycles. Mroz et al., (1979) described a model in which the hardening modulus varied with the distance from the yield surface, reducing from a very large value well away from yield to a proscribed value at the yield surface. Pender (1980), proposed a work hardening plastic model which is applicable to overconsolidated soil. The model involves the yield locus moving with the current stress point which gives plastic deformations on loading and unloading. The yield behaviour of the model depends on the state of the material at the last stress reversal.

2.7 EQUIPMENT

This section reports on some of the developments of triaxial equipment that have occurred over the years. The purpose is to investigate the particular advances made in the areas of interest to this research. Primarily, this included the ability to apply anisotropic consolidation, to accurately measure soil deformations and to be able to record transient changes in pore pressure.

2.7.1 Triaxial Consolidation

In the triaxial cell, isotropic consolidation of specimens is easy to perform. To better parallel field conditions consolidation should be anisotropic, possibly under K_o conditions. Brooker and Ireland (1965) measured K_o by enclosing a soil sample in a strain gauged steel membrane. They suggested an expression for K_o of normally consolidated samples of clay as:

$$K_o = 0.95 - \sin \Phi'$$

This is often confused with a similar expression for granular material, where

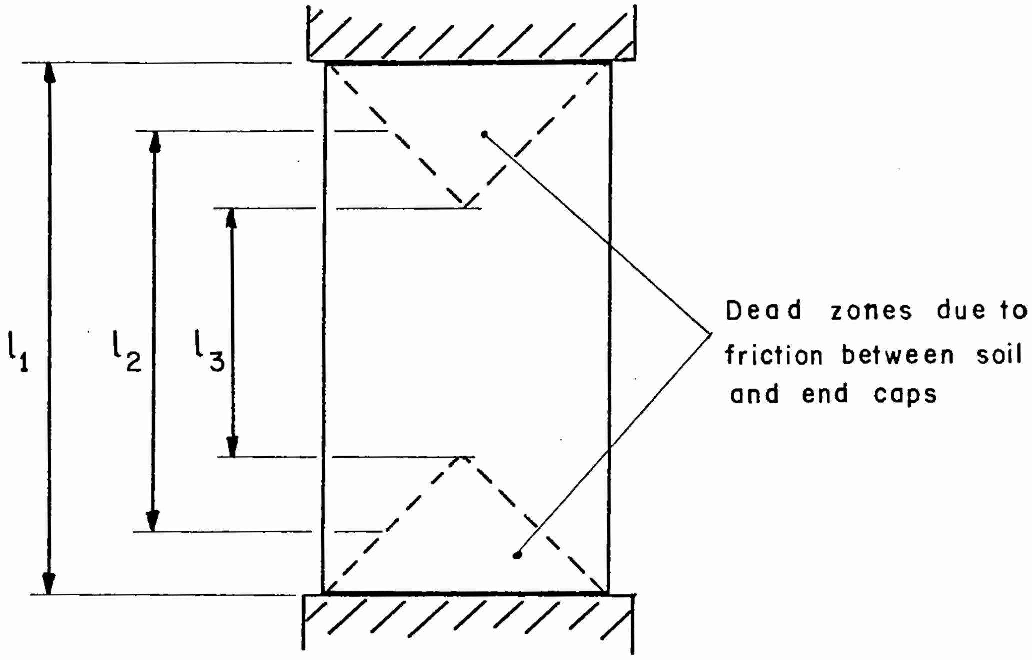
$$K_o = 1 - \sin \Phi'$$

which was proposed by Jaky (1948). Bishop and Henkel (1953) attempted K_o consolidation of a sand in a triaxial cell by slowly straining it whilst allowing drainage. The water from the soil was collected in a burette and by continuously adjusting the cell pressure, the volume outflow was kept equal to the axial deformation multiplied by the initial area. Bishop and Wesley (1975) used a triaxial cell where vertical load was applied by air pressure on bellofra̧ms to produce anisotropic consolidation. The K_o value was estimated for the soil used and assumed to give the correct result. Fixed ends were used and lateral strains were not measured but were calculated from the volume change and axial strain. This arrangement seems unlikely to produce accurate K_0 conditions. As Sowers (1963) pointed out, if there is end restraint in a triaxial specimen this causes conical dead zones on the platens and hence the axial strain is not uniform through the specimen as the gauge length varies, as shown in Figure 2.8.

Lewin and Burland (1970) consolidated specimens under different stress ratios by slowly raising mercury pots to increase the cell pressure while adding ball bearings at a known rate to a hanger on the vertical load ram. They then measured the final diameter of the specimen after consolidation and plotted the radial movement against stress ratio to find the K_0 condition. Lewin (1971) also used a servo burette to convert the volume change measured to linear movement of a piston connected to the vertical load ram. Holtz (1972) reported using a pair of metal plates resting on a sample to monitor the radial movement and adjusted the cell pressure accordingly.

2.7.2 Deformation Measurements

Chaddock (1973) working with a triaxial apparatus, devised a system of measuring vertical deformations by optical means. He attached small targets to his specimen, the targets being half black, half white, divided horizontally. By shining a beam of light from outside the cell on to the target, he recorded the reflected light from the target with a sensitive television camera. This required optical glass windows in the cell wall to work without distortion effects. He also measured lateral strains by attaching two lightweight proximity transducers to the specimen, one on either side of the diameter. This required cutting slots in the soil specimen to mount the transducers and would consequently cause significant stress concentrations. The transducers worked by measuring the capacitance



Gauge length (l) varies over cross section of specimen

TRIAXIAL SPECIMEN WITH FRICTIONAL END PLATENS

Figure 2.8

between the sensor and a suitable target; in this case, a metal plate in the cell. The transducers were specially made and only measured very small deformations. He found large inaccuracies were incurred if axial deformation was measured on the load ram.

Deformation measurements have been made by using X-ray opaque material in a soil. This has included the use of lead shot in sand as described by Wood and Budhu (1980) and the use of bismuth metal in a silicone fluid suspension by Cuckson (1975). The second method involved injecting clay with the bismuth mixture through a hypodermic needle, before taking photographs using an X-ray source and sensitive film. The strains could be obtained by measuring the inclination of the columns during shear and integrating.

Other methods of measuring deformations used instrumented collars. El-Ruwayih (1976) developed a lateral strain device for coarse granular material consisting of a strain gauged sprung steel band. Brown and Snaith (1974) devised a method for measuring deformations, both axially and laterally, on bituminous samples by using LVDTs mounted on strain collars. The collars were attached to location points which were demec pips stuck onto the sample. The lateral strain was measured across a central diameter by one collar (a hinged perspex ring with an LVDT at the open end) and the axial LVDTs then measured between two other collars. The instruments could be hung on the sample as it was strong compared to their weight. Brown and Snaith (1974) used transformer oil as a confining medium to keep the electrical equipment insulated. They reported that the system would follow frequencies up to 25 Hz. Boyce and Brown (1976) developed this system for granular materials by using strain gauged araldite rings to measure the radial deformations and LVDTs to measure the axial. Again, the specimen was able to support the instrument weight, the location studs were designed to be the same size as the large particles in the material and assumed to behave as part of it. Silicone oil was used as the confining medium.

Lo et al., (1977) measured deformations of a cuboidal clay specimen with LVDTs attached to the soil. They were concerned that the instruments should impart no load to the soil, so they attempted to support them independently. As they were only interested in small deformations, the LVDTs measuring the axial movement were rigidly supported and measured over half the specimen length. The location points were needles pushed into the soil through the membrane and sealed with silicone rubber. The lateral deformations were measured at mid-height with an LVDT floated in the cell so that it could move vertically with the soil. It was made buoyant by a styrofoam jacket. To insulate the instruments, a transformer oil was used as the confining medium but this entailed the use of special membranes which the oil would not attack. During setting up, the lateral LVDT was supported by a strip of latex rubber which quickly deteriorated in the oil.

Independent of this research, Cole (1978) developed a method of measuring radial deformations similar to that reported in Chapter Three. He supported non-contacting inductance transducers around the soil and used aluminium foil on the soil as the target.

2.7.3 Pore Pressure Measurements

The effective stresses in a soil specimen are calculated by knowing the applied total stress and subtracting the pore water pressure. Unfortunately, it is difficult to measure pore pressures accurately due to imperfections in the test specimen and the disturbance caused by the instrument. Traditionally, in the triaxial test, the pore pressure has been measured at the base of the specimen by a porous platen with a transducer of some kind behind it. This produces a rough platen and will cause end restraint thus affecting the pore pressures.

Crawford (1963) used hypodermic needles filled with de-aired water which was frozen in dry ice. He inserted one needle from the top cap and one through the rubber membrane. He found that during slow tests, he could measure pore pressures which compared well with readings from the end only if the test strain rate was low. Cooper (1970) used small probes on hypodermic needles which were consolidated into the soil slurry, but they were still relatively large compared to his specimen size and had a rigid connection which would not move with the soil during straining. However, using the centre probe, he found no variation in the measured pore pressures with strain rate between different failure tests until the strain reached about 5%, although he did find large variations between the centre and base readings with strain rate. Other probes have been tried by Blight (1965) and Rowe and Barden (1964). Austin (1979) used a base probe which protruded into the soil along the axis of symmetry. He cycled the deviator stress at a level well below failure over a frequency range of 0.1 to 8 Hz. He reported no loss of response below 2 Hz. Hight (1981) reported using a small electrical transducer with a porous face which could be positioned against the side of a specimen and then sealed through the membrane. This gave a reading at the specimen mid-height, had a very low flow and, therefore, a stiff response. He commented that it was important to have a sufficient gap between the porous face and electrical diaphragm such that the porous stone in its deflected position could not touch the diaphragm. Great care had to be taken to de-air the probe if the transient pore pressures occurring during cyclic loading were to be measured. It was also possible to generate gas bubbles due to electrolite action such that a back pressure was needed to prevent the bubble growing in cyclic loading.

2.7.4 <u>End Restraint</u>

In the triaxial test, friction between the soil and loading platens inhibits radial strain causing barrelling, non-uniform shear strains and, hence, non-uniform pore pressures, as well as inaccuracies in strength measurements. Most developments to overcome this problem have followed from Rowe and Barden (1964) who, after trying lead shot and water bags, concluded the best free end was obtained by using a hard, smooth platen with a layer of high vacuum silicone grease and a rubber membrane on it. They suggested that a pore pressure probe in the centre of a platen would not adversely affect the free end as the radial symmetry of the triaxial test requires that radial friction at the centre of a platen be zero. It also helps to stabilise and locate the sample when setting the test up.

Olson and Campbell (1964) used lubricated platens of teflon, again with a grease and rubber sandwich, but found their samples still barrelled due to a consolidation period prior to testing, during which the grease was squeezed out of the lubricated ends. They also had trouble setting up their tests as the samples tended to slip sidewards. Lee and Seed (1964) reported shear box tests on free ends using powdered molybdenum disulphide, oil mixed with molybdenum disulphide and silicone grease as the lubricant. They concluded that the silicone grease performed best. They also found the angle of friction to be between 1 and 3 degrees independent of the rate of slip and that the longer the free end was under the load before shear, the higher was the friction angle. Further work by Lee (1978) and Lee and Vernese (1978) agreed that high vacuum silicone grease with a hard platen and rubber membrane made the best lubricated ends. If the end was left under normal load for some time, grease was squeezed out but a small shear strain re-smeared the remaining grease. When testing sands, they found that a thicker rubber was advisable to avoid the particles penetrating to the end platen and increasing the friction. Hughes and Bahramian (1965) performed concrete cube tests using free ends made from blocks of rubber and molybdenum grease. They found that the cube strength was significantly lower but the samples failed in tension with cracks running vertically due to the much larger radial expansion of the rubber under axial compression than the concrete.

Barden and McDermott (1965) used free ends in extension testing and found that the samples did not neck. They also found that the free ends worked well in short tests but that the grease was lost in longer ones. This caused some barrelling in samples with a 2:1 ratio before the grease was re-smeared over the dry spots on the platen. Bishop and Green (1965), in testing sand, found that using two layers of grease and two rubber membranes gave some improvement.

Brown (1975) reported on the end conditions prevailing in the repeated load tests on Drammen clay reported by Andersen (1975) in which teflon ends were used. The ends exhibited total fixity and he recommended stainless steel platens with high vacuum silicone grease and a rubber membrane. Marsden (1976) investigated the effects of thickness of rubber used and the thickness of the grease layer. He noted that the thickness of the rubber became important as the grain size of the test material increased. However, the free end was lost after a few days and confirmed the effect in long term tests of a peak friction then a drop to a residual level when the grease was re-smeared. Marsden (1976) tested a grease reservoir developed by Austin (1975) that consisted of two rubber discs sealed around their rims with a small bleed hole for the grease. He found that the angle of friction was still below one degree after seven days under normal load.

CHAPTER THREE

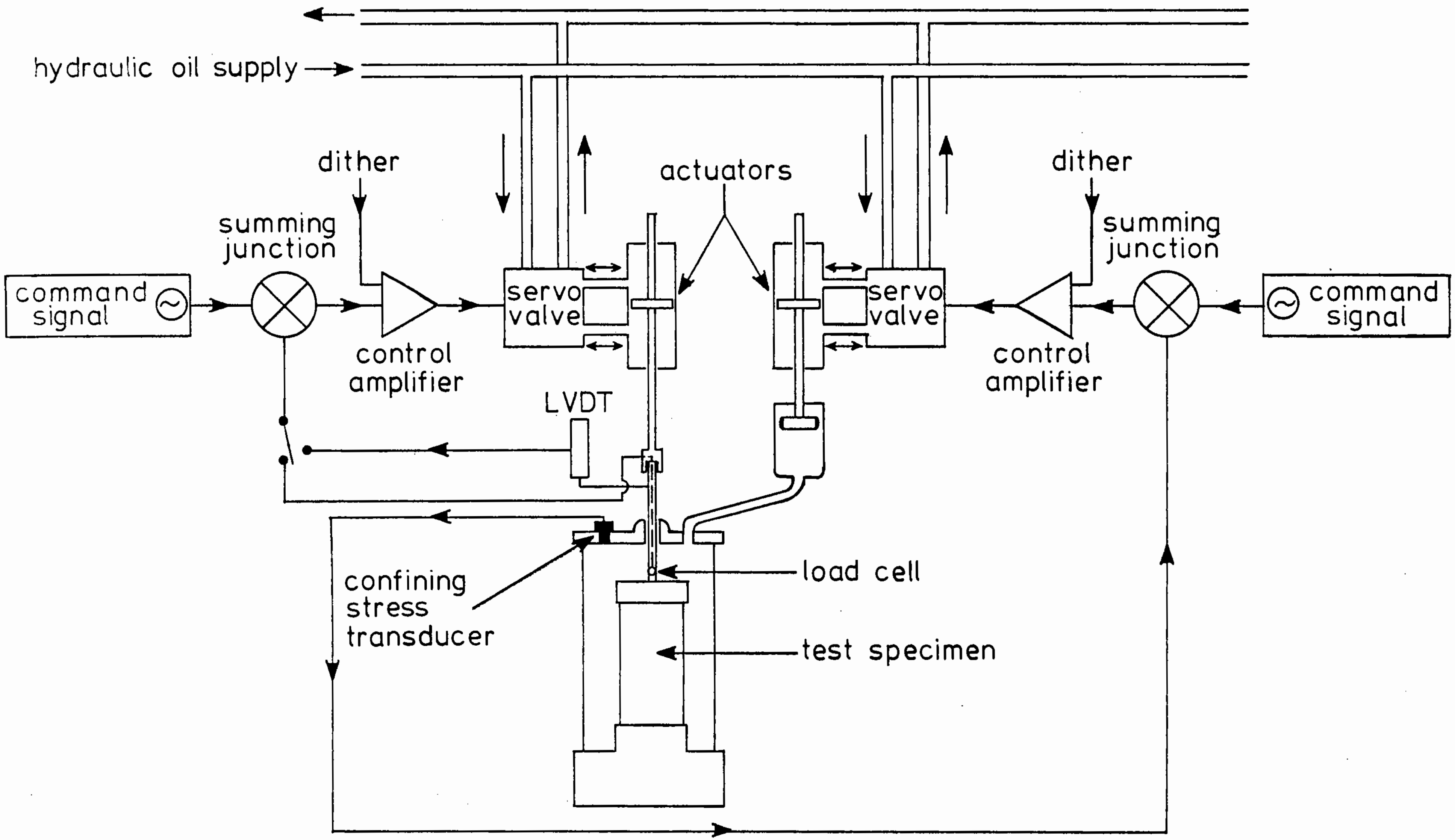
THE TRIAXIAL TEST FACILITY

Lashine (1971) developed a hydraulic servo-controlled triaxial testing facility for soils which formed a stiff system capable of applying well controlled loads to a test specimen. The original development is explained in detail by Lashine (1971) and modifications to the system are described by Cullingford et al., (1972), Parr (1972), Hyde (1974) and Austin (1979).

An important part of this research project was to develop equipment that would provide accurate measurements of the pressures on a test specimen and the resultant deformations. A short description of the equipment as it existed at the beginning of this project is given below, followed by the changes and improvements made by the author.

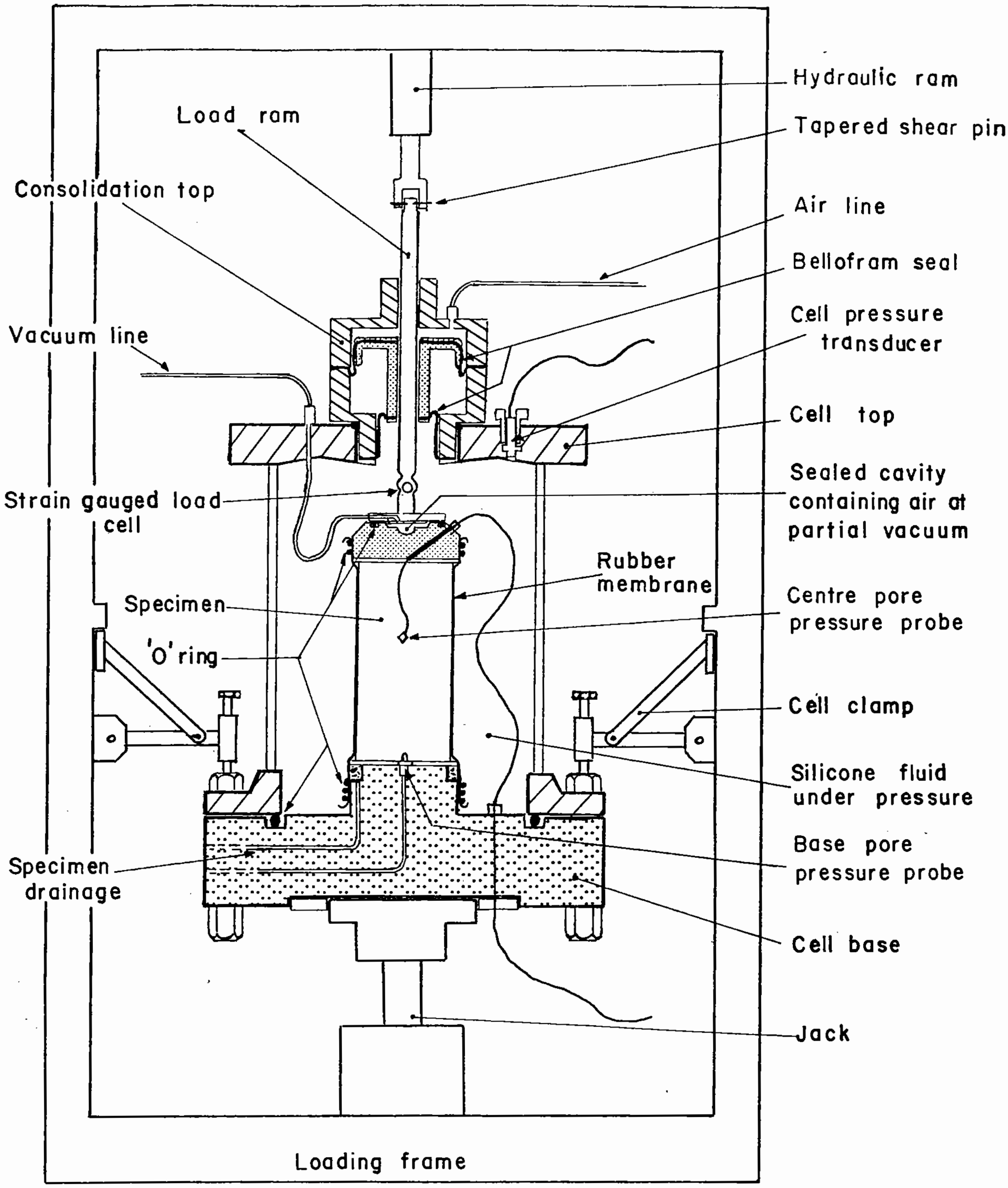
3.1 EXISTING EQUIPMENT

The loading equipment was housed in a constant temperature laboratory where the ambient temperature could be maintained at 20^{o} centigrade ($\pm$ 1^{o}C). A schematic diagram of the equipment and its operation is shown in Figure 3.1. Power was supplied by a pump which delivered hydraulic fluid at pressures of up to 21 MPa (3000 p.s.i.). Axial load and confining stress were then applied to a test specimen in a triaxial cell by hydraulic actuators. The input load values were measured with transducers. The systems were controlled electronically by providing an input command signal from an oscillator which was fed into a summing junction with the output from an appropriate transducer. The resulting error signal was fed to a servo-valve, which diverted the oil flow to the actuator to give the correct load. To prevent the actuators sticking due to friction, a high frequency "dither" signal was also applied to the servo valve.



SERVO-HYDRAULIC CONTROL

Figure 3.1



TRIAXIAL TEST FRAME

Figure 3.3

Axial load was applied to the test specimens by a load ram designed by Austin (1979), which incorporated a strain gauge bridge. This was located on the ram such that it was inside the triaxial cell thus avoiding errors from the friction of the cell bearing. This load cell provided feed back for the axial load system. Alternatively, control could be provided by an externally mounted Linear Variable Differential Transformer (LVDT), connected to the load ram and used to measure the axial deformation of test specimens. This gave a method of automatically controlling the axial load so that a constant stress could be applied; the electronic control increased the load as a specimen deformed to allow for its increase in cross-sectional area. The confining stress was pulsed by an actuator operating a piston with a bellofram seal. The piston was housed in a small chamber which was connected to the triaxial cell. The stress level was measured with a transducer consisting of a strain gauged diaphragm.

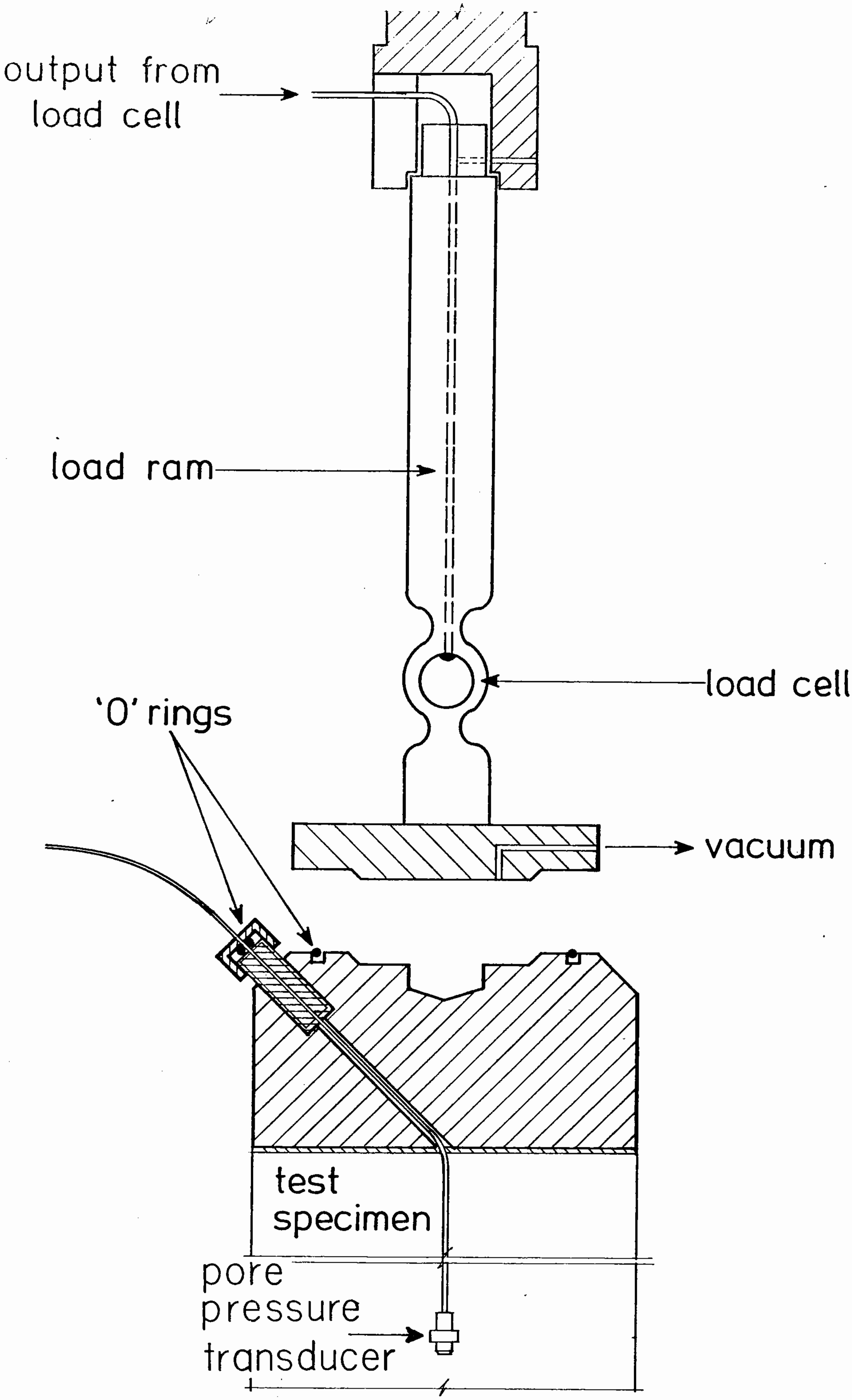
The triaxial cells were designed by Austin (1979) and incorporated epoxy resin bases to eliminate bi-metallic corrosion caused by the presence of water and several metals in contact. The cells took specimens of 150 mm height by 75 mm diameter which were enclosed in latex rubber membranes. Pore pressure was measured at the base of each specimen by a probe connected to a transducer. Both probe and transducer were mounted in the base to give a very low compliance system.

3.2 EQUIPMENT MODIFICATIONS

3.2.1 Axial Load

The equipment could provide a maximum deviator stress of 1200 kPa on test specimens but was only capable of applying compression. To develop the equipment to apply negative deviator stress, it was necessary to provide connections between the load ram and hydraulic actuator, as well as the load ram and specimen top cap. This development was desirable as it gave better control and response during the unloading portion of a cyclic load test and it also enabled the triaxial extension region of stress space to be investigated. This is of particular importance if anisotropic consolidation is required on overconsolidated soil where the lateral pressure can exceed the vertical (Henkel & Sowa, 1963; Brooker & Ireland, 1965).

Figure 3.2 shows how the connections to the load ram were made. An adaptor was manufactured for the hydraulic actuator; it had a housing machined to fit the top of the load ram, the connections being made by two shear pins which located in holes at the top of the ram. The adaptor was provided with a slot which allowed the leads from the load cell to exit. To provide the connection between the load ram and specimen top cap, first a plate was screwed into the end of the ram and the assembly then machined so that the ram and plate were at right angles. The specimen top cap was then machined to provide a groove for an 'O' ring plus a central recessed area with bevelled edges to match the bottom of the load plate thus ensuring that the ram seated centrally on the cap. The two could then be held together by a partial vacuum applied as shown in Figure 3.2. Bolts for holding down the cell during triaxial testing are shown in Figure 3.3 together with a general layout of the stress measuring systems described.



LOADING RAM AND TOP PLATEN

Figure 3.2

3.2.2 Confining Stress

Although the loading equipment was capable of cycling the confining stress, it had never been extensively used because of several drawbacks. The pressure chamber on which the actuator operated contained a bellofram* whose limits of travel were less than the actuator (100 mm) giving the danger of bursting the diaphragm. The apparatus was set up so that a long run of tubing to the triaxial cell was needed, the entry orifice to the cell was small and the monitoring transducer was connected to the small bleed hole in the cell top. All this cumulated in a set up with large compliance and slow response.

The system was improved by providing a pressure chamber manufactured by Schrader Pneumatics Ltd. which contained a piston with special seals to operate with liquids rather than air. The piston had a stroke of 150 mm and it was mounted so that it was close to the triaxial cell. A new large entry orifice to the triaxial cell was provided in the cell top together with a transducer made by Druck Ltd. incorporating a semi-conductor strain gauged silicon diaphragm. This resulted in a stiff system with a fast response able to apply a maximum confining stress of 530 kPa.

The confining medium in the triaxial cell was changed from de-aired water to silicone fluid (Dow Corning 250/20 cs), as it was planned to increase the amount of electronic equipment. This oil was chosen as it had low viscosity, was an excellent electrical insulator, chemically inert and had no detrimental effect on latex, strain gauges or transducers.

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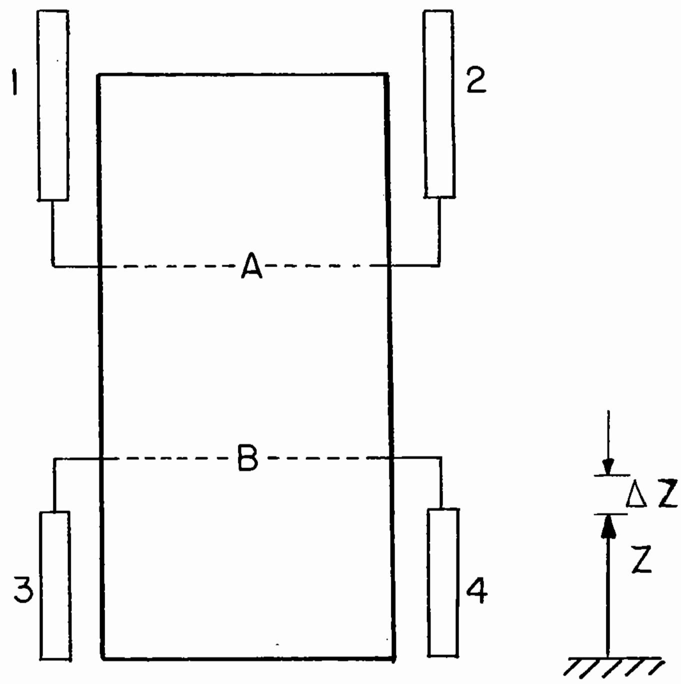
*A bellofram is a frictionless seal formed by a flexible rolling diaphragm. It has high and low pressure sides over which a pressure difference must exist to avoid convolutions occurring whilst it is in operation.

It is possible that osmosis could occur through the rubber membrane. Tavenas et al., (1978) tested silicone fluid and found that osmosis was significant for undrained tests on soil with high overconsolidation ratios. However, Crawford (1963) found osmosis through latex rubber membranes to be very small even with large osmotic gradients.

3.2.3 Axial Deformations

Axial deformations were previously measured by an LVDT connected to the load ram. This had the disadvantage of only measuring the overall deformation of the system and had to be calibrated to allow for deformations occurring other than in the soil. To improve the reliability of the results, a facility to measure deformations inside the triaxial cell was necessary. However, several limitations had to be considered; any equipment had to be sufficiently small to fit in the restricted space available, a large range of operation was needed to encompass deformations due to both consolidation and testing and little or no weight should be imparted to the soil.

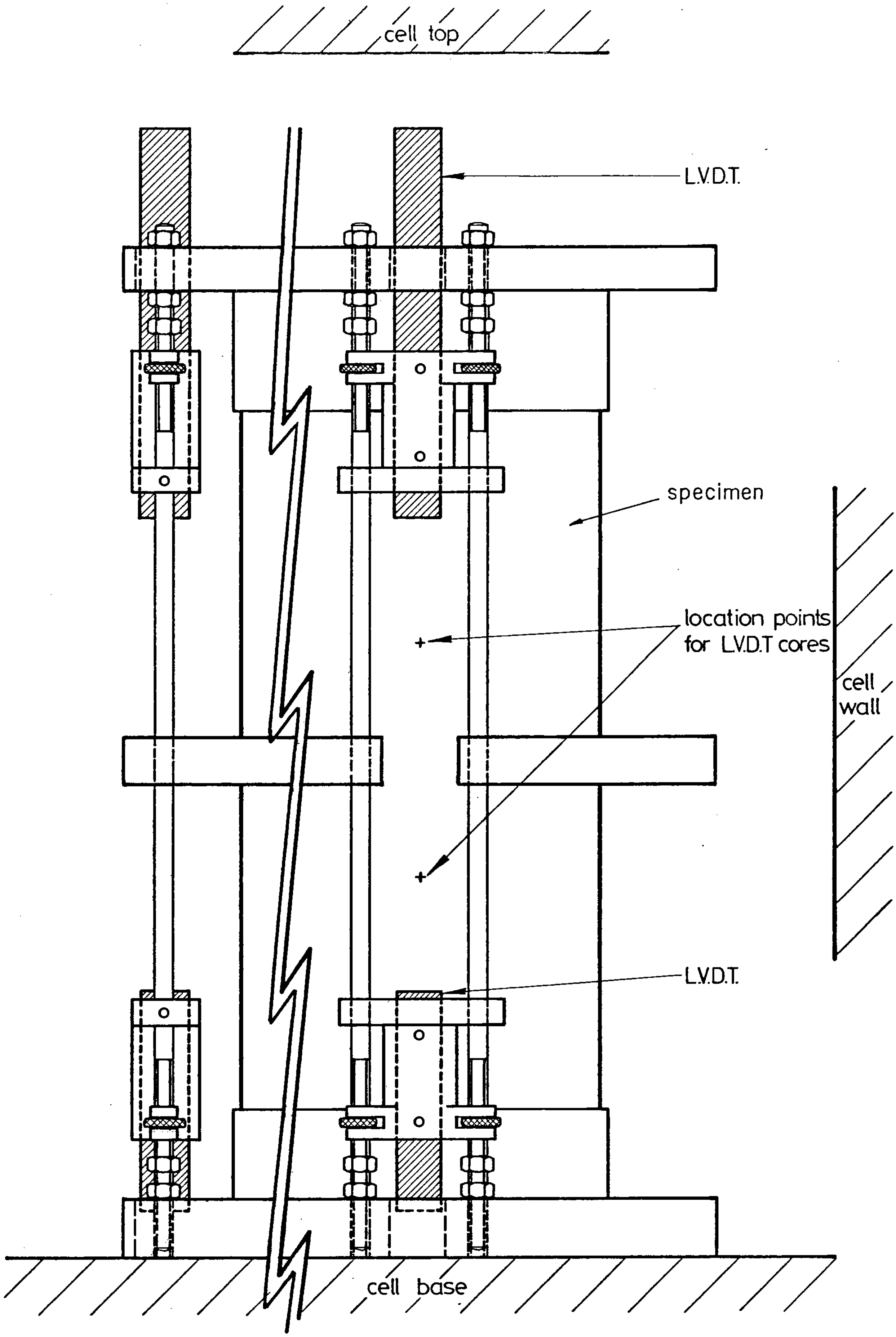
The arrangement chosen was four LVDTs for each cell, the principle of the system is shown in Figure 3.4. Each LVDT monitored one end of a gauge length (AB) over the central third of a specimen, relative to a common reference point. The arrangement can compensate for any tilt by electronically averaging the output of the upper two LVDTs and, similarly, the output of the lower two. By subtracting the averaged output, a measure of axial strain can be obtained over the gauge length. The gauge length chosen was 50 mm which allowed reasonable room for the instrumentation and recorded data from points remote from any possible end effects.



$$\varepsilon_a = \frac{\dfrac{\Delta Z_1 + \Delta Z_2}{2} - \dfrac{\Delta Z_3 + \Delta Z_4}{2}}{Z_A - Z_B}$$

POSITION OF LVDTs ON A SPECIMEN

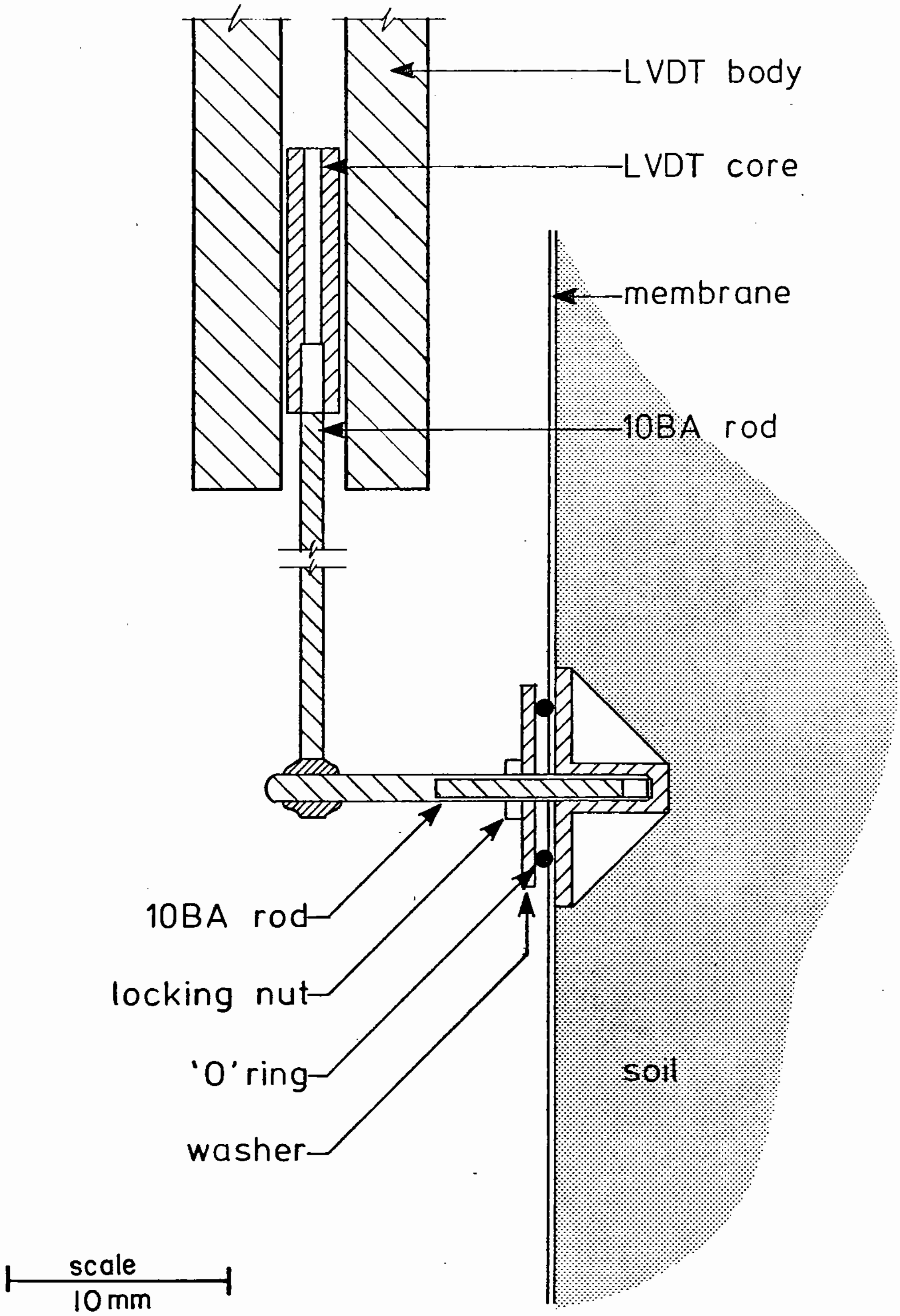
Figure 3.4



LVDT SUPPORT FRAME

(Diagram shows two views of the support)

Figure 3.5



LOCATION STUD

Figure 3.6

(Diagram shows original sliding joint)

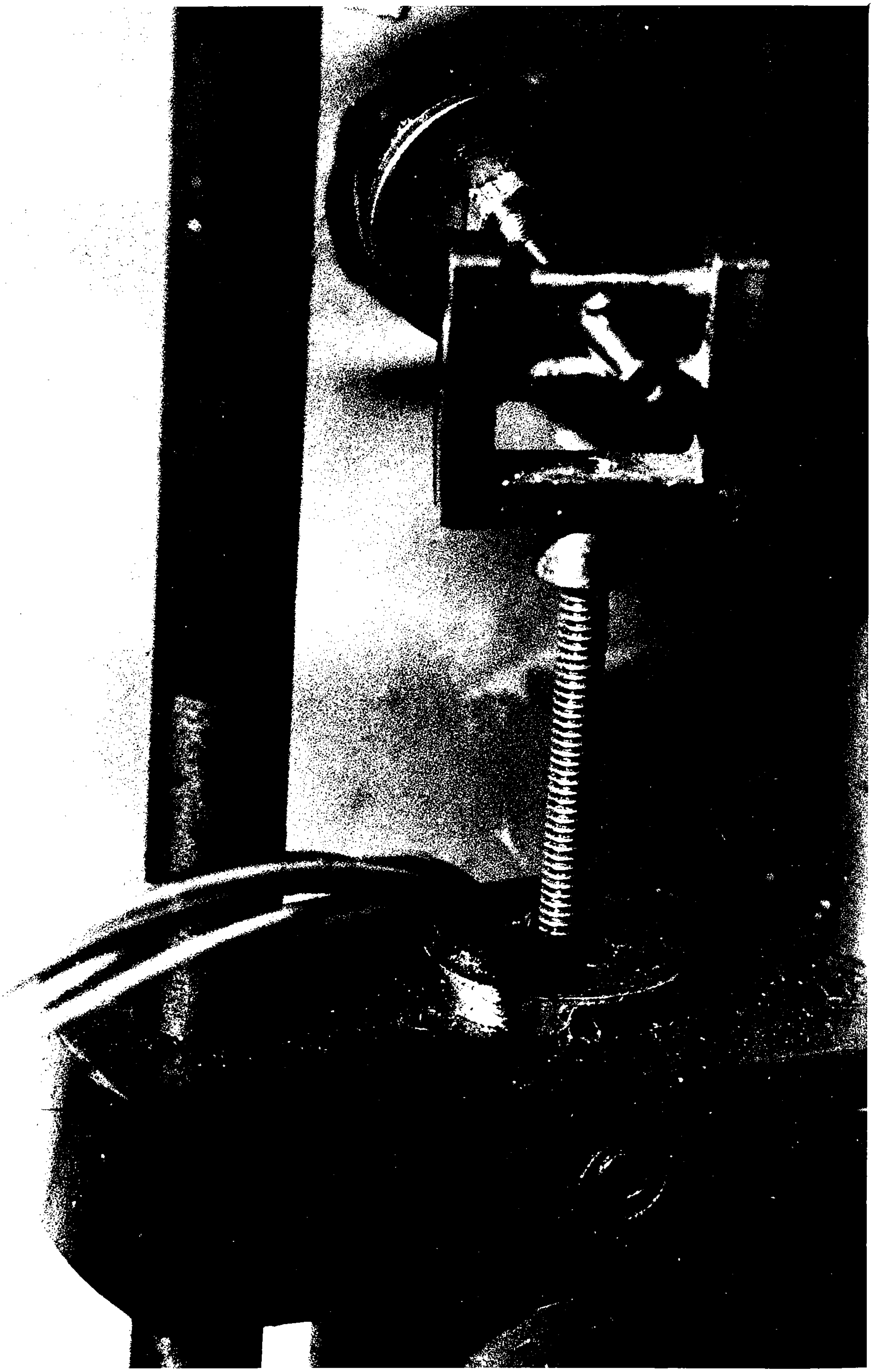


PLATE 3.1 LVDT CONNECTION

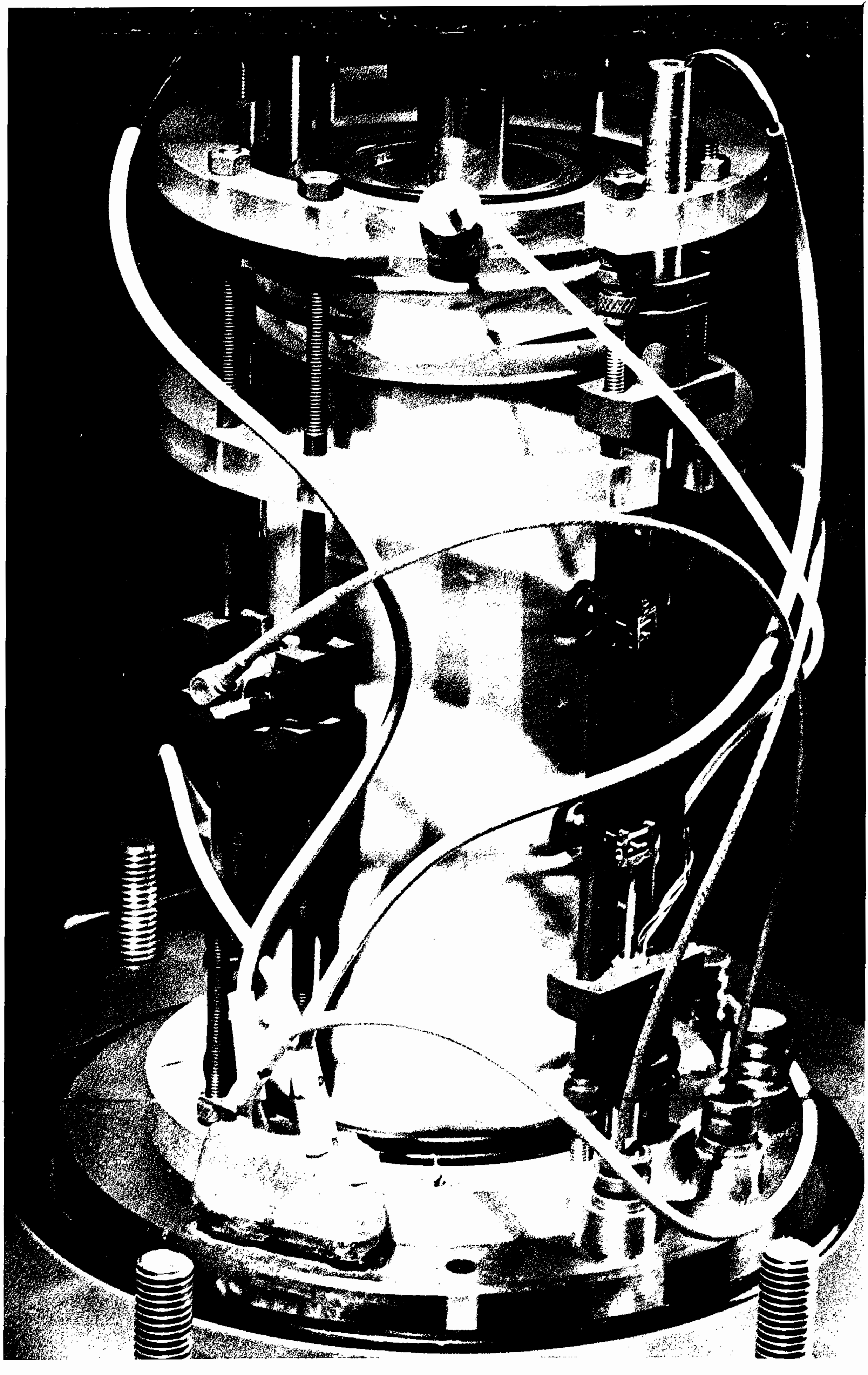


PLATE 3.2 TRIAXIAL CELL INSTRUMENTATION

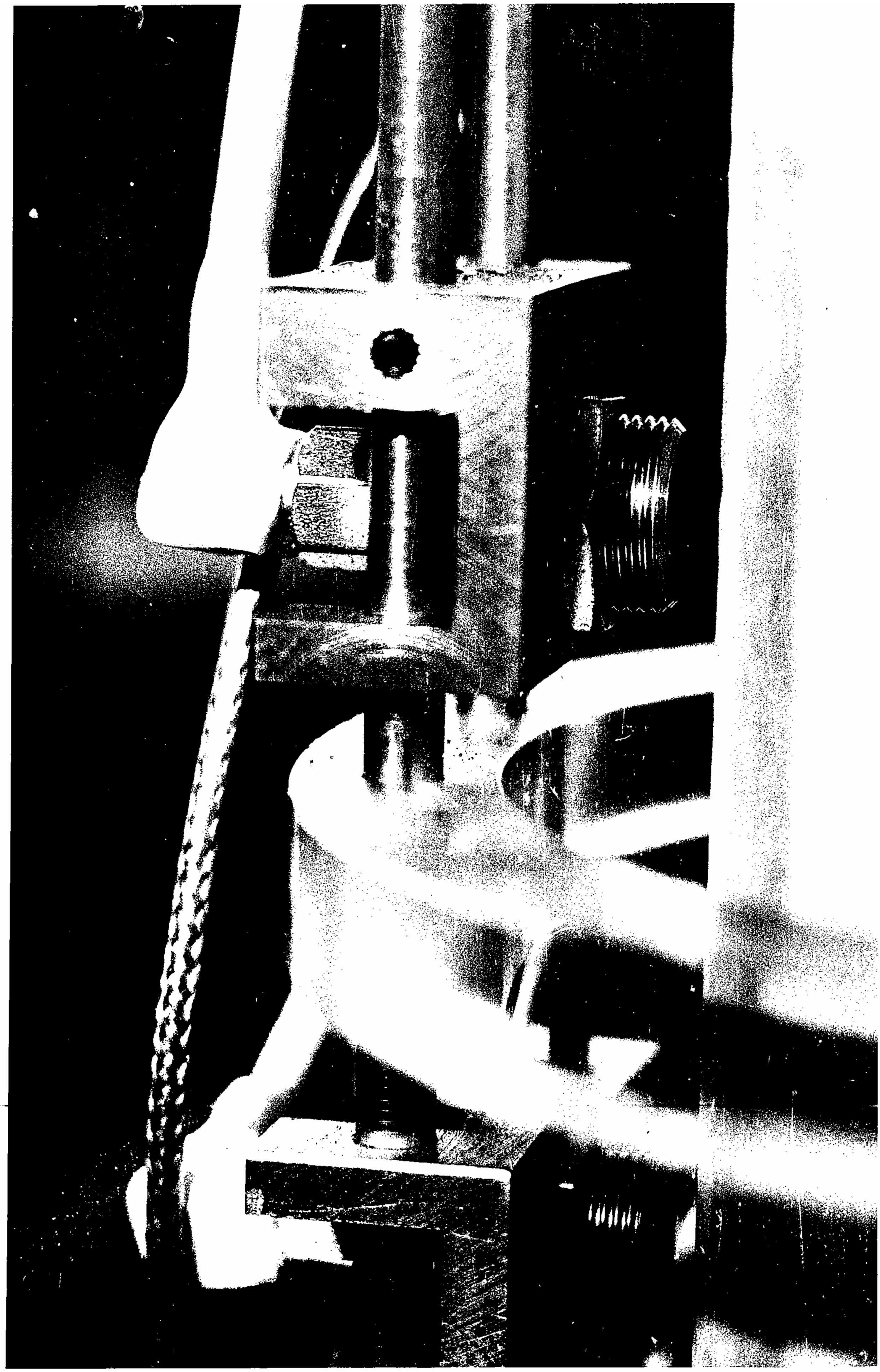
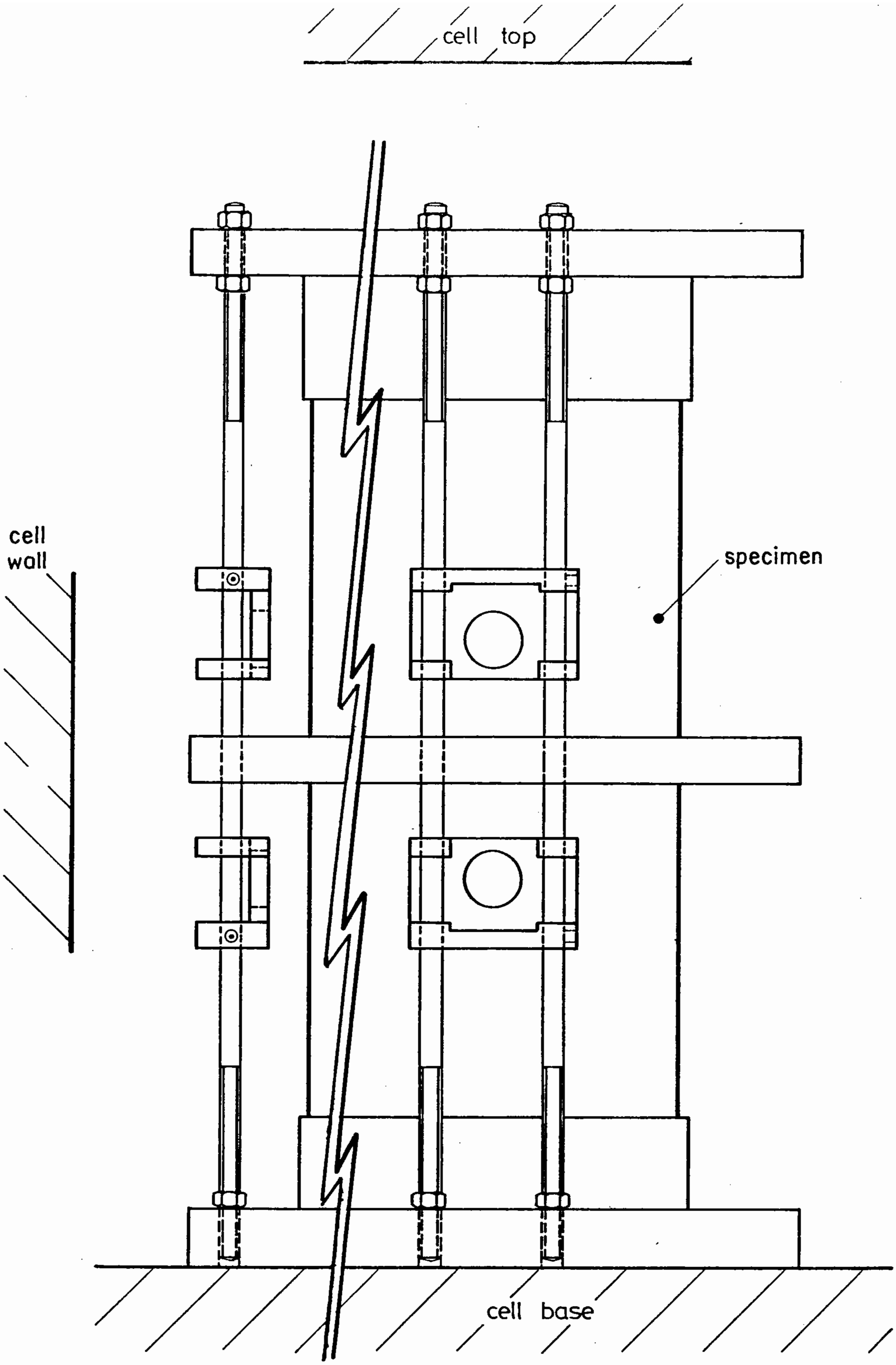


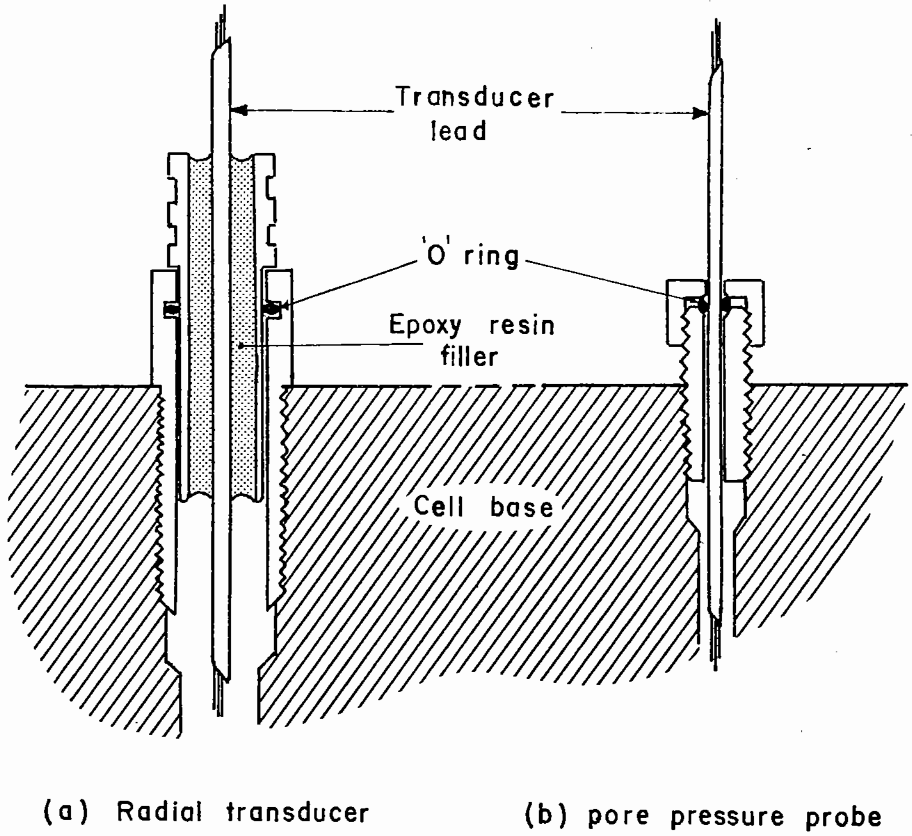
PLATE 3.3 RADIAL TRANSDUCER MOUNT



PROXIMITY TRANSDUCER SUPPORT FRAME

(Diagram shows two views of the support)

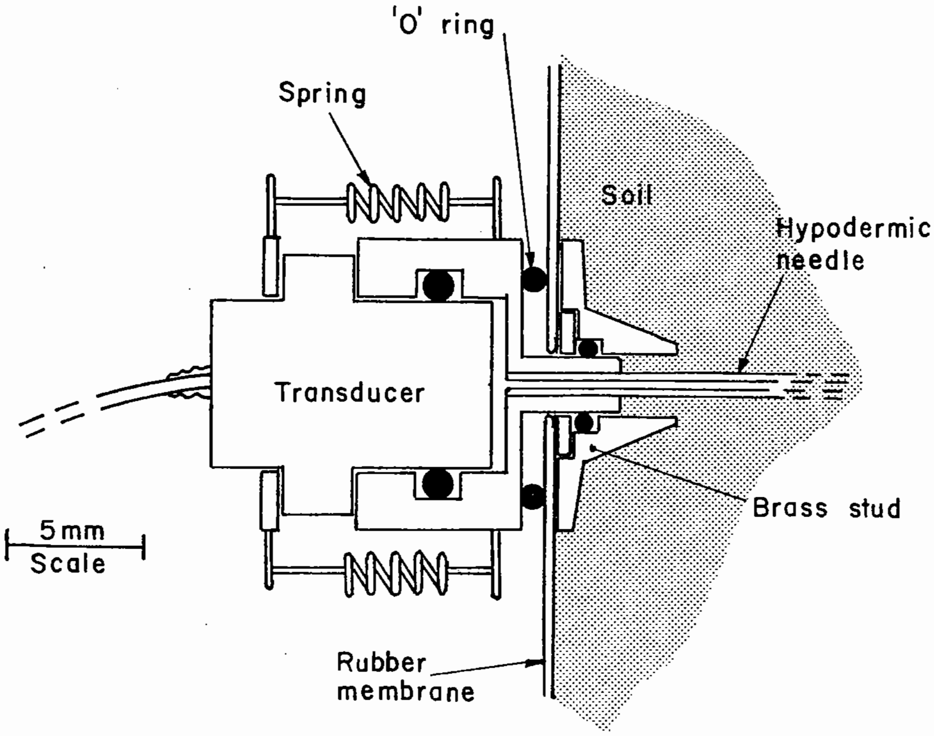
Figure 3.7



(a) Radial transducer (b) pore pressure probe

LEAD EXITS

Figure 3.8



CENTRAL PORE PRESSURE MEASUREMENT

Figure 3.9

specimen and instrument frame, the central perspex ring has been raised to avoid obscuring details. The plate also shows the radial deformation transducers described below and the transducer lead exits. Further details on the use and construction of the measuring system is given in Chapter Four.

To ensure alignment of the LVDTs on their frame and the location studs on the membrane, a special membrane stretcher was developed that could be located onto the fixing points in the cell base for the frame, thus allowing accurate positioning of the studs.

The top pair of LVDTs were Schaevitz MHR500 with a range of ±12.5 mm and the others were type MHR250 with half that range. The oscillator-demodulators for the LVDTs were obtained from R.D.P. Electronics Ltd. and are part of their Dataspan 2000 series. The lead exits from the cell were provided by microplugs and sockets produced by Radio Spares Ltd.
The araldite cell bases were machined to take the necessary electrical sockets and cable which were positioned and then sealed by casting more araldite around them.

3.2.4 Radial Deformations

To monitor specimen deformation in a radial direction either two or four proximity transducers were used. The devices give an electrical output proportional to the distance between their sensitive face and a metal foil target. The transducers work by inducing eddy currents in the target which in turn affect the output of a bridge circuit in the transducer. With suitable electronics, this gives a linear variation of voltage with distance.

As it was planned to test soft clays, it was necessary to support the instruments with a frame. The frame was made from one aluminium and two perspex rings of 100 mm internal diameter separated by eight vertical brass rods as shown in Figure 3.5. The bottom ring of aluminium could be locked onto a cell base, the perspex rings being at a specimen's mid-height and top cap level. The LVDTs were held in small carriages on the brass rods. The carriages were provided with small thumb screws whilst the brass rods of the frame were threaded for part of their length. This allowed the initial output of the LVDTs to be chosen as required when setting up a specimen. The carriages were held in position by lock nuts on the rods. The above system only required the soil to support the weight of the LVDT cores.

In order that any movement of a soil specimen was accurately followed by the LVDTs, the cores had to be attached to the soil through its enclosing rubber membrane. To achieve this, a small brass stud which penetrated the soil was used for each connection. The connection is shown in detail in Figure 3.6 and Plate 3.1. Each stud consisted of a 10 mm diameter brass disc, with a central shaft of sufficient diameter to take a 10 BA female thread 6 mm long. Four brass vanes were added to increase its resistance to movement in the soil. The studs were sealed to the membrane by glue (Loctite IS 495) and a rod screwed into each one so that it protruded from the membrane. An 'O' ring and washer were used as an extra seal. The protruding horizontal rod could then be attached to a vertical rod and the LVDT core. The connection between the two rods was originally a sleeve which allowed the horizontal rod to slide in the joint and not inhibit radial movement, whilst measuring vertical movement, as shown in Figure 3.6. This connection was later modified to a slot which would also allow a small amount of tangential movement at the joint as shown in Plate 3.1. Plate 3.2 shows an overall view of a

The transducers imparted no loading on the soil and were mounted on the frame that supports the LVDTs as shown in Figure 3.7, such that they were diametrically opposite each other and near the specimen mid-height. Plate 3.2 shows their position relative to the axial deformation LVDTs. The radial transducers were mounted on small carriages to allow vertical adjustment. Each transducer was manufactured with a threaded case so that with two locking nuts it could be set in the radial direction to use the full range of the transducer. The recommended target for the transducer is aluminium foil which can be placed on a specimen before it is enclosed with a rubber membrane. The induced eddy currents are very much surface phenomena and to avoid reinforcing the soil locally, very thin foil was used with a thickness of 0.0125 mm (0.5 thou). A detailed view of a transducer is given in Plate 3.3.

The transducers are made by Kamen Sciences Co.; are 14 mm in length and have a 12.5 mm diameter. The linear range is 2.5 mm. The manufacturer advised against cutting the transducer leads, thus making it difficult to seal the cell without fixing the leads permanently. To overcome this, a brass tube, of 12 mm internal diameter, containing an '0' ring seal was manufactured to screw into the base. A brass plug was made to fit the tube and a 10 mm hole drilled through it providing sufficient space to allow the electrical plug on the lead to pass. The lead was then positioned and the brass plug filled with epoxy resin. The lead exit detail is shown in Figure 3.8.

3.2.5 Pore Pressure Measurements

To try and improve the quality and reliability of the pore pressure measurements, it was decided that a probe should read pore pressures at the specimen mid-height. It was hoped that this would be able to follow the transitory values associated with cyclic loading as well as the permanent pore pressures developed.

Two methods have been tried to obtain the measurements. The transducer used in both attempts was a Druck PDCR 81 and had dimensions of 10 mm by 6 mm diameter. It had a maximum pressure rating of 700 kPa. The transducer was very stiff, very sensitive and was fully sealed allowing it to operate within a pressure medium.

The first method tried was to have the transducer in a housing outside the specimen, connected to a hypodermic needle which was pushed into the soil and sealed at the rubber membrane. The equipment is shown in Figure 3.9. A vacuum was used to de-air the parts, which were then assembled under water. The transducer was held in the housing by a collar and springs. To locate and seal the unit in the soil, a small brass disc was made with a hole and '0' ring seal. This was cemented to the membrane with the axial deformation studs (section 3.2.3) prior to enclosing the soil. A small brass plug was used to close the hole whilst building in the sample. The plug was then removed and an '0' ring stuck to the outside of the membrane, over the disc; the needle was pushed into the soil and the housing stuck to the '0' ring. The purpose of the '0' ring was to give a small area to push the housing against, thus reducing the force necessary to make good contact and form a seal. Finally, the area was painted with a rubber solution. The system worked well for the slow pore pressure changes during consolidation, but was completely insensitive to the faster changes during testing, being far inferior to that of the base probe.

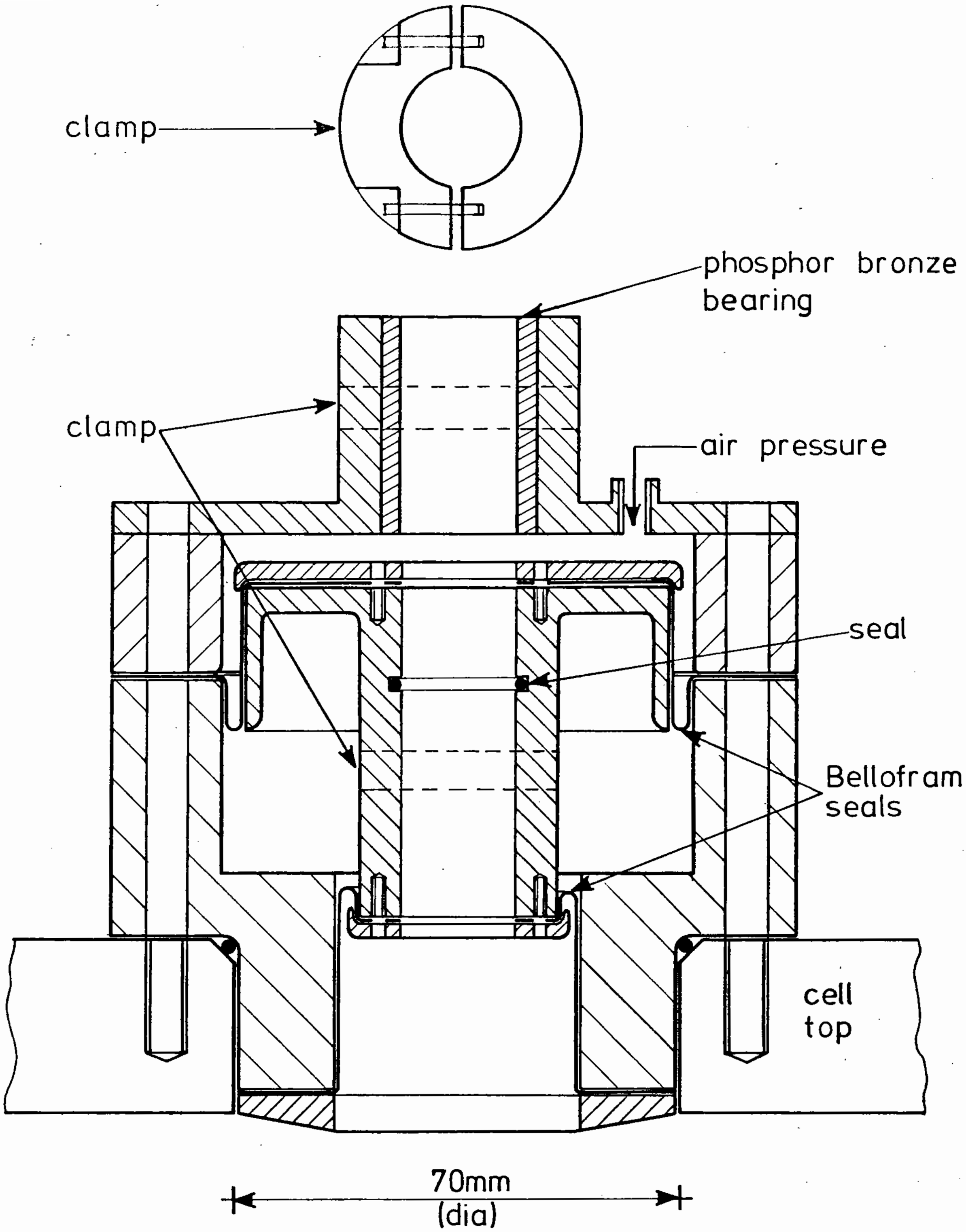
The second method involved consolidating the transducer into the soil slurry. The only equipment modification needed was to provide a lead exit from the soil through the top cap. This was effected as shown in Figure 3.2. This system was much more sensitive, especially when the ceramic face was replaced with sintered bronze, and was adopted for the main test programme. Its preparation and use is described in greater detail in Chapter Four. A lead exit from the cell, similar to that for the radial transducers, was used and is illustrated on Figure 3.8.

3.2.6 Anisotropic Consolidation

During isotropic consolidation, soil is subjected to an equal all round stress under which drainage occurs. To achieve anisotropic consolidation, it is necessary to change the ratio of the principle stresses. Of particular interest is K_0 consolidation where the horizontal strains are zero. In the triaxial cell, the principle stresses are the horizontal and vertical stresses so, for K_0 conditions during normal consolidation, a deviator stress must be applied over and above the confining stress.

To provide this, a servo-controlled system was built which used the radial deformation transducers as a control. A special unit fitted to the cell top could apply deviator stress through the load ram to the soil. The loading unit is shown in Figure 3.10. It consists of a piston in a housing. The piston could be clamped to the load ram for consolidation and had bellofram rolling diaphragms top and bottom. The lower bellofram formed part of the cell wall, the upper bellofram having air pressure above it to provide the downward force. The central clamp was reached through two slits cut in the housing so that the load ram could be freed from the piston at any stage. This also kept the low pressure side of the belloframs at atmospheric pressure avoiding convoluting the diaphragms. A second clamp was provided at the top of the unit to lock the load ram to the housing.

The upper bellofram had an area of 4,097 mm^2, the lower an area of 1,000 mm^2. This ratio was provided to give a four to one advantage so that the air pressure needed to counter the upthrust from the cell confining pressure, and apply the consolidation force, could be kept small. Details of the pressures needed for consolidation are given in Appendix A.



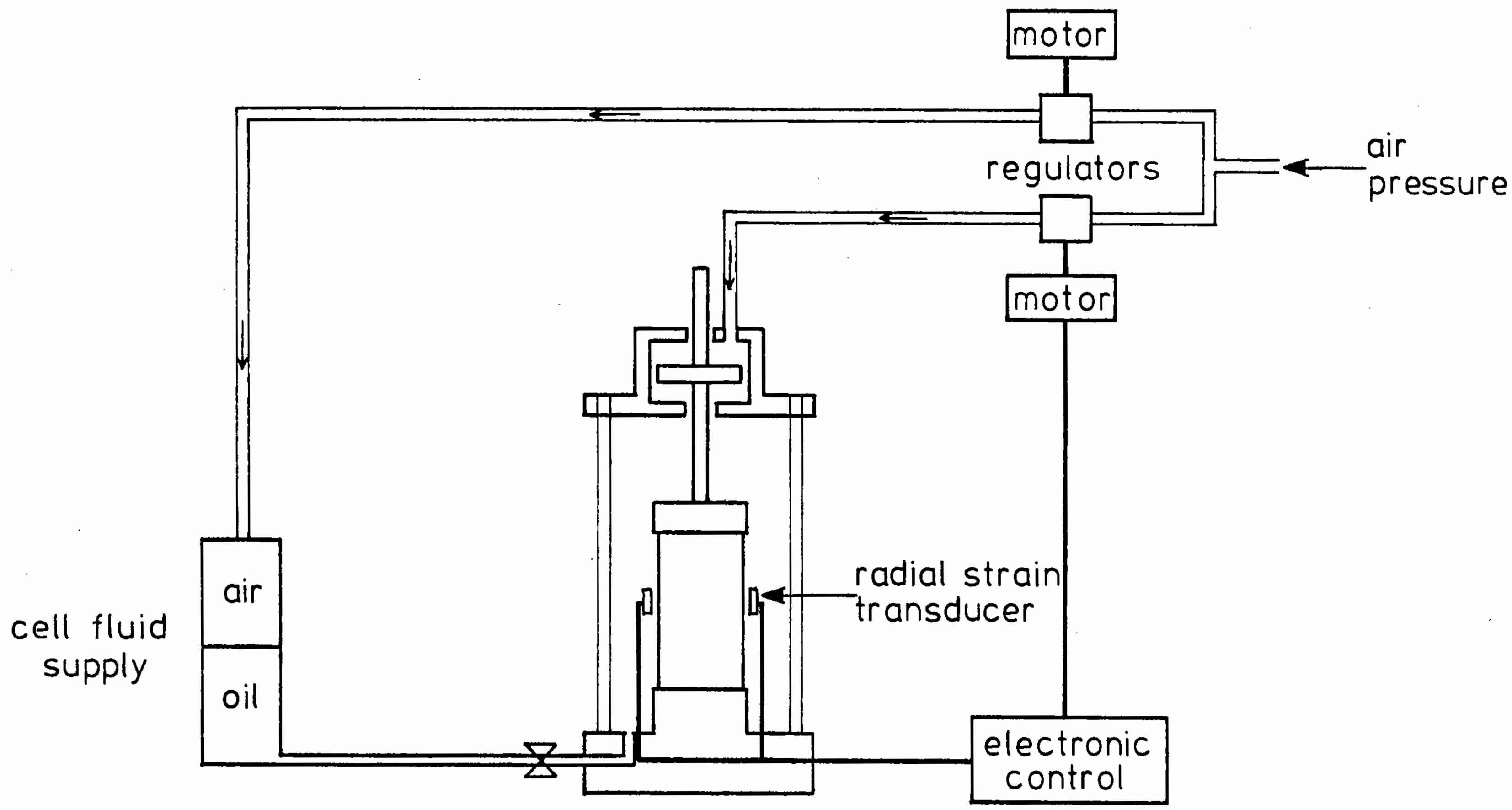
ANISOTROPIC CONSOLIDATION CELL TOP

Figure 3.10

The complete consolidation system is shown in Figure 3.11. The cell pressure was provided by an air compressor, controlled by a regulator and acting on an air/oil reservoir. The reservoir was connected to the triaxial cell so that oil was driven into the cell to provide the confining medium. Consolidation was effected by a regulator driven with an electric motor and chain drive that increased the confining stress at a slow rate of 3 kPa/hour. The radial transducers monitored the soil so that if deformation occurred, electronic control relays adjusted the vertical stress through a D.C. shunt motor and gearing. The system could respond to either an increase or decrease in the specimen diameter by decreasing or increasing the deviator stress. During normal consolidation the soil tended to decrease in volume and the deviator stress was always increasing. For over-consolidation, the confining stress could be decreased at a slow rate whilst the transducer control adjusted the vertical stress accordingly. For anisotropic overconsolidation ratios of above about 4, a principal stress reversal occurs with the axial stress becoming less than the radial. The unit could apply the necessary pressures as the upthrust of the cell pressure on the lower bellofram would produce a negative deviator stress.

3.2.7 Slurry Moulds

The soil specimens used in this research were all consolidated from slurry before being built into the triaxial cell. Equipment existed to do this at the start of the research but it was felt that the vertical pressure used in consolidating the slurry was too high, when compared with the stresses used in the triaxial cell. In addition, the equipment tended to give a moisture content gradient in the soil due to the loss of pressure caused by friction between the top cap, soil and side walls of the mould. The resultant specimens required trimming from 100 mm diameter to 75 mm diameter which added to sample disturbance.



CONSOLIDATION CONTROL

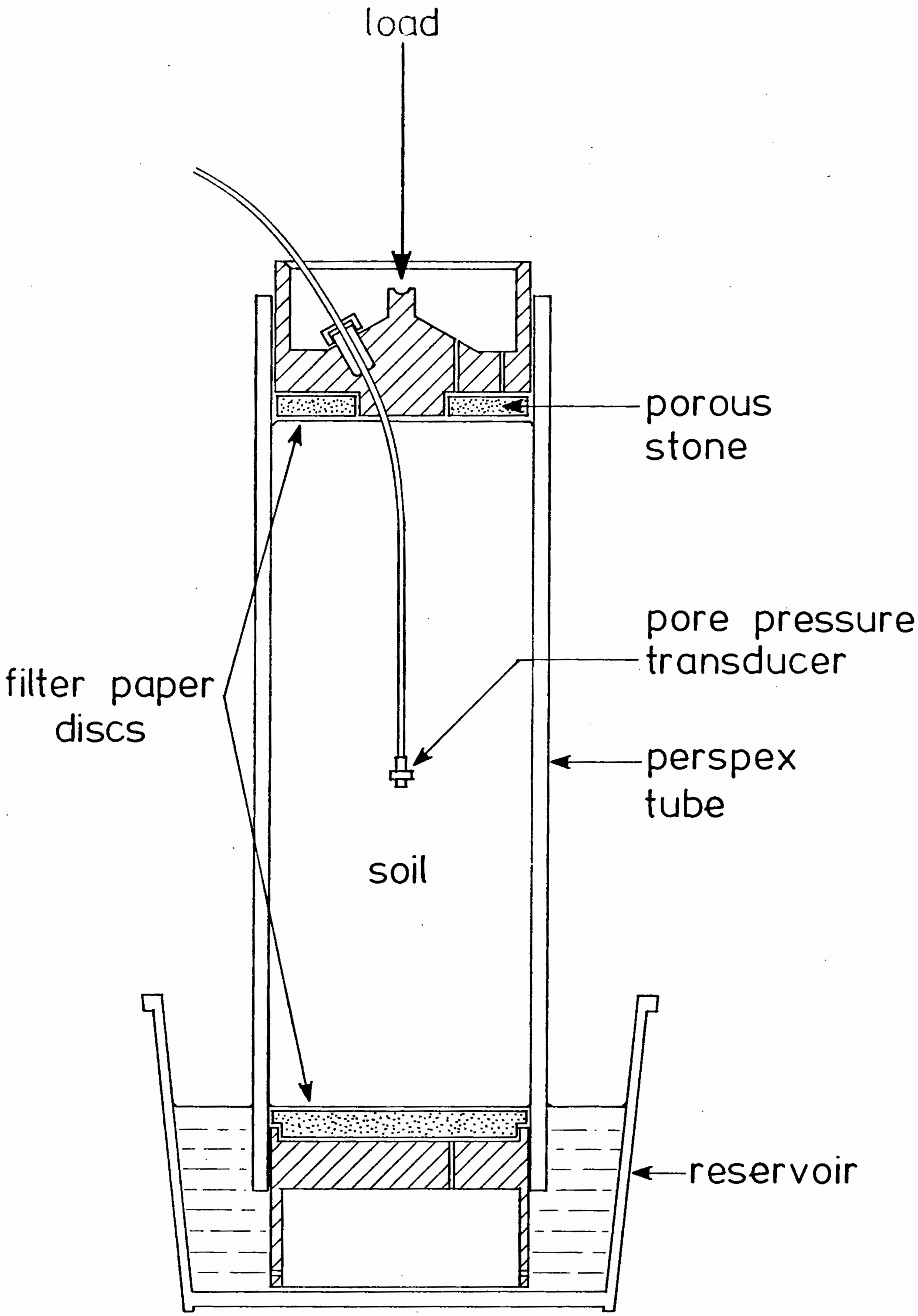
Figure 3.11

The applied pressure during consolidation is important because if the stresses are released from a normally consolidated soil, it wants to swell and take in water. If this is prevented, the soil develops negative pore pressures which can cause cavitation. Loudon (1967) suggested that on re-application of pressure to continue consolidation, soil does not return to the normally consolidated state at the previous maximum pressure. Rather the path taken by the soil tends gradually towards the normally consolidated condition. If the stress release is large, the soil cannot be considered normally consolidated again until the pressures on it are approximately three times the maximum past pressure. This stress release occurs when the soil is extruded from the slurry mould and built into the triaxial cell.

To overcome the above problems, a set of moulds were designed and built, based on a design for 37.5 mm diameter samples belonging to Lewin (1978). The new moulds are shown in Figure 3.12. They consist of 300 mm long perspex tubing having an internal diameter of 78 mm. Aluminium end caps were manufactured to fit the tubes with 0.125 mm clearance. Both end caps incorporated porous stones for drainage and were free to move relative to the perspex side walls. This produced manageable specimens under a vertical pressure of 70 kPa, which was approximately half that applied to the original moulds.

3.2.8 Lubricated End Platens

Lubricated ends consisting of a stainless steel end platen with a high vacuum silicone grease, rubber membrane sandwich have been in use for triaxial testing for some years. A disadvantage of this system is that the grease is lost from the end platen over a period of a few days, greatly reducing the effectiveness of the free end, at least until enough movement occurs to re-smear the remaining grease over high spots (Rowe and Barden, 1964; Lee, 1978). In an attempt to develop long term free ends for triaxial



SLURRY CONSOLIDATION MOULD

Figure 3.12

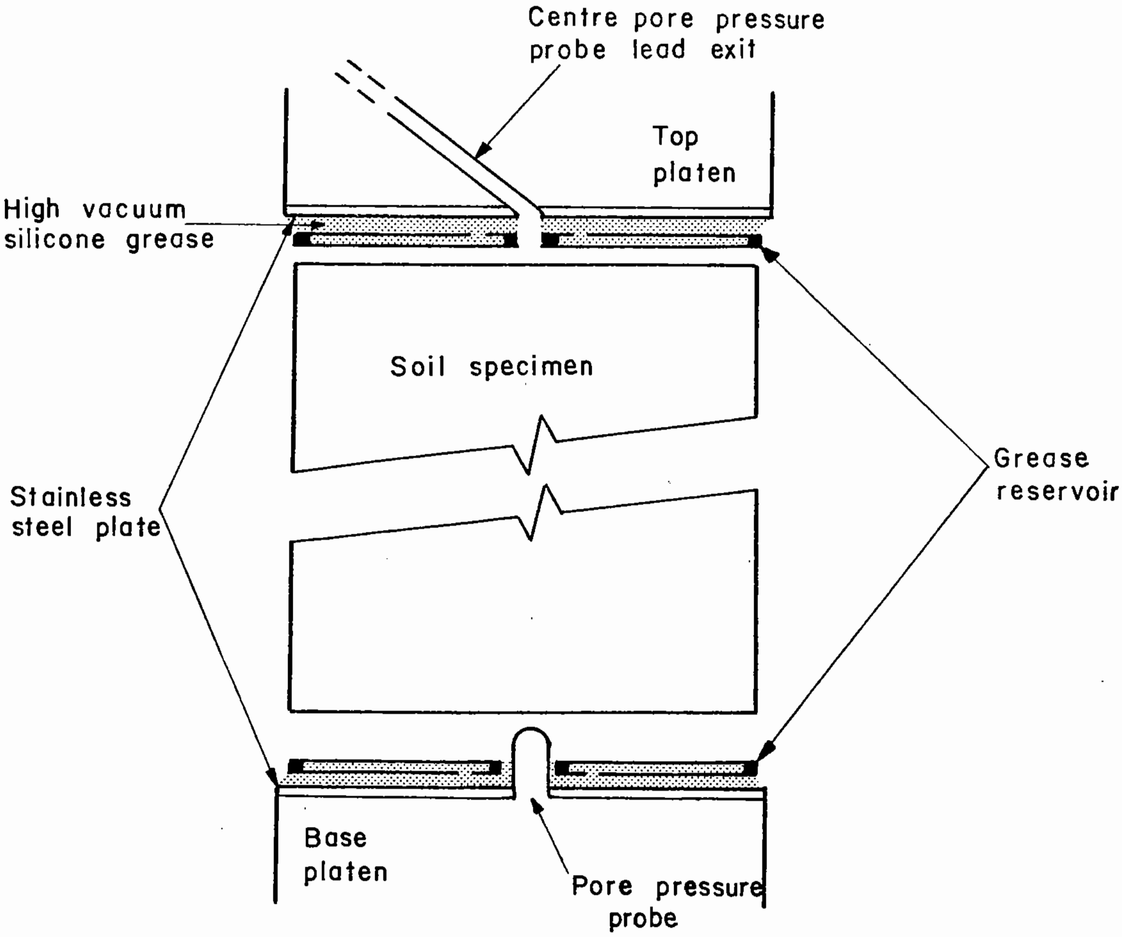
testing, use has been made of grease reservoirs on each loading platen. The reservoirs were made of discs of rubber cemented together by their rims and having small bleed holes to provide a continuous supply of grease to the steel platen (Marsden, 1976). Provision was made at the centre of each reservoir for a probe to be connected to the pore pressure systems which protrude into the soil from each end platen. The grease reservoirs are illustrated on Figure 3.13.

3.2.9 Data Collection

An ultra-violet chart recorder (S.E. Laboratories type 3000 D/L) was used for recording measurements from all stress and strain transducers (calibrations are given in Appendix A). The recording system has a high frequency response (200 Hz) and supplies a permanent analogue record of the results. Step gain switches were inserted into each of the transducer amplifiers. Using this system, it was possible to resolve permanent axial strains of 50 $\mu\varepsilon$ and permanent radial strains of 15 $\mu\varepsilon$ (microstrain).

For the resilient strain readings the strain signals were passed through a D.C. offset generator and then amplified. This ensured that the amplified strain signal remained within the scale of the recorder. Using this technique, small resilient strains (10 $\mu\varepsilon$) could be resolved even if superimposed on a large permanent strain.

The transducer outputs were also connected to an electronic unit which converted all the signals to a common sensitivity. This allowed direct recording of stress-strain and effective stress paths on an X-Y plotter.



LUBRICATED END PLATENS

Figure 3.13

CHAPTER FOUR

EXPERIMENTAL PROCEDURES

4.1 THE MATERIAL

The soil used in this project was Keuper marl. It is a red-brown mudstone formed in the triassic age and is found extensively in the Midlands (Hyde, 1974). The material was obtained from a local brickworks in Nottinghamshire and consisted of tailings from the process of compressing the clay to form green bricks (unfired). The tailings were air dried and then placed in a mixer which broke the material down. This was then sieved through a BS 52 sieve (150 micron).

The powdered soil was first mixed for a period of at least three days at an initial moisture content of 55% (1.8 x Liquid Limit). Any water loss through evaporation was made up by keeping the slurry level in the mixer constant. A series of standard tests have been performed to obtain the basic classification data. They are presented in Appendix B.

4.2 INITIAL CONSOLIDATION

The soil slurry was de-aired by pouring it into an aluminium tube which was placed on a vibrating table, covered and a vacuum applied.
The slurry mould was prepared by de-airing both end caps under water in a vacuum vessel. The bottom cap was placed in a water reservoir (Figure 3.12) and a perspex tube placed over it. A disc of filter paper was put on the porous stone such that it swelled sufficiently when wetted to prevent any soil filling the clearance gap between the tube sides and end cap.
The tube was then carefully filled with de-aired slurry, using a long handled pot. At the same time the mould was gently agitated to remove any entrapped air. When the mould was full, it was gently raised until most of the bottom cap protruded. The top of the mould was cleaned and refilled with de-aired water before a second filter paper disc and the top

cap were positioned.

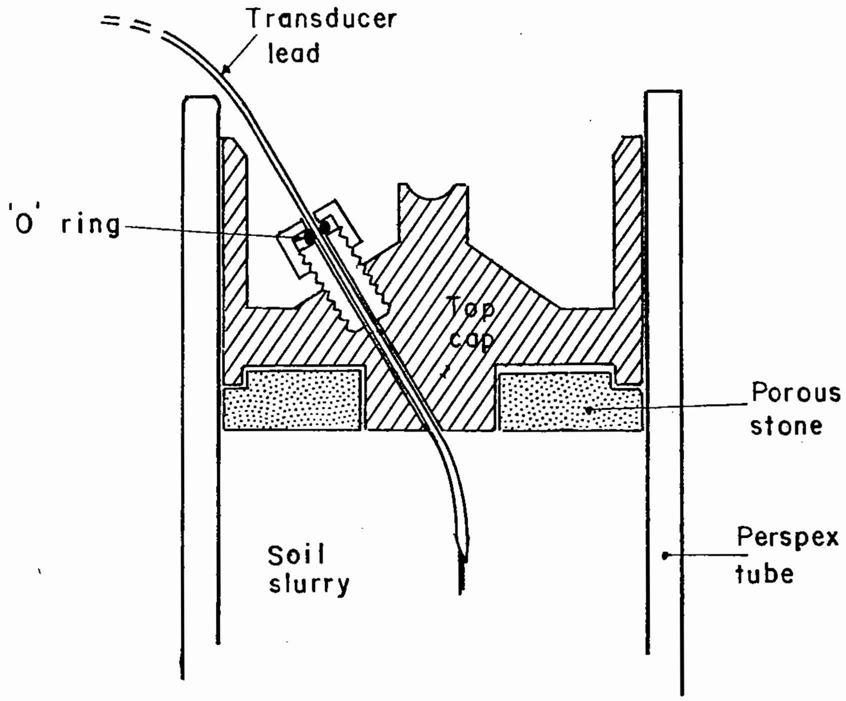
If a pore pressure transducer was to be consolidated into the slurry, the transducer was first de-aired and kept under water. The lead was threaded through the top cap by the lead exit shown in Figure 4.1 and the length of lead adjusted so that the transducer hung about 100 mm below the cap. To position the transducer in the soil the top filter paper disc was slit at its centre before being placed in the mould. The top cap and transducer were then positioned, care being taken to keep the transducer immersed.

The mould was placed in a loading frame, a vertical load of 70 kPa applied and the soil left to consolidate. A series of experiments determined that under 70 kPa the soil would take 14 days to reach a moisture content under the Liquid Limit. Details are given in Chapter Six and Appendix D.

4.3 TRIAXIAL CELL PREPARATION

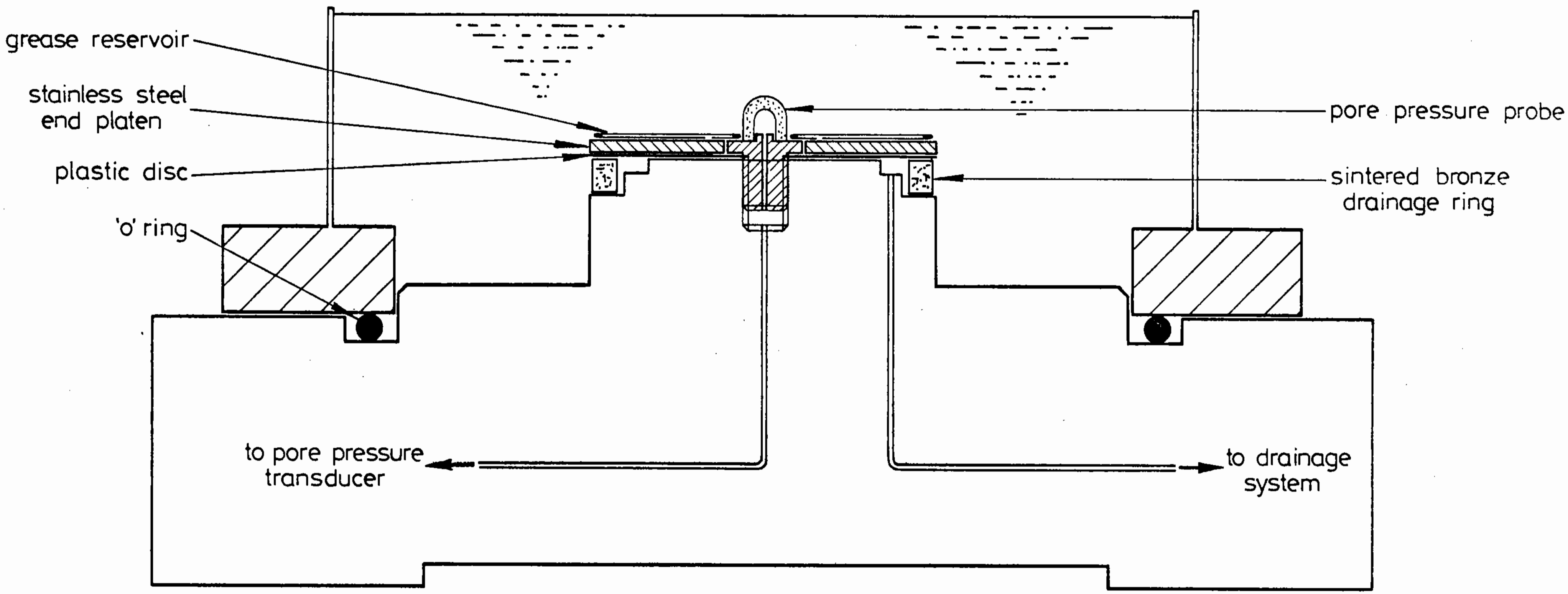
4.3.1 Cell Base

A section through a triaxial cell base is shown in Figure 4.2. In order that the base pore pressure and drainage systems could be de-aired, a metal collar 70 mm high was clamped to the base and filled with de-aired water. All pipe work in the base was flushed with de-aired water during this process. Meanwhile, a sintered bronze drainage ring and pore pressure probe were saturated under a vacuum. They were then transferred, under water, to the cell and put in position on the pedestal. The sides of the pedestal were coated with high vacuum silicone grease to help seal the rubber membrane which was added later. The lower platen was fitted with a lubricated end and placed on the pedestal, the stainless steel of the platen being separated from the bronze ring by a thin disc of plastic.



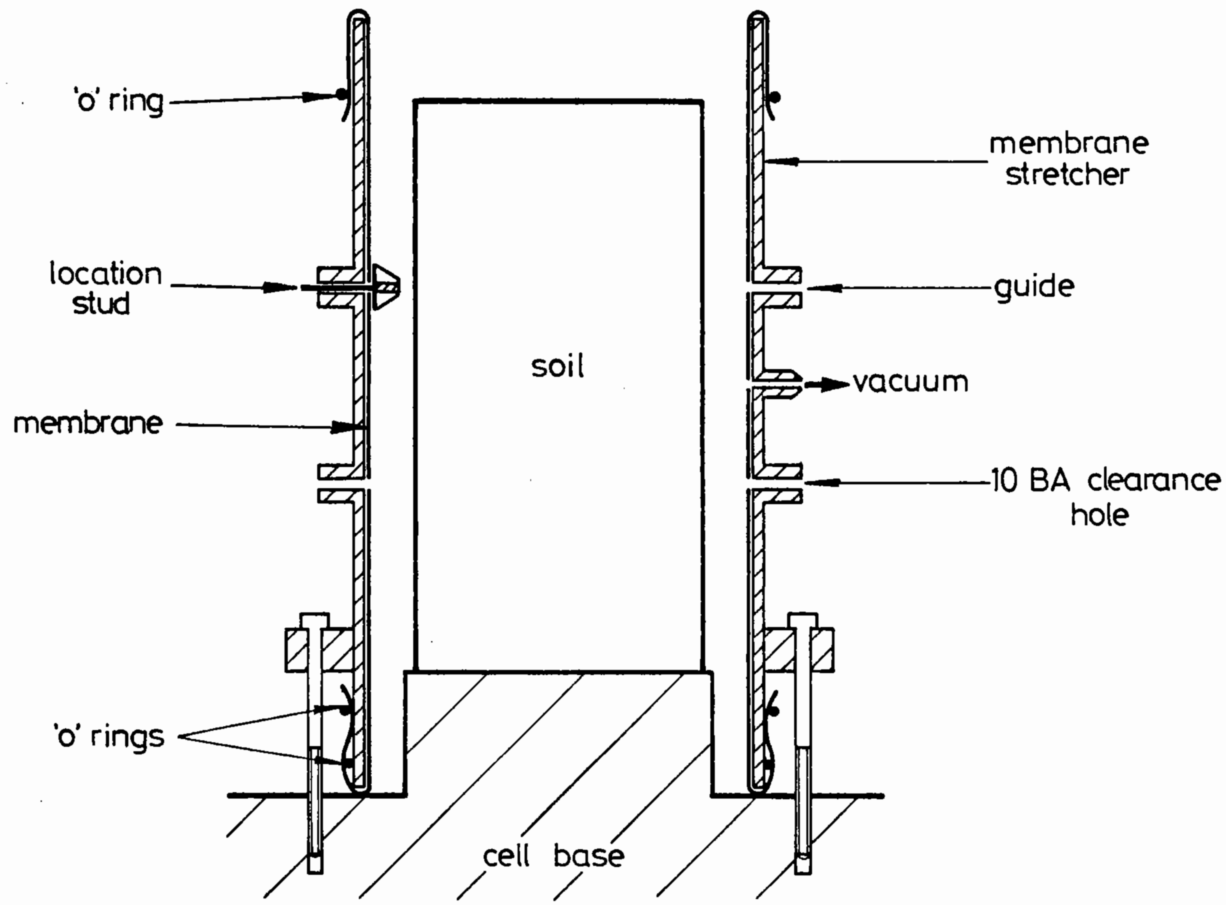
LEAD EXIT FOR CENTRAL PORE PRESSURE TRANSDUCER

Figure 4.1



DETAIL OF CELL BASE

Figure 4.2



MEMBRANE STRETCHER

Figure 4.3

4.3.2 Lubricated Ends

One gramme of high vacuum silicone grease was inserted into each grease reservoir with a syringe. The reservoir was then carefully rolled to squeeze out any trapped air. A stainless steel end plate was covered with a thin layer of grease and a reservoir laid on it. Any trapped air was again removed and a small weight placed on the platen to give an initial even distribution of grease.

4.3.3 Membrane Preparation

A latex rubber membrane 78 mm in diameter by 267 mm long was checked for obvious flaws and, if free of them, was prepared by placing it over a flat template. The template was designed to just fit inside the membrane without stretching it and contained 2 holes spaced 50 mm apart. A soldering iron with a fine tip was then used to puncture the membrane from either side of the template, resulting in 2 pairs of holes, each pair spanning a diameter and spaced 50 mm apart.

Before the four brass locating studs for deformation measurements were stuck over the holes, the brass rods that locate in them had their threads coated with silicone grease and were screwed into the studs. The grease prevented the parts being accidentally cemented together when each stud was glued to the membrane. Both membrane and stud face were cleaned with "inhibisol", a cleaning solvent, and a small amount of adhesive put on the membrane round the holes. Each stud was then pressed to the membrane, locating over a hole.

When all four studs were positioned they were left overnight to allow the bond to strengthen. The membrane was then turned inside out so that the studs were on the inside and the membrane put on the stretcher. 'O' rings were used as shown in Figure 4.3 to form a seal between the membrane and stretcher while the brass rods were positioned in the guides provided. The lowest 'O' ring shown in Figure 4.3 is inside the membrane to facilitate the de-airing of the specimen when being built in. Finally, a vacuum was applied to pull the membrane flush against the stretcher.

4.4 SETTING UP PROCEDURE

A specimen in a slurry mould was weighed. The seal in the cap for the pore pressure transducer lead was unscrewed, the bottom platen removed and the soil carefully extruded a short distance. The end was trimmed with a wire saw to ensure it was plane before the specimen was completely extruded onto the triaxial cell base pedestal. The top cap was then carefully lifted whilst unthreading the pore pressure lead and the filter paper disc removed. The soil was carefully trimmed to a height of 150 mm using a wire saw and former. The soil trimmings were weighed and used for moisture content determination and all parts of the mould were weighed to give the initial weight of the soil.

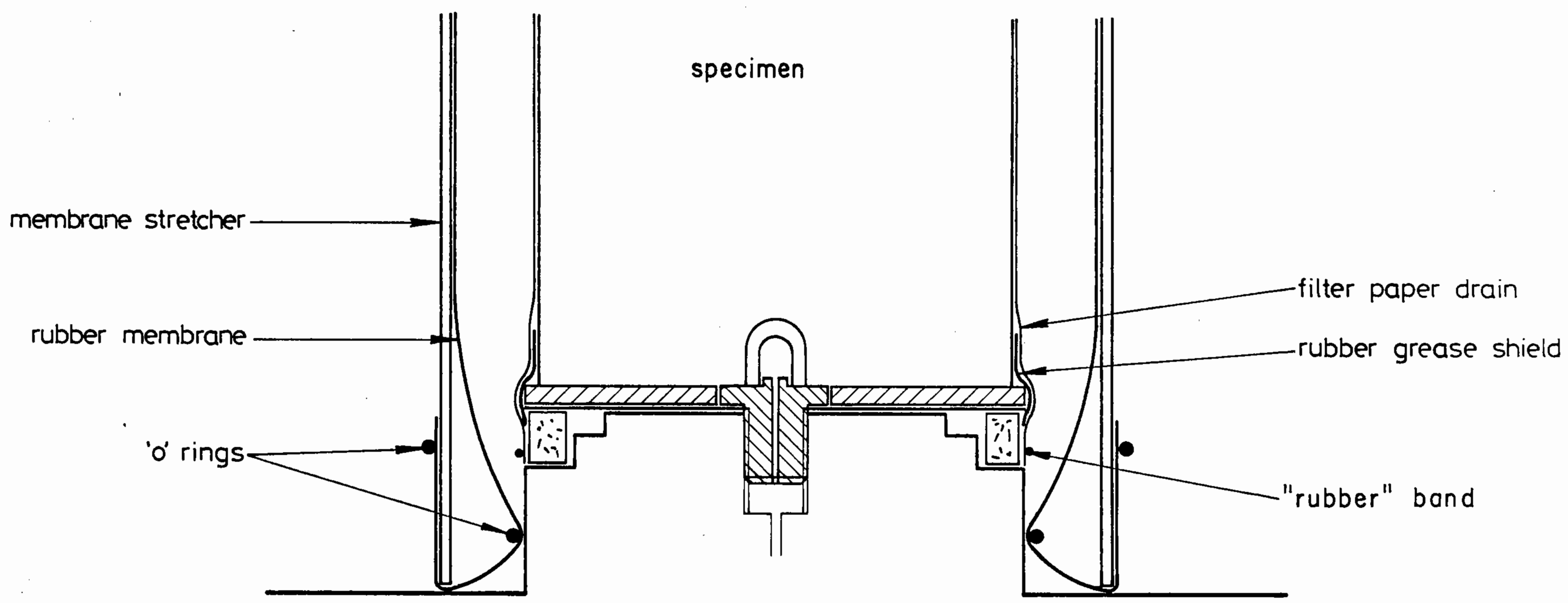
Before a specimen could be enclosed in a rubber membrane, it was necessary to provide a drainage path from the specimen to the sintered bronze drainage ring and to position the foil targets for the radial transducers.

Firstly, aluminium foil was cut into strips 80 mm long by 15 mm wide. These were positioned on the soil using marks on the cell base corresponding to the eventual positions of the proximity transducers. Each transducer had a 12.5 mm diameter sensor face so the wider foil strip allowed for small errors in positioning. The foil adhered to the wet soil sufficiently well to require no other means of support. It was located so as to run downwards from about 30 mm below the top cap, the length of foil being sufficient to allow for the axial movements of both consolidation and testing.

A 25 mm wide band of latex rubber was cut from an old membrane and placed over the lower end of the specimen. It ran from the drainage ring, over the lower end platen and onto the specimen to prevent any silicone grease, squeezed out of the lubricated end, from clogging the filter paper drains, as shown in Figure 4.4.

The filter paper drains were cut from Whatmans No. 52 filter paper in a comb shape such that they covered 50% of a specimen's surface area, as recommended by Bishop and Henkel (1962). These were moistened and put round the soil so that they ran the full length of the specimen and overlapped the drainage ring, where they were held by a rubber band as shown in Figure 4.4. Care was taken that no drain covered the aluminium foil and that the strips of filter paper in line with the axial deformation locating studs were removed.

The membrane stretcher was placed over the soil and the lowest 'O' ring slipped off the stretcher onto the pedestal as shown in Figure 4.4. The stretcher was then orientated by using the holes in the cell base for the instrument frame which put the brass studs in the correct position. A small amount of water was poured into the open end of the stretcher (now sealed at the bottom by the 'O' ring). This facilitated the removal of air from between the specimen and membrane. The top cap was assembled with a lubricated end and the sides were smeared with silicone grease. It was carefully positioned whilst, at the same time, the pore pressure transducer lead was threaded through the exit in the top cap. The lead exit is shown in Figure 3.2. The vacuum was then removed from the membrane stretcher allowing the membrane to move in against the soil whilst the stretcher guides kept the studs in position. The upper end of the membrane was then slipped from the stretcher over the top cap and the rods removed from the studs. The stretcher could then be removed whilst freeing the lower end of the membrane. Finally, the trough was drained, additional 'O' rings placed over both ends of the membrane and excess water inside



SPECIMEN PREPARATION DETAIL

Figure 4.4

the membrane run off through the drainage line.

The instrument frame was positioned and a yoke bolted to the cell base. The yoke had a load ram in it which located in the top cap and ensured the specimen was correctly positioned whilst the LVDTs were connected and all the instruments zeroed. The yoke was then removed, the cell top positioned and silicone fluid admitted. The load ram was brought gently into position so that it located in the top cap and was then clamped in position using the upper clamp in the consolidation unit. Plate 3.2, shows a specimen held in position by a load ram and the yoke, together with all the deformation transducers and the lead exit, from the top cap, of the centre pore pressure probe.

CHAPTER FIVE

THE TEST PROGRAMME

The main test programme was designed to investigate the response of a clay to cyclic loading. Particular emphasis was placed on investigating the soil response to a sequence of undrained cyclic loading and drained rest periods. Also of interest was whether the soil response to complex loading patterns could be predicted from tests with simple loading. The sequence of complex cyclic loading and drained rest periods was intended to model the response of a clay forming part of the foundation of an offshore structure subjected to storms and calm periods. In addition to this, a limited number of tests were performed to investigate the effective stress soil response to a variety of applied total stress paths. Wherever possible, hysteresis loops were recorded in all these tests. As it was necessary to develop the testing equipment, as set out in Chapter Three, before the aims of the research could be realised, some preliminary tests were performed. The intention being to determine basic soil data and to develop the necessary experimental techniques.

This chapter sets out all the tests performed and gives a short explanation of what the tests involved and why they were performed. The tests are listed in Tables 5.1 to 5.3 and 5.5. As the equipment was being developed during the same period and some modifications were found necessary, comments are given in the tables at the relevant points.

5.1 PRELIMINARY TESTS

These tests were performed on isotropically consolidated specimens with overconsolidation ratios between 1 and 50. Pore pressures were measured at the base of each specimen and the axial deformations were measured with an external LVDT, connected to the load ram. The tests are detailed in Table 5.1 and are designated series IF. The first six specimens

Test No.	Effective Confining Pressure max. (kPa)	Effective Confining Pressure final (kPa)	O.C.R.	Compression (C) Extension (E)	Comments
IF 1	70	70	1	C	
IF 2	140	140	1	C	
IF 3	280	280	1	C	
IF 4	280	140	2	C	
IF 5	280	70	4	C	
IF 6	280	35	8	C	
IF 7	280	280	1	C	New slurry moulds & back pressure 140 kPa
IF 8	140	140	1	C	
IF 9	420	420	1	C	
IF 10	420	420	1	E	Connection between load ram & specimen top cap
IF 11	140	140	1	E	
IF 12	420	210	2	C	
IF 13	280	280	1	E	
IF 14	140	140	1	E	
IF 15	585	11.7	50	C	
IF 16	140	140	1	E	
IF 17	420	420	1	E	Initial excess pore pressure = 80 kPa
IF 18	420	105	4	C	
IF 19	420	52.5	8	C	

ISOTROPIC FAILURE TESTS (I.F.)

Table 5.1

were consolidated from slurry using the original slurry moulds and when consolidated in the triaxial cells were subjected to a back pressure of 210 kPa. The remaining tests were consolidated in the new slurry moulds and were subjected to a back pressure of 140 kPa in the triaxial cells. Results from these tests are presented and discussed in Chapter Six.

5.2 THE MAIN TEST PROGRAMME

The soil specimens used for all the remaining tests were anisotropically consolidated in the triaxial cells under conditions of zero lateral strain and were all subjected to a back pressure of 140 kPa. The cyclic tests in the main programme have been divided into four series.

5.2.1 Anisotropic Failure Tests

These tests have been labelled series AF and are presented in Table 5.2. All specimens were monotonically loaded to failure in compression without any previous cyclic loading. Five were normally consolidated to various maximum pressures and two were anisotropically unloaded under K_0 conditions. The aim of the tests was to provide an undrained strength for the soil so that the cyclic stress levels could be chosen. The results are presented and discussed in Chapter Ten.

5.2.2 Cyclic Load Tests

The tests subjected to cyclic loading were divided into four series. All specimens were consolidated to a maximum normal stress of 183 kPa. For series 1 to 3, five periods of undrained cyclic loading were applied to each specimen. Each loading period lasted up to six hours and they were separated by drained rest periods of between 18 and 66 hours. The levels of repeated deviator stress were expressed as proportions of the maximum deviator stress obtained by a specimen at the same initial stress state, when tested under a constant rate of strain to failure. The maximum deviator stress was taken as 180 kPa and the cyclic levels were chosen as 30, 50 and 70%.

Test Number	O.C.R.	p'_{max} (kPa)
AF 1	1	367
AF 2	1	367
AF 3	1	183
AF 4	1	183
AF 5	1	183
AF 6	4	183
AF 7	4	183

ANISOTROPIC FAILURE TESTS (A.F.)

Table 5.2

Series 1 formed the major part of the cyclic load tests, all the specimens were normally consolidated after which most were tested under a single level of deviator stress. The tests are listed in Table 5.3. The table also shows whether deformations were measured inside the triaxial cell and where the pore pressures were measured. Three specimens were subjected to all of the stress levels in each loading period. These tests have been designated "storm" loading tests.

Test No.	Cyclic stress level as % of q_{max}	Pore pressure measurement	Deformation measurement	Comments
Series 1 1	50	Centre & base	internal	Drainage line open on day 1 until cycle 400
2	30	base	external	
3	70	Centre & base	internal	
4	70	base	external	
5	Storm	Centre & base	internal	
6	Storm	base	external	
7	Storm	Centre & base	internal	
8	30	base	external	Three days testing only
9	50	Centre & base	internal	
10	50	Centre & base	external	
11	30	Centre & base	internal	Centre pore pressure probe porous face changed from ceramic to sintered bronze. Axial deformation connection modified.
12	30	Centre & base	internal	
13	50	Centre & base	internal	
14	50	Centre & base	internal	
15	50	Centre & base	internal	

SERIES 1 CYCLIC LOAD TESTS

Table 5.3

The purpose of this series was to compare the soil response to the two loading regimes to see if the response to the complex loading of the "storm" tests could be predicted from the single stress level tests and to investigate the soil behaviour after drainage. It was also intended that the experimental data should be used to aid the development of the Cam clay soil model to describe repeated loading.

The number of applications of each stress level in a storm loading test were adapted from North Sea storm records which have been statistically analysed and reported by Bjerrum (1973). He suggested a typical storm would build up over a 3 to 9 hour period, be at a peak for 6 hours and then wane over a further 6 to 9 hours. During the significant 6-hour peak, he suggested that a certain number of different size waves would occur and that they would be applied as a normal distribution. By assigning a stress ratio to the largest wave size, he obtained a spectrum of stresses for the storm as shown in Table 5.4.

The maximum stress ratio Bjerrum used for his storm was $\tau_h/\sigma_{vc} = 0.3$, where τ_h is the horizontal shear stress and σ_{vc} is the vertical stress. This description of stress is suited to simple shear testing. It has been assumed that the 70% repeated loading used in this research is equal to the same maximum stress level. This gives the 50% and 30% cyclic loads equivalent τ_h/σ_{vc} values of 0.21 and 0.13. It can be seen from Table 5.4 that this covers the range of Bjerrum's lower stress levels.

Bjerrum assigned different wave periods to the spectrum of wave heights in his design storm. This resulted in a 6-hour storm containing a maximum of 1394 waves. To obtain a comparable storm, but with all the wave periods at a frequency of 0.1 Hz, 2160 cycles are required. Hence, Bjerrum's wave numbers have been multiplied by 2160/1394. The permanent soil response of series 1 tests is presented in Chapter Seven and the resilient response in Chapter Eight.

Bjerrum			Laboratory test representation		
Wave height m	Number of waves N	Stress level τ_h/σ_{vc}	Stress level q_r as % of q_{max}	Comparison with τ_h/σ_{vc} stress level	Number of waves N
4-8	485	.07	30	.13	1482
8-12	471	.12			
12-16	282	.17	50	.21	624
16-20	121	.22			
20-24	32	.26	70	.30	54
24-26	3	.30			
N = 1394					N = 2160

100-YEAR STORM LOADING DETAILS

Table 5.4

Series 2 to 4 tests are shown in Table 5.5. Series 2 specimens were overconsolidated by first using a larger preconsolidation pressure, then swelling back to the same final effective stress used in series 1, whilst maintaining the normally consolidated stress ratio. An overconsolidation ratio of 1.3 was achieved and the specimens were tested in the same way as series 1. The purpose was to compare the response of series 1 tests, after drainage had been allowed, with series 2. Both series having reached the same specific volume and stress state by different paths.

Series 3 tests were used to investigate the effect of testing about different mean levels of deviator stress. The soil, after consolidation, was subjected to a change in deviator stress, under undrained conditions, before cyclic loading was applied. This resulted in cyclic loading with either the maximum or minimum deviator stress in a cycle being the consolidation value. So that, whereas series 1 consisted of two-way loading about the K_o line, series 3 consisted of one-way loading. The results of series 2 and 3 are presented in Chapter Seven.

Series 4 investigated the influence of applying a range of total stress paths on the effective stress response. To avoid large permanent deformations only stress paths between the K_o line and p' axis were used. The results of series 4 tests are presented and discussed in Chapter Nine.

Test No.		Cyclic stress level as % of q_{max}	Comments
Series 2	1	50	OCR 1.3
	2	50	OCR 1.3
Series 3	1	30	high mean q = 155 kPa
	2	30	high mean q = 145 kPa
	3	30	high mean q = 145 kPa
	4	30	low mean q = 115 kPa
	5	30	Frequency 0.01 Hz
Series 4	1	-	Continuation from test 1.11
	2	-	Continuation from test 1.1
	3	-	
	4	-	
	5	-	Continuation from test 1.14

SERIES 2, 3 AND 4 CYCLIC LOAD TESTS

Table 5.5

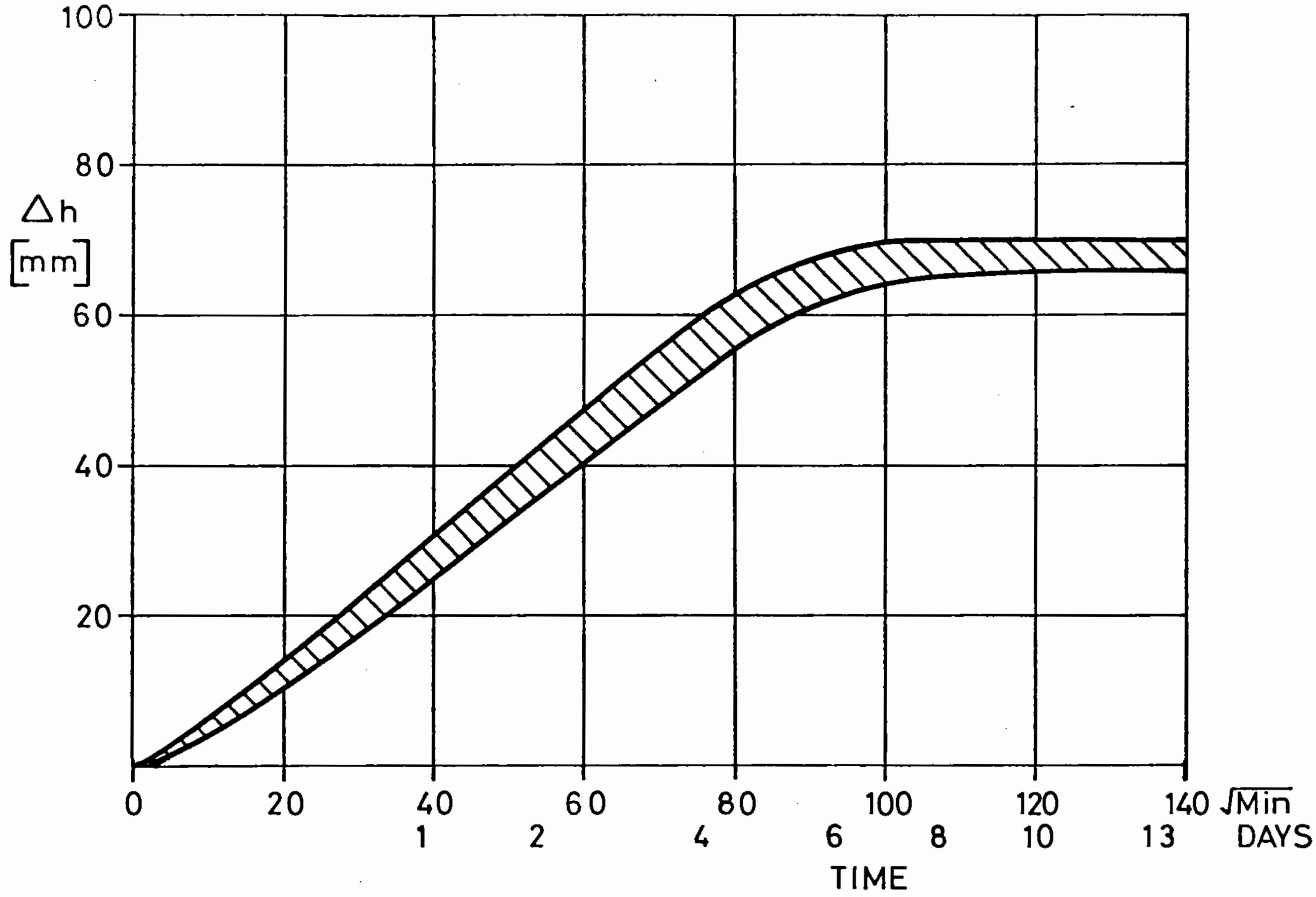
CHAPTER SIX

PRELIMINARY TEST RESULTS

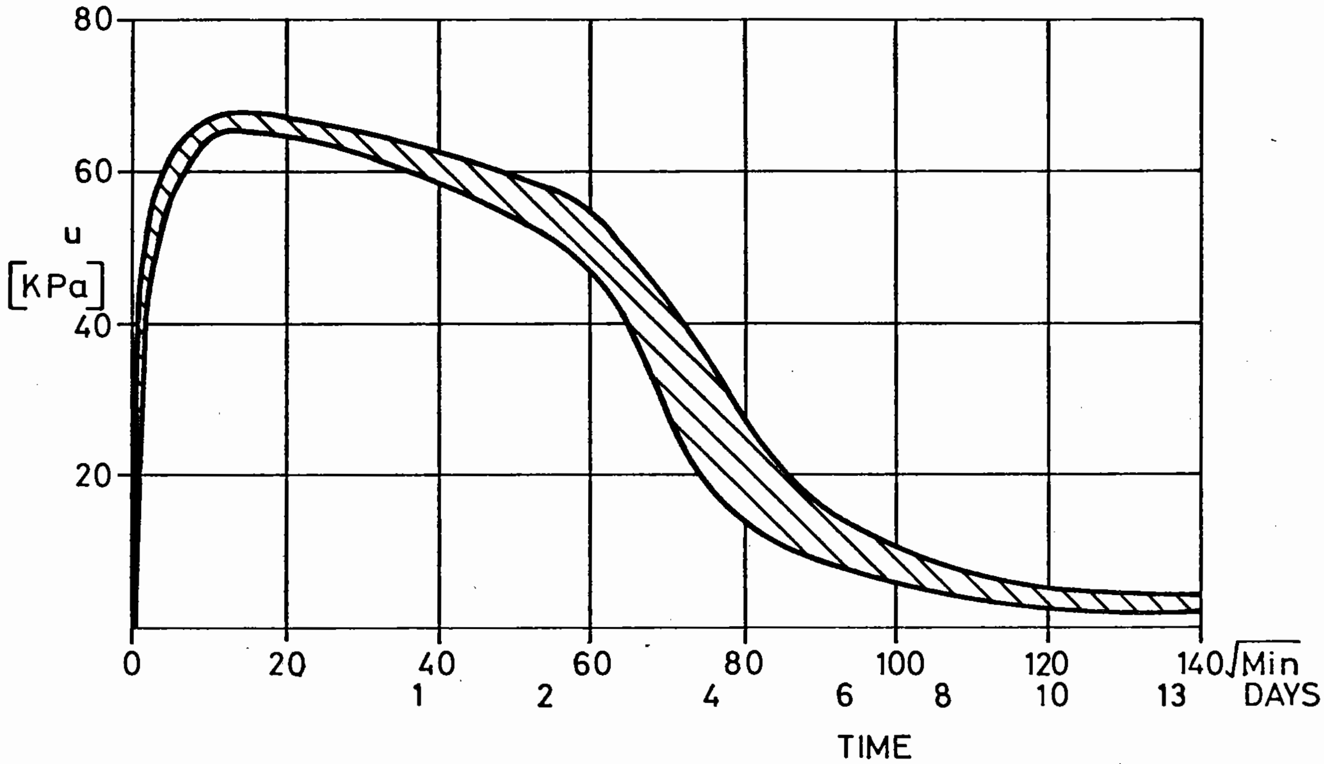
6.1 SLURRY CONSOLIDATION

The slurry moulds developed to produce standard specimens for this research allowed drainage and movement at both ends. A vertical pressure of 70 kPa was used to consolidate the slurry. During consolidation, it was possible to monitor the variation in specimen height and pore pressure. Figure 6.1(a) shows the change in height of a specimen over 14 days. The initial height was about 250 mm and the shaded band gives the variation between specimens. Figure 6.1(b) shows typical pore pressure response. The pore pressures peaked at about 65 kPa when all the vertical load had been applied. As drainage occurred from the ends of the mould there was a delay before the pore pressure, measured by the probe at the specimen mid-height started to reduce appreciably. The rate of dissipation at the transducer position increased to a maximum on day 2 and remained constant until day 5 after which the flow of water decreased and the pore pressure stabilised. This curve is one of the family of curves which would be obtained if the pore pressures were measured at different points in the soil.

The soil specimens produced by this consolidation had a moisture content gradient (see Appendix D), where the mid-height of the specimen was 3-4% wetter than the ends. This was probably due to the fact that the slurry at first behaved as a liquid with a K_0 of 1.0. As water was expelled, the slurry started to behave as a particulate material and K_0 dropped. This also resulted in friction developing between the mould and the soil which reduced the consolidating stress towards the centre of the specimen.



(a) Loss of Height



(b) Variation of pore pressure

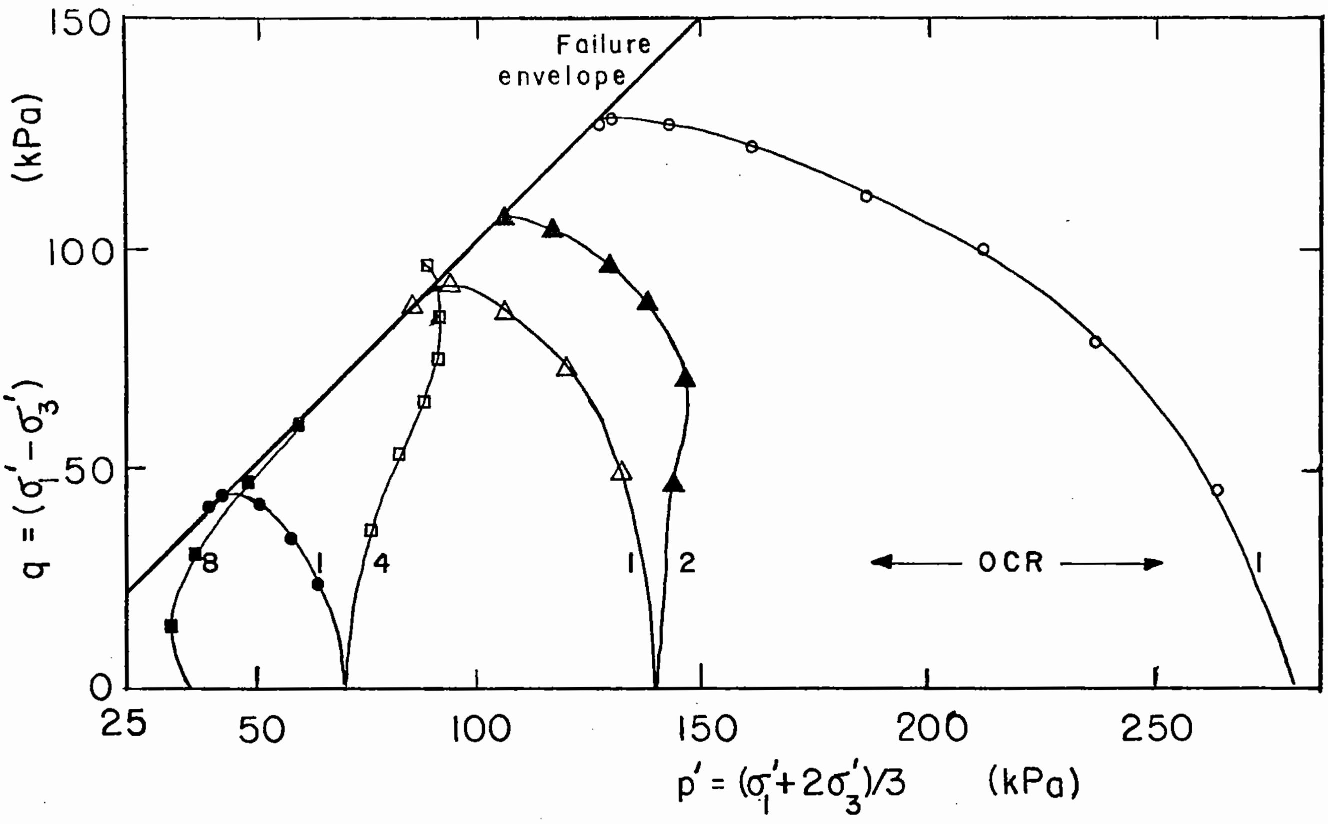
Figure 6.1 SLURRY CONSOLIDATION CURVES

6.2 ISOTROPICALLY CONSOLIDATED SPECIMENS

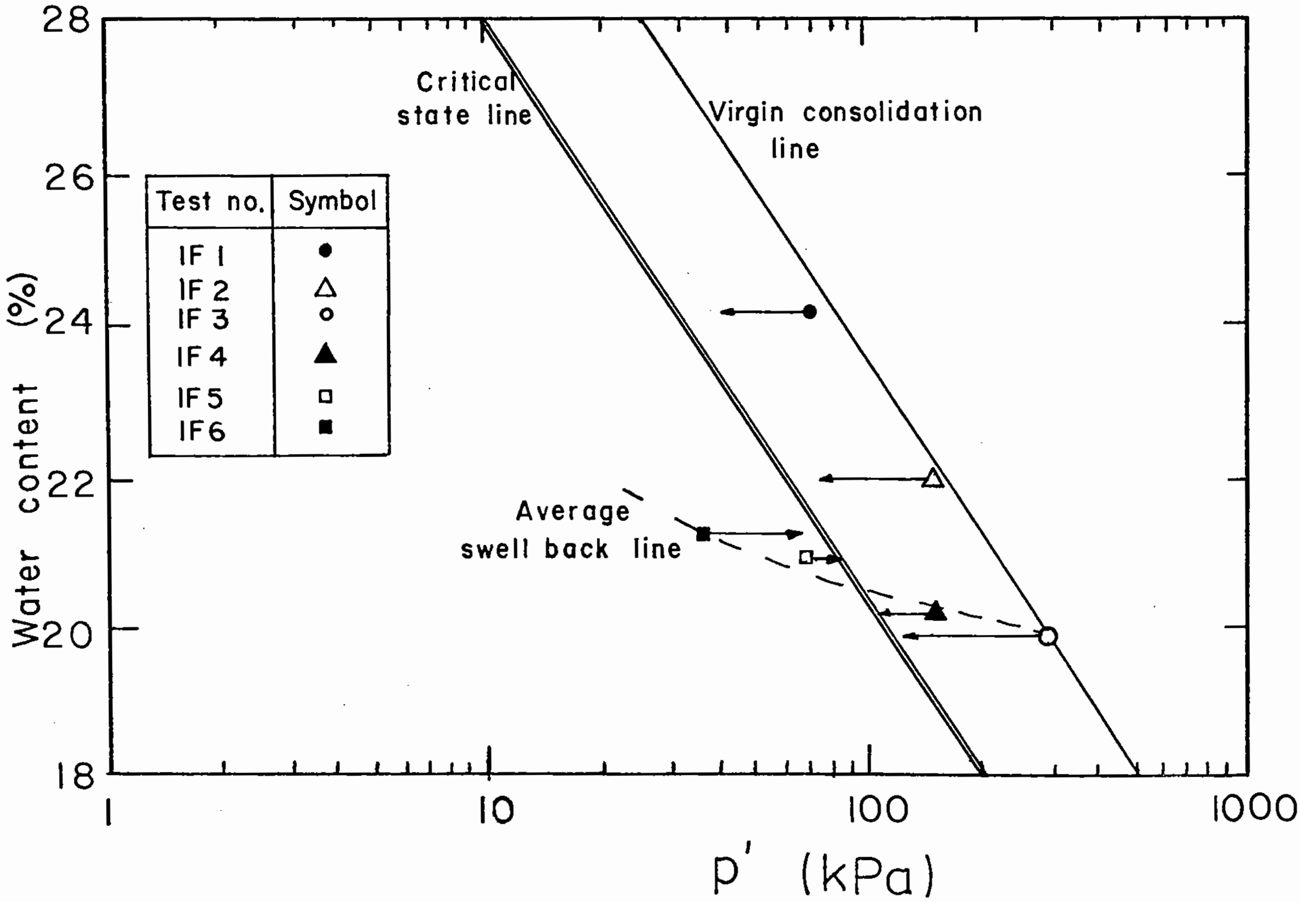
Nineteen specimens were isotropically consolidated in the triaxial cells forming series IF, listed in Table 5.1. They were consolidated by applying the required cell pressure in one increment then allowing the soil to consolidate against a back pressure whilst measuring the outflow of water. When the soil came to equilibrium the specimens were either sheared, undrained to failure or overconsolidated and then sheared. The results are presented graphically in Figures 6.2 and 6.3.

Figure 6.2 gives the results of tests IF1 to IF6, which were performed before the new slurry moulds were used. The figure clearly shows that the pressures used in the triaxial cell were not sufficiently large compared with those in the slurry moulds. The disturbance caused by stress relief while setting up the specimens in the triaxial cells was not overcome. If the stress paths of the three normally consolidated specimens are compared in Figure 6.2(a), it can be seen that the tests IF1 and IF2 behaved as though overconsolidated. In Figure 6.2(b) the best straight line obtained for the virgin consolidation and critical state line from all the tests performed are shown. The final consolidation moisture contents of tests IF1 and IF2 are inside the virgin compression line. Figure 6.2(b) also shows the average swell back line to be somewhat curved. The tests do, however, define the position of the critical state line in the plane of water content against p'. Whilst in p' - q stress space all the specimens tend to fail on the same envelope with no obvious cohesion intercept.

Figure 6.3(b) shows the stress paths of the remaining tests in series IF, that were sheared in compression. Again, the critical state line is well defined and the average swell back line is also indicated. All the normally consolidated specimens lie on the virgin consolidation line showing that the soil had been consolidated sufficiently for the

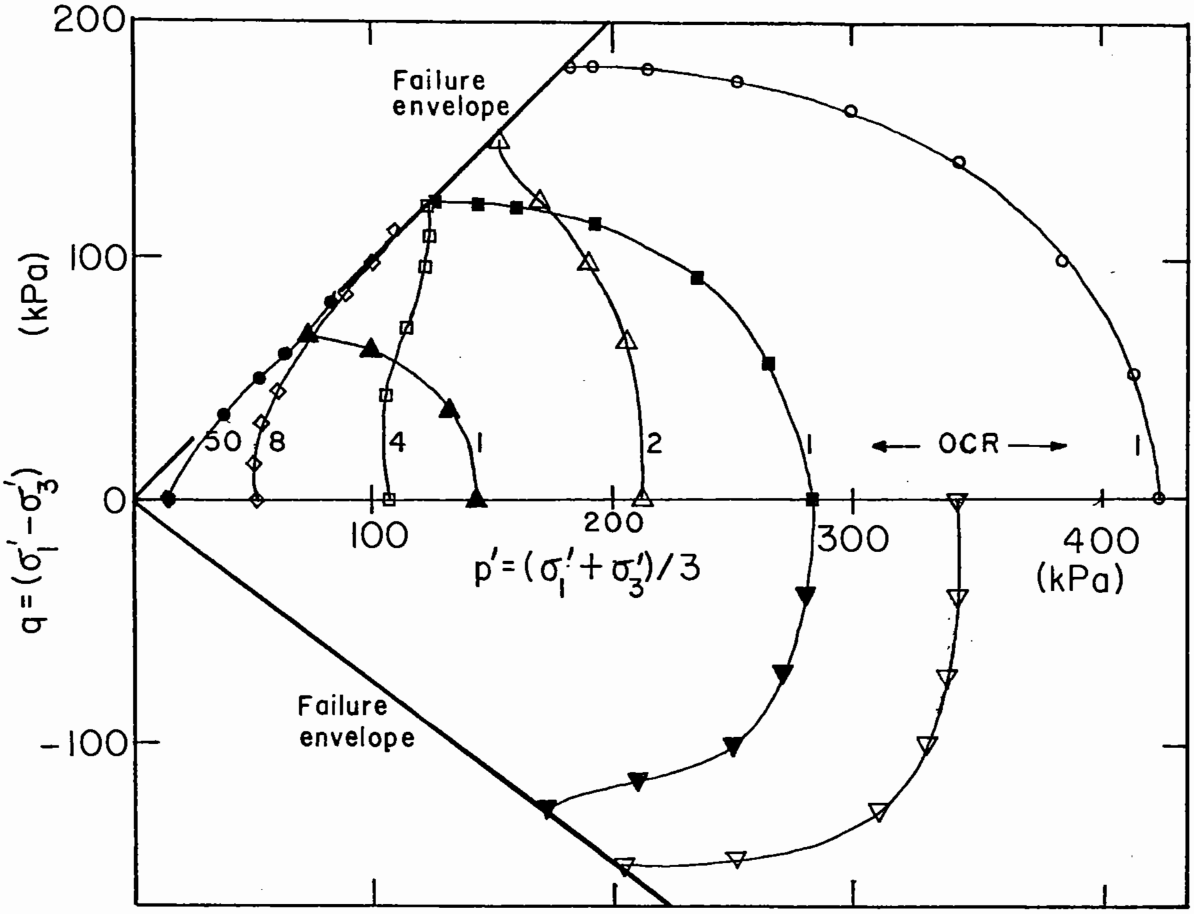


(a) p' - q space

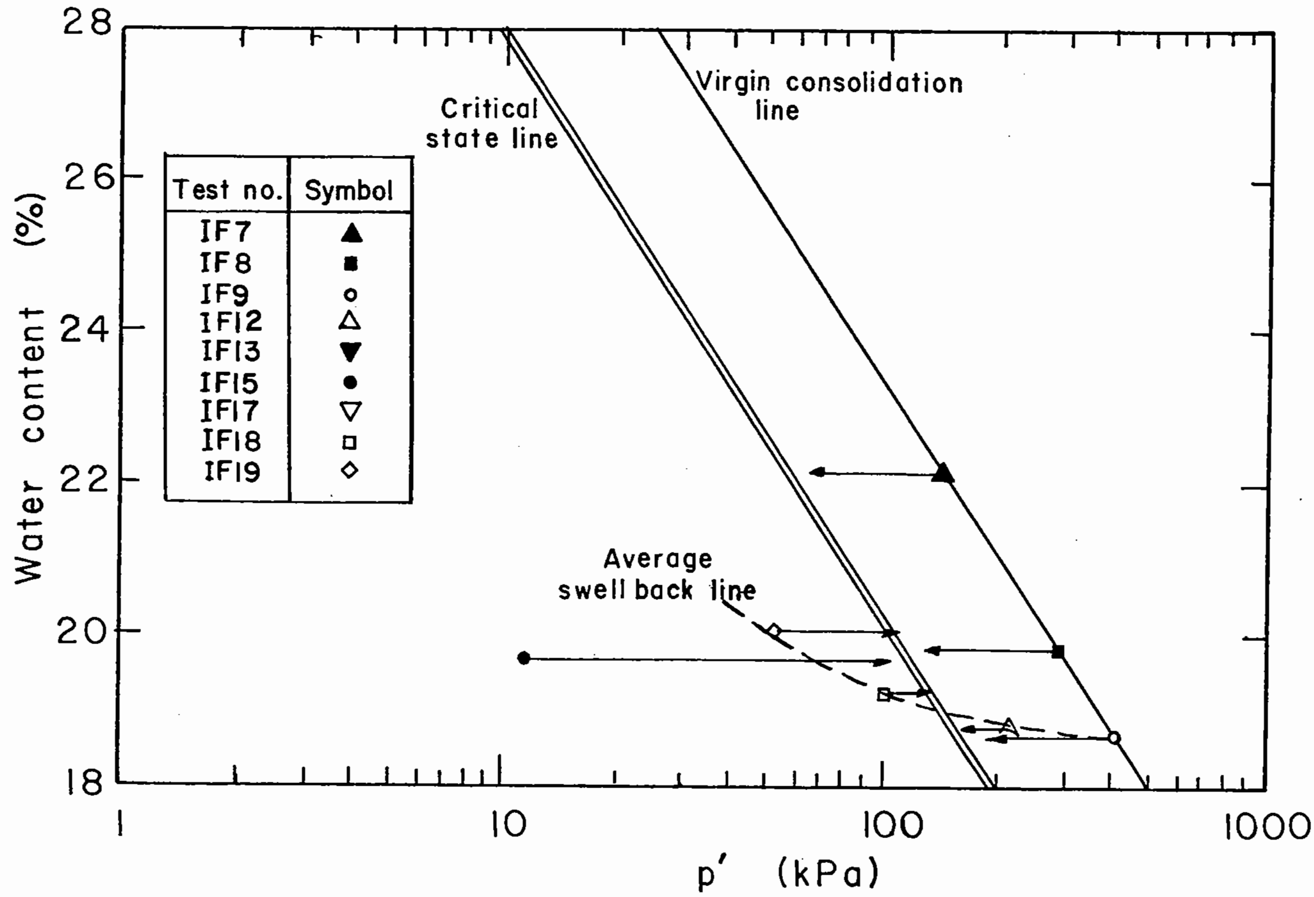


(b) p' - water content

Figure 6.2 SERIES IF STRESS PATHS



(a) p' - q space



Test no.	Symbol
IF7	▲
IF8	■
IF9	○
IF12	△
IF13	▼
IF15	●
IF17	▽
IF18	□
IF19	◇

(b) p' - water content

Figure 6.3 SERIES IF STRESS PATHS

effects of the stress relief to be obliterated. Figure 6.3(a) shows the stress paths of both extension and compression tests. The normally consolidated stress paths are homeopathic (of the same shape) but again, no cohesion intercept is obvious from the overconsolidated specimens. The failure envelope in compression is well defined and identical to the one drawn in Figure 6.2(a). Of the tests performed in extension, only the stress paths of tests IF13 and IF17 are shown. Due to experimental difficulties in connecting the load ram and top cap, together with the use of standard filter drains, the tests were subject to errors. Tests IF13 and IF17 gave credible results and the failure envelope in triaxial extension has been constructed from these tests.

6.3 ANISOTROPIC CONSOLIDATION

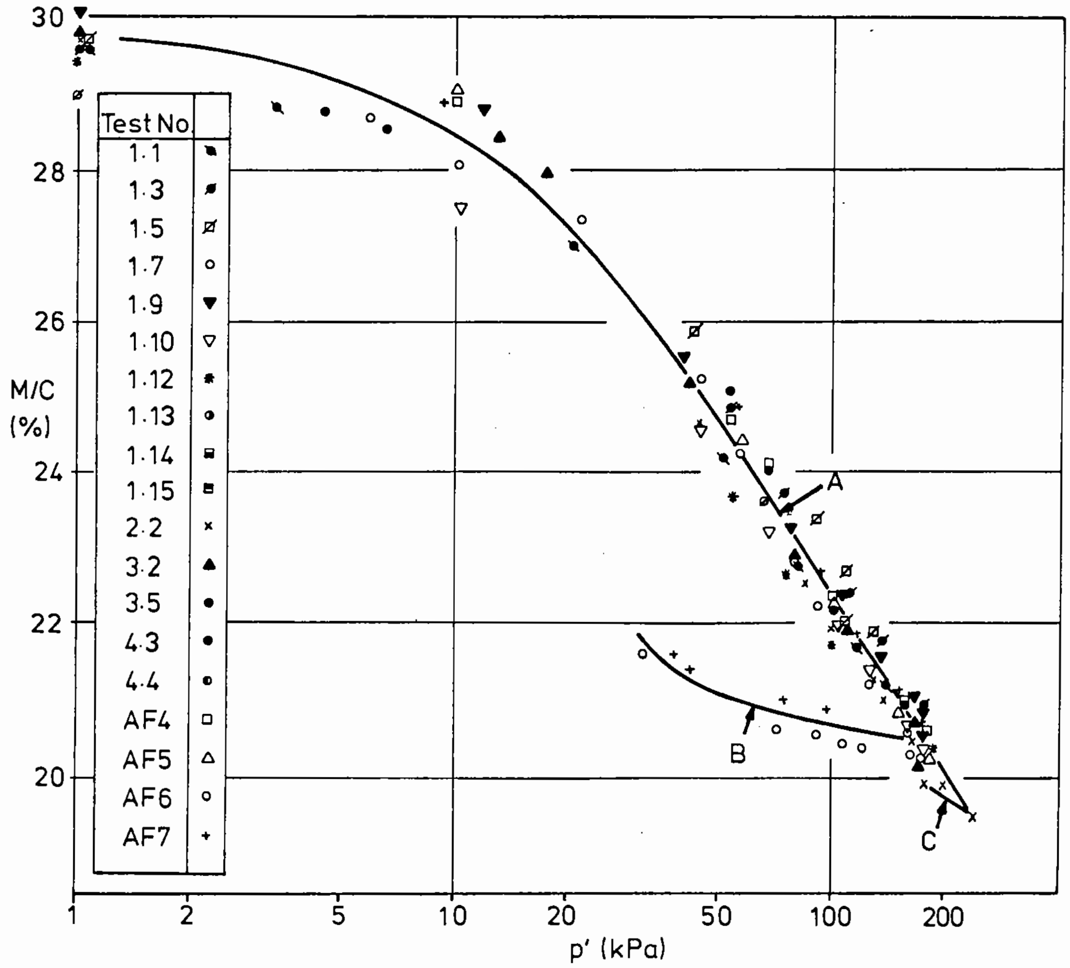
For the main test programme, the soil was consolidated under K_0 conditions. The radial deformation transducers provided the servo-control by which the vertical stress on the specimen was adjusted, so as to keep the specimen diameter constant. The transducers controlled electric motors which drove regulators on a pressurised air line. The air pressure provided a force on the axial loading ram.

6.3.1 Normal Consolidation

To start the consolidation in the triaxial cell, a confining stress of 160 kPa was applied before the drainage line was opened. This confining stress was applied in three increments and the pore pressures monitored. On applying the first increment of 70 kPa the pore pressure of the specimens rose to values between 55-65 kPa showing that the residual effective stress remaining in the soil after the building in process was between 5-15 kPa. As the probable mean normal effective stress in the soil at the end of consolidation in the slurry moulds was about 50 kPa (σ_1' = 70 kPa, $K_o \simeq 0.5$) the difference has been lost due to specimen disturbance. On applying the remaining two increments of confining stress the pore pressure rose rapidly by equal amounts showing the soil to be saturated. The drainage system was pressurised to give a back pressure of 140 kPa. The initial radial transducer readings were set at null or off positions for the electric motors. Any deviation from this reading caused an adjustment to the vertical load tending to restore the initial reading. As the drainage line was opened, the confining stress was set to increase at 3 kPa/hr until the required value was attained. Readings of confining stress, deviator stress, pore pressure, water outflow and axial deformation were recorded at intervals.

A plot of moisture content against p' is shown in Figure 6.4 for the anisotropically consolidated specimens. The points on the graph were obtained by calculation from the final moisture content of the soil at the end of testing, together with the water outflow at each effective stress level. The normally consolidated part of the graph (A) becomes linear for a mean normal effective stress (p') greater than 40 kPa. All specimens were consolidated with a confining stress of 280 kPa which gave a final p' of 183.3 kPa and a deviator stress (q) of 130 kPa.

Figure 6.5 shows the K_o normal consolidation line in p' - q space. The effective stress points for all specimens form a unique straight line with q/p' = 0.71, K_o = 0.52. The scatter of the points is due, in some measure, to the fact that it takes a small but finite movement of the soil to activate the servo-control. Thus, if part of the consolidation line is looked at in detail and the effective stress state of the soil is, for instance, at point A in Figure 6.6, then as the soil drains, the effective stress state moves from A to B, causing a small change in specimen diameter. Line AB is the net effective stress change due to the



AN ANISOTROPIC COMPRESSION

Figure 6.4

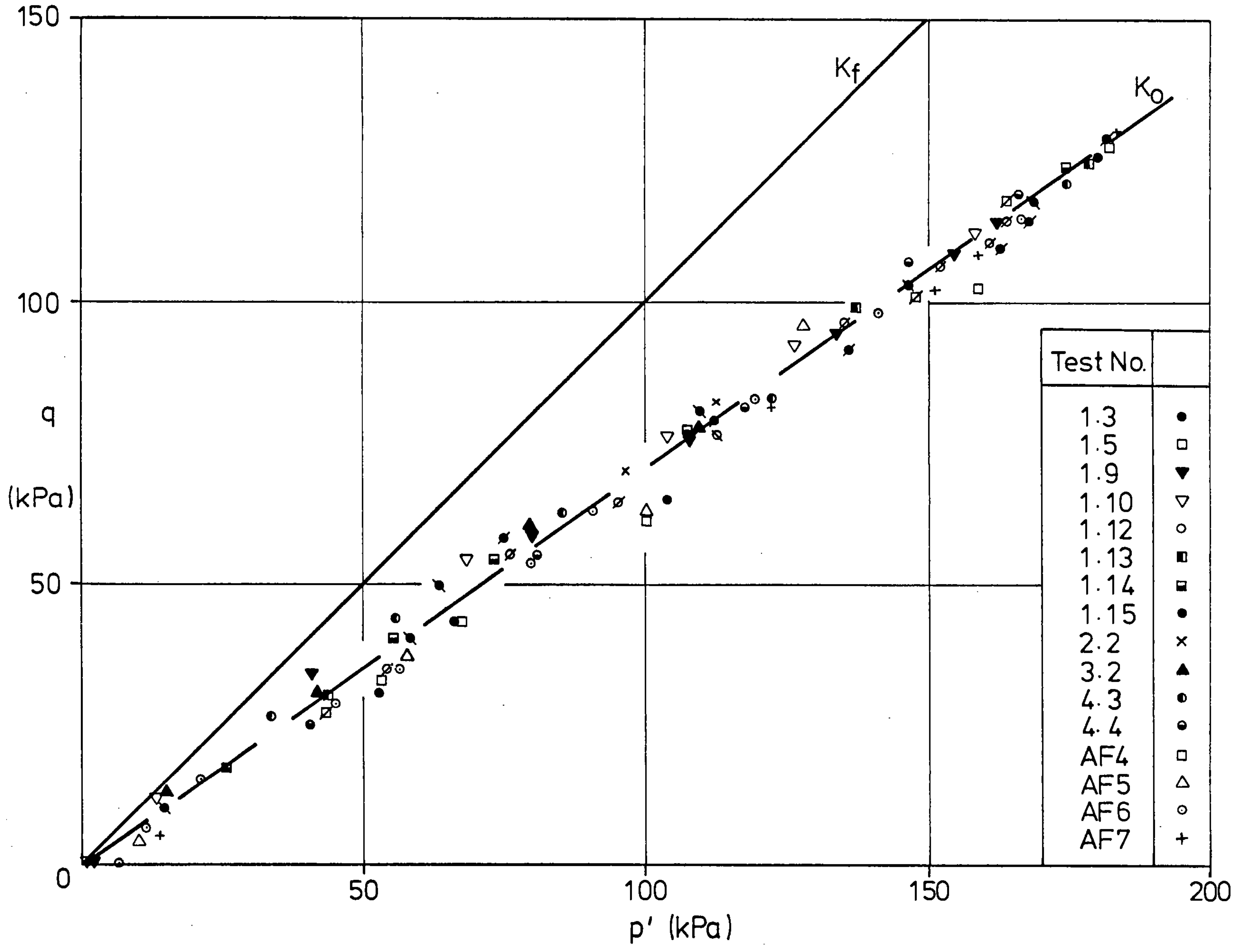
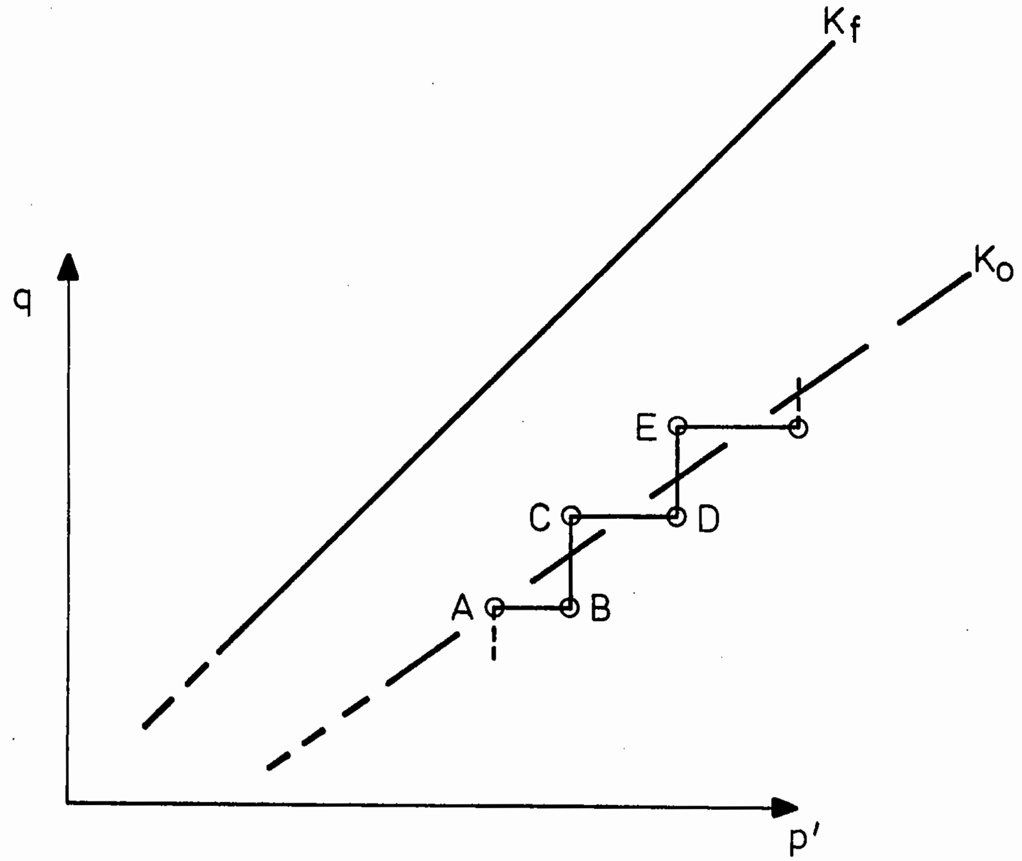


Figure 6.5 K_o LINE FOR NORMALLY CONSOLIDATED SPECIMENS



STRESS PATH BEHAVIOUR OF ANISOTROPICALLY CONSOLIDATED SPECIMEN IN TRIAXIAL CELL

Figure 6.6

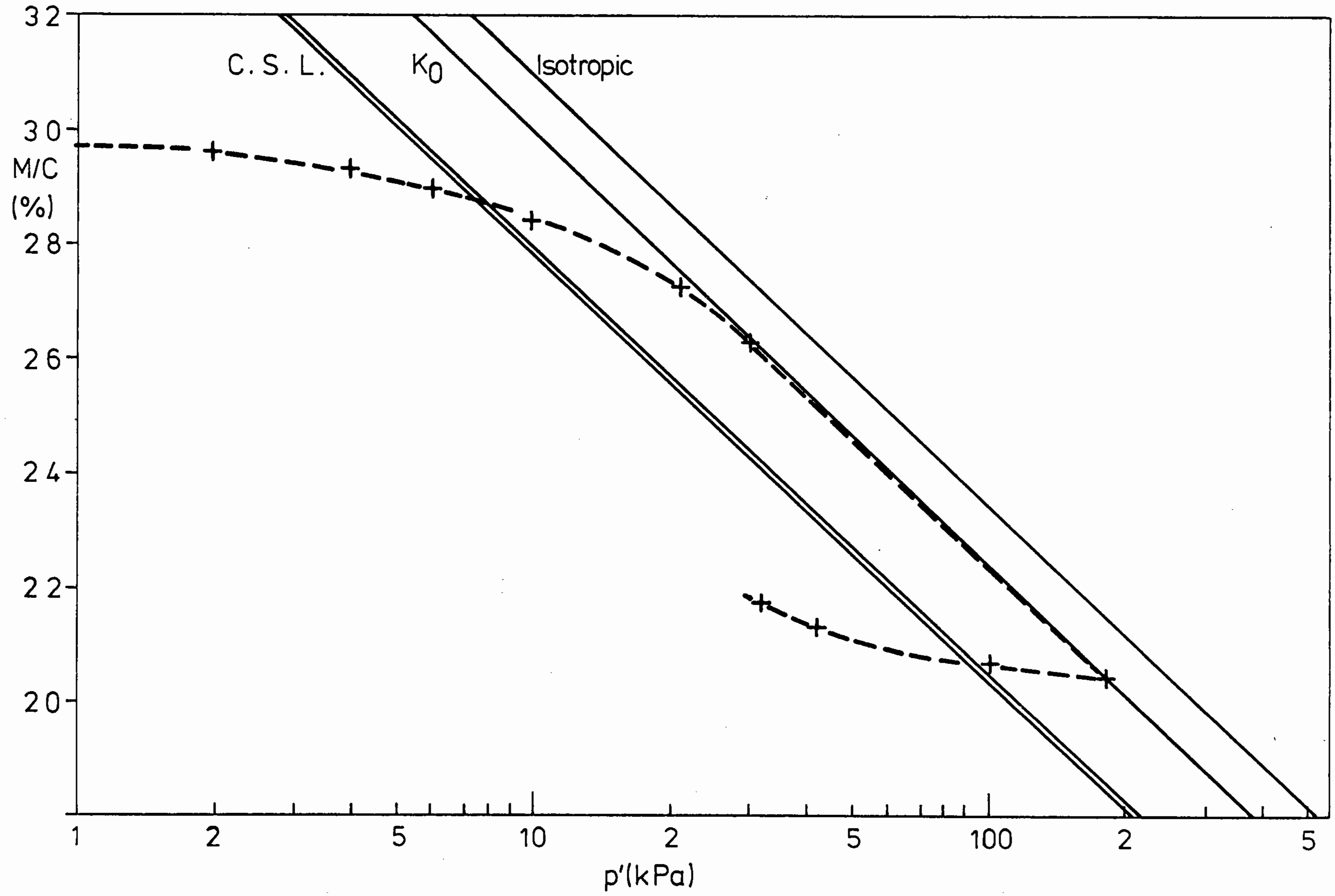
amount of drainage minus the increase in cell pressure for that period. At point B, because of the change in diameter, the servo-control will apply an increment of q moving the effective stress state to C and causing a small increase in the soil diameter. The soil state thus oscillates about the K_0 line as shown in Figure 6.6.

The relative positions of the K_0, isotropic and critical state lines are given in Figure 6.7. The critical state line was obtained from the tests on isotropically consolidated specimens. It should be noted that the K_0 and critical state lines are shown as projections on to the moisture content-p' plane.

The variation of moisture content with time for anisotropic consolidation is shown in Figure 6.8. The figure shows primary consolidation for the first seven days followed by secondary creep consolidation if the soil is left for longer.

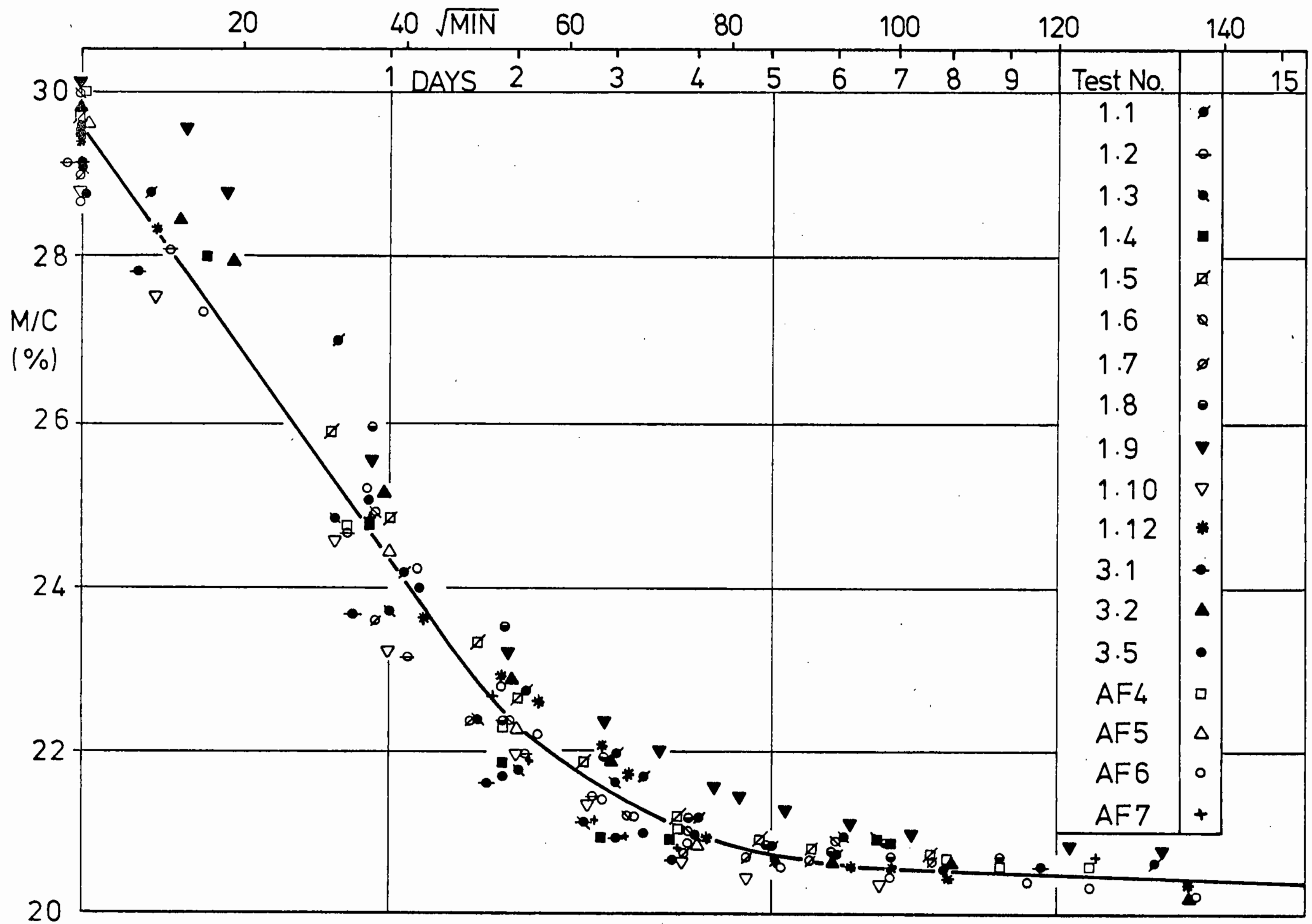
6.3.2 Overconsolidation

A few specimens were overconsolidated, tests AF6 and AF7 under K_0 conditions (B in Figure 6.4) and tests 2.1 and 2.2 at a constant total stress ratio (C in Figure 6.4). For the series 2 tests, the confining stress was reduced at a constant rate and the servo-system kept the soil diameter constant. Figure 6.4 shows that the overconsolidation line is initially straight with a small slope until the overconsolidation ratio is about 2.5, after which the swell back line gets progressively steeper. Figure 6.9 shows the overconsolidation in p',q space. The line is not so well defined as that for normal consolidation, because the volume changes during overconsolidation were small so that the servo-control did not respond as quickly and only two tests were performed.



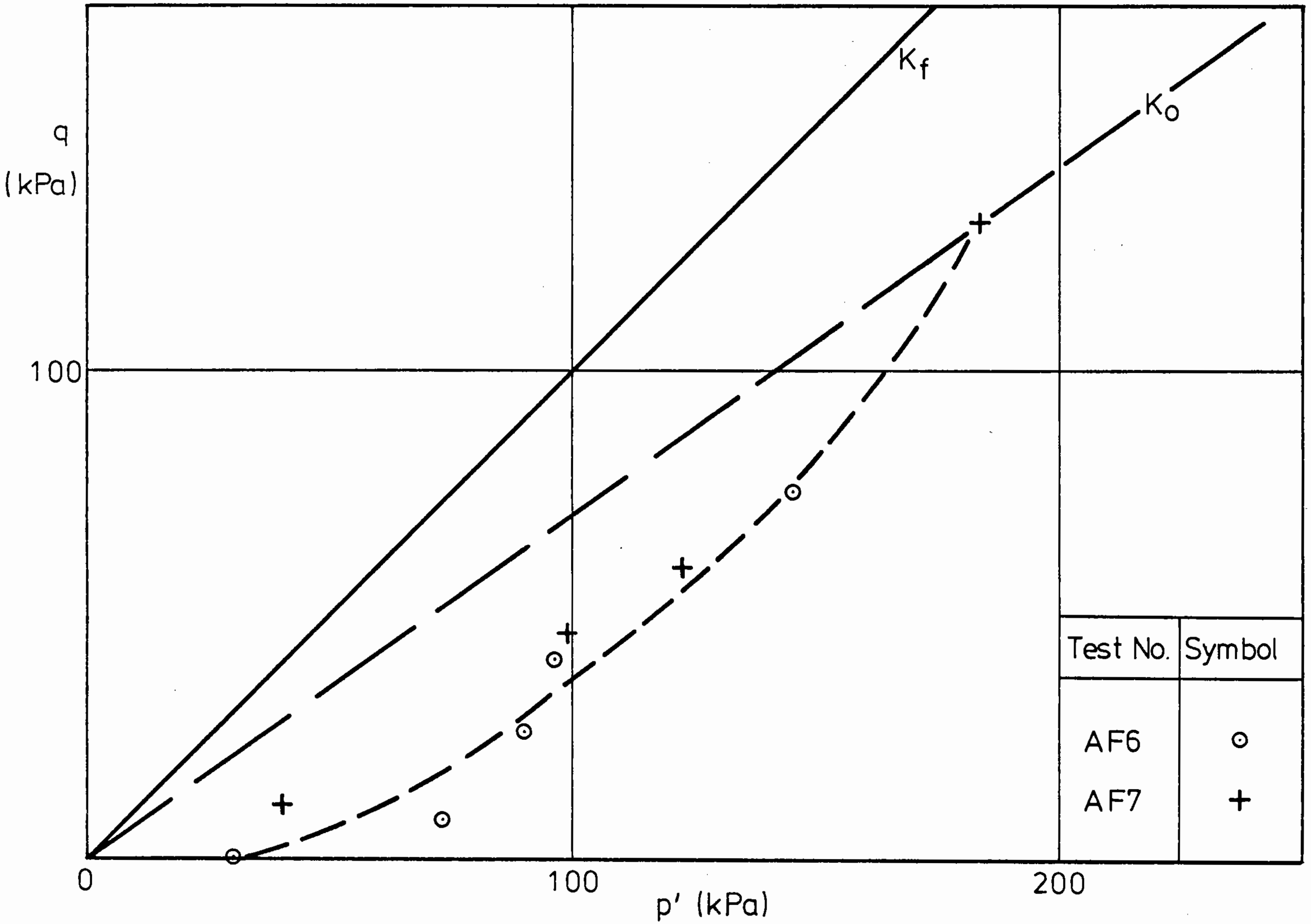
RELATIONSHIP BETWEEN WATER CONTENT AND MEAN NORMAL EFFECTIVE STRESS

Figure 6.7



CONSOLIDATION UNDER K_o CONDITIONS IN TRIAXIAL CELL

Figure 6.8



K_o LINE FOR OVERCONSOLIDATED SPECIMENS

Figure 6.9

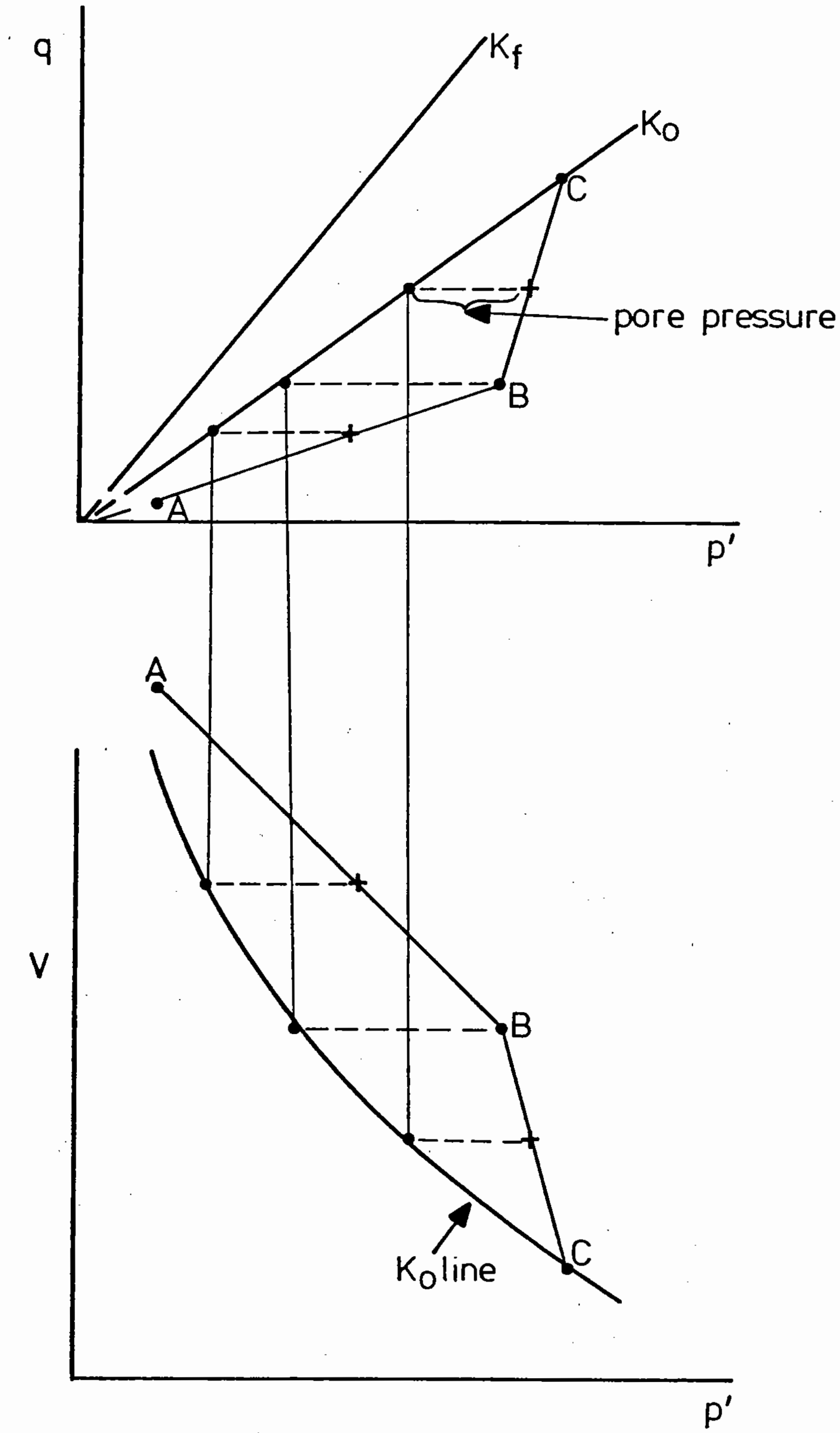
The other overconsolidated specimens (C in Figure 6.4) were first consolidated to a higher stress, the total stresses were then reduced to a (p,q) of (183,130) kPa, which was the final stress state of the normally consolidated specimens, and the soil allowed to swell back. This built in an initial OCR of 1.33.

6.4 SOIL PARAMETERS

The results presented in Figures 6.4 and 6.5 show that the K_o line for Keuper marl is unique, as the initial pore pressures compensate for whatever total stress is applied to the soil, the value of K_o being 0.52. Figure 6.10 shows typical positions of the total stress paths in both p' - q and p' - V space for a triaxial specimen. On the line AB, the confining stress is increasing at a fixed rate and the applied deviator stress increases as the pore pressure dissipates. The position of this line (AB) for different tests can vary even if the confining stress is always increased at the same rate, since the slope is controlled by the build up of deviator stress. Point B is defined by the maximum required confining stress and line BC is due to the change in q applied by the control system to keep the soil at the K_o condition after this maximum confining stress has been reached.

The specimens were fully saturated and void ratios (e) were calculated using the equation $e = w.G_s$, where w is the moisture content and G_s the specific gravity of the solids.

From the preceding graphs in this Chapter, it is possible to obtain the consolidation and critical state parameters for the soil. For normal consolidation, and from Figure 6.4, the equation for the K_o line is:



USE OF INTERNALLY MEASURED PORE PRESSURES
TO OBTAIN COMPRESSION CHARACTERISTICS

Figure 6.10

$V = V_\lambda - \lambda \ln p'$ where V_λ is the specific volume at $p' = 1$ kPa

$V_\lambda = 1.99, \ \lambda = 0.0866$ λ is the slope of the line

Similarly, from Figures 6.2(b) and 6.3(b), the positions of the isotropic normally consolidated line and critical state line can be defined. These lines are parallel to the K_o line and have the same form of equation with $\lambda = 0.0866$. For the isotropic line $V_\lambda = 2.01$ and for the critical state line $V_\lambda = \Gamma = 1.94$.

The coefficient of volume compressibility (m_v) which relates the volumetric strain to vertical effective stress can be calculated for the linear range in Figure 6.4 from:

$$\delta\varepsilon_v = \frac{\delta v}{v} = m_v \, \delta\sigma'_v$$

which gives $m_v = 3.53 \times 10^{-4} \ m^2/kN$

$$\text{The compression index } C_c = -\frac{de}{d(\log \sigma'_v)}$$

$$= 0.182$$

Terzaghi's theory of one-dimensional consolidation gives a method of obtaining the times for various degrees of consolidation in a soil. The K_o consolidation in the triaxial specimen gives movement in the axial direction whilst the flow is radial. The theory is normally given for the outflow of water and consolidation in the same direction but it can be modified and holds for flow in a radial direction. This is given in Appendix C, and it is shown that the coefficient of consolidation:

$$c_v = \frac{k}{m_v \gamma_w}$$

where k is the coefficient of permeability,

γ_w is the unit weight of water.

The permeability of Keuper marl was measured in a falling head permeameter as 2.5×10^{-10} m/s,

$$\therefore \quad c_v = 7.2 \times 10^{-8}\ m^2/s \quad \text{or} \quad 2.28\ m^2/\text{year}$$

From the solution of Terzaghi's consolidation theory, 90% consolidation will then occur in five hours.

For anisotropic overconsolidation, the relevant parameters are not so well defined. The fact that the swell-back line is not linear in p' - V space gives a range of possible values of κ, the slope of the swell back line. The initial part of the swell back line, for low overconsolidation ratios, is reasonably linear and in the equation:

$$V = V_\kappa - \kappa \ln p'$$

will give $\kappa = 0.0093$

On reloading, the value of κ as it approaches the normal consolidation line will be much greater and for modelling purposes, Houlsby (1981) suggests a value of $\kappa = \lambda/3$ as a first approximation.

From Figures 6.2(a) and 6.3(a), the slopes of the failure lines in p' - q stress space (M) can be calculated, giving M = 1.0 in compression and M = 0.75 in extension. This compares well with the Mohr-Coulomb expression for failure of:

$$M = q_f/p'_f = \frac{6\ \text{Sin}\ \Phi'}{3 \pm \text{Sin}\ \Phi'}$$

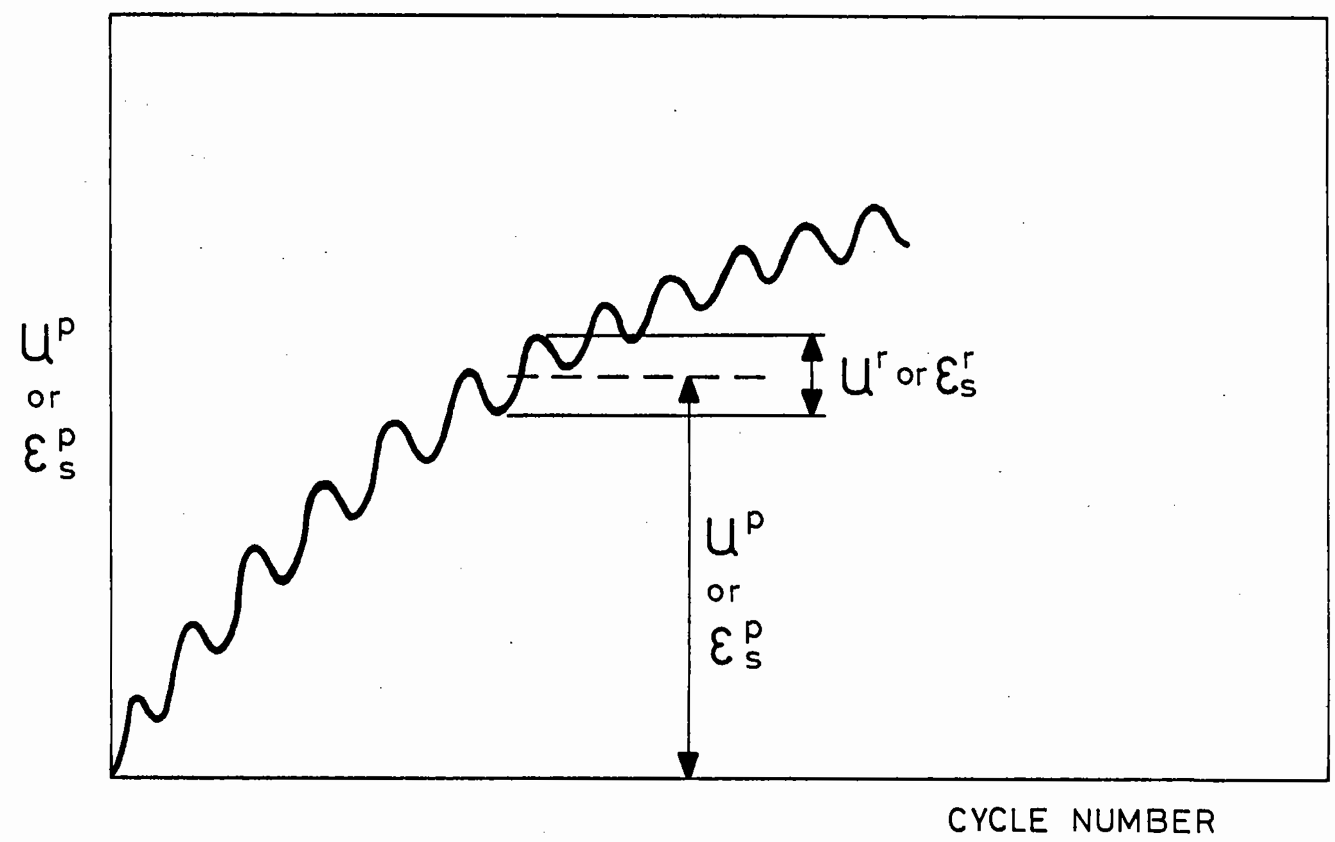
where $\Phi' = 25^{o}$, giving M values of 0.98 and 0.74 for compression and extension, respectively.

CHAPTER SEVEN

PERMANENT RESPONSE TO CYCLIC LOADING

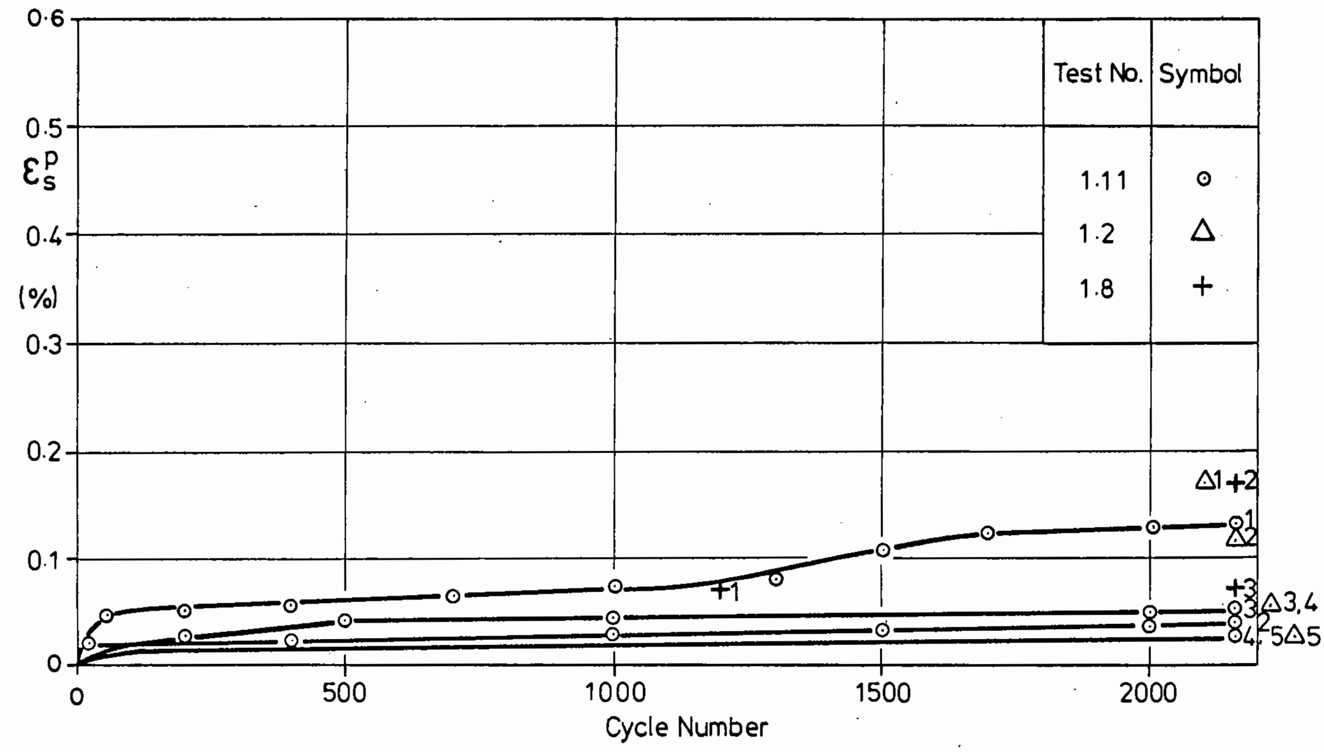
This chapter presents and discusses the permanent shear strain and pore pressure response of anisotropic normally consolidated Keuper marl, when subjected to undrained cyclic loading and drained rest periods, as set out in series 1, 2 and 3 in Tables 5.3 and 5.5. For these three series, each test included five periods of undrained cyclic loading. The loading periods lasted up to six hours and they were separated by drained rest periods. Each load period contained a maximum of 2160 cycles of load, which represented six hours of testing at 0.1 Hz. However, during some load periods the specimens approached failure in less than 2160 cycles and the loading was terminated prematurely. The point at which failure was deemed to be imminent was determined arbitrarily by inspection of both the amount of permanent strain developing in a single cycle and the amount of strain already accumulated. This accumulated shear strain was typically of the order of 0.6%. When it was necessary to stop testing due to the rate of strain development, the soil continued to deform (creep) at a decreasing rate, both whilst the stresses were returned to the final consolidation pressures (K_0 values) and during drainage.

As the cyclic loading tests were two-way tests about a mean stress level (usually the K_0 line), the shear strains and pore pressures were defined with respect to a mean value as shown in Figure 7.1. On all the graphs of permanent shear strain or permanent pore pressure which follow, each set of lines relating to one test specimen has the day of test written on the line. If little permanent response occurred during a load period, only the final point of the line is shown to avoid confusion. It is further assumed that the critical state line determined for the isotropic tests can be used as a failure criterion for the anisotropic tests. It will be seen from the series AF tests in Chapter Ten that this is reasonable.

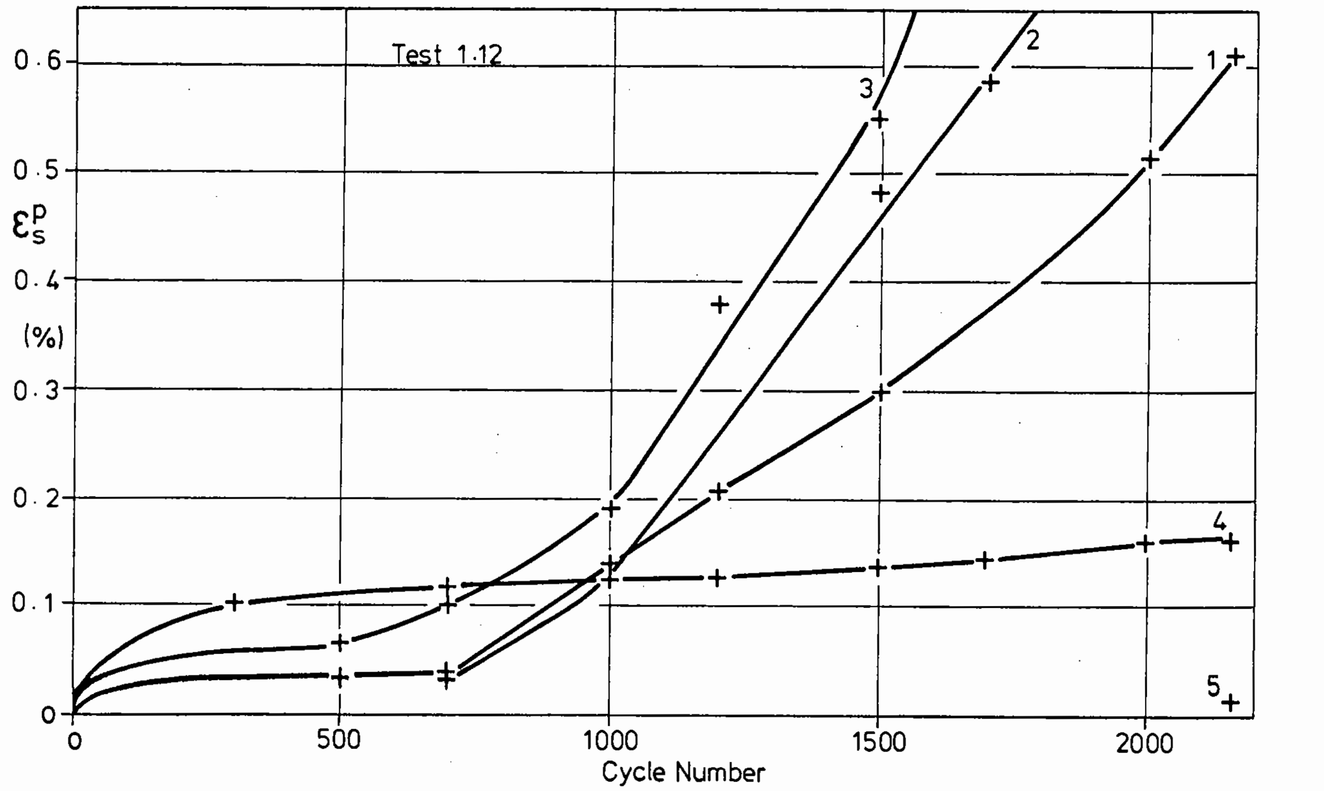


DEFINITION OF SHEAR STRAIN AND PORE PRESSURE PARAMETERS

Figure 7.1



(a) Test Numbers 1.2, 1.8 and 1.11



(b) Test Number 1.12

Figure 7.2 PERMANENT SHEAR STRAIN DEVELOPMENT UNDER 30% CYCLIC LOADING

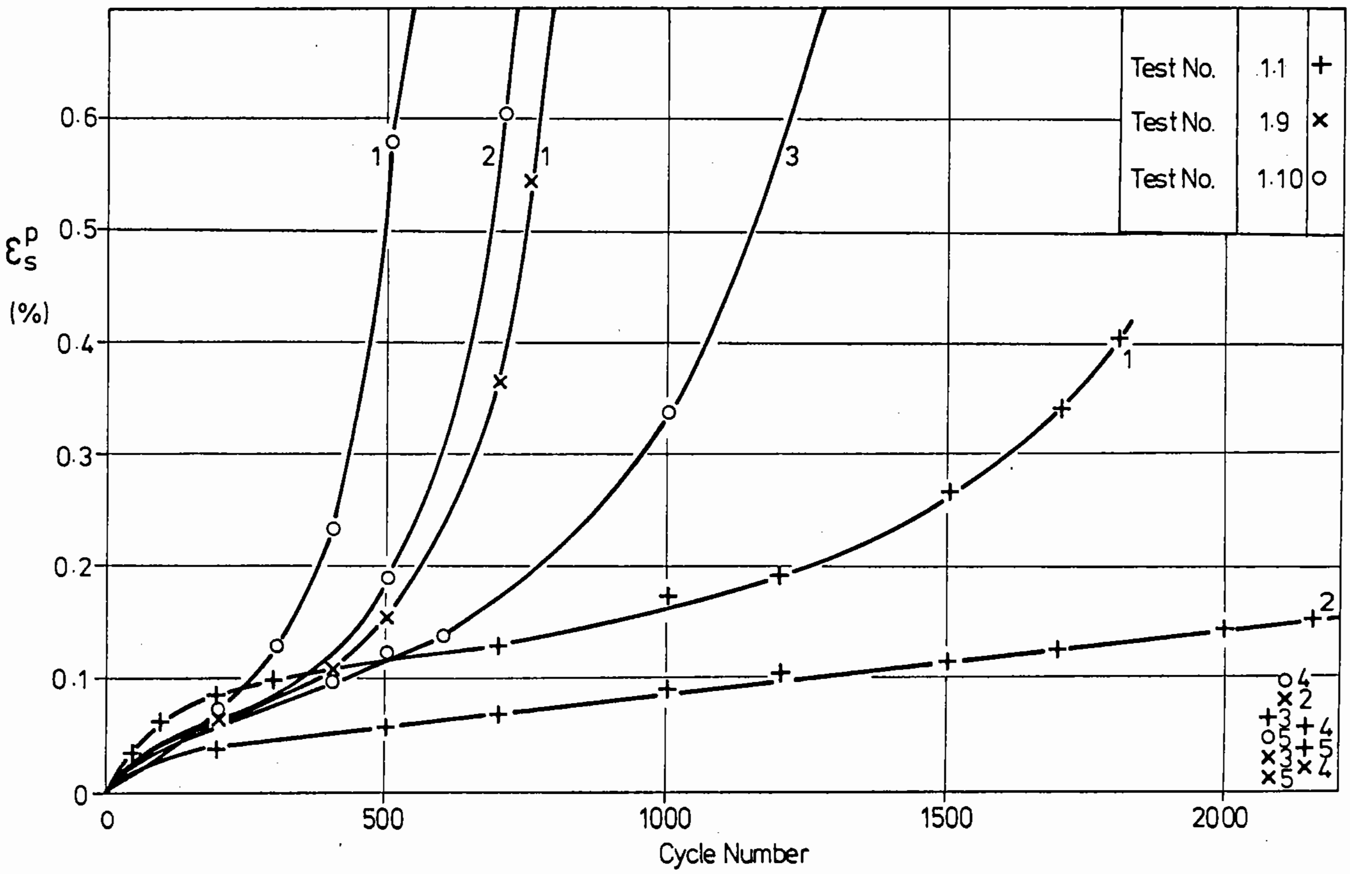
7.1 PERMANENT SHEAR STRAIN

The following graphs of shear strain versus number of cycles have been plotted from zero each day for ease of comparison because shear and volume strains also occurred during the drained rest periods.

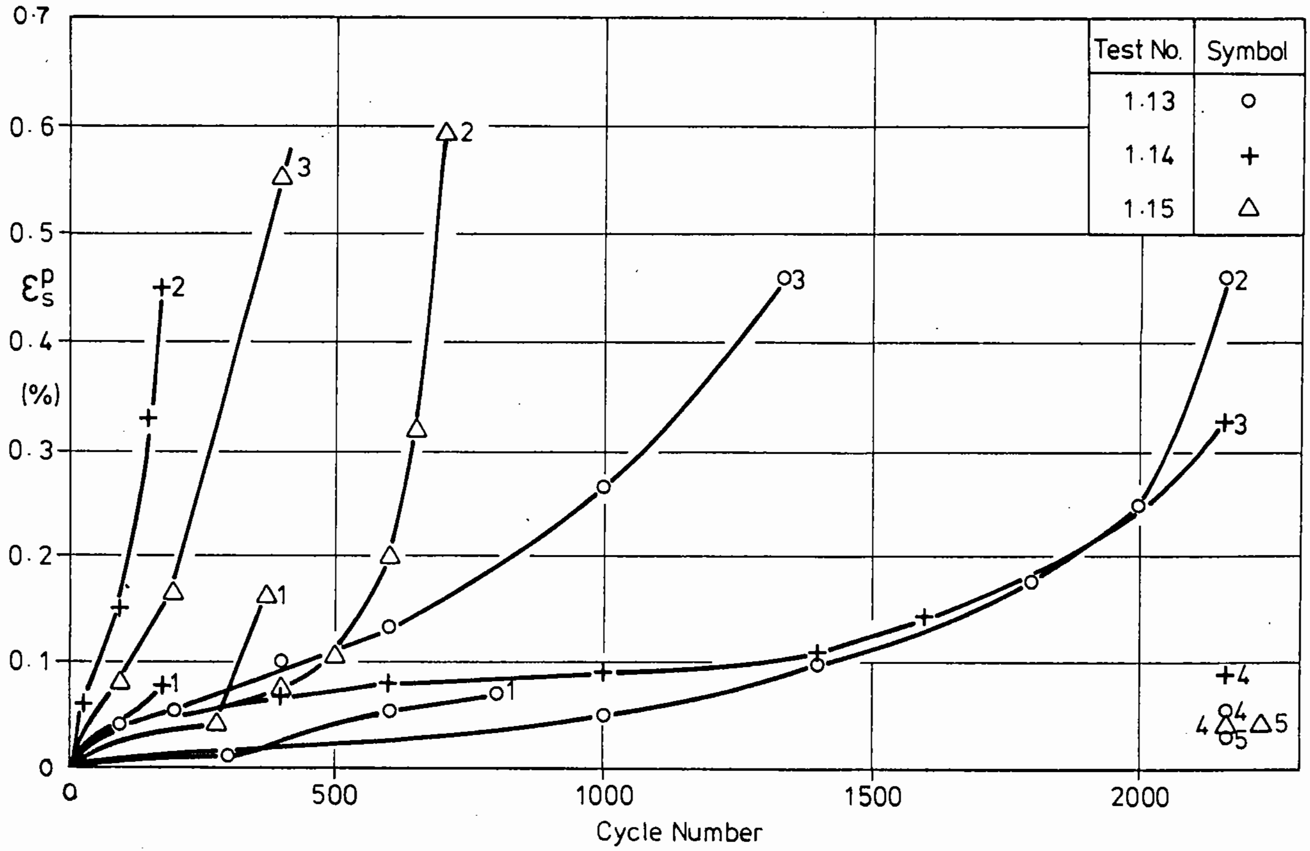
7.1.1 Series 1

Specimens 1.2, 1.8, 1.11 and 1.12 were all tested at the 30% cyclic stress level. The shear strain developed by test 1.11 is shown in Figure 7.2(a) together with an indication of results for tests 1.2 and 1.8. All three specimens had developed similar strains by the end of the loading sequence. On day 1 of test 1.8, the behaviour was similar to the other two tests until cycle 1200, when the specimen started to develop large strains and the test was stopped. The other two survived the full six hours. The development of strain varied in different specimens. In 1.2 and 1.8 the strain built up evenly over the 2160 cycles; 1.11 developed more strain in the first 100 cycles after which the rate of strain was lower.

Specimen 1.12, by contrast, although loaded at the same stress level, failed on each of the first three days of test and is shown in Figure 7.2(b). The strain development was the same as the other three tests for the first 700 cycles on days 1 and 2, at which point the soil started to deform rapidly. The pattern was the same for day 3 with a rapid increase in strain rate from cycle 500. Day 4 was only recorded from cycle 300 on, but shows a lower rate of strain, while day 5 shows similar behaviour to the other tests with little permanent strain developing. The anomalous behaviour of the strains was due to high initial pore pressures which are discussed in section 7.3.1.



(a) Test Numbers 1.1, 1.9 and 1.10



(b) Test Numbers 1.13, 1.14 and 1.15

Figure 7.3 PERMANENT SHEAR STRAIN DEVELOPMENT UNDER 50% CYCLIC LOADING

Six specimens were tested at the 50% cyclic stress level, the development of permanent strain is shown in Figure 7.3. One drainage period was sufficient to give tests 1.1 and 1.9 the ability to withstand the loading on all subsequent days without developing large strains although it should be noted that the first 400 cycles of test 1.1 on day 1, were applied with the drainage line open. This could have contributed to the soil's resistance by allowing some pore pressure to dissipate. Test 1.10, although brought to the same stress state and subjected to the same loading, required three drainage periods before it could survive 2160 cycles of load.

The strain developed in tests 1.13, 1.14 and 1.15 are shown in Figure 7.3(b). The test procedure was slightly modified for these three tests as a few hundred cycles of the 30% stress level were applied first as part of an investigation of cyclic pore pressure response which is discussed in Chapter Eight. After this low stress level had been applied, the soil was either allowed to drain or a few cycles of the 50% stress level was applied prior to drainage. The soil in each test developed large permanent strains on days 2 and 3, although the number of cycles applied before the tests were halted, varied from only a few hundred to 2000. On day 3 of test 1.15 the laboratory temperature control failed and the temperature rose from 20 to 23^{o}C which altered the transducer readings and a higher load was inadvertently put on the soil. On subsequent days, the soil survived the six hours of loading showing little development of shear strain.

Figure 7.4 shows the soil response when subjected to 70% loading. As might be expected, the higher stress levels quickly caused failure on days 1 and 2, requiring less than 100 cycles on day 1 and 250 cycles on day 2 before the test was stopped. By day 3, however, some increased resistance to the loading was noticeable, with test 1.4 lasting some 400 cycles and test 1.3 surviving 2000 cycles. After this, the samples showed a marked change in behaviour and seemed quite stable throughout the testing periods.

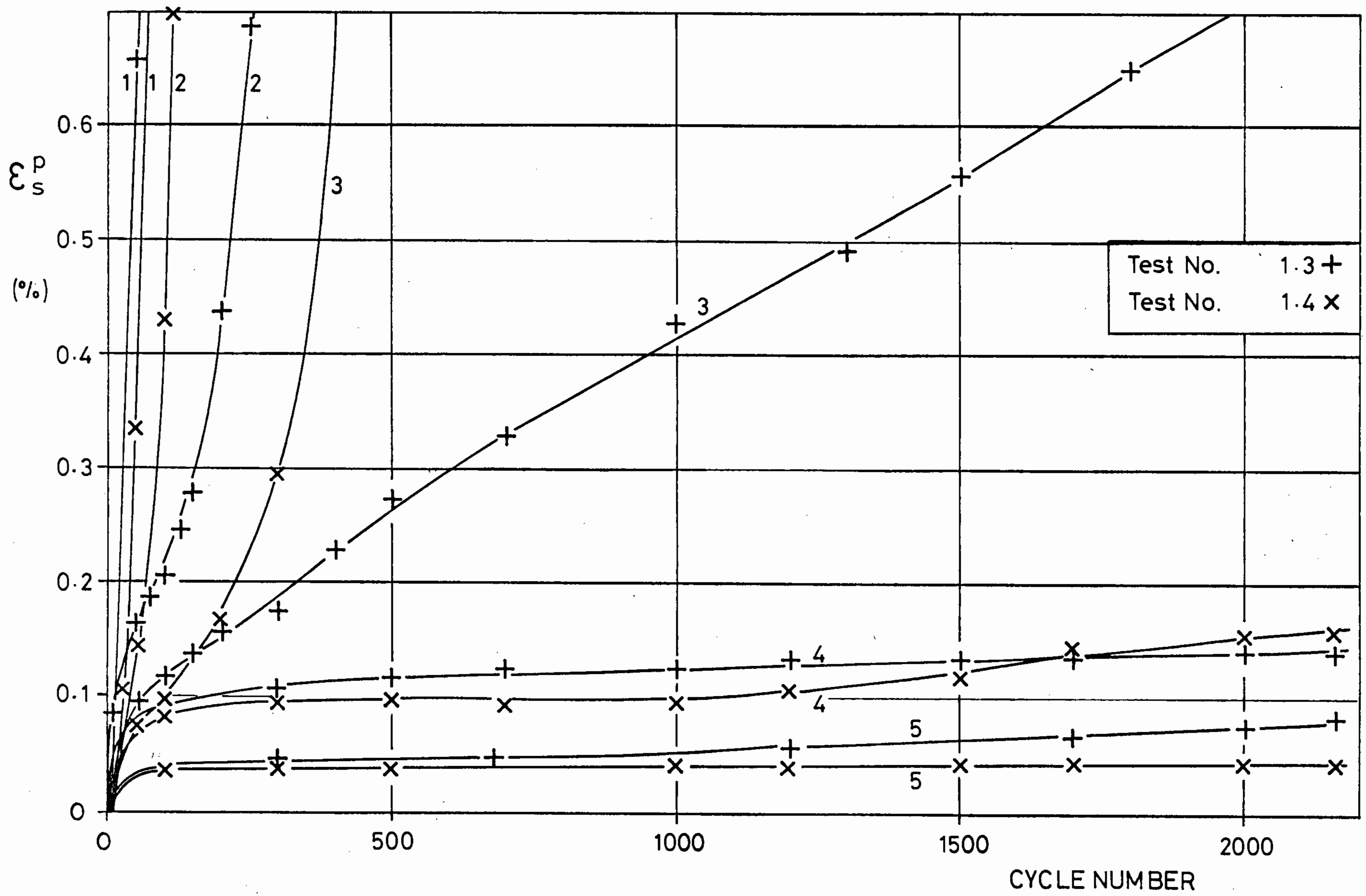
7.1.2 Series 2

Two specimens were overconsolidated by initial anisotropic consolidation to a mean normal effective stress of 244 kPa and a deviator stress of 173 kPa, before the deviator stress was reduced to 130 kPa and the normal stress to 183 kPa, giving an overconsolidation ratio of 1.33. This procedure brought the soil to the same initial mean stresses as series 1, but at a lower moisture content. The moisture content was similar to that of the series 1 tests after five periods of loading and drainage. This allowed the behaviour of the soil brought to the same moisture content by different stress paths to be investigated. The results of the overconsolidated tests are given in Table 7.1. Both specimens were tested at the 50% stress level and developed little permanent strain. Specimen 2.1 was tested for only three days but showed negligible permanent response. On day 3, a few cycles at the 70% level were applied but with no additional effect. Specimen 2.2 did develop a small amount of strain on days 1 to 3.

The strain response of these two tests suggests that the overconsolidation had brought the specimens inside the yield surface and that the loading produced a response that was chiefly elastic.

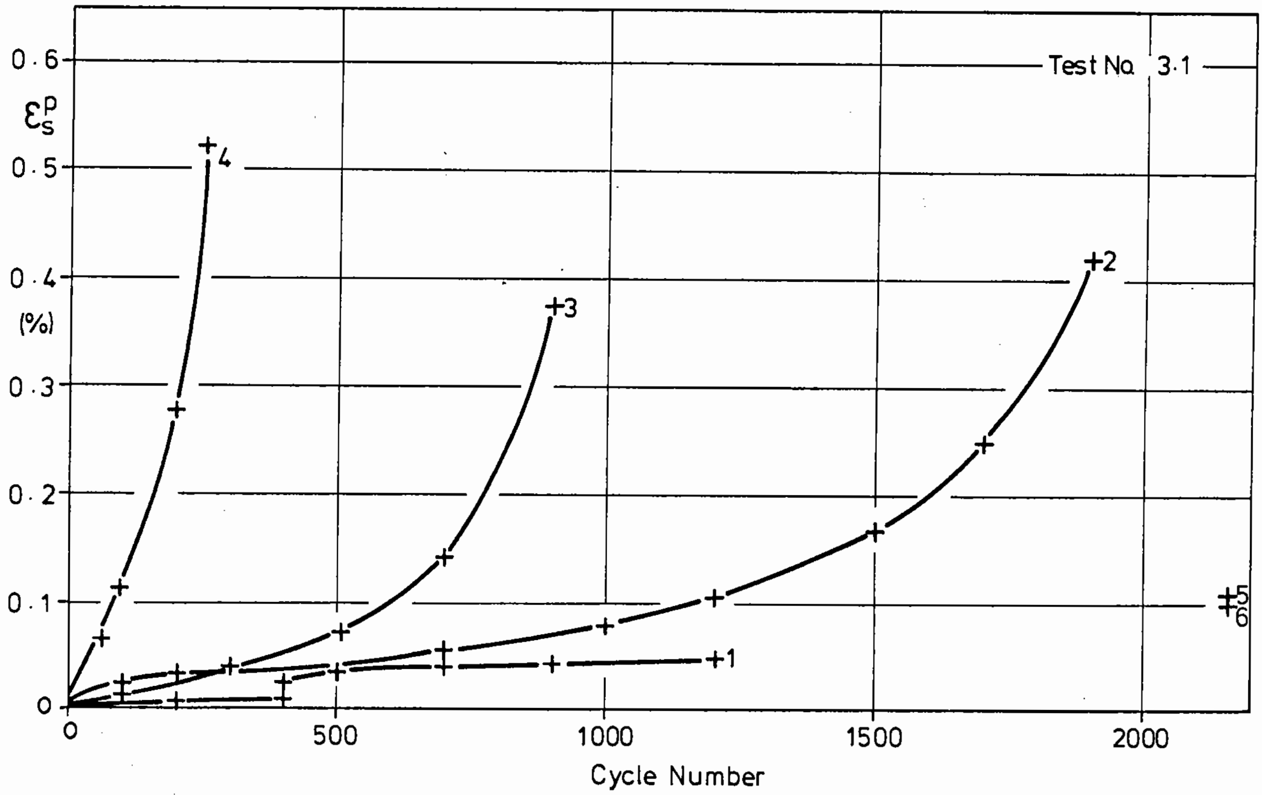
7.1.3 Series 3

The tests in this series were used mainly to investigate the effect of cycling q about different mean values. Test 3.1 is shown in Figure 7.5(a). On day 1, it was subjected to 400 cycles at the 50% cyclic stress level and the usual mean q of 130 kPa, before the mean level was raised to 155 kPa and the cyclic stress dropped to the 30% level. The soil developed less shear strain than expected when compared with previous tests under similar loading over 400 cycles. On raising the mean level, there was an immediate rise in permanent shear strain, but the subsequent cyclic loading had little further effect and the test was halted at cycle 1200.

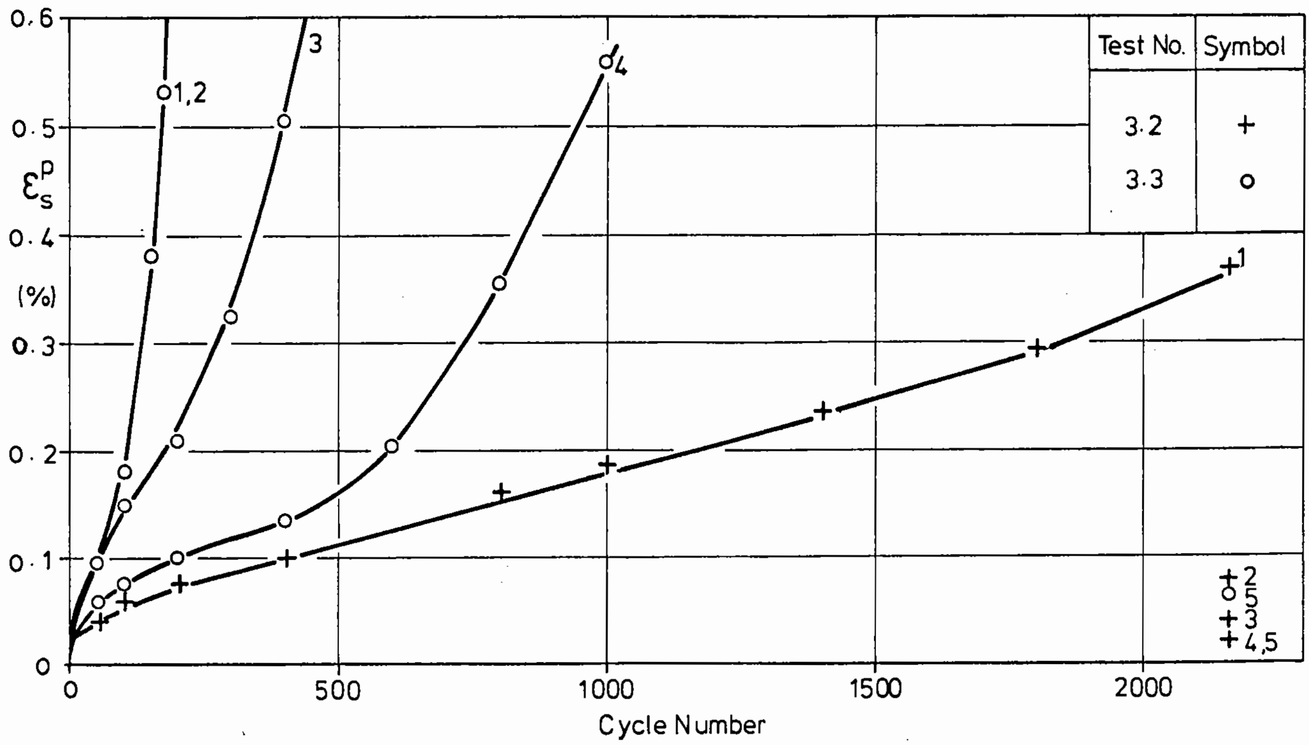


PERMANENT SHEAR STRAIN DEVELOPMENT UNDER 70% CYCLIC LOADING

Figure 7.4



(a) Test Number 3.1



(b) Test Numbers 3.2 and 3.3

Figure 7.5 PERMANENT SHEAR STRAIN DEVELOPMENT UNDER 30% CYCLIC LOADING AND A HIGH MEAN DEVIATOR STRESS LEVEL

Test No.	Variable	Day of test									
		1		2		3		4		5	
		Cycle 1	Cycle 2160	1	2160	1	2160				
2.1	ε_s (%)	.0001	.0024	.0022	.0017	.0048	.0054				
	Pore pressure (kPa) (Base)	-0.05	2.04	0.97	0.76	-0.28	0.00				
2.2	ε_s (%)	.0078	.0101	.0029	.0103	.0041	.0075	.0013	.0021	.0017	.0004
	Pore pressure (kPa) (Centre)	0.59	3.07	0.02	2.95	-0.56	1.60	0.08	0.31	0.13	0.92
	Pore pressure (kPa) (Base)	-0.27	-0.31	0.92	-0.33	1.13	-1.09	0.77	-2.36	0.84	-1.41

PERMANENT SHEAR STRAIN AND PORE PRESSURE FOR SERIES 2 TESTS

Table 7.1

Test No.	Variable	Day of test									
		1		2		3		4		5	
		Cycle 1	end	Cycle 1	end	Cycle 1	end	Cycle 1	end	Cycle 1	end
3.4	ε_s (%)	.0049	-.0035	.0019	-.0012	.0061	.0033	.0000	.0000		
	Pore pressure (kPa) (Base)	-4.23	12.54	-5.77	+5.6	-5.25	7.00	-4.2	2.8		
3.5	ε_s (%)	.0138	.0653	.0075	.0507	.0129	.0729	.0028	.018	.0065	.0042
	Pore pressure (kPa) (Centre)	-0.95	15.66	3.82	12.86	2.65	10.13	1.70	6.79	1.79	3.08

TABLE OF PERMANENT PORE PRESSURES AND STRAIN

Table 7.2

However, after the drained rest period, the soil, when reloaded at the high mean level, developed large strains and the test was stopped at cycle 1900. Days 3 and 4 showed the soil surviving for shorter periods each day. Two more days' testing at the same stress level was, therefore, allowed to investigate the lower resistance to the loads. The soil increased its resistance to last the full 6-hour loading period whilst developing little strain.

Tests 3.2 and 3.3 were cycled at a mean level of 145 kPa and the 30% cyclic stress level. The development of shear strain is shown in Figure 7.5(b). The two specimens, although at the same stress state, behaved differently. Test 3.2 developed a large strain on day 1 but survived on all the subsequent days, whilst 3.3 failed on all but the fifth day. Both specimens showed that they were getting stronger by either lasting more cycles or developing less strain each day.

Test 3.4 involved the lower mean level of 115 kPa and the result is given in Table 7.2. Very little shear strain developed although there was a slight tendency for it to be negative, i.e. the specimen was extending rather than compressing.

Test 3.5 used the 30% stress level and a mean q of 130 kPa but at a frequency of 0.01 Hz instead of the ususal 0.1 Hz. The soil did not develop very large shear strains in the 216 cycles of load possible in six hours. The results are also shown in Table 7.2.

7.2 APPARENT PERMANENT VOLUMETRIC STRAIN

Both axial and radial deformations were recorded during the tests. In an undrained triaxial test on a saturated clay specimen there can be no overall volume change. As a check, an apparent volumetric strain was calculated from the sum of the permanent axial strain plus twice the permanent radial strain. For the soil to be acting as a single element, this sum should always be zero.

Test No.	Day of Test				
	1	2	3	4	5
1.1	85	54	-6	68	04
1.2	267	94	55	45	65
1.3		430	81	303	147
1.4	53	-81	43	90	56
1.6	09	-51	58	05	10
1.7	13	58	-03	14	32
1.8	-19	24	46	-	-
1.9	06	-08	12	-06	-10
1.10	99	14	34	-08	19
1.11	-105	54	-72	19	-08
1.12	07	72	41	-42	72
1.13	07	-94	-11	51	25
1.14	-	36	110	-09	-
1.15	51	22	-18	68	17
2.1	-04	-09	01	-	-
2.2	41	13	34	-37	54
3.1	-02	32	01	-28	02
3.2	01	14	30	-05	08
3.3	15	-07	-118	27	07
3.4	-22	-04	-15	61	-
3.5	-02	01	-11	51	25

APPARENT PERMANENT VOLUMETRIC STRAINS

(all figures microstrain)

Table 7.3

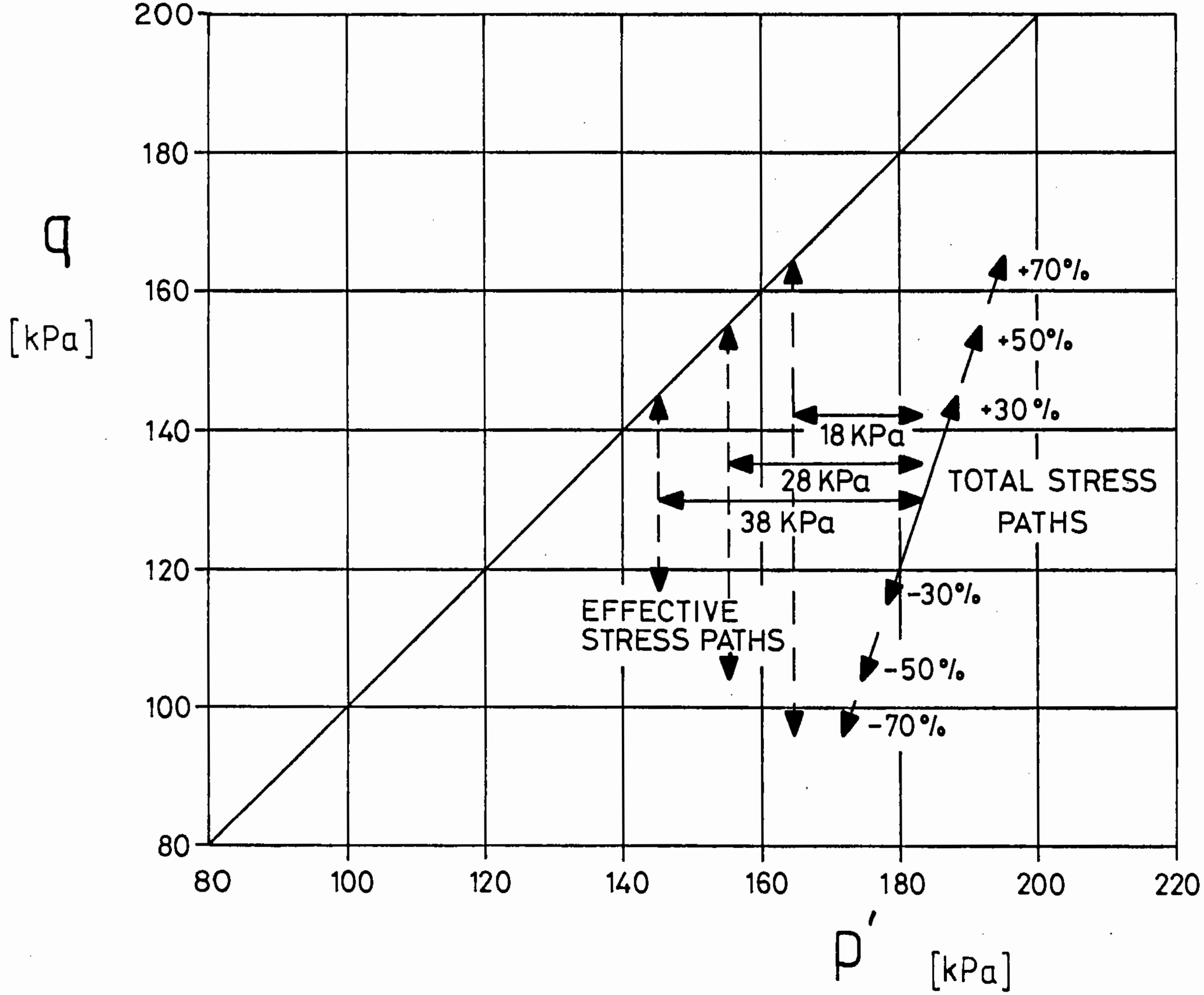
Table 7.3 shows the deviation that occurred from the ideal. The numbers given in the table are the maximum values recorded up until the strains began to develop rapidly with each cycle, indicating failure was imminent. If no failure occurred the values are those at the end of a load period. The figures are in microstrain and a minus sign indicates that the soil was barrelling. That is, the radial strain was greater than was expected for right cyclinder deformation.

It was found that when the permanent strains were small the apparent volume strain was zero and the soil could be considered as an element but this was not true as the strains became larger. The strain at which the soil could no longer be considered as a single element was not constant for all the specimens.

7.3 PERMANENT PORE PRESSURE

At the start of some loading periods, a residual pore pressure still existed in the soil. The amounts are shown in Table 7.4. All graphs of pore pressure against number of cycles show only the changes during the cyclic loading periods. They are, therefore, compatible with the permanent shear strain graphs.

Assuming there is little change in effective normal stress in a cycle (pore pressures compensating) and given adequate pore pressure development, the effective stress path can reach the failure envelope at the peak q while the rest of a cycle will be at sub-failure conditions. The mean pore pressure at which this first occurs is constant for a given mean stress and cyclic stress level as shown in Figure 7.6, but as the plots of pore pressure are not always the absolute values, the point where the peak of a cycle reached failure is shown, where relevant, on the lines in the following graphs by an asterisk. Where a specimen contained both a centre and base pore pressure probe the centre probe readings are given.



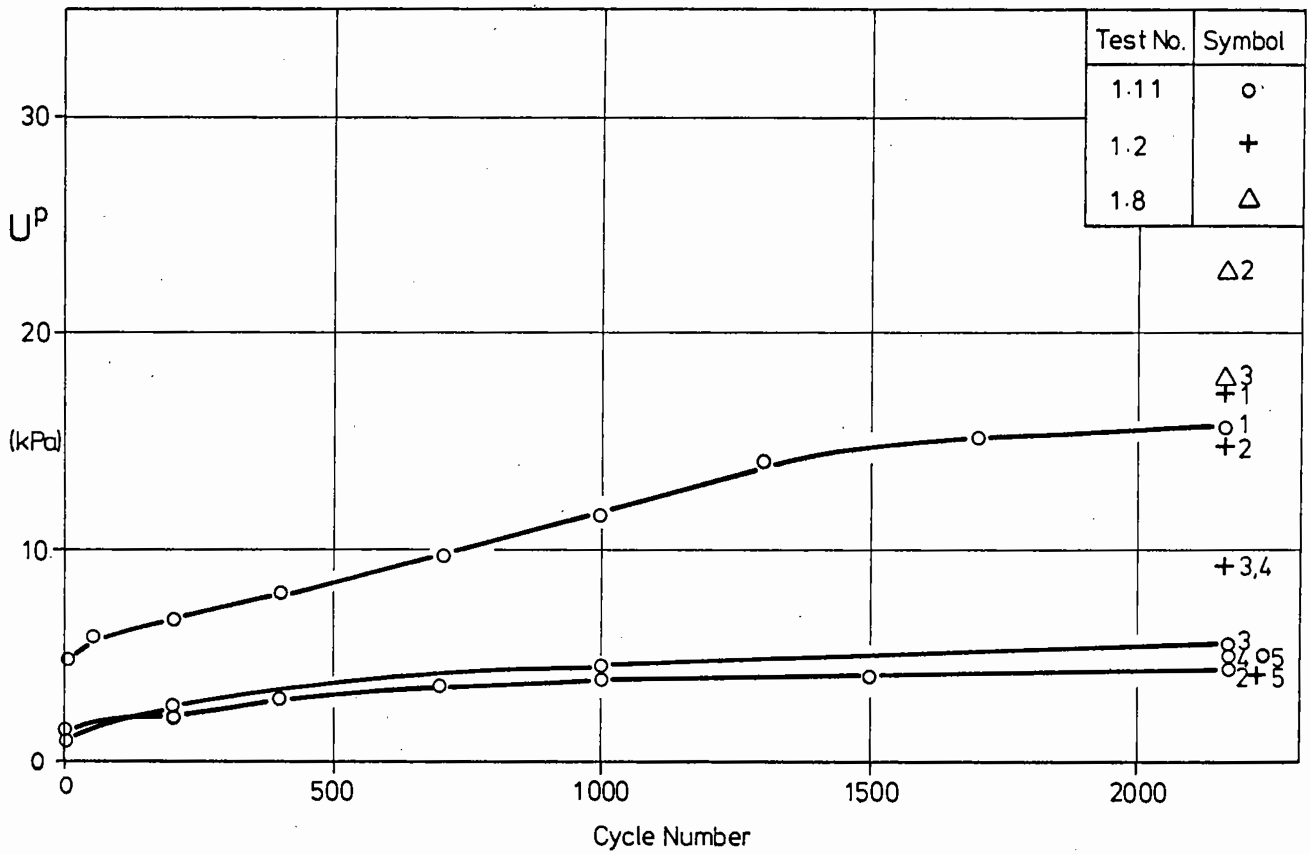
MEAN PERMANENT PORE PRESSURES REQUIRED TO CAUSE FAILURE

Figure 7.6

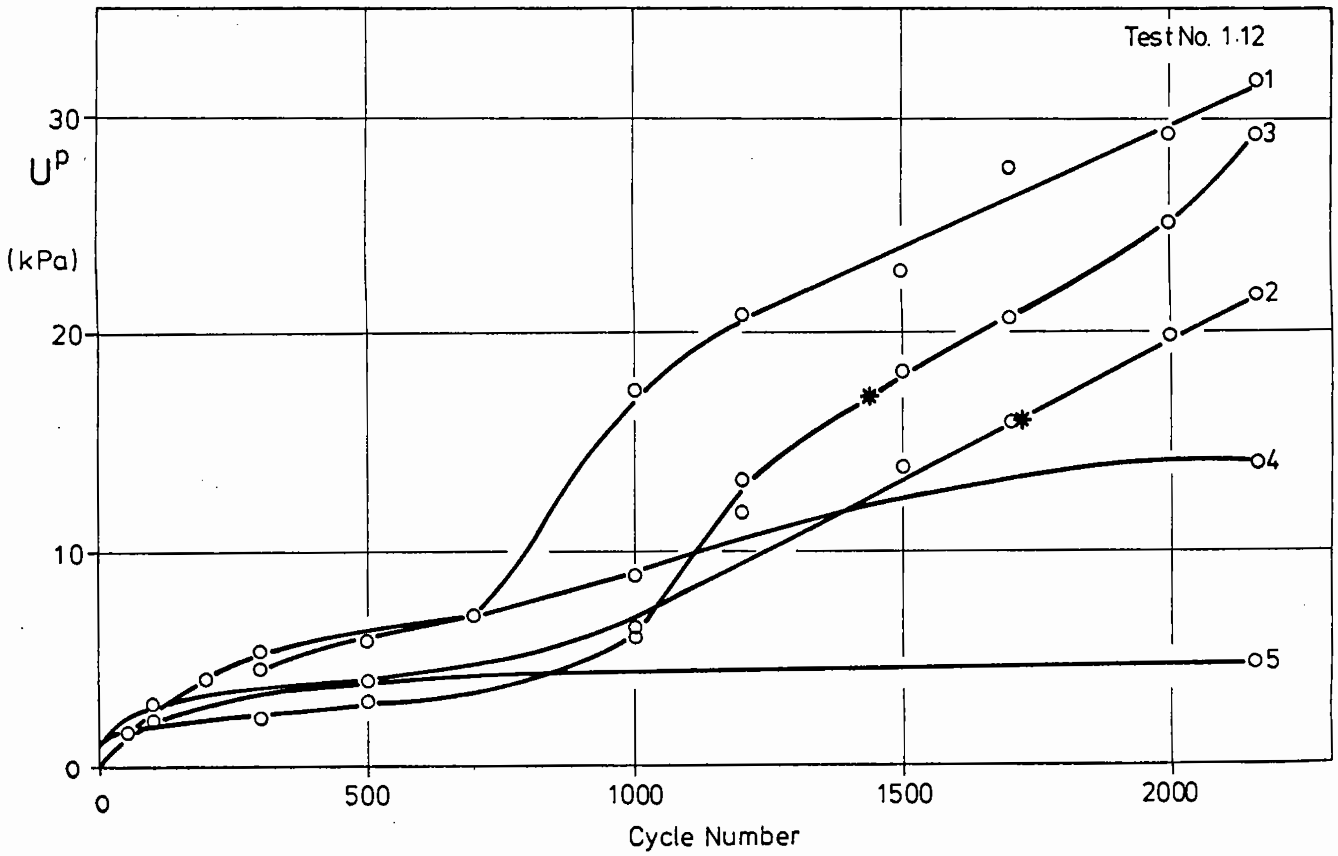
Test No.	Day of test				
	1	2	3	4	5
1.1	--	7.1	1.3	3.8	1.9
1.2	--	--	--	--	--
1.3	--	1.8	8.4	4.6	--
1.4	--	--	--	--	--
1.5	--	3.8	4.6	--	3.3
1.6	3.1	12.5	3.7	3.6	1.3
1.7	--	--	--	--	--
1.8	--	8.4	--		
1.9	--	--	--	--	--
1.10	--	4.6	4.7	7.6	7.8
1.11	--	6.6	1.8	--	--
1.12	--	22.0	21.0	26.0	9.7
1.13	2.7	--	4.0	2.0	4.0
1.14	5.0	--	--	--	2.0
1.15	2.0	--	5.5	5.5	8.0
2.1	--	--	--	--	--
2.2	--	--	--	--	--
3.1	--	--	--	--	--
3.2	--	6.6	2.6	0.9	--
3.3	--	7.0	2.8	2.6	3.7
3.4	--	--	--	--	--
3.5	--	--	--	--	--

INITIAL PORE PRESSURES (kPa)

Table 7.4



(a) Test Numbers 1.2, 1.8 and 1.11



(b) Test Number 1.12

Figure 7.7 PERMANENT PORE PRESSURE DEVELOPMENT UNDER 30% CYCLIC LOADING

7.3.1 Series 1

Of the four specimens tested at the 30% stress level, tests 1.2 and 1.8 had pore pressure measurement taken at the base of the specimen while 1.11 and 1.12 had centre pore pressure probes as well. Test 1.11 is shown in Figure 7.7(a) together with 1.2 and 1.8. The non-failing parts of the tests all show levels of pore pressure well below the 38 kPa needed to reach failure at this stress level (Figure 7.6). However, the pore pressures, like the shear strains, sometimes developed steadily over the loading period and sometimes developed mainly in the first 100 cycles. Specimen 1.12 (Figure 7.7(b)), which failed on each of the first three days, did not dissipate much of its excess pore pressures during the overnight drainage periods. On day 1, the mean pore pressures reached 31 kPa but during drainage this only reduced to 22 kPa. On reloading, the soil reached the failure envelope after 1740 cycles on day 2 and 1400 cycles on day 3. On day 1 the pore pressures showed a sudden rise at cycle 700 which corresponded to the rise in strain (Figure 7.2(b)). On days 2 and 3, there was not such a corresponding sharp rise, although the rate of pore pressure development did increase. The soil survived the loading on days 4 and 5 despite high pore pressure on day 4.

The development of pore pressure in the tests with the 50% stress level are shown in Figure 7.8. Figure 7.8(a) shows the results from tests 1.1, 1.9 and 1.10. The general pattern is similar to that of the shear strains, with large pore pressures developing on day 1 and smaller levels after the drainage periods. Figure 7.8(b) shows the development of pore pressure in tests 1.13, 1.14 and 1.15 measured by the centre probe. On day 1, a few hundred cycles of the 30% stress level were applied and, if the pore pressures and strains were low, some cycles at 50% were added, otherwise the 50% loading was applied after a drainage period. These tests reached the failure envelope on days 2 and 3 with a wide variation in the number of cycles needed for this to happen. After drainage and further loading, the soil survived the full six hours.

The pore pressure response of tests 1.3 and 1.4, subjected to the 70% load, is shown in Figure 7.9. The development of large pore pressures was very rapid on the first three days but, by day 4, the specimens survived the full loading periods without reaching failure.

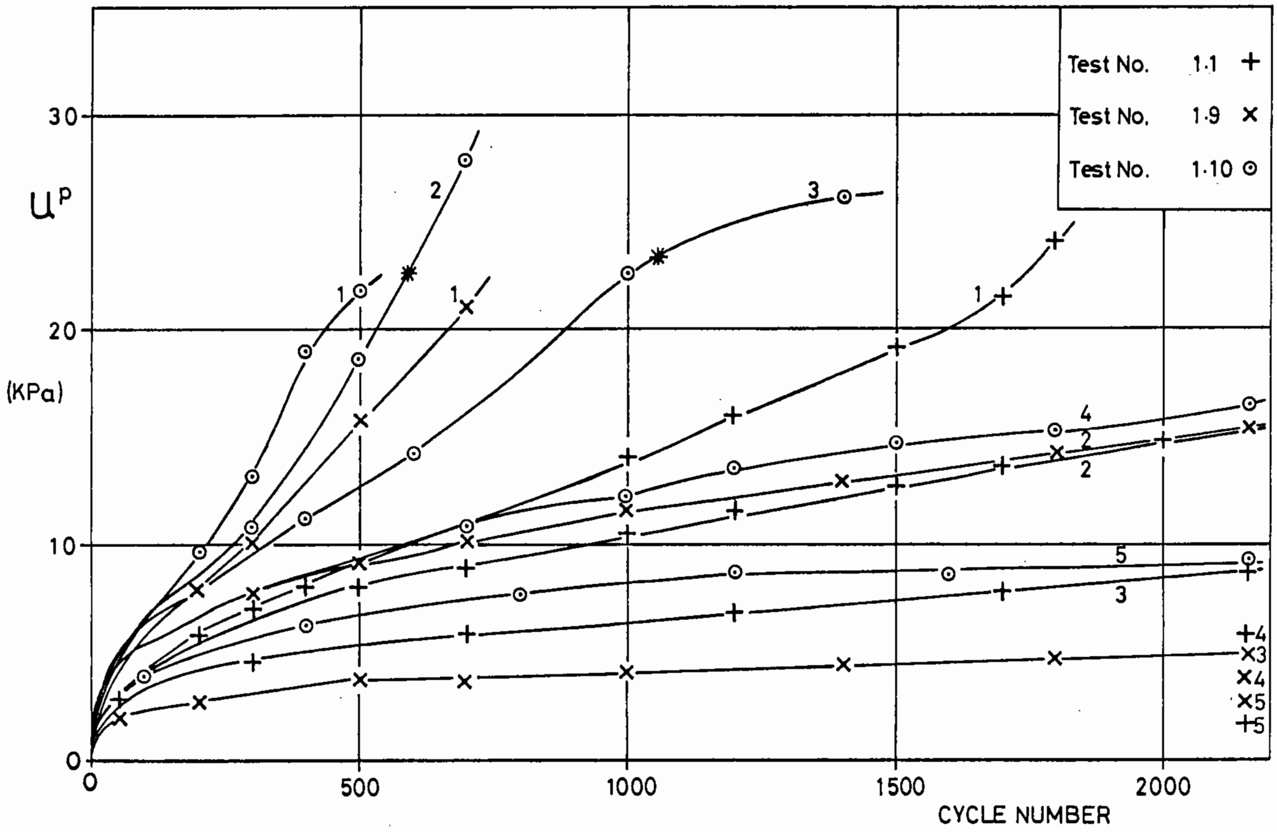
7.3.2 Series 2

The pore pressures developed by the overconsolidated samples are shown in Table 7.1. Specimen 2.1, with the base probe, showed a small increase in pore pressure on day 1 but no development subsequently. Specimen 2.2 had both centre and base probes which produced different results. The centre probe registered a slight positive pore pressure whilst the base probe indicated a slight negative value.

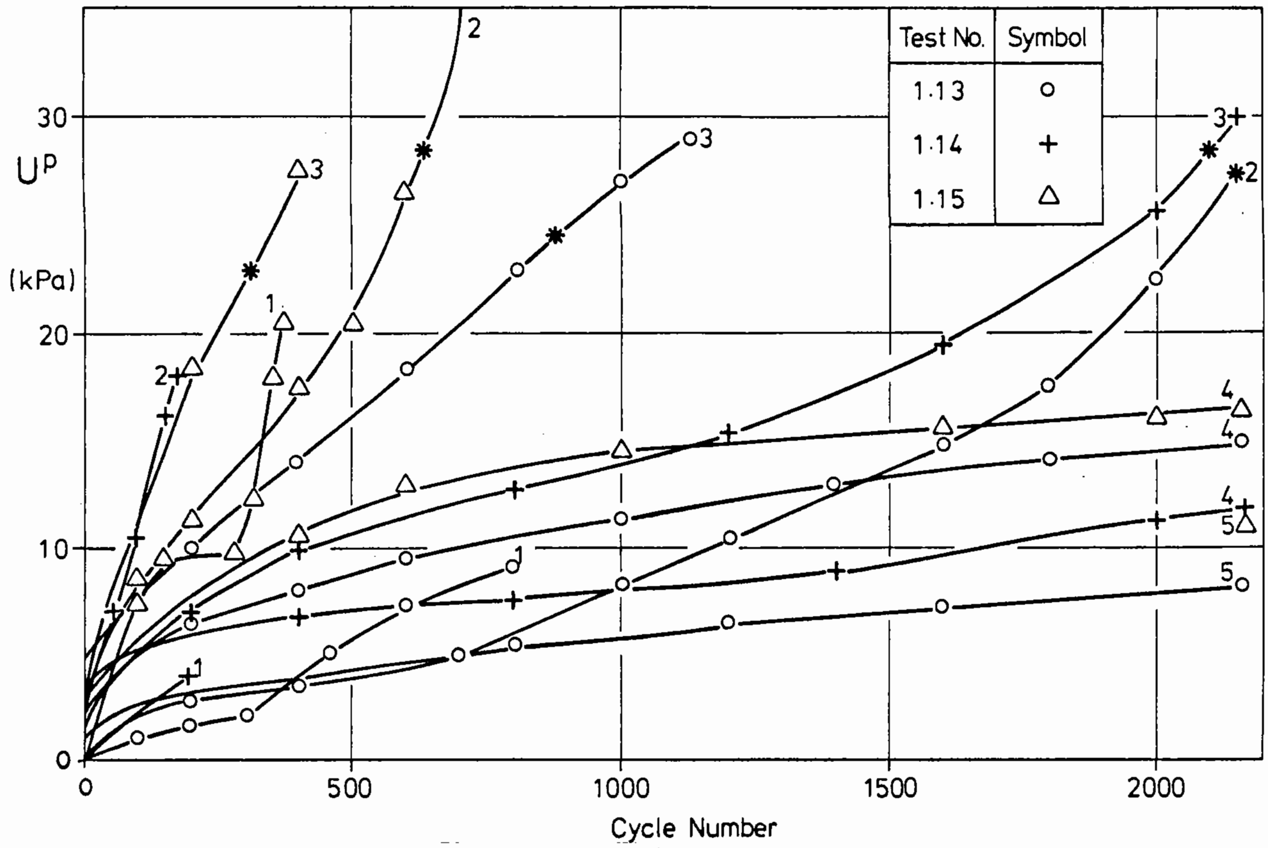
7.3.3. Series 3

Test 3.1 was given 400 cycles of 50% loading before the mean deviator stress level was raised from 130 kPa to 155 kPa. Figure 7.10(a) shows that the pore pressure increased immediately by about 8 kPa, which is approximately the rise in mean normal stress ($\Delta p = \Delta q/3$). On subsequent days, the mean level was raised at the start of each load period and the pore pressure rose accordingly. The build up of pore pressure during cyclic loading was greater each day on days 2, 3 and 4 but eventually the specimen survived on days 5 and 6.

The pore pressure response for tests 3.2 and 3.3 is shown in Figure 7.10(b); 3.3 had a base probe, 3.2 had a centre probe and they were tested at a mean q of 145 kPa. Both showed an initial increase of 5 kPa or more as expected on the basis of constant p'. The repeated loading brought 3.3 to the failure envelope on the first four days, while 3.2

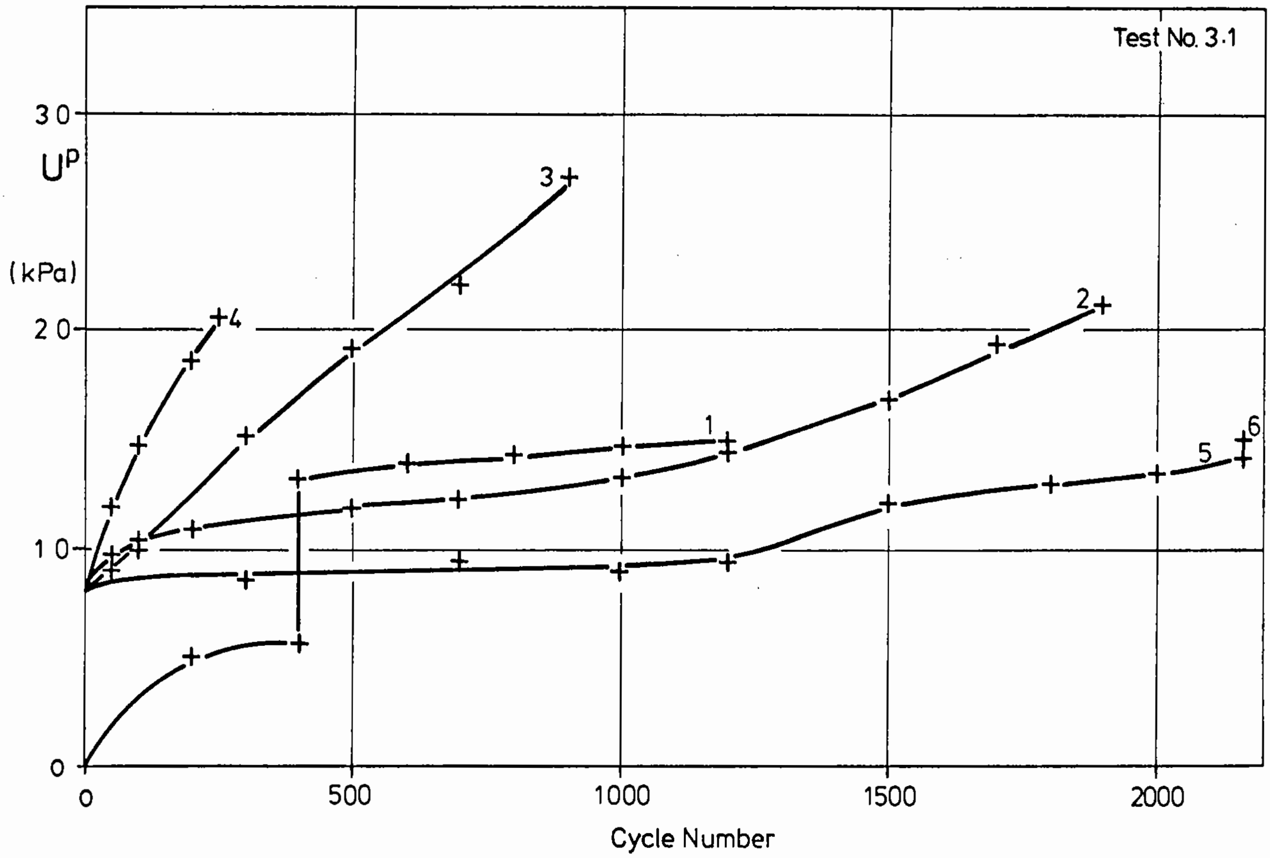


(a) Test Numbers 1.1, 1.9 and 1.10

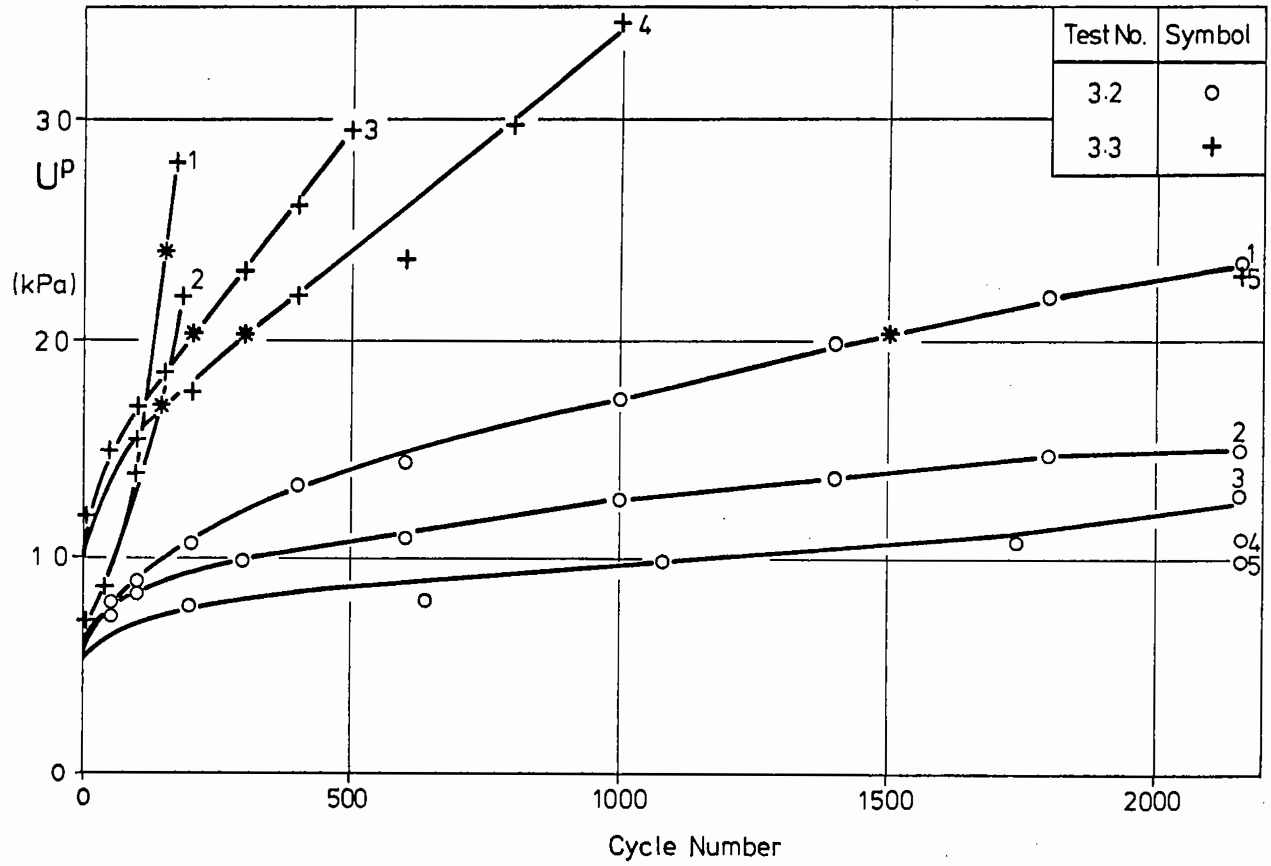


(b) Test Numbers 1.13, 1.14 and 1.15

Figure 7.8 PERMANENT PORE PRESSURE DEVELOPMENT UNDER 50% CYCLIC LOADING

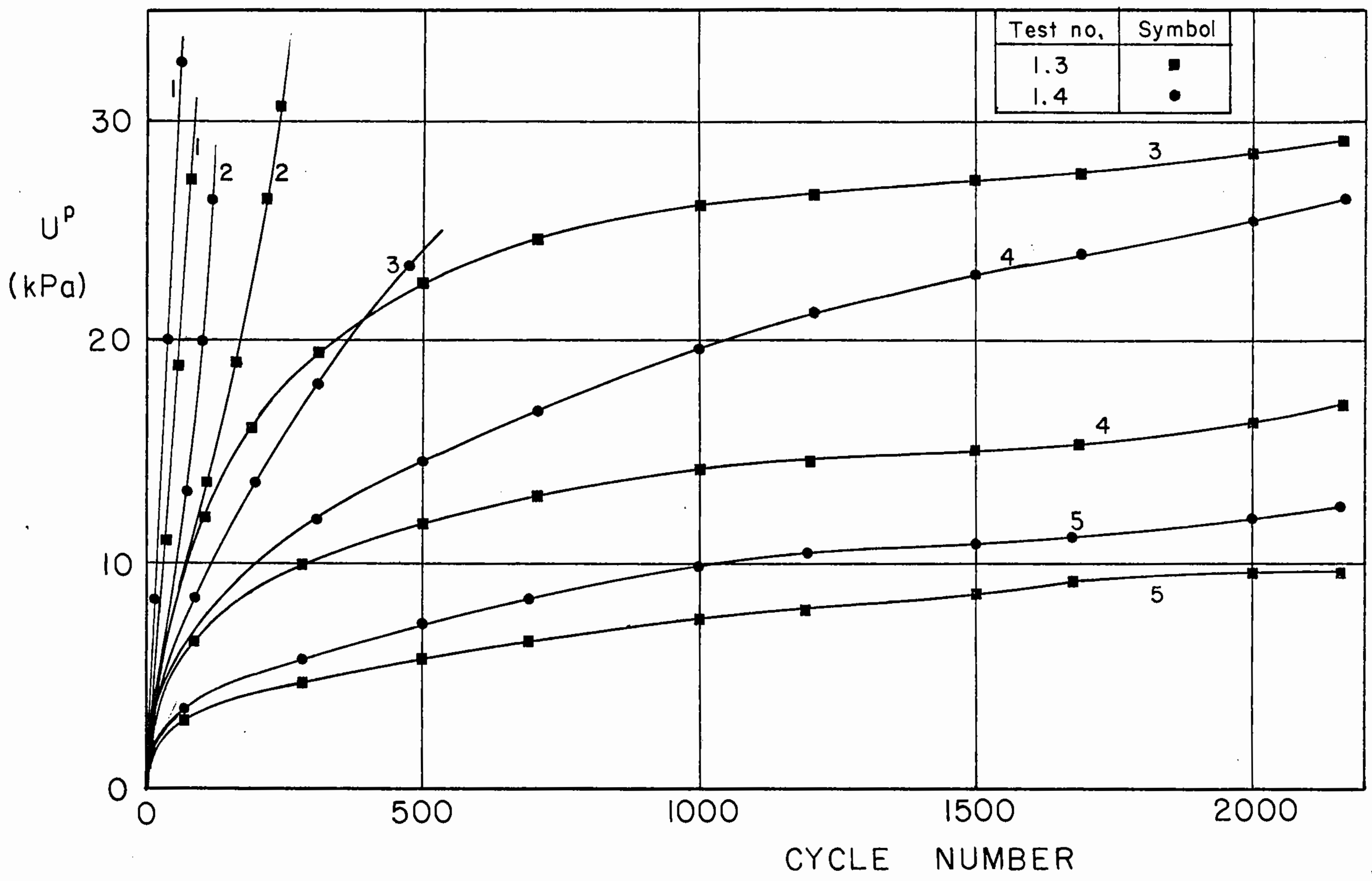


(a) Test Number 3.1



(b) Test Numbers 3.2 and 3.3

Figure 7.10 PERMANENT PORE PRESSURE DEVELOPMENT UNDER 30% CYCLIC LOADING AND A HIGH MEAN DEVIATOR STRESS LEVEL



PERMANENT PORE PRESSURE DEVELOPMENT UNDER 70% CYCLIC LOADING

Figure 7.9

7.4 DRAINED REST PERIODS

Between each load period the soil was allowed to drain under the stress conditions reached at the end of consolidation. The outflow of water in the drainage periods was small, so a burette with a 5 ml capacity and divisions to 0.01 ml was used. Samples 1.1, 1.2 and 1.11 were tested before the burette was available and readings for these tests were taken from a 100 ml capacity burette with divisions to 0.2 ml. Table 7.5 gives the outflow of water in each case.

For the normally consolidated specimens, initially consolidated to a mean normal effective stress of 183 kPa and deviator stress of 130 kPa, the range of moisture contents was 20.9% to 20.2% whilst the change in moisture content was never more than 1% over the five days of test. The actual moisture content of a specimen within this range did not conclusively determine the amount of damage caused to the specimen. For example, tests 1.9 and 1.10 were both subjected to the 50% stress level. Specimen 1.9 was nominally at a higher moisture content but survived all but the first day's loading, whilst the slightly drier initial state of 1.10 did not prevent it failing on the first three days. Despite this, the amount of drainage does correlate with the amount of damage caused by the loading periods. Examples of this are given in Figures 7.11 to 7.13, which show plots of V (specific volume = 1 + e) against ln p' over a 1% moisture content range. The normal consolidation line is shown together with the slope of the swell back line. The swell back line is shown to be linear and at a small angle to the p' axis. It should be remembered that the slope may well be larger during reconsolidation as the soil approaches the normally consolidated line. Furthermore, the line shown is for the K_o overconsolidation where both q and p' are varying.

survived the loading with less pore pressure development each day. On reducing the mean level of q at the end of each load period, all three specimens showed a drop in pore pressure although the fall was less than the amount required to keep p' constant.

Test 3.4 involved a mean level of 115 kPa and the pore pressure response of the base probe is given in Table 7.2. There was an initial drop of about 5 kPa as the mean level was changed, followed by a build up in positive pore pressure as the repeated loading was applied. There was a corresponding rise in pore pressure at the end of a load period when the mean level of stress was raised back to 130 kPa.

The pore pressures developed by test 3.5 are shown in Table 7.2. There was insufficient development to bring the soil to the failure envelope. The amount of strain developed was comparable with the series 1 tests at the 30% level. It was thought that the slow frequency used in test 3.5 would be a more severe loading regime, but this was not apparent.

7.3.4 Centre and base probes

Some specimens were tested with only a base pore pressure probe, others had a centre probe as well. The permanent pore pressure readings from each probe were compared. Although there was some scatter between the individual readings, no significant difference was obvious provided the pore pressure was less than 10 kPa (and the shear strain 0.1% or less). Above these values, the base probe tended to read a few kPa higher than the centre probe.

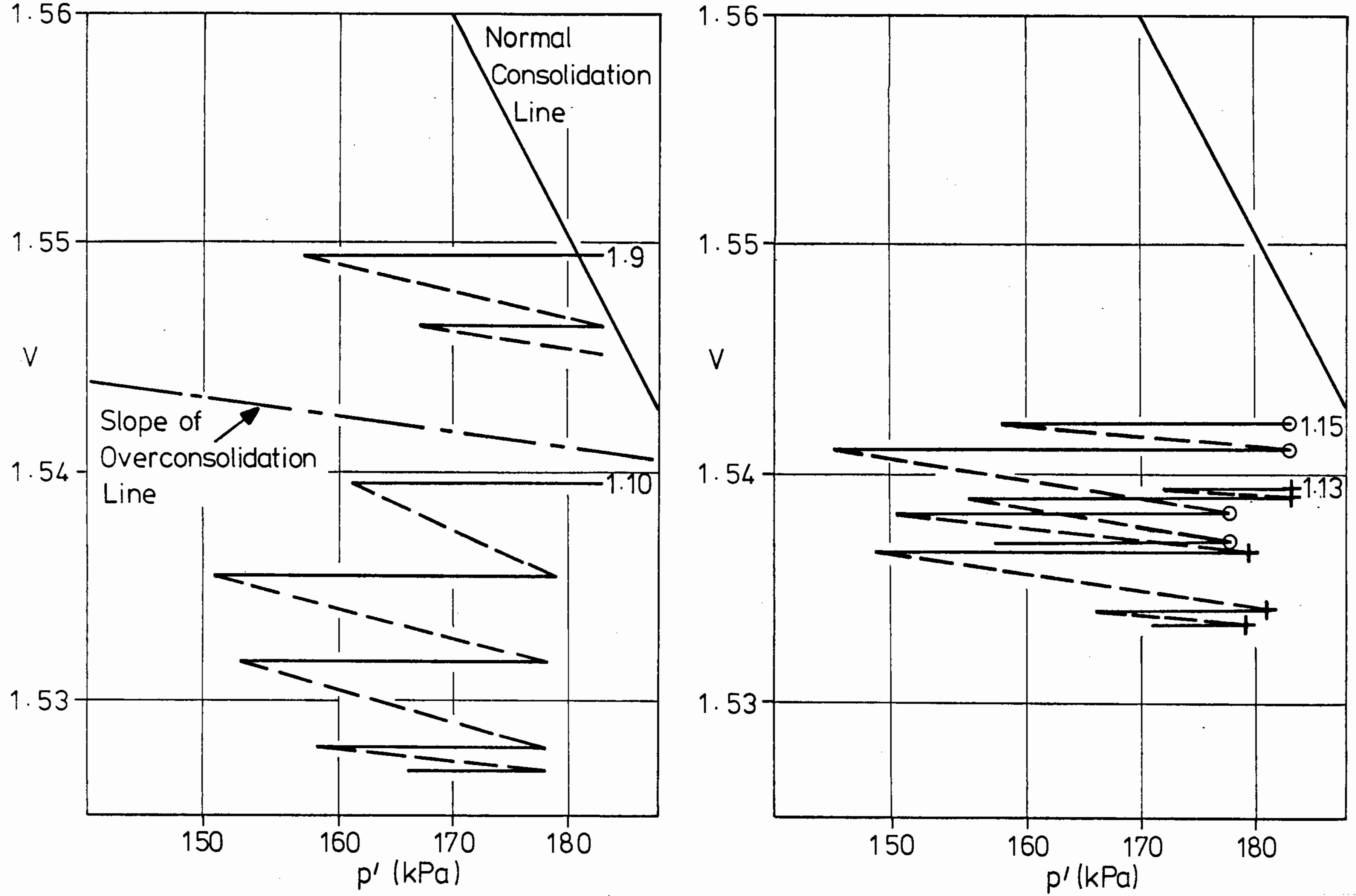


Figure 7.11 CHANGE IN SPECIMEN STATE DURING DRAINED REST PERIODS BETWEEN 50% CYCLIC LOADING

Test No.	Day of test and drainage periods								
	1		2		3		4		5
	%	ml	%	ml	%	ml	%	ml	%
1.1	20.64	0.60	20.59	0.60	20.54	0.20	20.52	-	20.52
1.2	20.89	0.41	20.85	0.34	20.82	0.19	20.80	0.04	20.80
1.3	20.89	6.47	20.33	2.89	20.07	1.55	19.93	0.86	19.86
1.4	20.80	4.98	20.35	2.58	20.13	2.45	19.91	0.37	19.88
1.5	20.67	3.29	20.38	1.43	20.25	2.51	20.02	0.25	20.00
1.6	20.90	4.20	20.52	2.34	20.31	0.23	20.28	0.12	20.27
1.7	20.68	1.77	20.52	1.81	20.37	0.22	20.35	0.97	20.26
1.8	20.66	2.58	20.43	0.88	20.35	-	-	-	-
1.9	20.78	1.50	20.65	0.43	20.61	0.03	20.61	0.02	20.61
1.10	20.38	1.77	20.22	1.71	20.07	1.81	19.92	0.44	19.88
1.11*	20.80								
1.12	20.52	0.38	20.49	0.74	20.42	0.26	20.40	1.09	20.30
1.13	20.37	0.20	20.36	0.91	20.27	1.17	20.17	0.27	20.14
1.14	20.36	0.19	20.67	0.93	20.58	0.85	20.51	1.32	20.39
1.15	20.49	0.37	20.45	1.20	20.35	0.77	20.28	0.10	20.27
2.1	19.76								
2.2	19.95								
3.1	20.60	0.20	20.58	2.60	20.35	2.40	20.14	1.08	19.98
3.2	20.20	0.61	20.14	0.31	20.12	0.06	2o.11	0.03	20.11
3.3	20.64	1.61	20.50	1.26	20.39	1.47	20.26	1.13	20.16
3.4	20.54	0.16	20.52	0.07	20.52	0.02	20.52		
3.5	20.55	0.47	20.51	0.17	20.49	0.07	20.49	0.17	20.47

*The water outflow from test 1.11 was measured in the 100 ml capacity burette, as little permanent strain or pore pressure developed in the test it was not possible to measure the flow occurring.

MOISTURE CONTENTS AND WATER OUTFLOW DURING DRAINAGE

Table 7.5

Figure 7.11 shows specimens subjected to the 50% stress level. Specimen 1.10 reached the failure envelope on the first three days and the slopes of the drainage lines were steep compared with the fourth day when the sample survived. Specimen 1.9 failed on day 1 and the drainage line was also steep. It survived subsequently and little drainage occurred. Specimens 1.13 and 1.15 show the same trend although the lines are less steep. This pattern is repeated for the 30% stress level tests (Figure 7.12) where, if failure occurred (1.8 on day 1), the drainage line was steep and for the high stress level where the lines are steepest of all (Figure 7.13). Test 1.12 did not dissipate its pore pressures so that, although the slope of the lines are similar, the change in water content was small.

The overconsolidated specimens in series 2 showed no tendency to drain that could be measured. Series 3 tests (Figure 7.14) do show an effect of initial moisture content. Tests 3.2 and 3.3 were both tested under the same stress levels and it has already been seen that 3.2 failed only on day 1 whilst 3.3 failed on days 1 to 4, but 3.2 was at a low initial moisture content which corresponds to the stronger behaviour. Test 3.1 survived day 1 with little damage and a resultant small drainage. Failure occurred on days 2, 3 and 4 and the drainage is correspondingly larger.

The dissipation of pore pressure during the drainage periods was recorded for some tests. Tests 1.1 and 4.3 had all four of their drainage periods recorded, and the measurements are plotted in Figure 7.15(a). All other records of pore pressure dissipation from the tests are given in Figure 7.15(b). The soil needed about five hours to dissipate pore pressure up to 10 kPa, 15 hours for pore pressure up to 15 kPa, and 30 hours for 20 kPa or more. A typical drainage period was 18 hours.

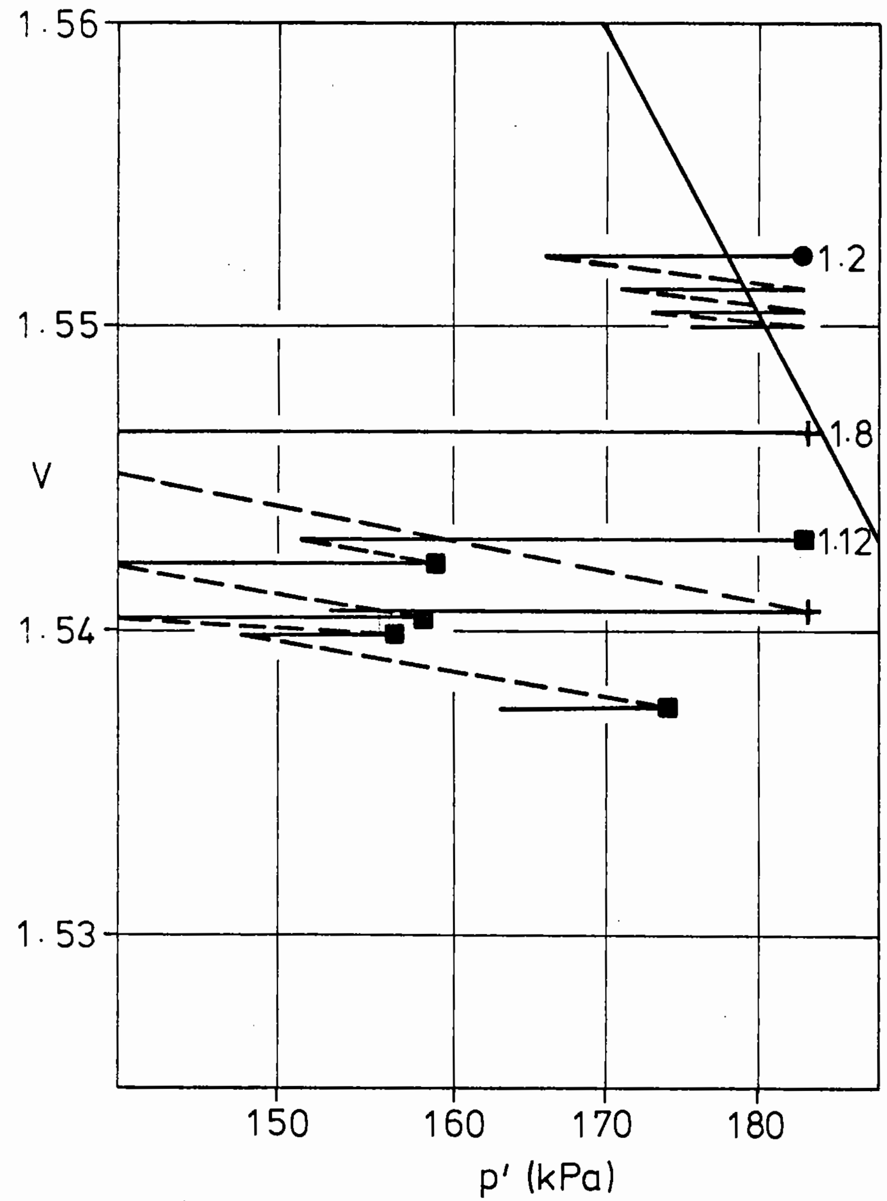


Fig. 7.12 CHANGE IN SPECIMEN STATE DURING DRAINED REST PERIODS BETWEEN 30% CYCLIC LOADING

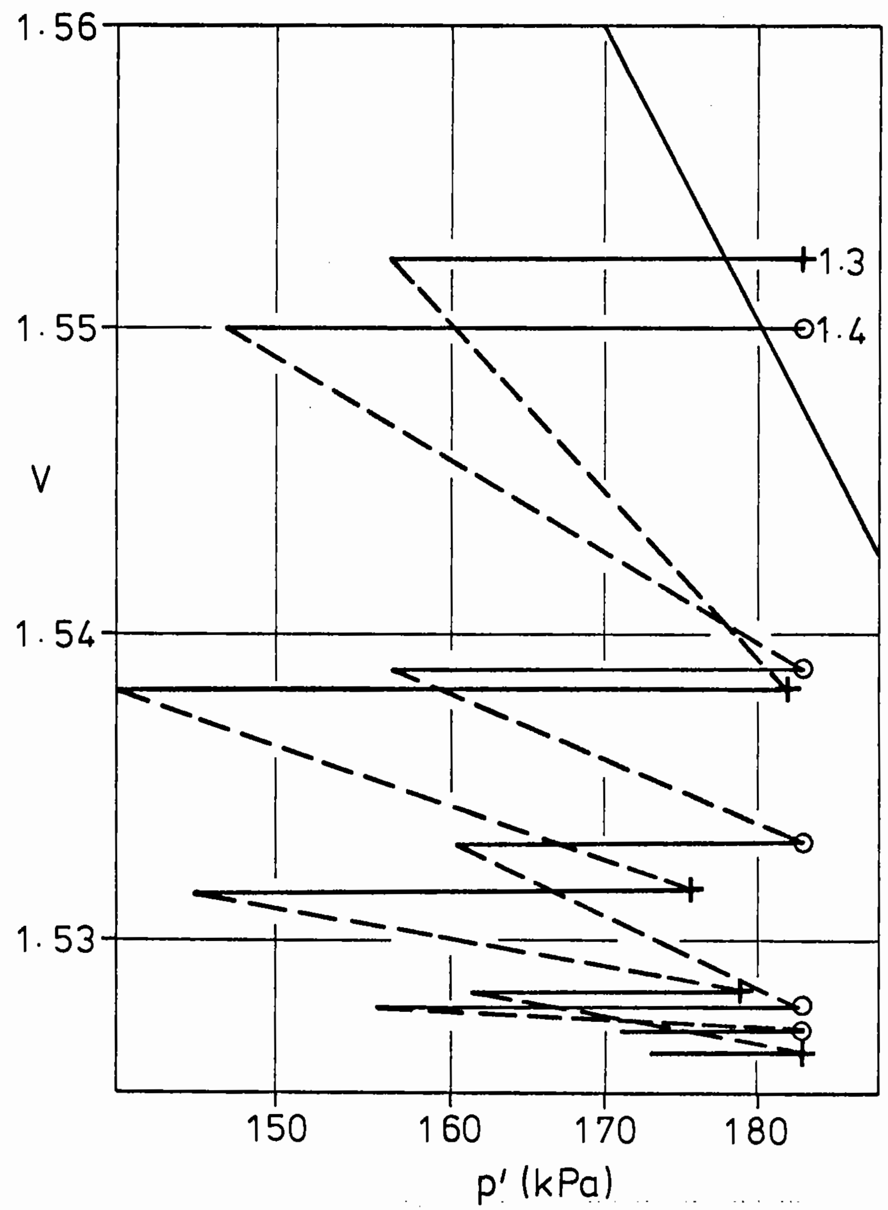
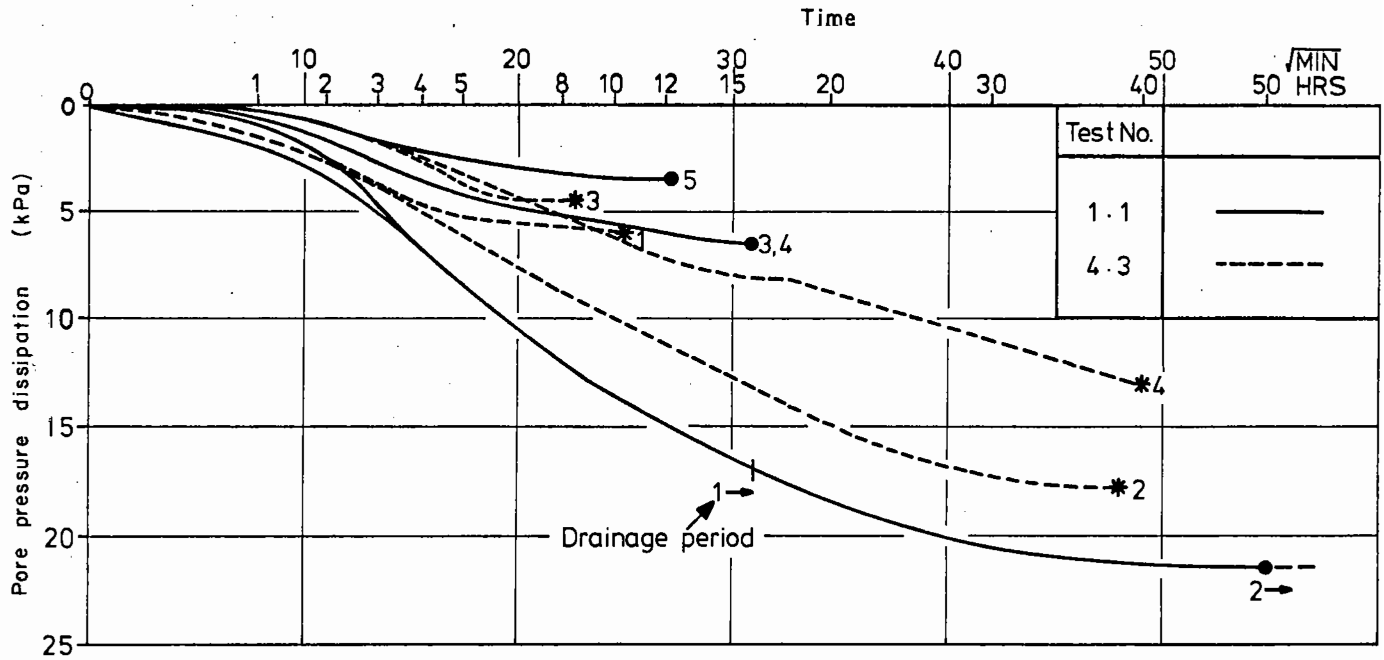
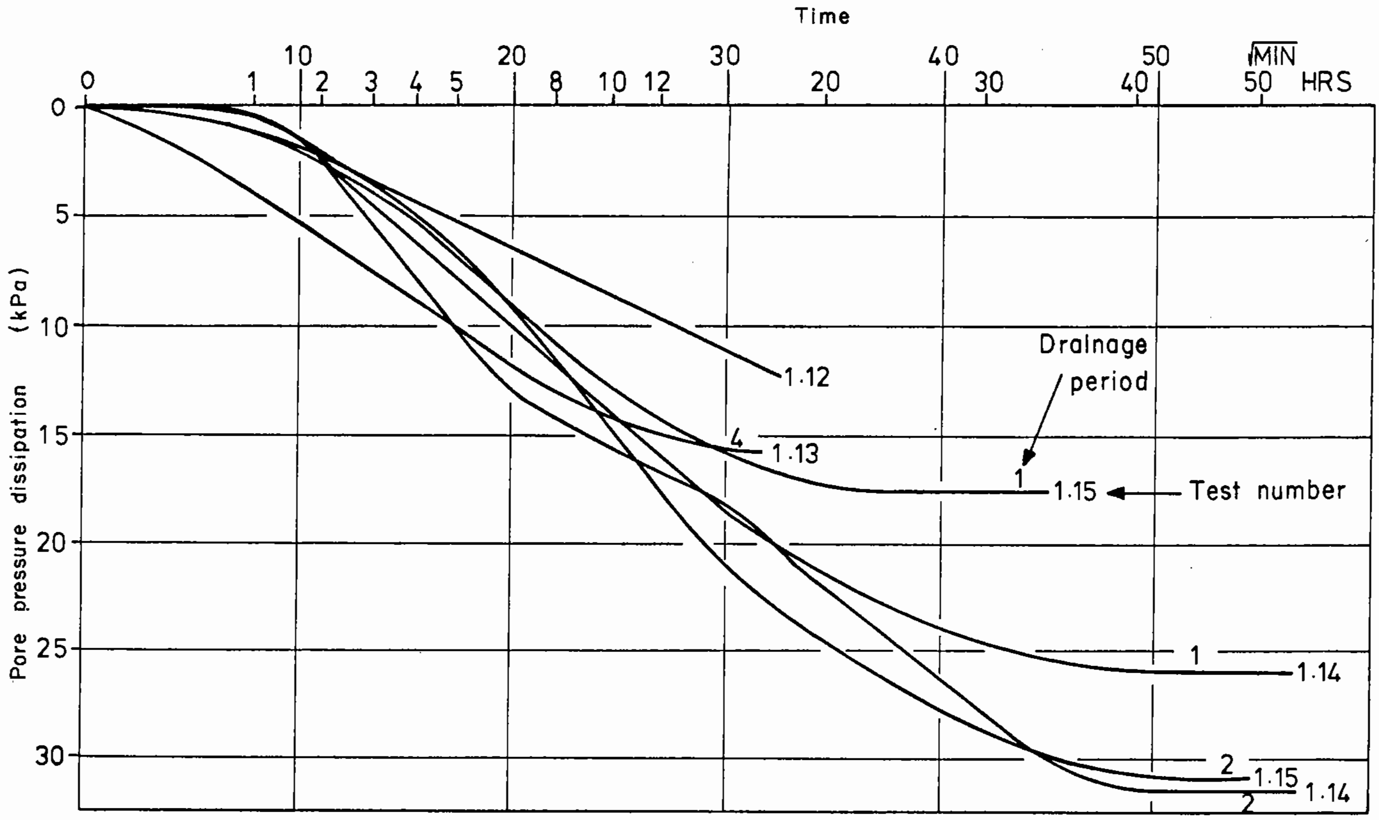


Fig. 7.13 CHANGE IN SPECIMEN STATE DURING DRAINED REST PERIODS BETWEEN 70% CYCLIC LOADING



(a) Test Numbers 1.1 and 4.3



(b) Other Tests

DISSIPATION OF PORE PRESSURE WITH TIME DURING DRAINED REST PERIODS

Figure 7.15

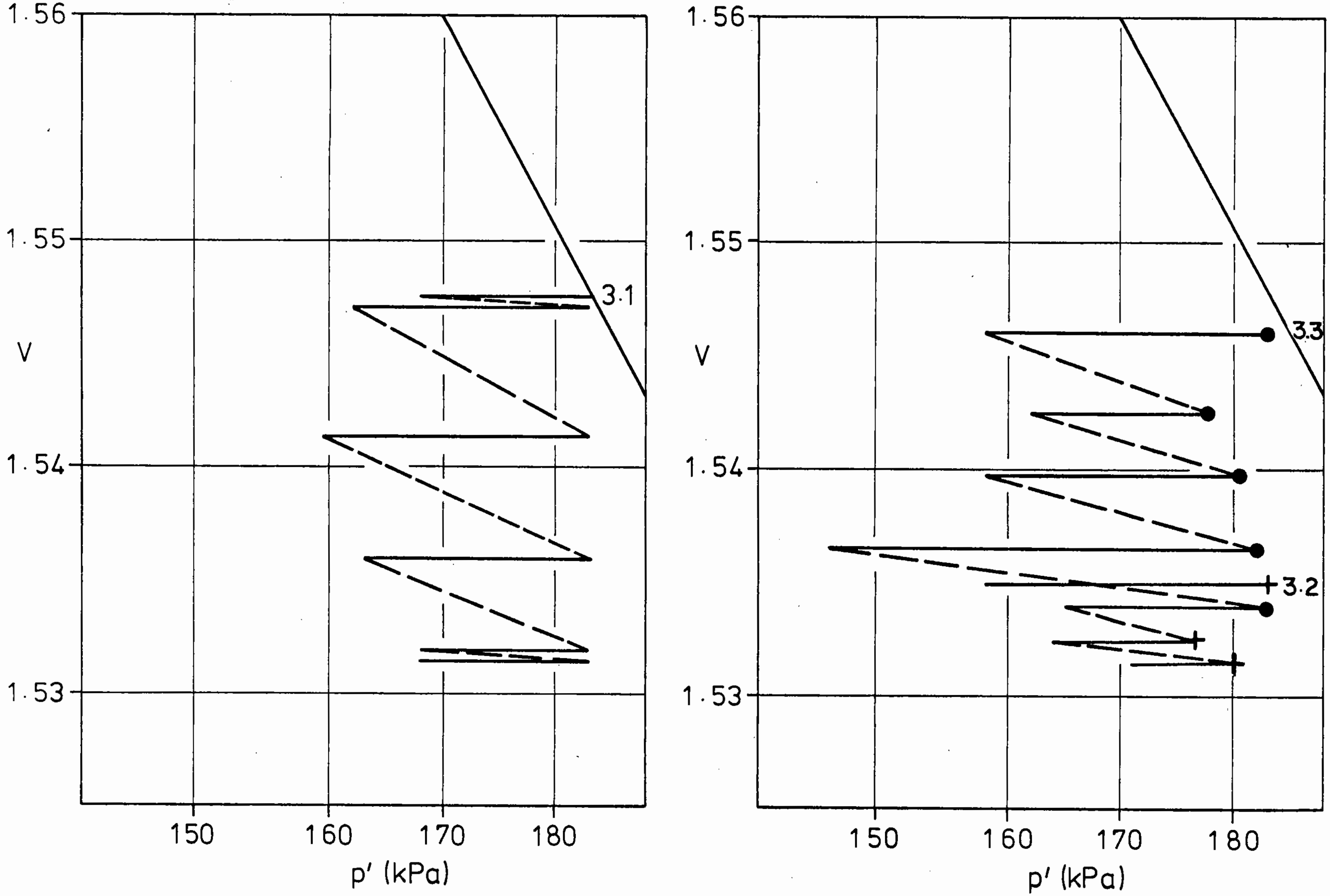


Figure 7.14 CHANGE IN SPECIMEN STATE DURING DRAINED REST PERIODS BETWEEN 30% CYCLIC LOADING AND A HIGH MEAN DEVIATOR STRESS LEVEL

significantly increased the soil's resistance.

The rate at which pore pressures dissipated during drainage periods varied with the time for dissipation. This, in turn, depended on the c_v of the soil. Consolidation varies with permeability and volume compressibility, both of which vary non-linearly with changes in stress although they are often considered constant over the range of effective stress experienced by the soil during drainage. If the soil drains along a swell back line, it can be expected that m_v will also vary with the slope of the line.

7.6 COMPARISON OF SINGLE STRESS LEVEL TESTS WITH "STORM" TESTS

Storm loading tests were performed by applying the three different cyclic stress levels used for the earlier tests in each period of loading. Tests 1.5, 1.6 and 1.7 were subjected to these stresses. The 2160 cycles of load possible in six hours' testing at 0.1 Hz was divided up into a sequence of 641 cycles at 30% stress, 312 cycles at 50%, 54 cycles at 70%, 312 cycles at 50% stress and finally 741 cycles at 30% stress. This gave the pattern of a storm waxing and waning over six hours as shown in Figure 7.16. Due to the variability of the soil response, it was difficult to compare the actual data obtained from each test. However, it is possible to compare the trends.

Figures 7.17 and 7.18 show the strain and pore pressure response of three specimens subjected to the mixed loading. Comparison of the shear strain developed at set cycle numbers in the three "storm" loading tests suggested that the behaviour on certain days of each test could be linked, as shown in Table 7.6. This does not correlate with the initial moisture contents as specimen 1.6 was initially wetter than the other two. Again, the range of initial moisture contents was small (Figure 7.19).

7.5 SUMMARY

The results from the tests presented so far show that anisotropically normally consolidated specimens, when subjected to undrained cyclic loading, develop positive pore pressures with each load cycle, which move the effective stress state of the soil towards failure. The number of cycles needed to do this decreased with increasing cyclic deviator stress.

The inclusion of drainage periods under the initial (consolidation) stresses produces a strengthening effect and more cycles of a given stress level are required to develop the same strain or pore pressure. Although all specimens were consolidated to the same initial stresses, the response of different specimens to the same loading was not identical. Generally, under the 30% cyclic stress level, one drainage period was needed to guarantee the soil surviving a subsequent six hour loading period, whilst the 50 and 70% stress levels needed three drainage periods.

The final day's testing of the series 1 specimens and the over-consolidated specimens of series 2 showed almost no development of strain or pore pressure suggesting that the soil was behaving in an essentially elastic manner.

Pore pressure measurements from the centre and base probes suggested that the soil behaved uniformly throughout the specimen only when the permanent strain development was small (0.1%). This is supported by the negligible apparent permanent volumetric strains recorded under these conditions.

The amount of drainage from the soil seemed to depend on the applied cyclic stress level and the amount of damage caused. The overall amount of drainage from any one specimen was small, compared with the range of moisture contents obtained at the end of consolidation. The small variation in initial moisture content did not have a decisive effect on the soil behaviour, but a change in moisture content after cyclic loading

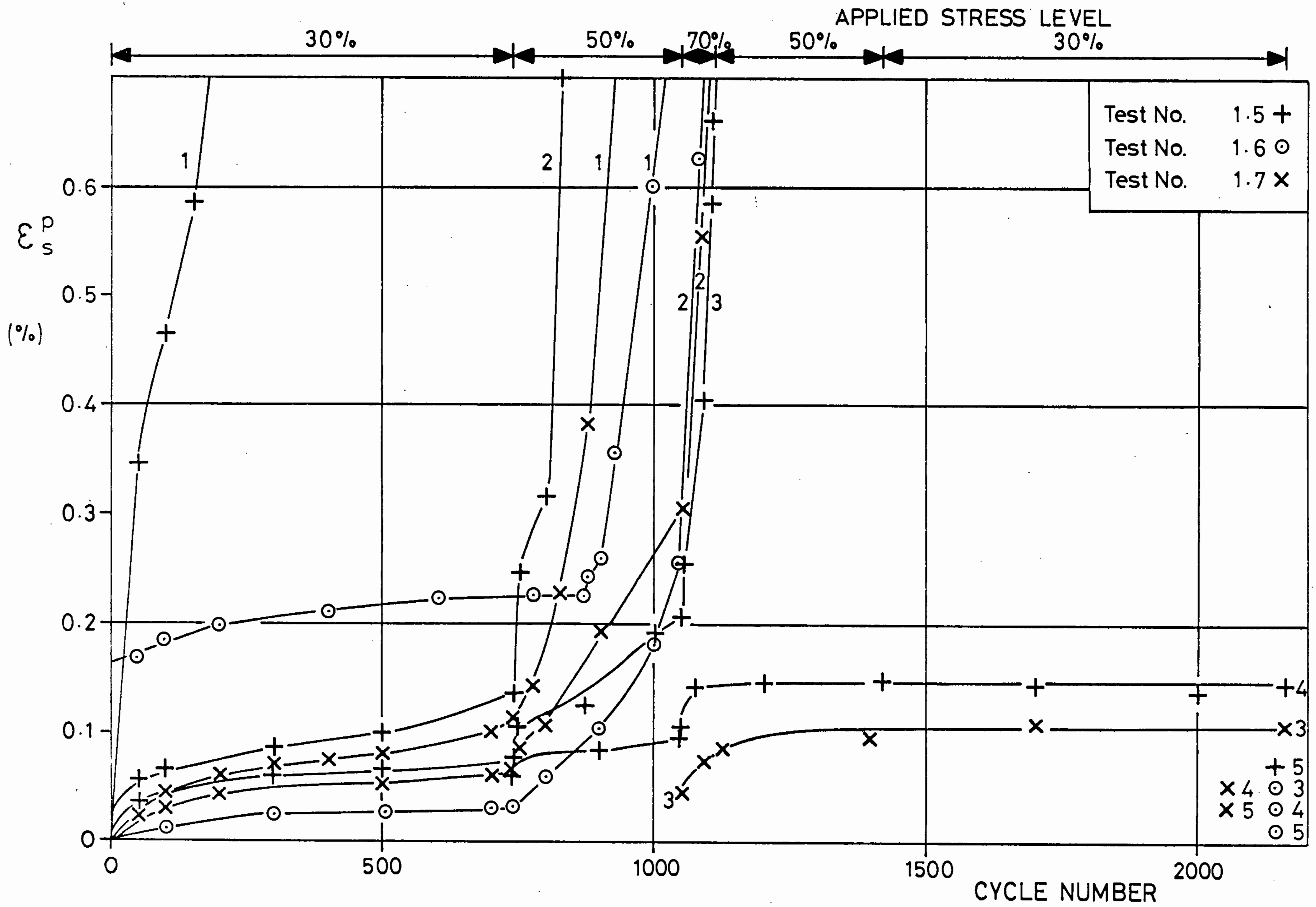
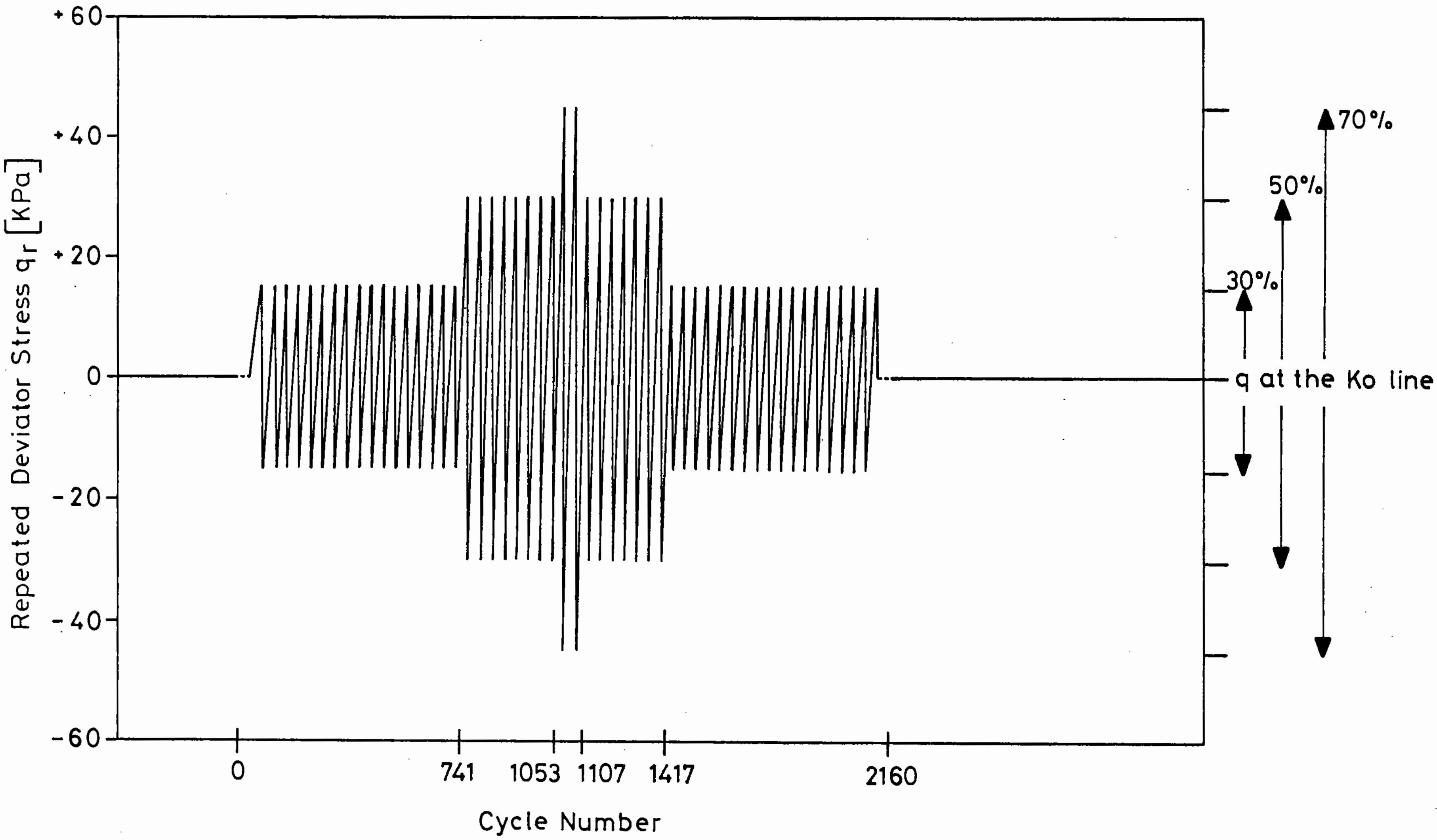


Figure 7.17 PERMANENT SHEAR STRAIN DEVELOPMENT UNDER "STORM" LOADING



REPRESENTATION OF A SIX HOUR "STORM"

Figure 7.16

Each column shows comparable specimen response

Test No. 1.5	Day 1	Day 2	Day 3	Day 4	Day 5	
Test No. 1.6		Day 1	Day 2		Day 3	Days 4 & 5
Test No. 1.7		Day 1	Day 2	Day 3	Day 4	Day 5

EQUIVALENT RESPONSE TO STORM LOADING

Table 7.6

It is difficult to compare quantitatively, the actual values obtained from the simple loading and "storm" loading tests but the trends in both tests can be examined. The initial 30% loading of the storm tests is directly comparable with the simple 30% load tests. Except for 1.5 on day 1, the build up of strain was as would be expected from the simple tests. The strains developed slowly and with each drainage period the accrued permanent strain was less. The 50% loading started from an initial strain and pore pressure and was sufficient on days 1 and 2 to bring the soil to failure. The rate of strain development was greater than for a single load test at this strain and pore pressure. By day 3, the 70% loading could be applied but only 54 cycles were involved. Test 1.5 had already developed a high strain and pore pressure and quickly approached failure whilst 1.6 and 1.7 had lower strains and survived. It should be noted that on the first application of the 70% stress, the rate of strain over the 54 cycles was comparable with the rate of strain on day 1 of the simple load tests at this stress level. If more cycles at this level had been applied, all three tests would presumably have reached failure. On reducing the applied

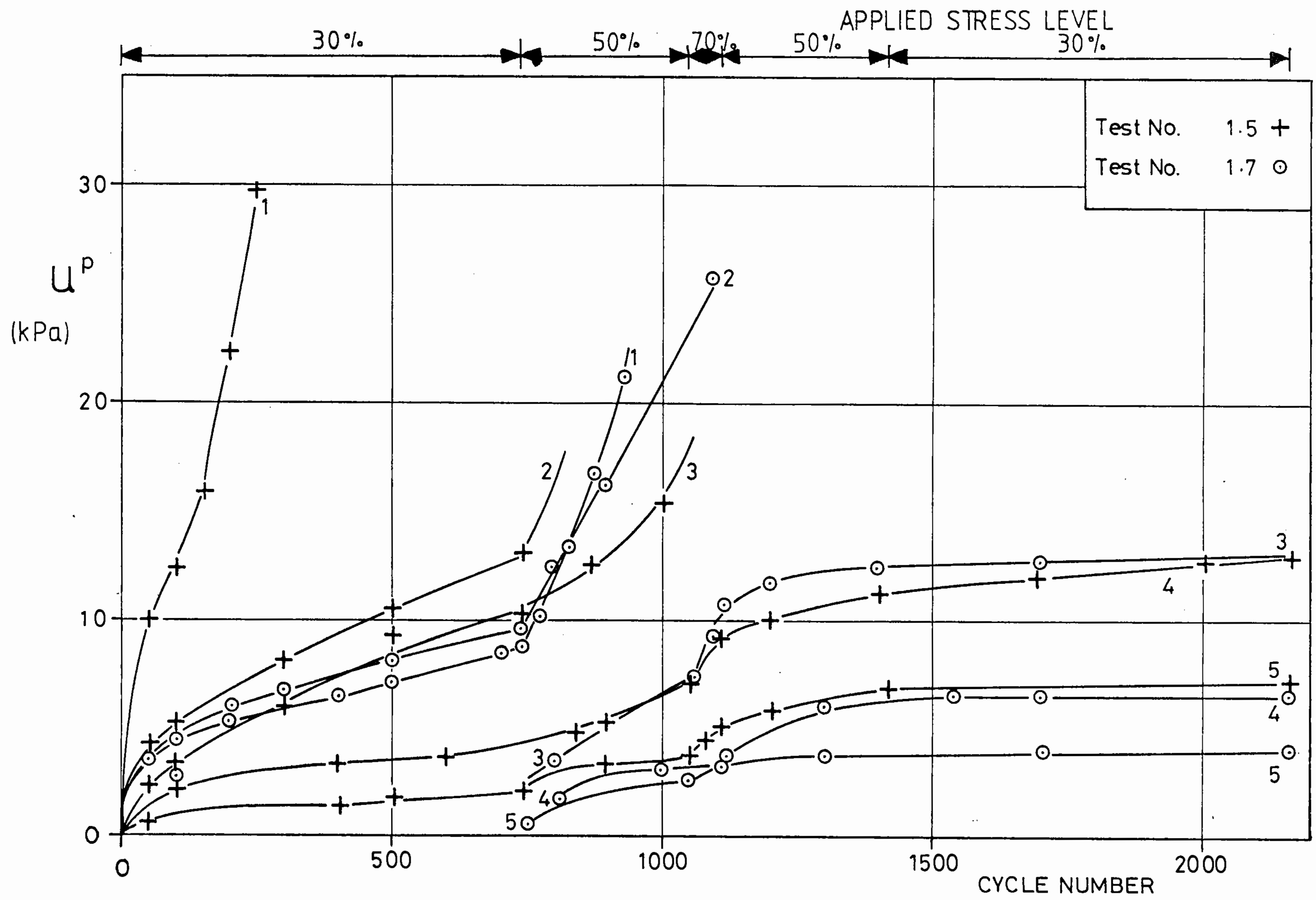


Figure 7.18 PERMANENT PORE PRESSURE DEVELOPMENT UNDER "STORM" LOADING

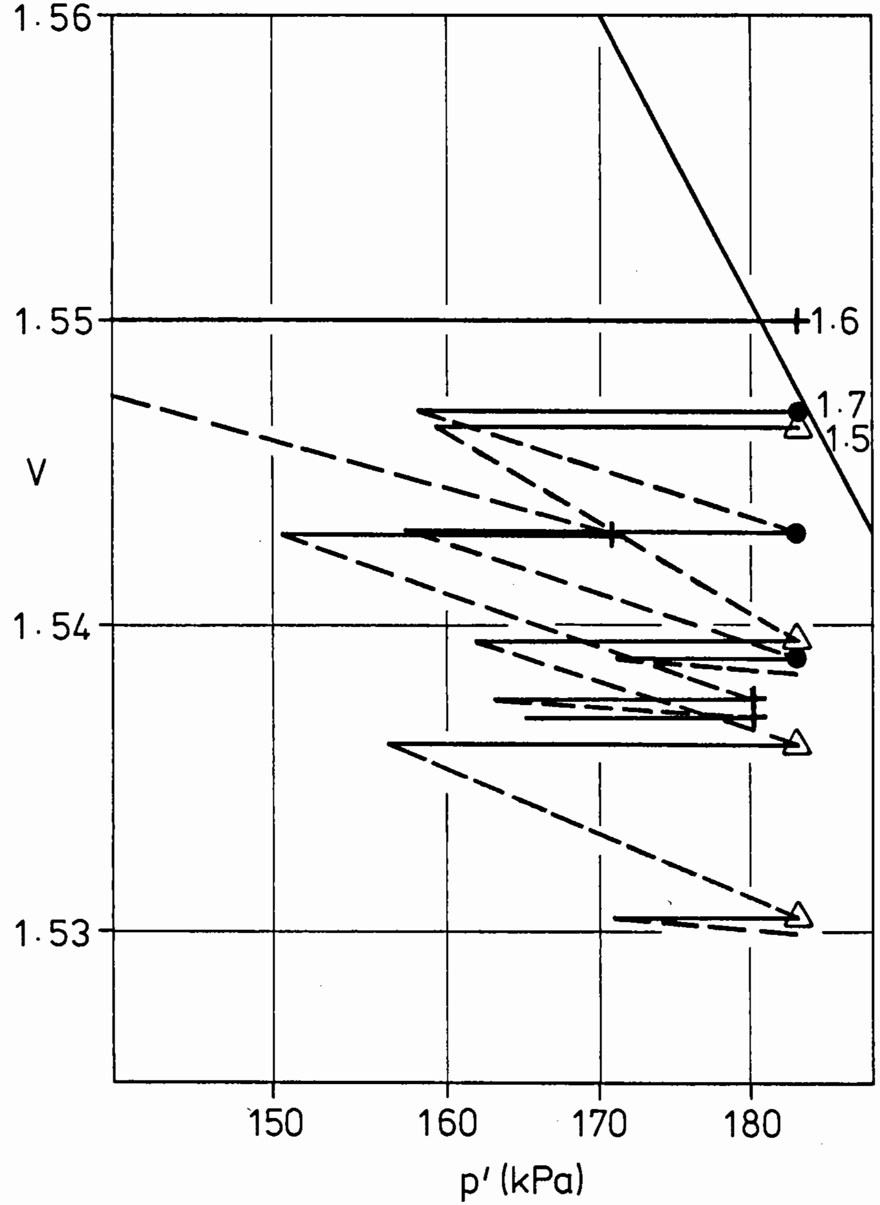


Figure 7.19 CHANGE IN SPECIMEN STATE DURING DRAINED REST PERIODS BETWEEN "STORM" LOADING

stress, the soil developed no further permanent shear strain, unlike the single load tests which continued developing a small amount of strain throughout the loading periods. This suggests the soil was behaving elastically. However, in contrast, the pore pressures did show a continued rise although at a decreasing rate.

CHAPTER EIGHT

RESILIENT RESPONSE TO CYCLIC LOADING

Cyclic pore pressures and resilient strains were recorded during each test and the results from series 1 and 2 are discussed in this chapter. The resilient strain behaviour was investigated by considering the change in a shear modulus with effective stress. Difficulties were experienced in measuring and interpreting the cyclic pore pressures, so five tests were used to investigate the cyclic pore pressure response to cycling both deviator stress (q) and confining stress (σ_3). Cyclic pore pressures are discussed further for series 4 in Chapter Nine.

Some hysteresis loops were plotted as the tests were performed using a facility which was being developed for the series 4 tests. The plots were of q against ε_s (shear strain). As the general pattern of the loops was the same for all tests, the results are presented by illustrating selected examples.

8.1 HYSTERESIS LOOPS

During the unloading portion of each cycle the soil recovered some strain and pore pressure. If there was no permanent strain build up, the recovered strain was equal to that developed during the cycle resulting in a closed path on a stress-strain plot. Energy was dissipated by the soil during each cycle of load and the area enclosed by the stress-strain path was a measure of this. When the permanent shear strain was developing slowly, as happened in many tests, the hysteresis loops were still essentially closed. It was only when the permanent strain developed rapidly that the stress-strain plot became a line with small retrograde loops.

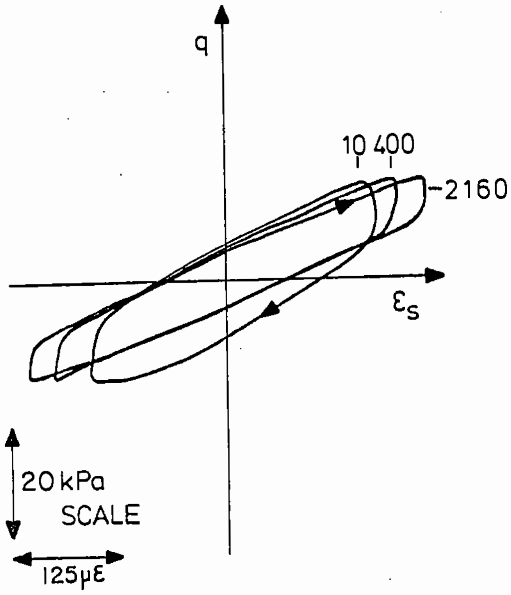
For many of the testing periods which did not reach failure, the change in resilient strain was small. Figure 8.1(a) shows test 1.11 in day 1 at the 30% cyclic stress level. Resilient shear strain (equal to axial strain if there is no volume change)* is illustrated with the cycle numbers written on the loops. As the permanent deformation was small in this test, all the loops appeared to be closed. The only change noticeable is that the loops got slightly longer and thinner as the test progressed showing that the shear modulus fell by a small amount. The energy dissipated in each cycle was fairly constant.

Figure 8.1(b) shows test 1.8 on day 1 also under 30% loading. This test survived with little strain development for 1200 cycles and the hysteresis loops were closed. Between cycle 1200 and 1600 the rate of permanent shear strain development increased although the change in any one cycle was still sufficiently small to give an approximate hysteresis loop. However, between 1600 and 1650 cycles the permanent shear strain had become significant and by cycle 1730, when the test was stopped, the hysteresis loops had almost disappeared. It is interesting to note that the slope and length of the unloading part of the trace was reasonably constant at all stages and that the permanent shear developed at the top part of the load cycle.

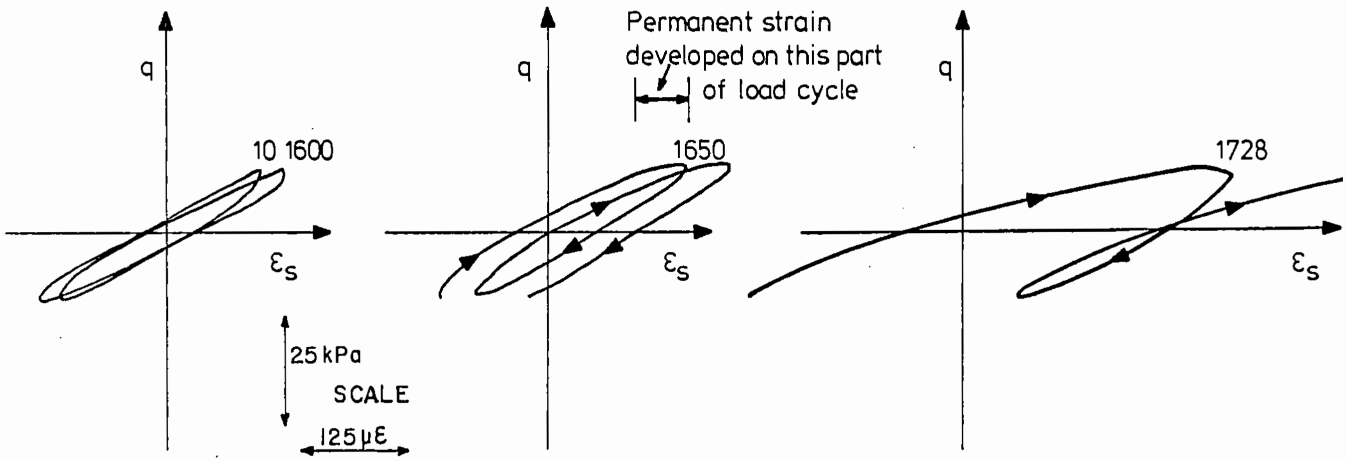
Test 1.7 was subjected to all three levels of load. On day 1, the 30% level produced closed loops, shown in Figure 8.2(a). On increasing the load to 50% the loops were, at first, still closed (cycle 750) but by cycle 900 the permanent shear strain was sufficiently large for the test to be halted. Again, the incremental permanent shear strain occurred over the peak part of a cycle. Figure 8.2(b) shows the same test on day 2,

---

*During shear of a saturated undrained clay, there can be no overall volume change, therefore, $\varepsilon_v = (\varepsilon_a + 2\varepsilon_r) = 0$ or $\varepsilon_a = -2\varepsilon_r$ (Poissons ratio = 0.5). By definition shear strain $\varepsilon_s = 2(\varepsilon_a - \varepsilon_r)/3 = \varepsilon_a$.



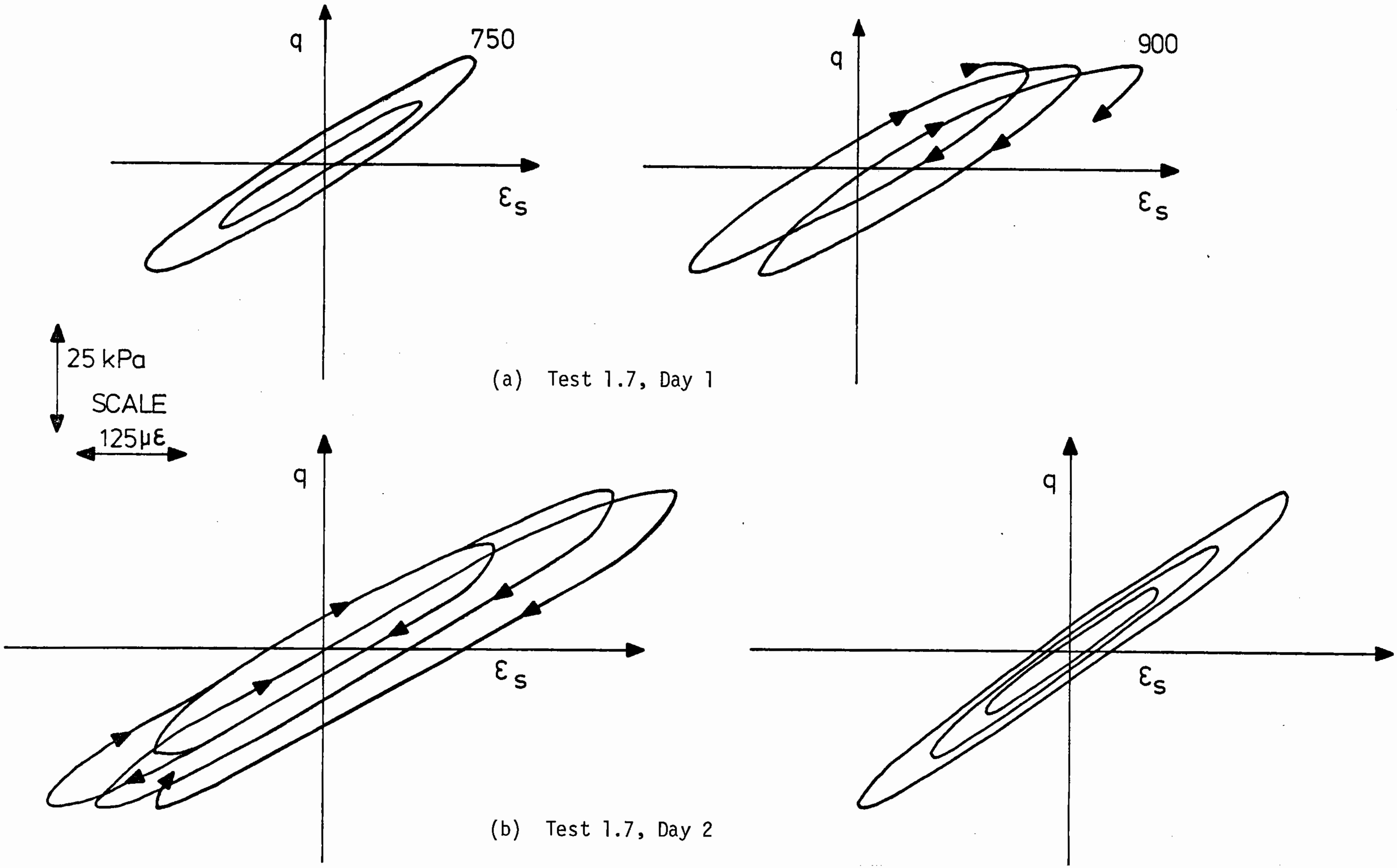
(a) Test 1.11, Day 1



(b) Test 1.8, Day 1

HYSTERESIS LOOPS

Figure 8.1



(a) Test 1.7, Day 1

(b) Test 1.7, Day 2

Figure 8.2 HYSTERESIS LOOPS

the 50% load gave closed loops so the transition to 70% load is shown. The first half-cycle at 70% was unloading and the only effect was to increase the size of the strain, the width of the loop being the same. As the load approached its peak, permanent strain began to develop. On day 3, the soil survived the full six hours and the strains were similar in size to the closed loops on days 1 and 2 but the loops were slightly thinner.

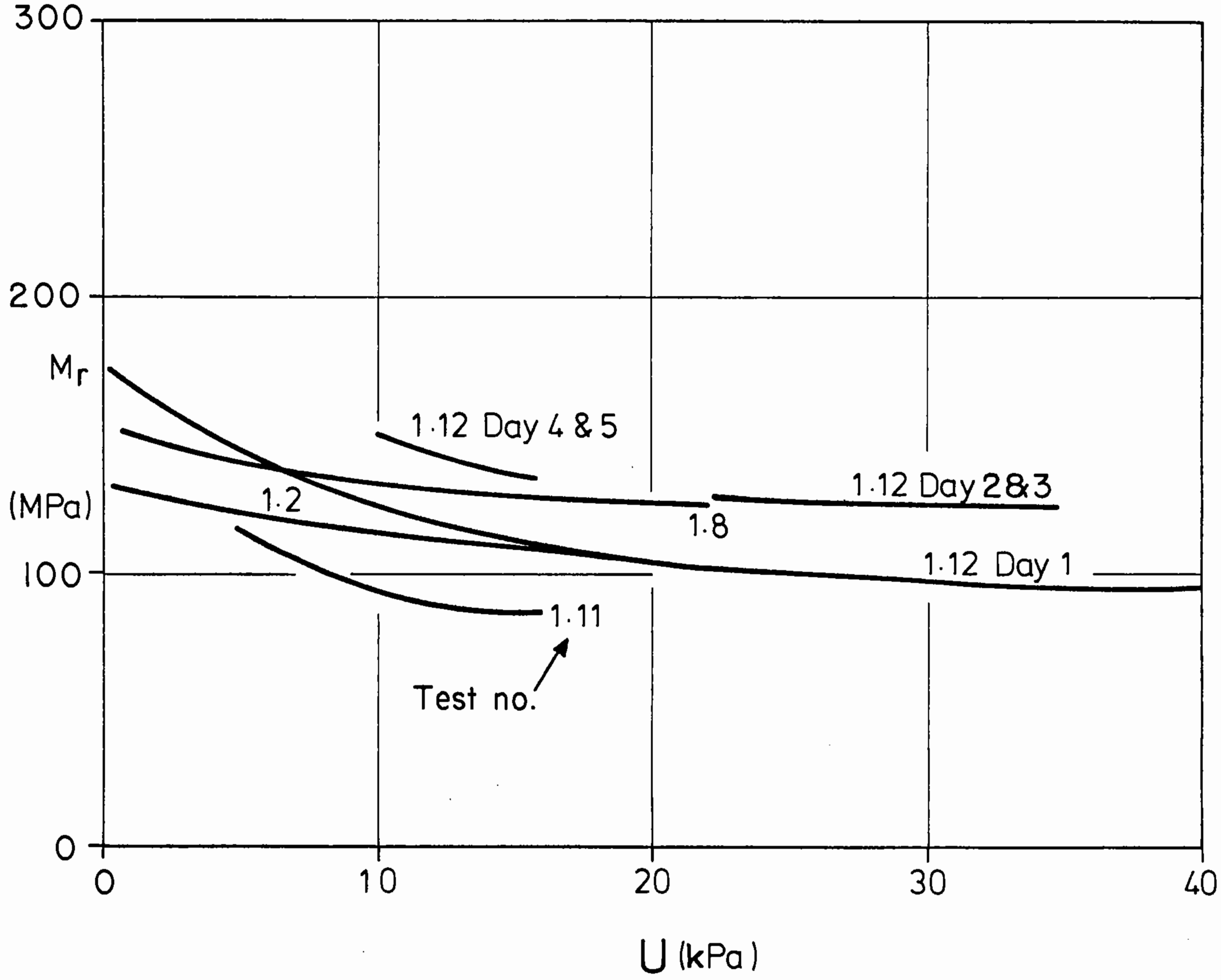
8.2 RESILIENT MODULUS

The resilient behaviour can also be described by considering the resilient modulus (M_r); defined as the repeated deviator stress divided by the axial resilient strain. This parameter was introduced for repeated load testing of soils in connection with pavement design.

$$M_r = q_c/\varepsilon_a\left(= q_c/\varepsilon_s^r\right)$$

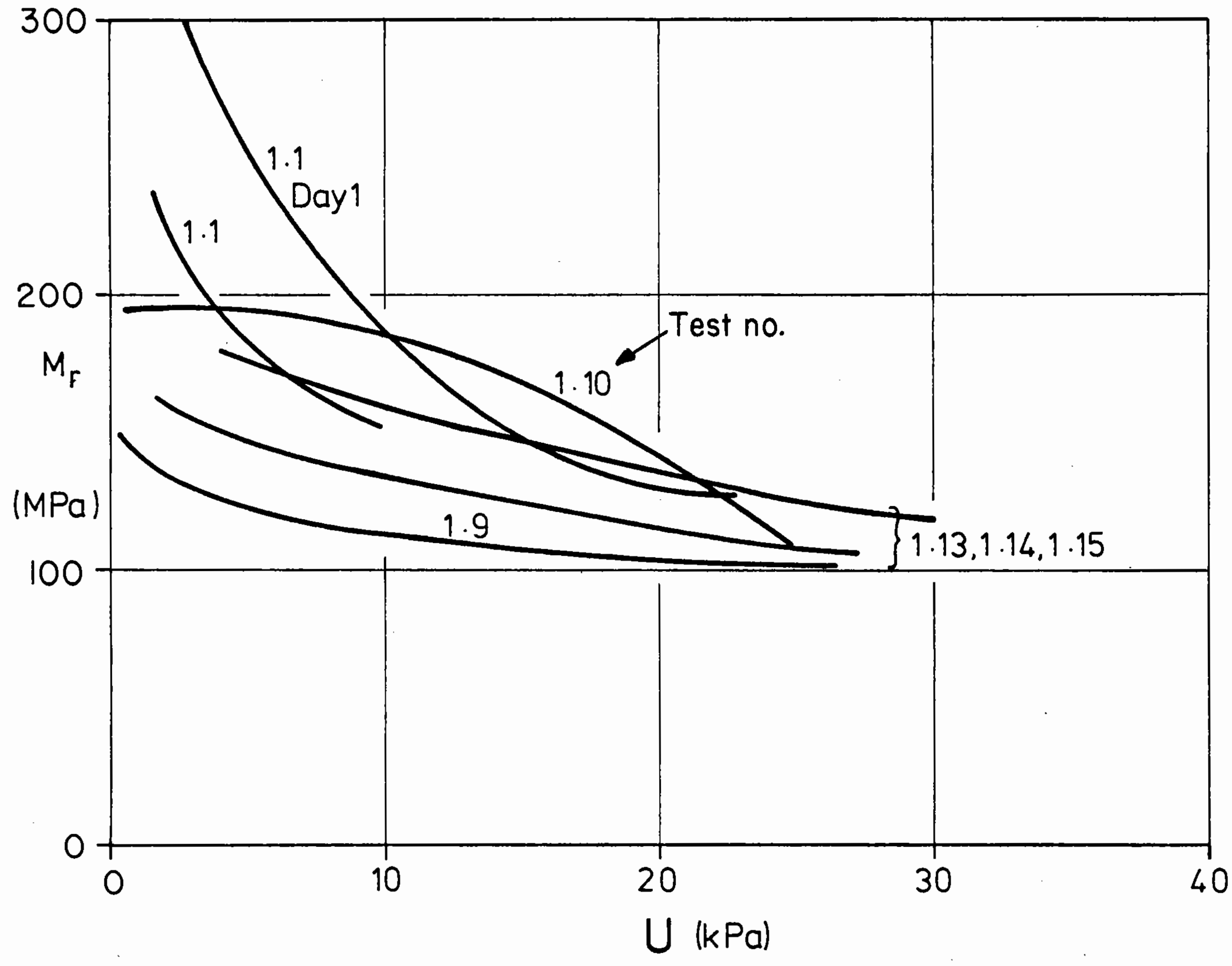
Since shear modulus $G = q/3\varepsilon_s$, it will be seen that $M_r = 3G$. The variation of M_r with the development of pore pressure is given in Figures 8.3 to 8.5. There was some variation in the value of M_r in different tests under the same load as well as scatter from cycle to cycle in any one test. This was, in part, due to small fluctuations in the load control. Because of this, the plots in Figures 8.3 to 8.5 are the average trend of M_r values for each specimen.

For the 30% loading, Figure 8.3 shows the modulus falling slightly with the build up of pore pressure. All the specimens tended towards an M_r value of 100 to 125 MPa. Specimen 1.12 showed stiffer behaviour after drainage. It was this test that reached failure on three days but did not dissipate its pore pressures very quickly. The other specimens tended not to fail and did not change in stiffness, regardless of the day of testing.



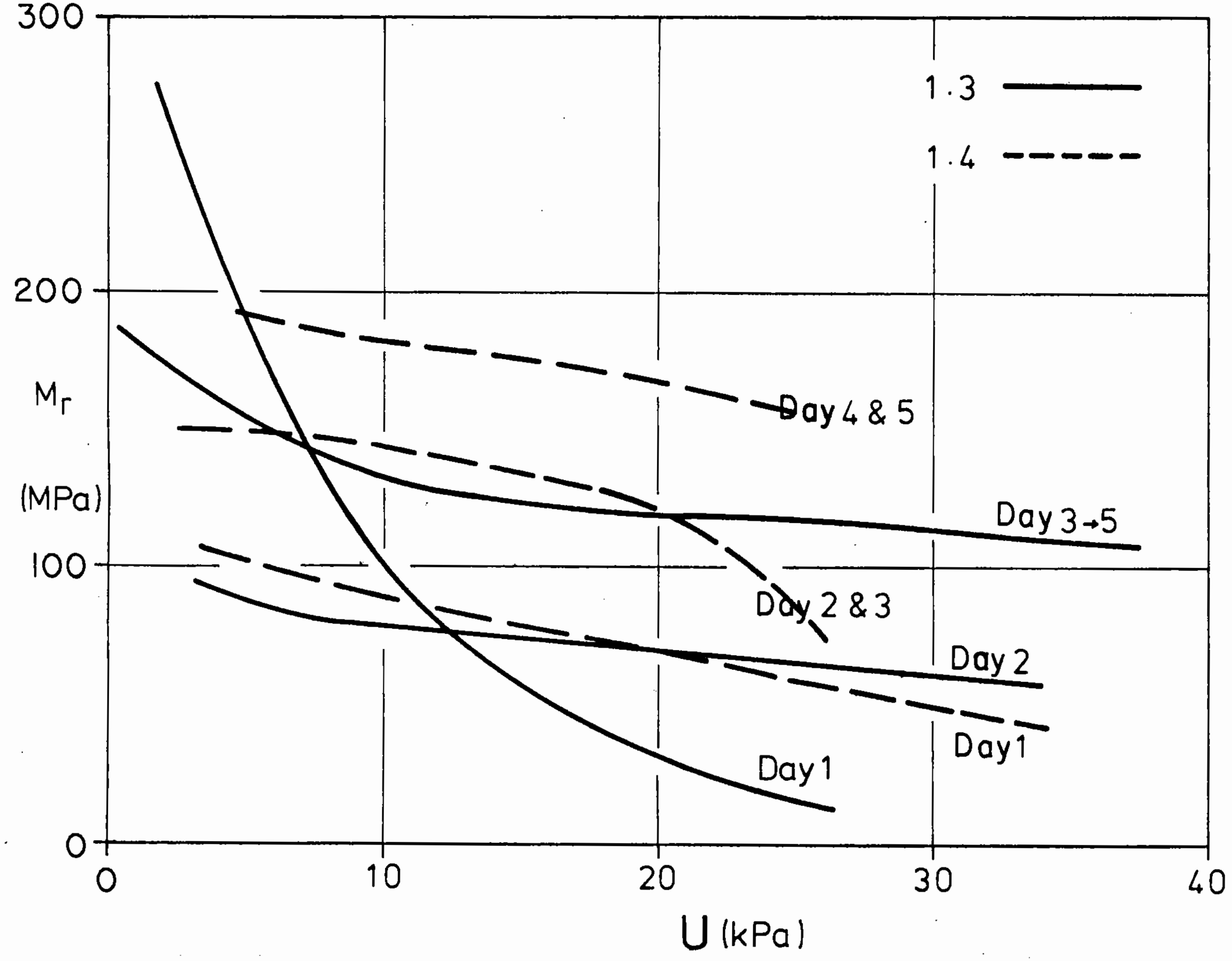
VARIATION OF RESILIENT MODULUS FOR SPECIMENS UNDER 30% CYCLIC LOADING

Figure 8.3



VARIATION OF RESILIENT MODULUS FOR SPECIMENS UNDER 50% CYCLIC LOADING

Figure 8.4



VARIATION OF RESILIENT MODULUS FOR SPECIMENS UNDER 70% CYCLIC LOAD

Figure 8.5

Although test 1.8 developed large strains on day 1, the modulus did not show a subsequent change. For these tests there was often little change in effective stress during a load period and a constant modulus.

Figure 8.4 shows the results for the 50% stress level. Again, M_r tended to the same value but the variation between tests was greater. Test 1.1 started with a very high modulus on day 1 and, therefore, showed a steep decline in M_r. This steep decrease happened over the 300 cycles which were performed with the drainage tap open. It was less stiff on subsequent days but still began each day with a higher modulus than the other tests at this stress level. Test 1.10 showed a different curve from the other tests; its M_r being fairly high until failure was approached, at which point the modulus fell sharply. Two lines are shown for tests 1.13, 1.14 and 1.15. These cover the range of M_r values that occurred over the five days of each test. Generally, the soil stiffened each day and the lines show the increase in M_r between day 1 and day 5.

The 70% stress level tests showed the greatest stiffening effect, illustrated in Figure 8.5. Both specimens (1.3 and 1.4) reached failure rapidly on days 1 and 2 and had correspondingly low M_r values. With each period of drainage the soil became stiffer. The storm load tests showed the same behaviour as the single stress level tests. The modulus started at around 200 MPa falling to around 100 MPa as the effective stress decreased. No significant stiffening was observed. Series 2 tests did not develop significant pore pressures and the modulus was around 200 MPa.

8.3 APPARENT RESILIENT VOLUMETRIC STRAINS

The apparent resilient volumetric strain measured in each loading period is shown in Table 8.1. The values given are averaged over the whole of each load period and were generally small whether failure occurred or not, suggesting that the idealisation of the soil as a single element is more reasonable when considering resilient behaviour rather than permanent, as discussed in section 7.2. A negative sign indicates the soil was barrelling.

8.4 CYCLIC PORE PRESSURES

During the test programme, the recorded cyclic pore pressures varied greatly from test to test and between centre and base probes. As the change in permanent pore pressure in any cycle was small, it was expected that the cyclic pore pressures after the first cycle would be of sufficient size to mirror the change in normal stress to give a constant p', as for much of a cycle the soil should be inside the current yield surface. However, it was found that the base probe often over-read the expected value whilst the centre probe under-read.

To investigate this anomaly, some specimens were subjected to cyclic confining stress over a range of frequencies from 10^{-3} to 1.0 Hz to investigate the value of the pore pressure parameter B under cyclic loading. The results from five tests are shown in Figure 8.6. The centre probe responded fully up to 0.1 Hz in three of the five tests, after which the response dropped off by varying amounts. The base probe showed a drop off in response at various frequencies which were between 10^{-2} and 10^{-3} Hz.

These tests were augmented by cycling the deviator stress over a range of frequencies at the 30% stress level. The centre probe still showed a reduced response and the base probe tended to over-read. However, there was no obvious trend with frequency. As the centre probe was

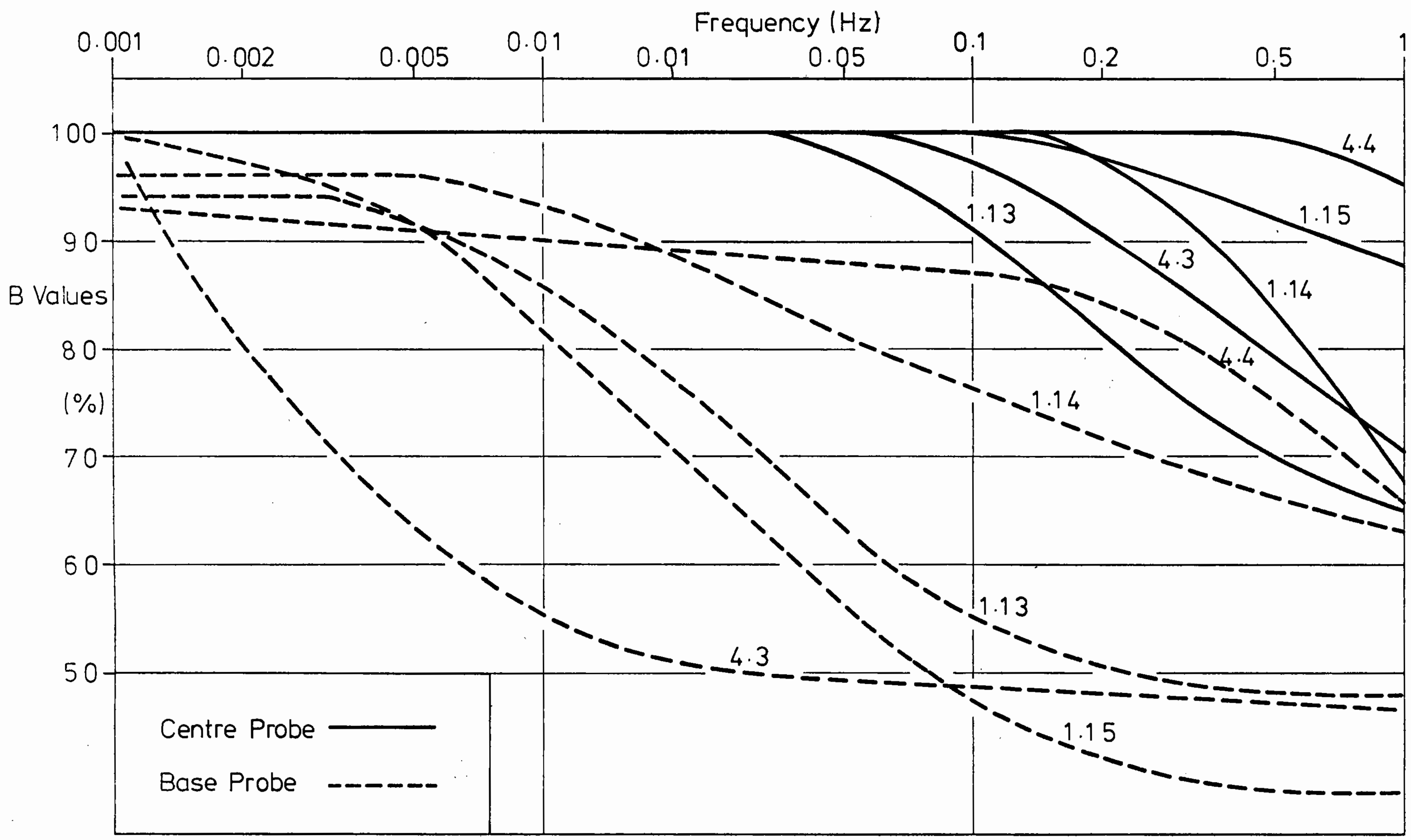


Figure 8.6 PORE PRESSURE RESPONSE TO VARIATIONS IN CONFINING STRESS

Test No.	Day of Test				
	1	2	3	4	5
1.1	14	64	53	53	55
1.2	38	04	10	47	55
1.3		649	156	136	134
1.4	06	30	28	-10	05
1.6	-40	-40	-23	-44	-04
1.7	10	57	99	22	48
1.8	17	24	30	-	-
1.9	93	153	63	71	76
1.10	32	49	34	-51	-40
1.11	36	12	22	9	-16
1.12	15	54	81	84	133
1.13	-38	-48	-06	18	15
1.14	03	-35	-01	-	-
1.15	15	17	00	29	27
2.1	-22	-39	-68	-	-
2.2	66	-6	-16	8	-37
3.1	50	-22	03	-28	-36
3.2	35	31	18	12	03
3.3	-14	-21	-23	-28	-04
3.4	-45	08	-03	-07	-

APPARENT RESILIENT VOLUMETRIC STRAINS

(all figures microstrain)

Table 8.1

consolidated into the soil, its final position could vary. Fifteen tests which were subjected to cyclic deviator stress at a frequency of 0.1 Hz were analysed for a correlation between the measured cyclic pore pressures and position of the central pore pressure probe. Table 8.2 gives the transducer position and the corresponding cyclic pore pressure response as a percentage of the cyclic normal stress. The transducer position was related to the grid indicated beside the table. It can be seen that full response was only obtained when the transducer was in zone 1, the response in zones 2 and 3 was less with zone 2 generally being slightly higher than zone 3. There was no difference in average response between bands a and b.

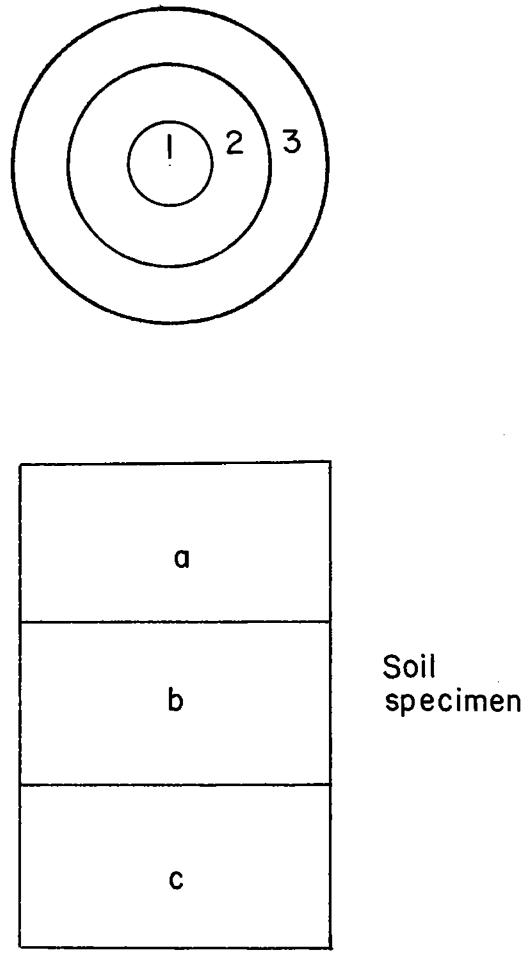
8.5 SUMMARY

The resilient strains showed an increase with decrease in effective stress, the decrease generally suggested that the value of M_r would tend towards a value of around 100 MPa. With drainage, the soil became stiffer only if the loading caused a significant amount of pore pressure development and subsequent drainage. This stiffer response could be explained as the development of a slight overconsolidation.

The hysteresis loops showed that the permanent strain only developed during the top part of a load cycle. The area inside each loop decreased slightly in succeeding load periods and the soil developed less permanent strain. For much of the loading, the development of permanent strain was small in any one cycle and each individual stress-strain loop appeared to form a closed path.

The cyclic pore pressure proved to be difficult to measure with accuracy. The B values obtained from cycling the confining stress suggested that the lack of response was not due to the presence of air. The base probe may well suffer from end restraints as it was relatively insensitive to the change in confining stress and oversensitive to cyclic deviator

Test Number	Transducer position	u/p (%)
1.1	3b	38
1.3	3a	8
1.5	1b	98
1.7	2a	43
1.9	3a	13
1.10	1b	100
1.11	3b	30
1.12	3a	62
1.13	3a	45
1.14	2b	50
1.15	2a	60
2.2	3a	33
3.2	3b	20
4.3	3a	35
4.4	3a	30



CENTRE PORE PRESSURE TRANSDUCER POSITIONS

Table 8.2

stress. The position of the centre probe, however, suggested that the full pore pressures under cyclic deviator stress were only developed away from the edge of the specimens.

CHAPTER NINE

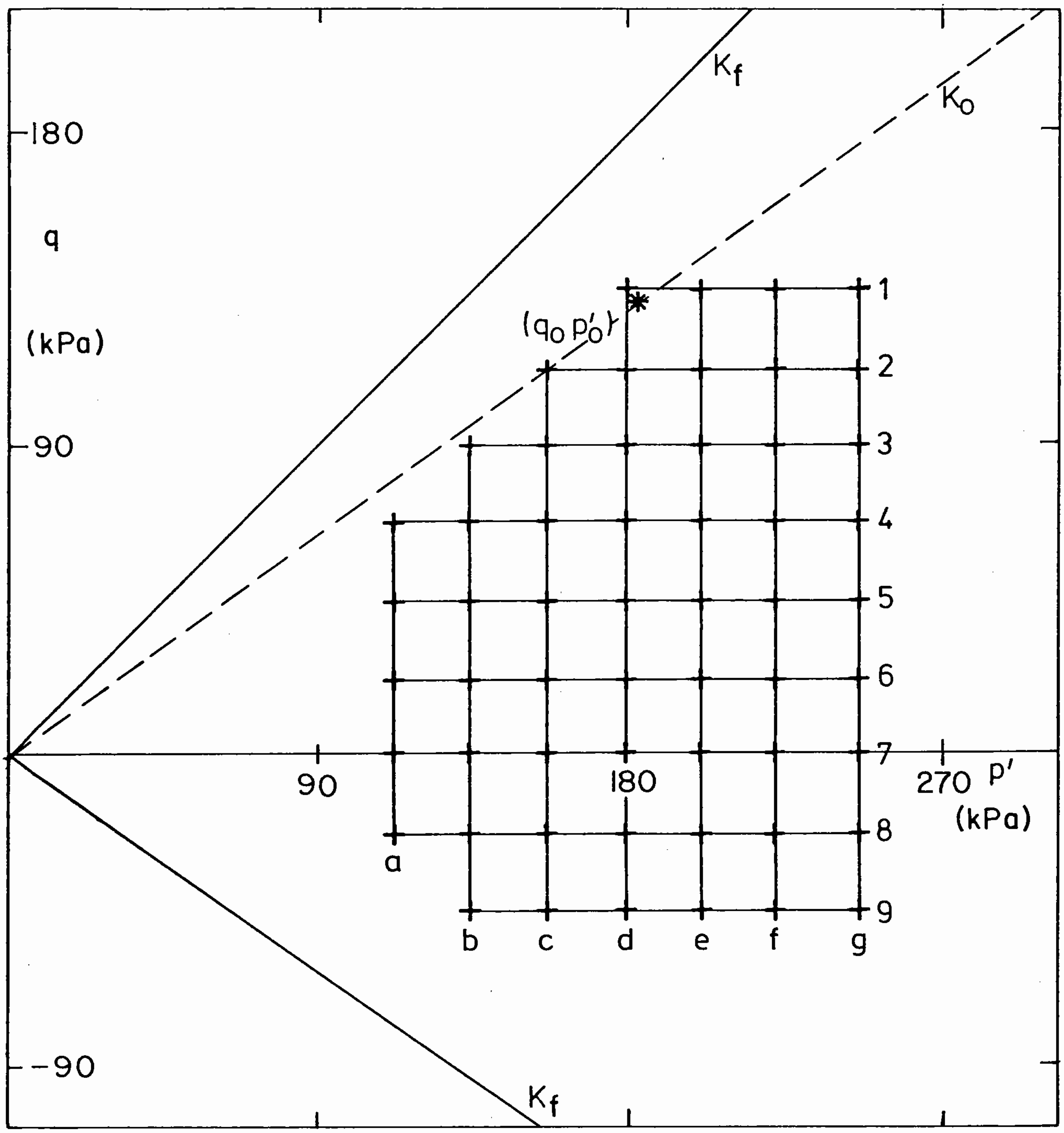
STRESS PATH TESTS

Series 4 tests are listed in Table 5.5; they involved the application of a range of cyclic total stress paths to the soil and, via pore pressure measurement, evaluation of the corresponding effective stress paths.
A facility developed by Pappin (1979), to record hysteresis loops, was adapted for this research so that it could not only record stress-strain loops but could also plot any two stresses together, either in total or effective stress space.

Test 4.3 was used in the investigation of pore pressure response detailed in Chapter Eight, but the specimen failed unexpectedly before it could be used in this investigation. The results of the other tests are discussed by presenting examples which were representative of the general observed behaviour.

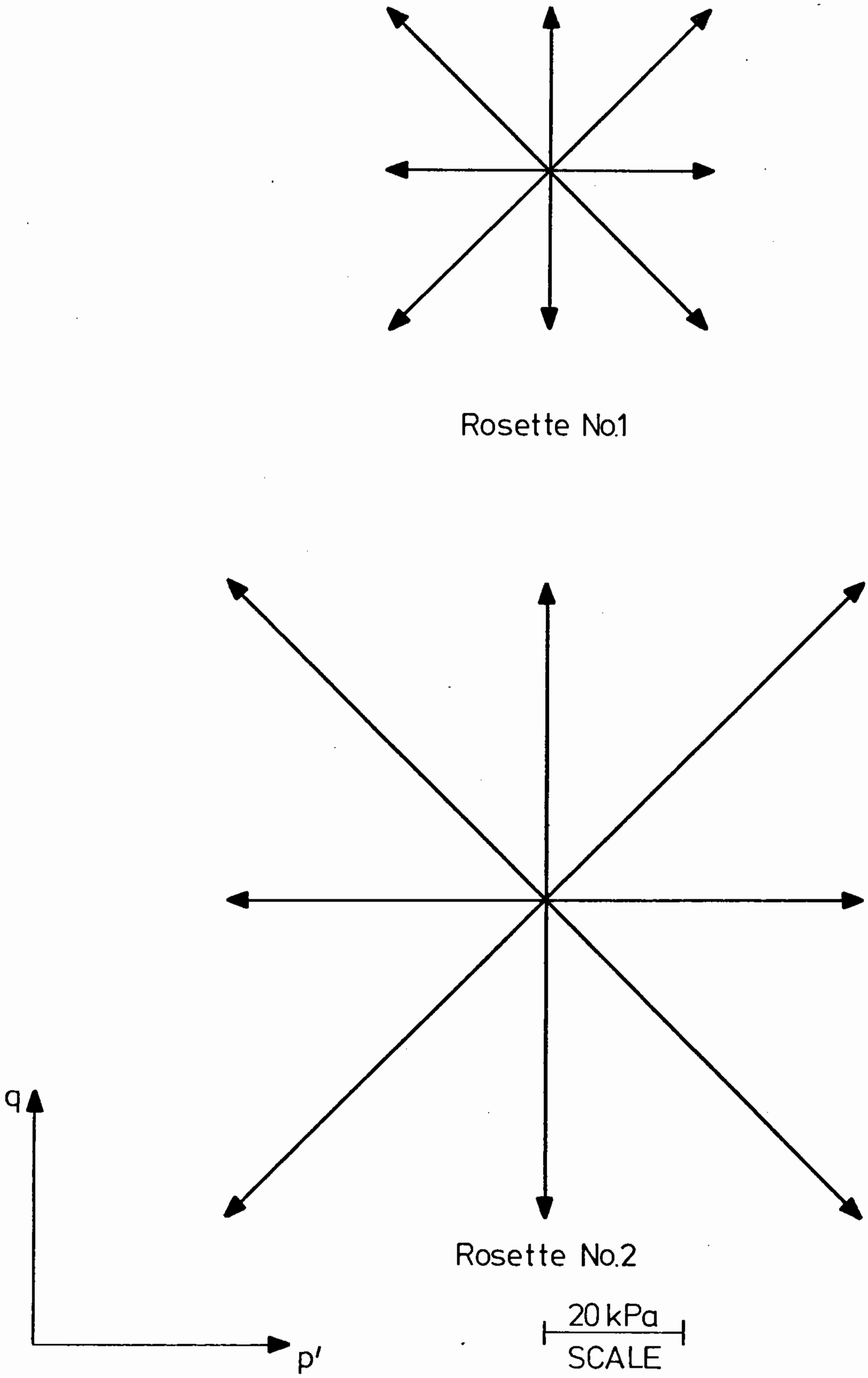
In planning the stress paths, a graph of p'-q space was divided up into a grid as illustrated in Figure 9.1. Each node of the grid was given a reference letter and number. The grid was chosen so that it was applicable to the scale of the oscillograph used to record the outputs of the confining stress and load transducers. It was, therefore, possible to cycle the stresses so that a total stress path between any two nodes of the grid could be obtained. The testing was performed at a frequency of 0.1 Hz.

The individual total stress paths are shown in Figure 9.2. It was planned to use the first configuration (rosette) at every node position and the second rosette at the nodes with labels that were any combination of 1,3,5,7,9 and b,d,f (Figure 9.1). This would give, in total stress space, an overlapping field of stress paths.



GRID REFERENCE FOR APPLICATION OF TOTAL STRESS PATHS

Figure 9.1



APPLIED TOTAL STRESS PATHS

Figure 9.2

It was hoped that by staying below the K_0 line, permanent strain and pore pressure in the soil would only develop when changing the mean level of q, giving only resilient behaviour during the application of a stress rosette. This was found to be reasonably practical provided the triaxial extension region was not included. Because of this, no paths were used with mean levels below the nodes at level 7 (Figure 9.1).

The total stress paths were applied to the specimens by cycling the deviator and confining stresses in various combinations, either in or out of phase. Because of lag in the system, the phase angle between the input signals had to be adjusted from the ideal 0 or 180^0 to give an output at the correct phase from the transducers. This was achieved by using an oscilloscope which would allow the two variables to be plotted against each other and adjusting the phase angle to give the minimum hysteresis.

9.1 EFFECTIVE STRESS PATHS

The base pore pressure probe has already been shown to be insensitive to cyclic confining stress at 0.1 Hz (Chapter Eight), whilst the centre probe was often insensitive to cyclic deviator stress. Despite this, the results showed that in any one test the effective stress path was the same regardless of the applied total stress path. This is shown for test 4.5 at node 5d (as defined in Figure 9.1), in Figure 9.3 where the complete rosette of stress paths are illustrated. The loops shown are, from left to right, the applied total stress path, the effective stress path using the base probe, the effective stress path using the centre probe and the deviator stress-shear strain path. As the mean stress level is below the K_0 line (inside the yield surface) and at a constant mean deviator stress, the behaviour is predominantly elastic. The centre pore pressures show the effective stress path to be unique and furthermore, to keep the effective normal stress constant. When the total stresses were applied at different

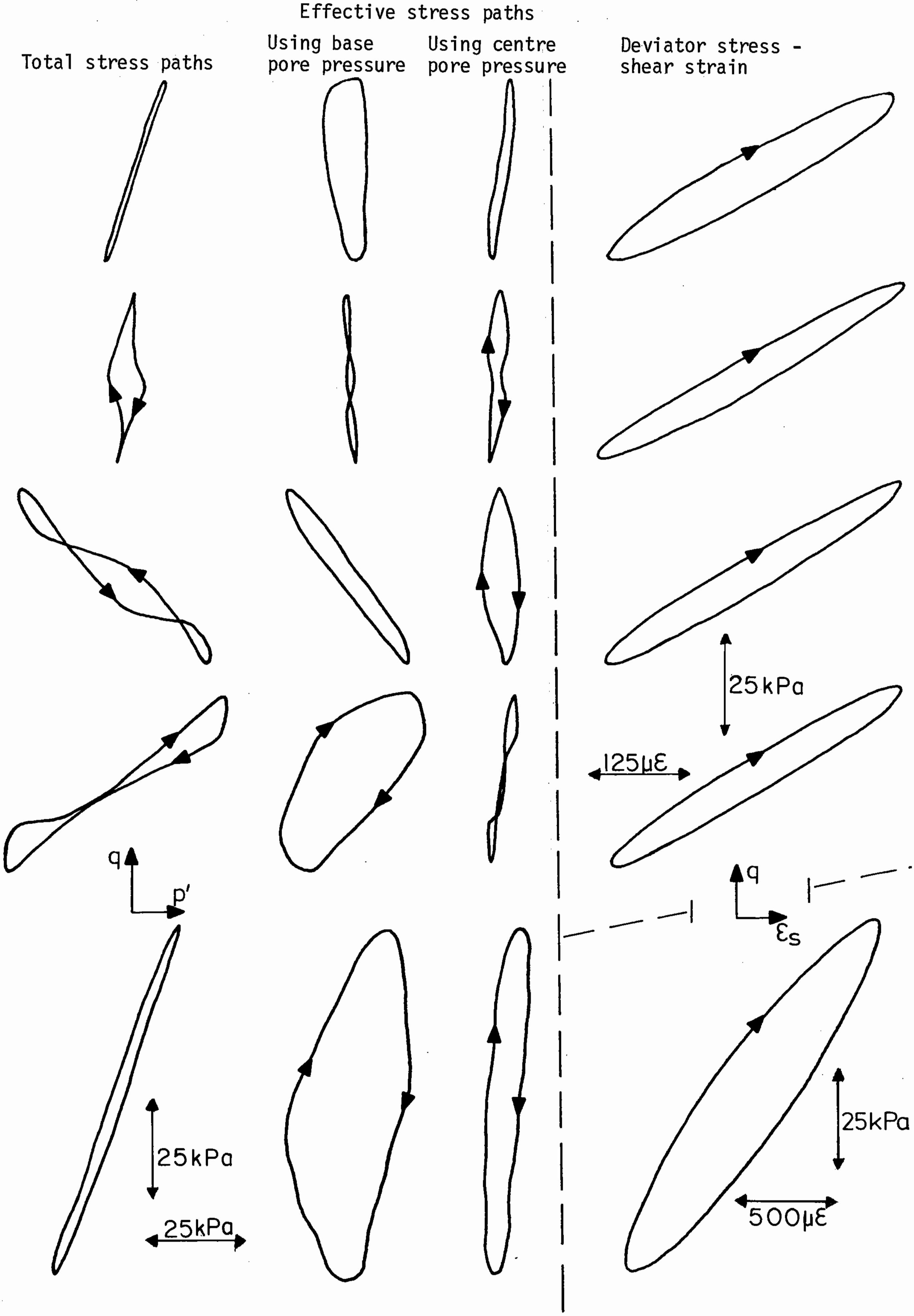


Figure 9.3(a) HYSTERESIS LOOPS FOR TEST 4.5

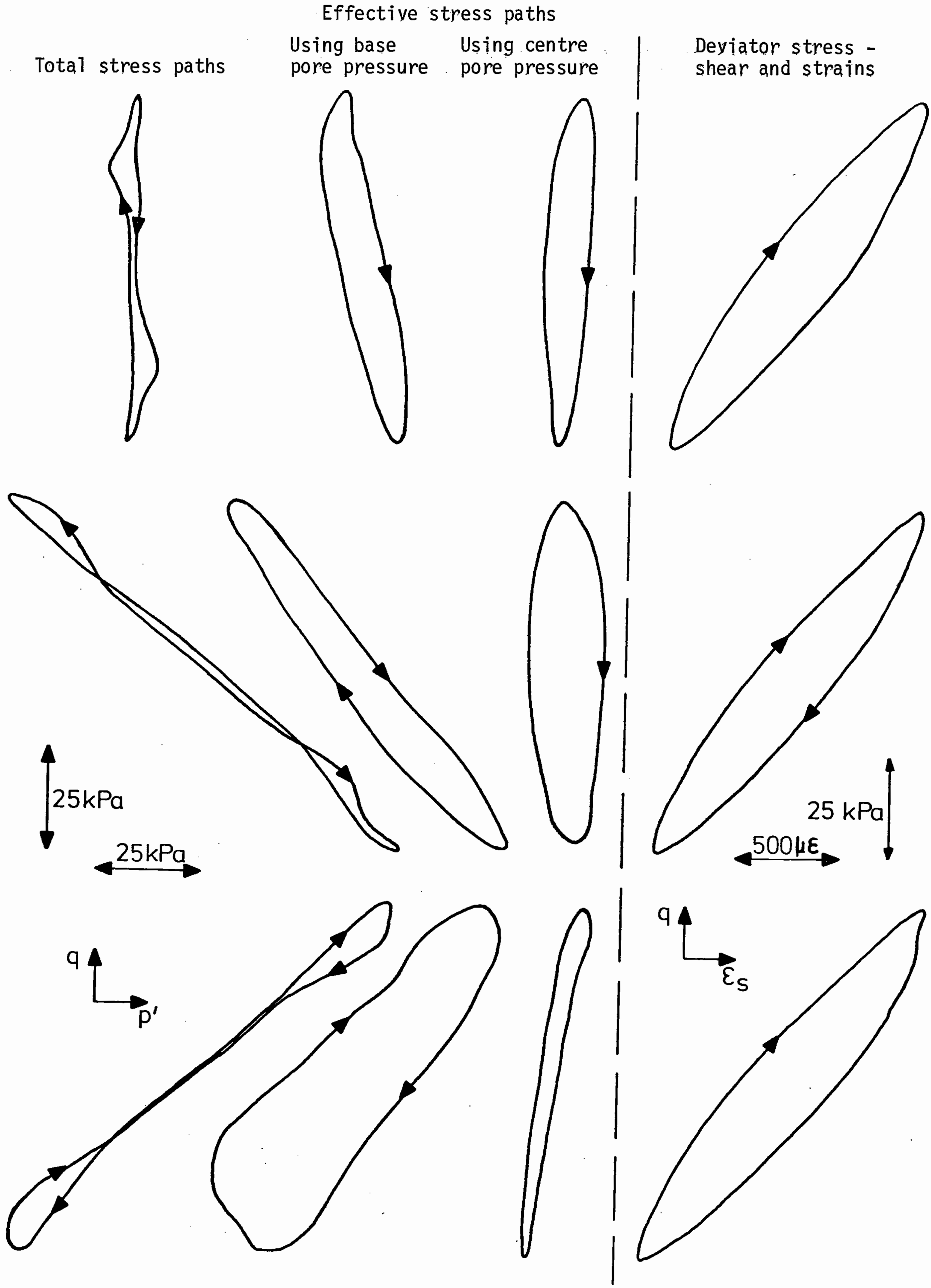


Figure 9.3(b) HYSTERESIS LOOPS FOR TEST 4.5

nodes at the same mean deviator stress level the pore pressures changed to keep the effective stresses constant.

The equivalent stress paths for test 4.4 at the same node position are shown in Figure 9.4. Again, the effective stress response measured with the centre probe shows the path to be unique. Here, however, the probe showed an insensitivity to the change in deviator stress. The base probe response in this test was much improved compared to test 4.5. Again, the stress path tended to be the same for all applied stress paths and to keep the mean normal stress constant.

9.2 STRESS-STRAIN PATHS

The stress-strain loops for test 4.5, illustrated in Figure 9.3, show that the resilient shear strain was little affected by the different total stress paths. The length of the loops did vary a little but this was probably due to slight fluctuations in the applied peak deviator stress values.

The stress-strain loops in Figure 9.3(a) and (b) are to different scales. Figure 9.5 gives an example of the stress-strain loops from test 4.4 plotted to the same scale with the idealised applied total stress paths. It can be seen that the largest stress path caused a greater resilient shear strain than the sum of the two smaller stress paths. However, the small hysteresis loops fit into the large one suggesting that the modulus values for the different loops are related.

Overall, provided the soil behaviour was showing little or no change in permanent response, the resilient strain was constant for any mean level of deviator stress (between the K_0 line and p' axis), and varied non-linearly with the cyclic deviator stress.

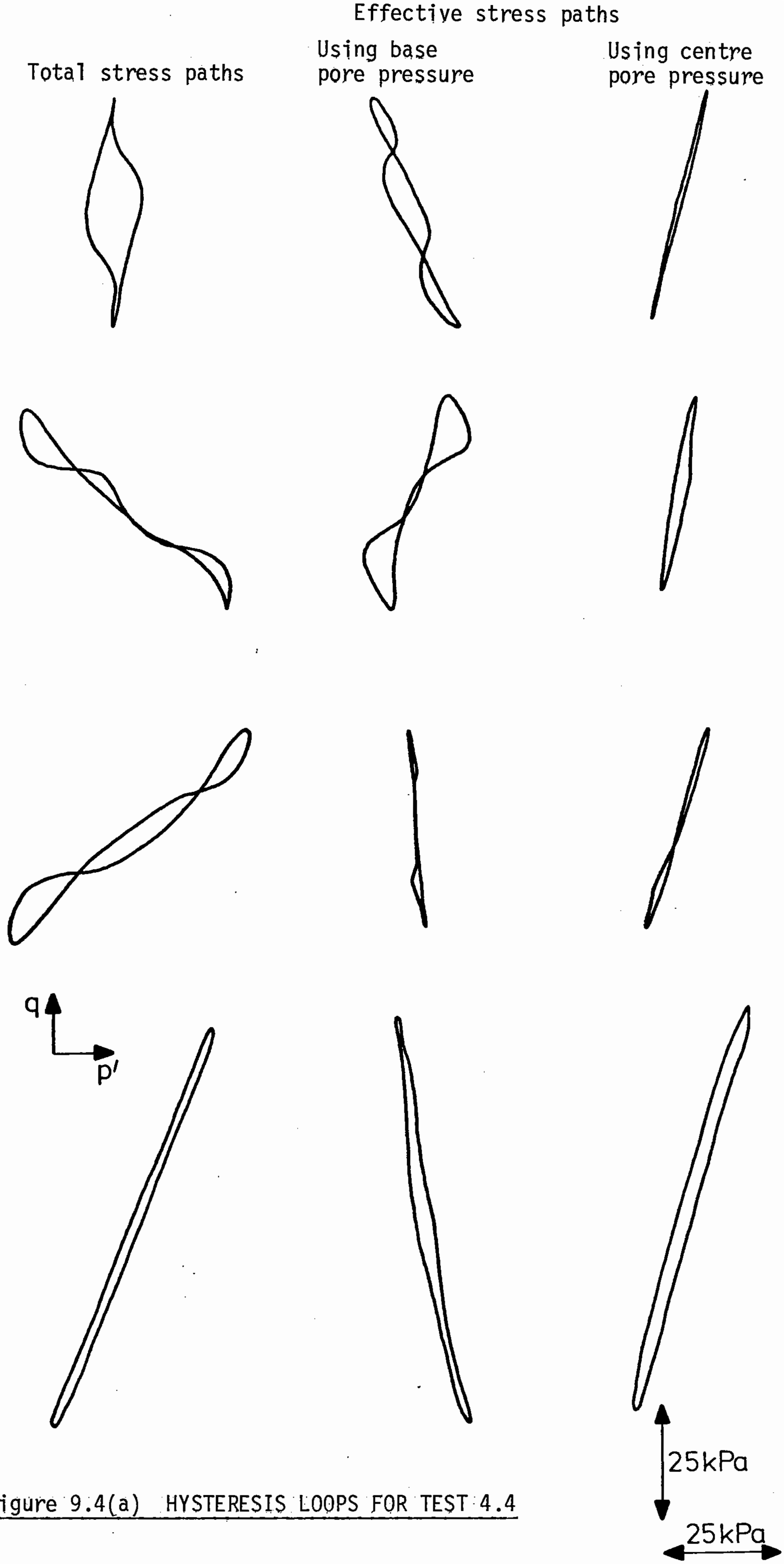


Figure 9.4(a) HYSTERESIS LOOPS FOR TEST 4.4

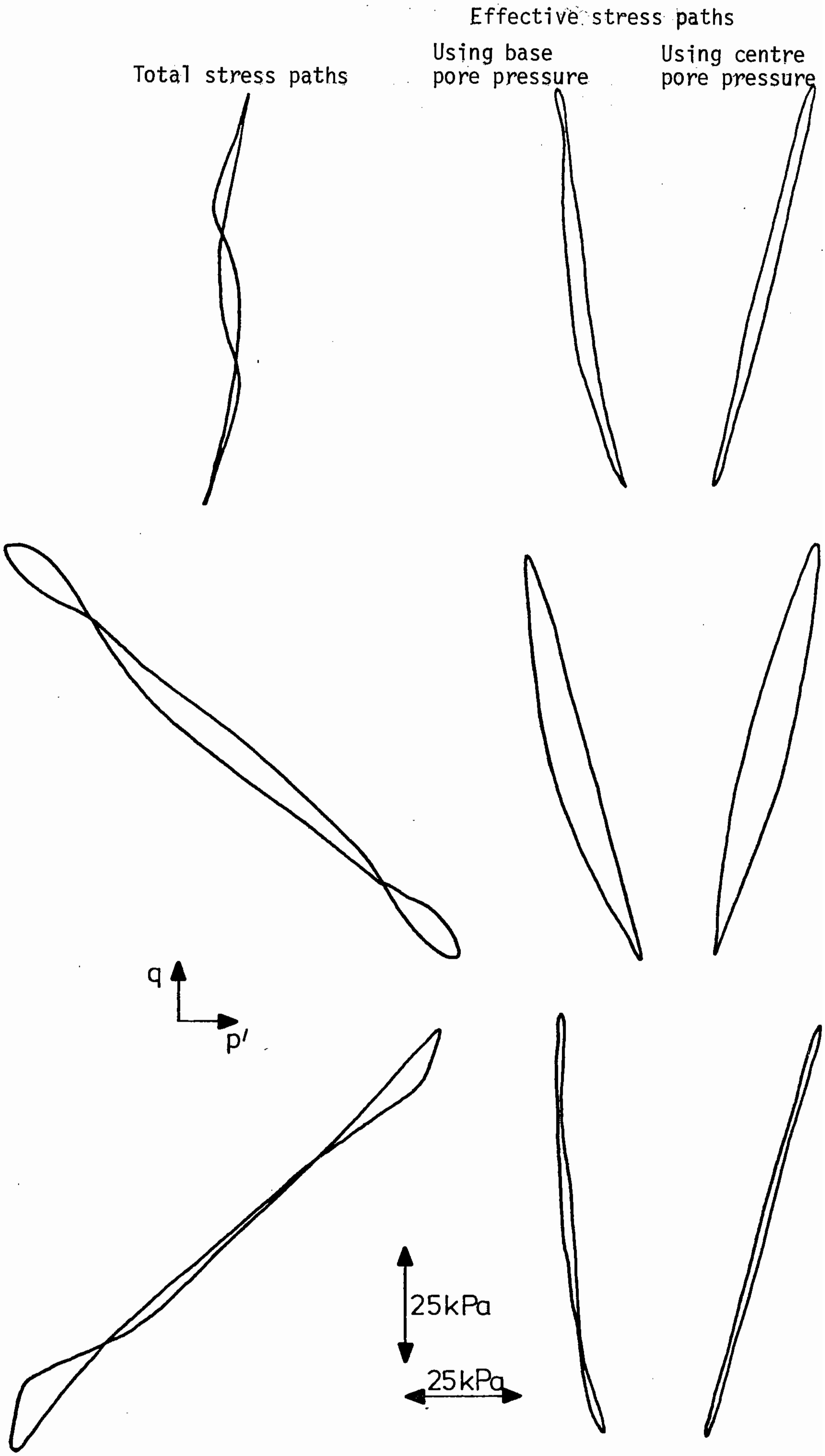


Figure 9.4(b) HYSTERESIS LOOPS FOR TEST 4.4

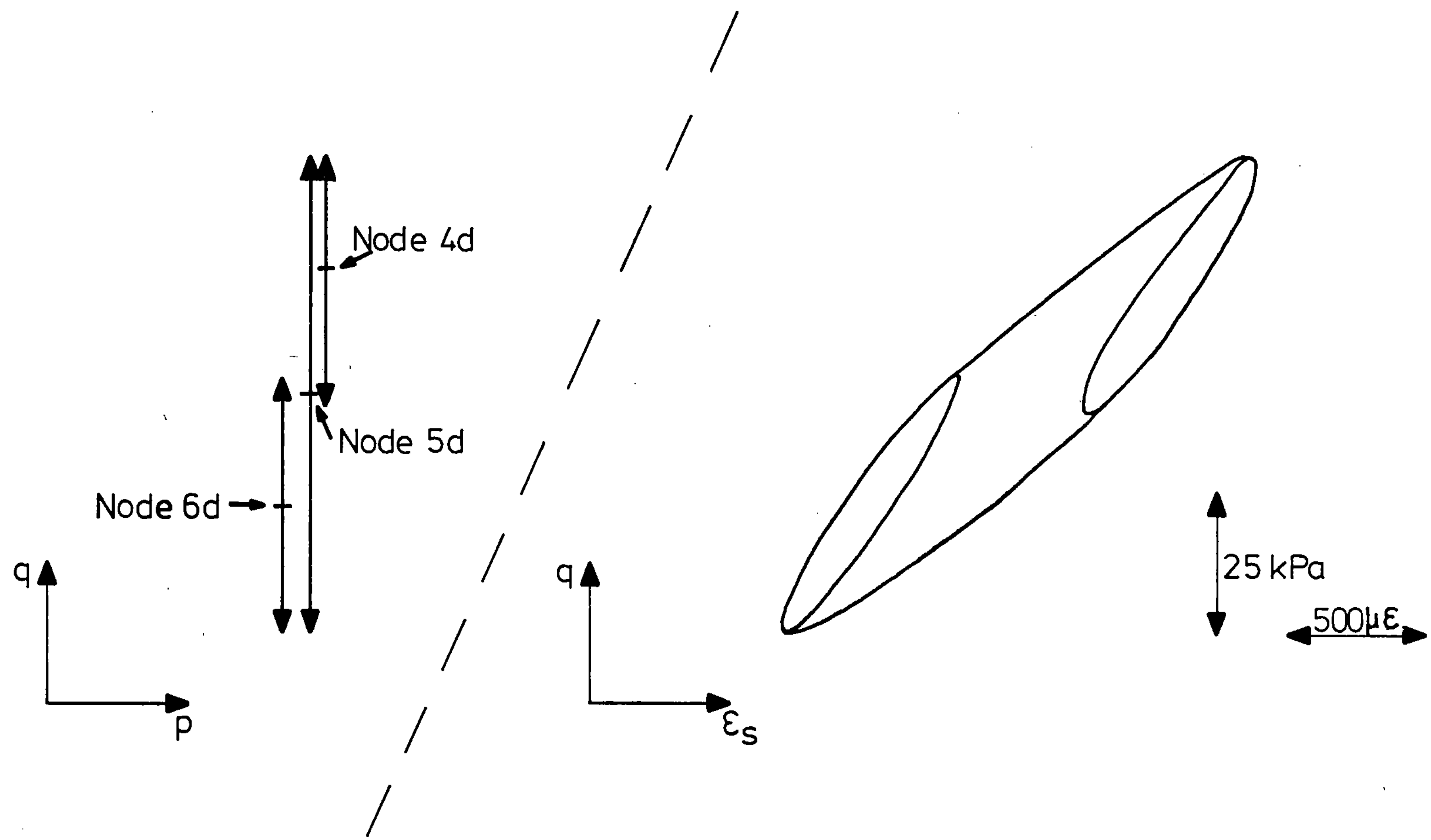


Figure 9.5 HYSTERESIS LOOPS FOR THREE APPLIED TOTAL STRESS PATHS

The two levels of cyclic deviator stress used were 45 and 90 kPa for which the shear strains were approximately 400 and 1200 microstrain, respectively.

9.3 PERMANENT STRAINS

As the mean level of deviator stress was reduced in a test, the soil underwent an immediate axial extension. On applying cycles of deviator stress, this extension continued. However, the change in one cycle was always sufficiently small for the resilient strain loops to appear to be a closed path.

The deformation measuring equipment continued to give good resilient strain results with small apparent resilient volumetric strains but as the permanent shear strain became progressively more negative (extension) the measuring equipment began to show an apparent permanent volumetric strain.

9.4 SUMMARY

In an undrained test on saturated Keuper marl the elastic response, regardless of the applied total stress path, gave a unique effective stress path. In addition, the variation in pore pressure during a cycle compensated for changes in total stress such that the effective mean normal stress remained constant.

For a given cyclic deviator stress in the same undrained test, the resilient shear strain was also constant. The size of the resilient strain was non linear with the size of cyclic q but the shear moduli for different hysteresis loops were related.

CHAPTER TEN

DEVELOPMENT OF THEORETICAL MODEL FOR CYCLIC LOADING

The results of this research were used to check the theoretical developments of the Cam Clay model, with particular reference to a paper by Carter et al., (1979) where cyclic load behaviour was described. First, the results of the monotonic tests to failure performed in this research are discussed followed by a brief resumé of the repeated load Cam Clay model. Developments to the model suggested by the test results are then set out and are applied to a simplified version of it. Finally, a short section on the resulting theoretical developments is given.

10.1 STRENGTH TESTS

Following cyclic loading, each specimen was tested to failure at a constant rate of strain. The radial transducers sometimes went out of range after the peak strength was reached as the shear strains became large. This resulted in an under-estimation of high shear strains. The shear strain when this occurred could be anything between 0.5 and 6%. In Figures 10.1 to 10.8, the stresses have been normalised by p_e', the mean normal effective stress on the normally consolidated line at the same specific volume as the specimen. The failure envelope shown in the figures was established from the isotropic test series.

The first strength tests were done without any prior cyclic loading and were called series AF. They are set out in Table 5.2. They were designed to establish the proportions of maximum deviator stress (q_{max}) to be applied in the cyclic tests. These tests were performed at strain rates at which it was thought pore pressure equilisation throughout the specimen would occur. The stress-strain plots are shown in Figure 10.1 and the corresponding stress paths in Figure 10.2. Figure 10.1 shows an initial

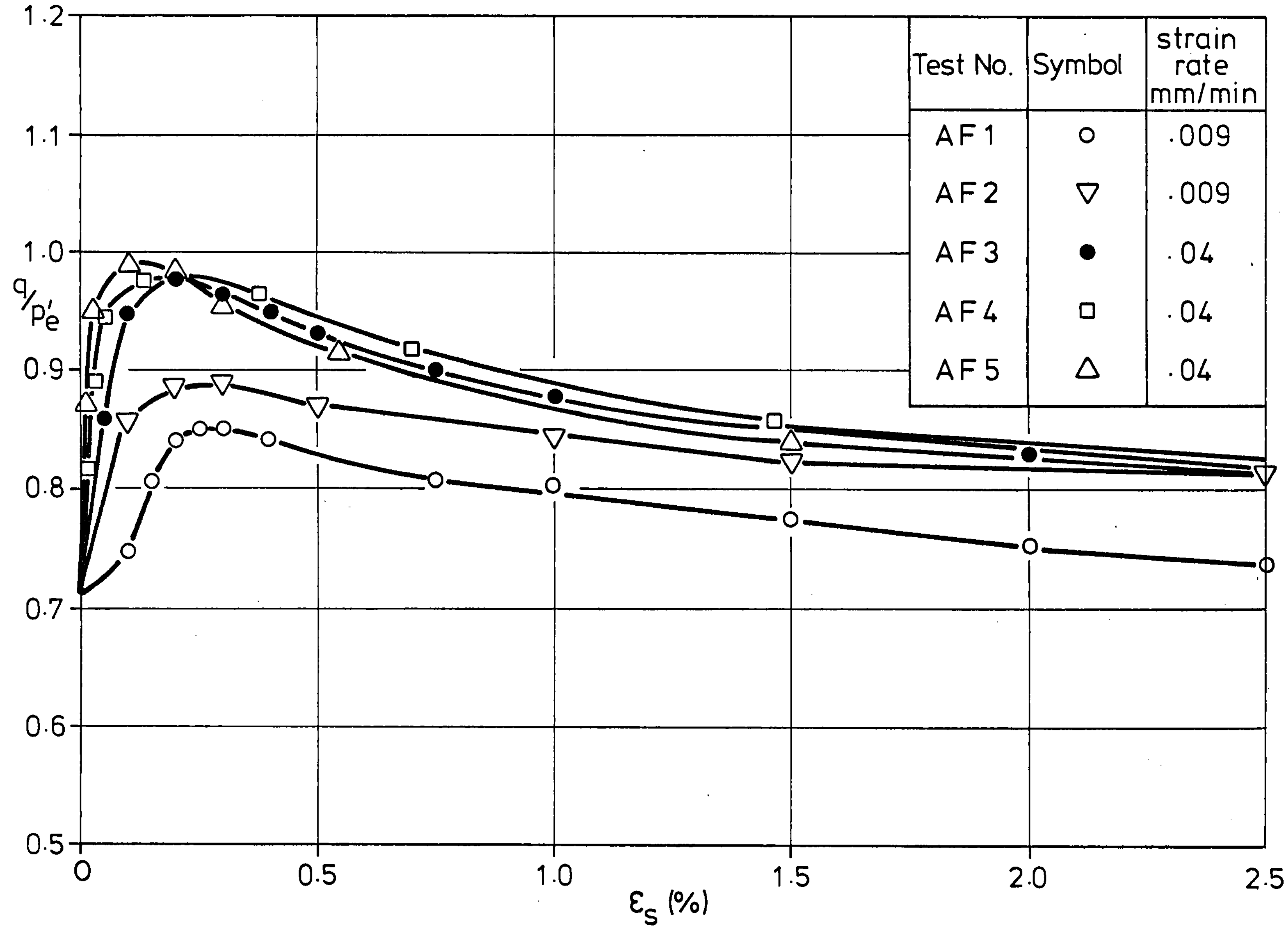


Figure 10.1 STRESS-STRAIN CURVES DURING FAILURE TESTS - SERIES AF

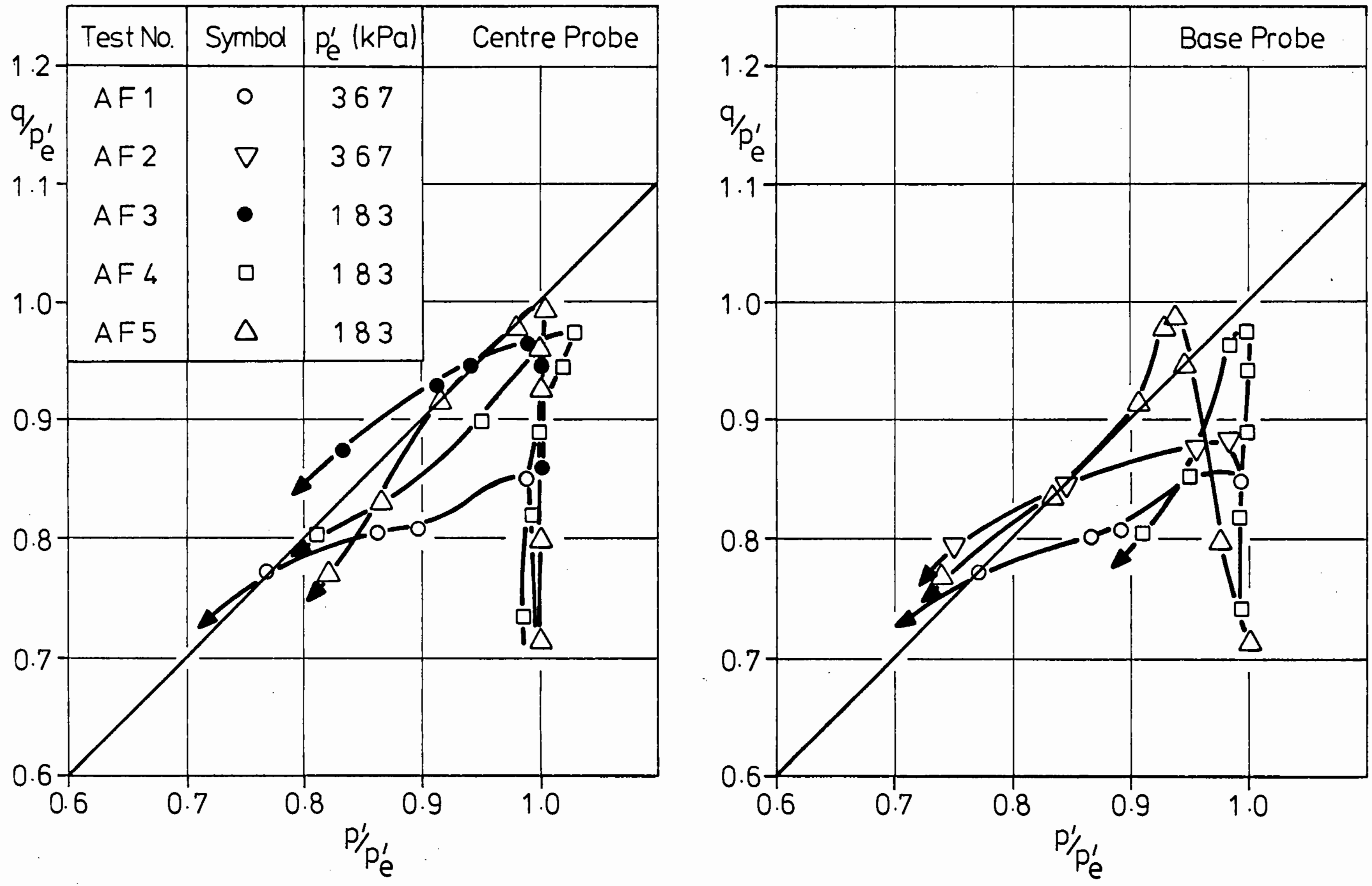


Figure 10.2 STRESS PATHS DURING FAILURE TESTS - SERIES AF

steep rise in deviator stress (q) with little strain developing. As the strain subsequently developed, the specimens reached a maximum q after which the strain continued to increase with a drop in q to a residual value. The stress paths in Figure 10.2 showed that the pore pressures which developed at first were only sufficient to keep a constant mean normal effective stress (p') until the peak q was approached after which the pore pressures became large and q dropped so that the stress path moved down the failure line. Tests AF1 and AF2 were consolidated to a higher stress level (p' = 367 kPa), than the rest of the test programme (p' = 183 kPa).

The strength tests on specimens previously subjected to cyclic loading were performed at various strain rates, the plots of stress against strain are given in Figure 10.3 and the stress paths in Figure 10.4. The stress paths obtained using pore pressures measured with the centre probe in Figure 10.4 showed the soil moving to failure by increasing q at a fairly constant p' until the failure envelope was approached, after which the stress path moved down the failure envelope. Stress paths based on the base probe pore pressures, also given in Figure 10.4, showed somewhat more erratic behaviour. On occasions, the stress path was the same shape as that based on the centre probe readings, but in other tests, due to the base probe reading much higher values of pore pressure, the peak q attained was well outside the failure envelope. This base probe response was also noted by Austin (1979). The post peak behaviour always tended to bring the soil back to the failure envelope.

The tests used as a basis for establishing the levels of cyclic deviator stress reached a peak q of about 180 kPa. The strength tests, carried out after cyclic loading, reached peaks of anything between 180 and 216 kPa. This was first thought to indicate that the soil was gaining strength from the cyclic loading and drainage regime but when some later tests were performed at slower rates of strain, a different conclusion

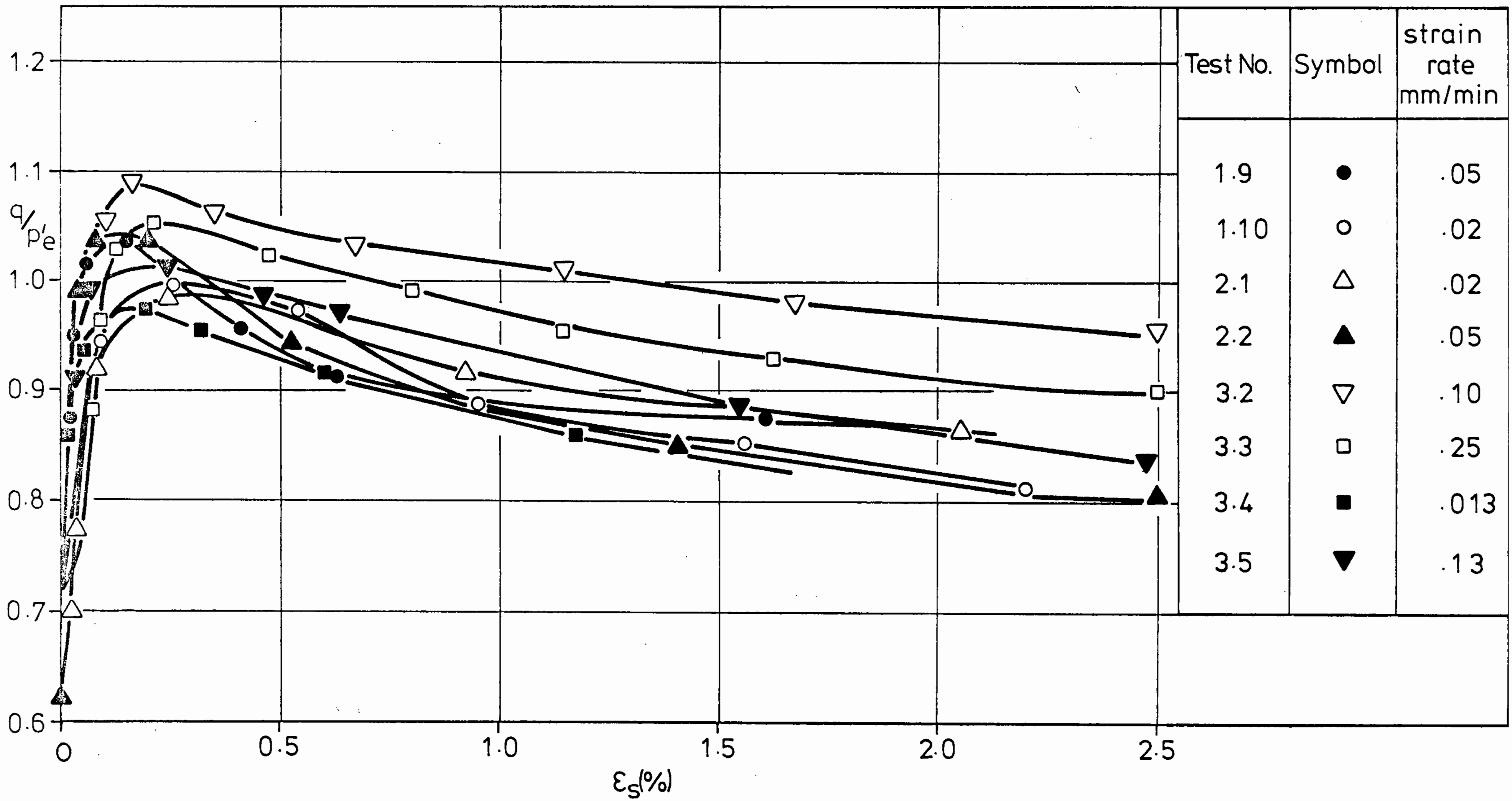
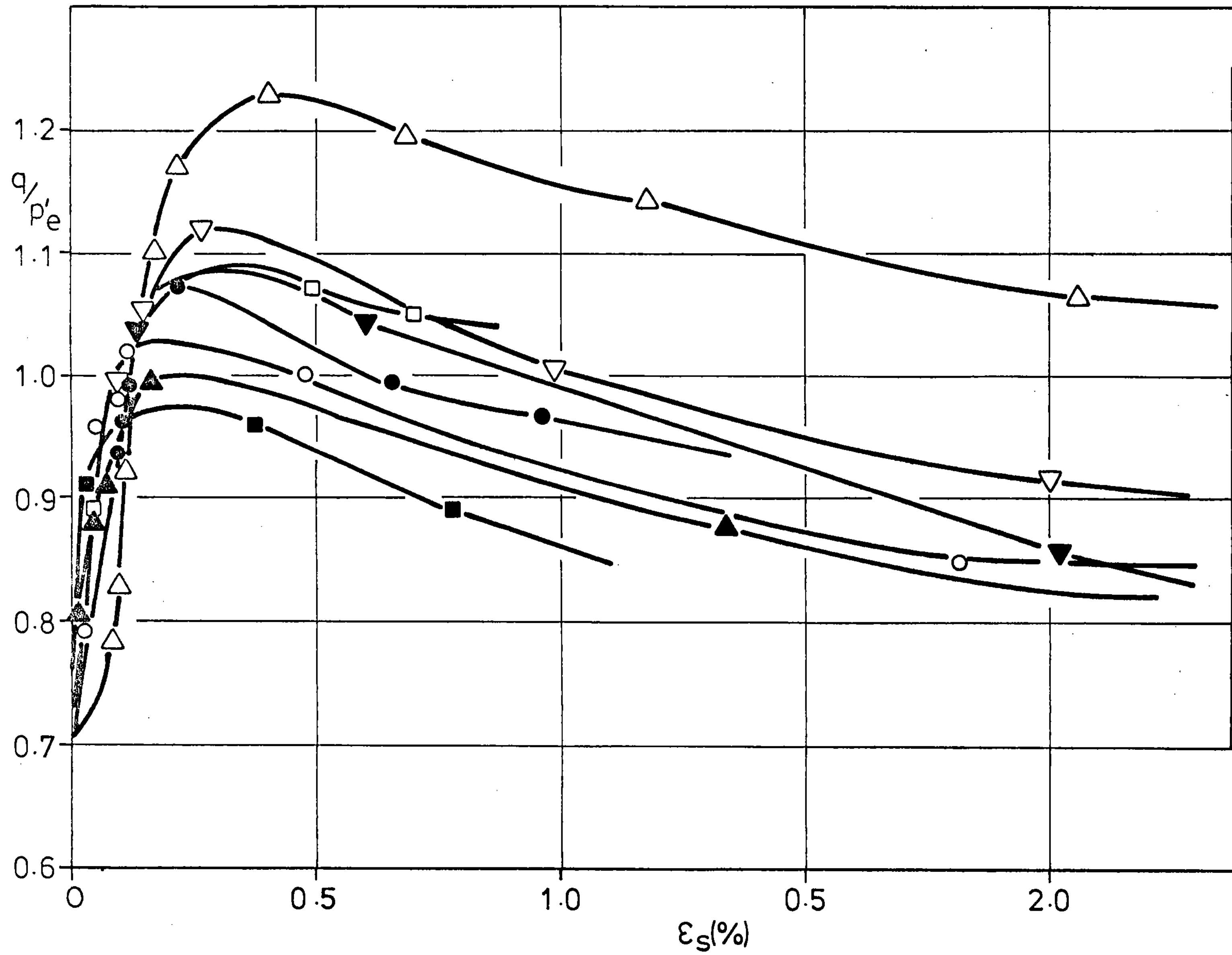


Figure 10.3(a) STRESS-STRAIN CURVES DURING FAILURE TESTS AFTER CYCLIC LOADING



Test No.	Symbol	strain rate mm/min
1.2	▲	.025
1.3	△	.04
1.5	▼	.05
1.6	▽	.1
1.7	□	.1
1.8	■	.05
1.12	○	.025
3.1	●	.1

Figure 10.3(b) STRESS-STRAIN CURVES DURING FAILURE TESTS AFTER CYCLIC LOADING

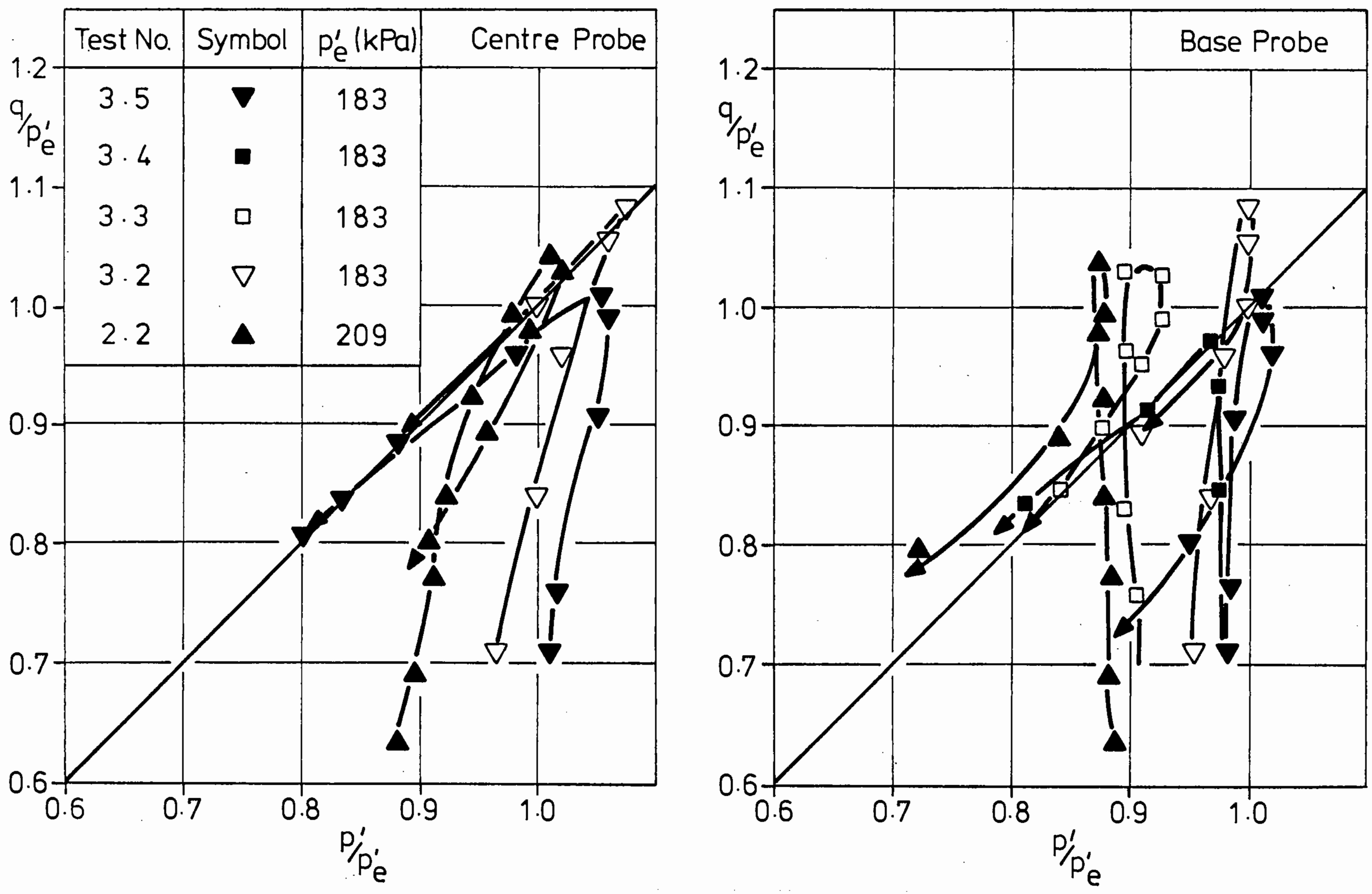


Figure 10.4 STRESS PATHS DURING FAILURE TESTS AFTER CYCLIC LOADING

emerged. The slower rate tests are given in Figures 10.5 and 10.6. Tests 1.13 and 1.14 involved a strain rate of 0.02 mm/min and only reached 170 and 175 kPa (q/p'_e = 0.94 and 0.96), respectively. Test 4.4 at 0.004 mm/min reached 165 kPa, while test 1.15 at 0.0008 mm/min reached 148 kPa. By the time test 1.15 reached the failure envelope, q was well below its initial value (Figure 10.6).

Hence, it became clear that the rate of loading significantly affected the apparent peak strength of the soil and that there was no unique value of strength for any of the loading rates. It can be seen, therefore, that a time effect must be included in any attempt to model the soil response theoretically. The strain at which the peak q occurred in all the tests was between 0.1 and 0.4% regardless of the rate of strain.

Two specimens were overconsolidated under K_0 conditions and then tested to failure. The results are shown in Figures 10.7 and 10.8. The shear strain required to develop the maximum q was 3-5% compared with about 0.2% for the normally consolidated specimens. The specimens showed similar stress paths in which p' increased on loading, allowing the soil to move towards the critical state point as defined by Schofield and Wroth (1968). The failure envelope in compression and extension obtained from isotropic tests in Series IF (Chapter Six) are also shown. Unlike the stress paths of anisotropic and isotropic normally consolidated specimens, the stress paths to failure of anisotropically overconsolidated specimens were very similar in shape to those obtained for isotropically overconsolidated specimens.

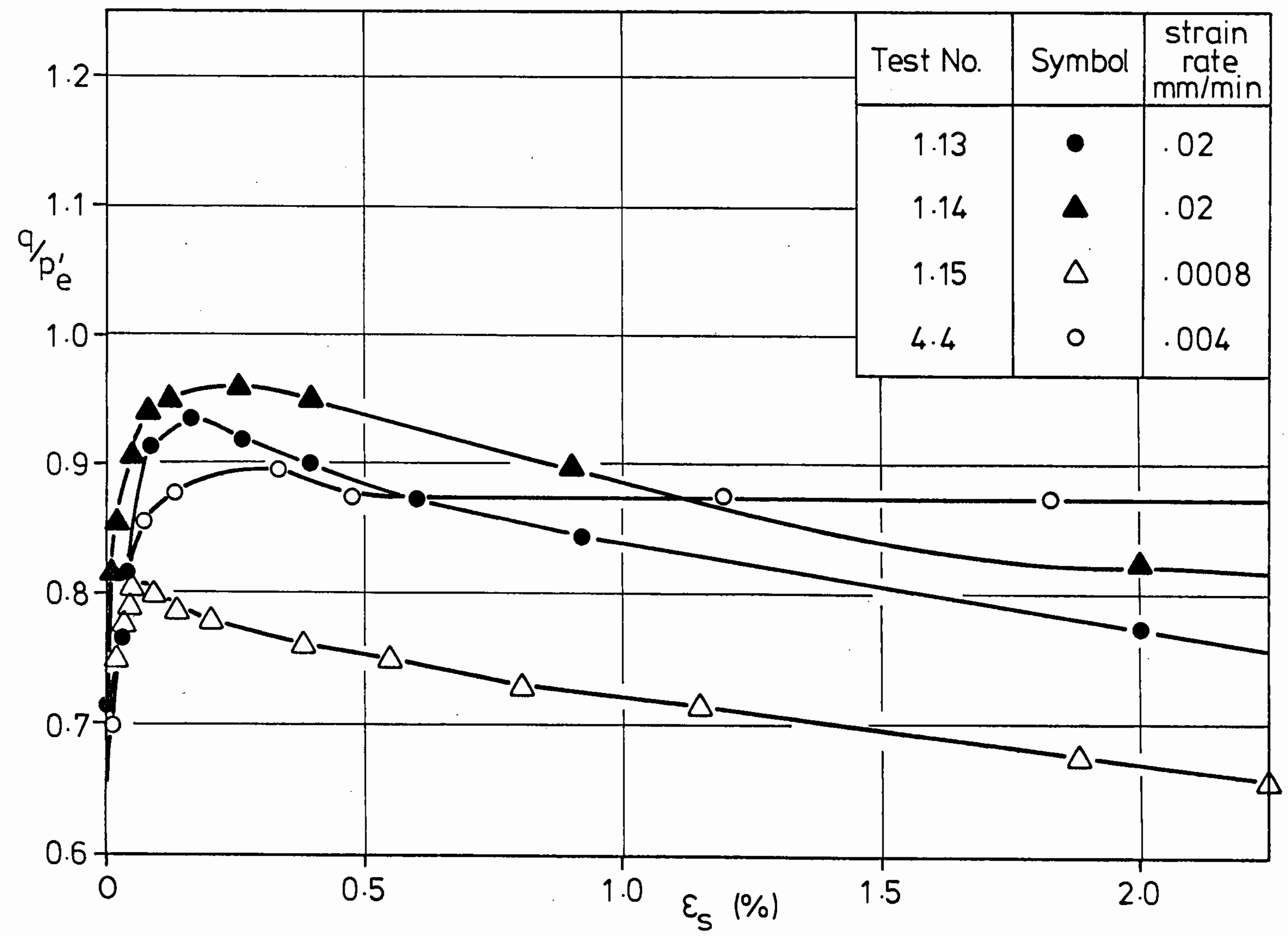


Figure 10.5 STRESS-STRAIN CURVES DURING SLOW FAILURE TESTS AFTER CYCLIC LOADING

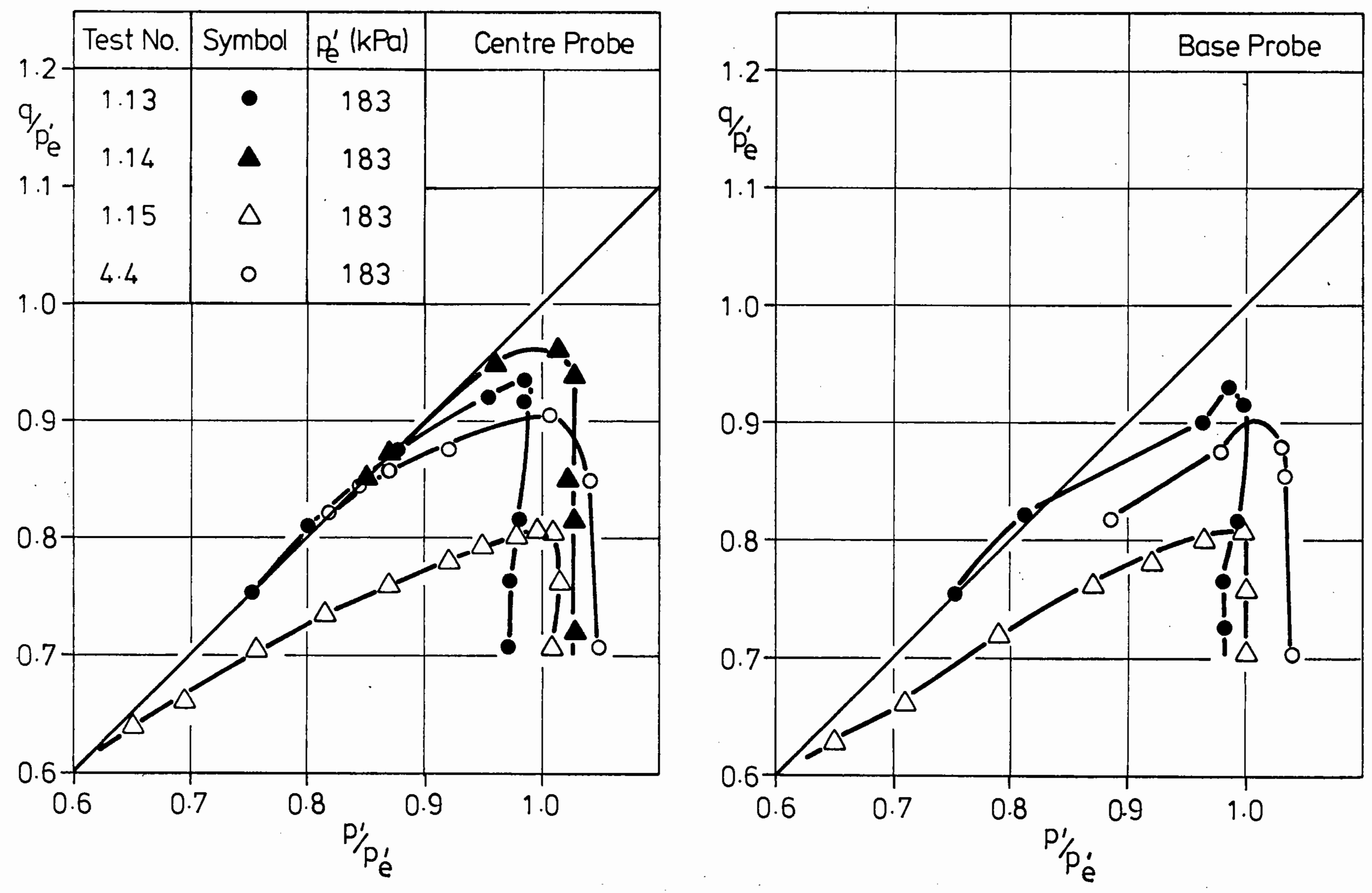


Figure 10.6 STRESS PATHS DURING SLOW FAILURE TESTS AFTER CYCLIC LOADING

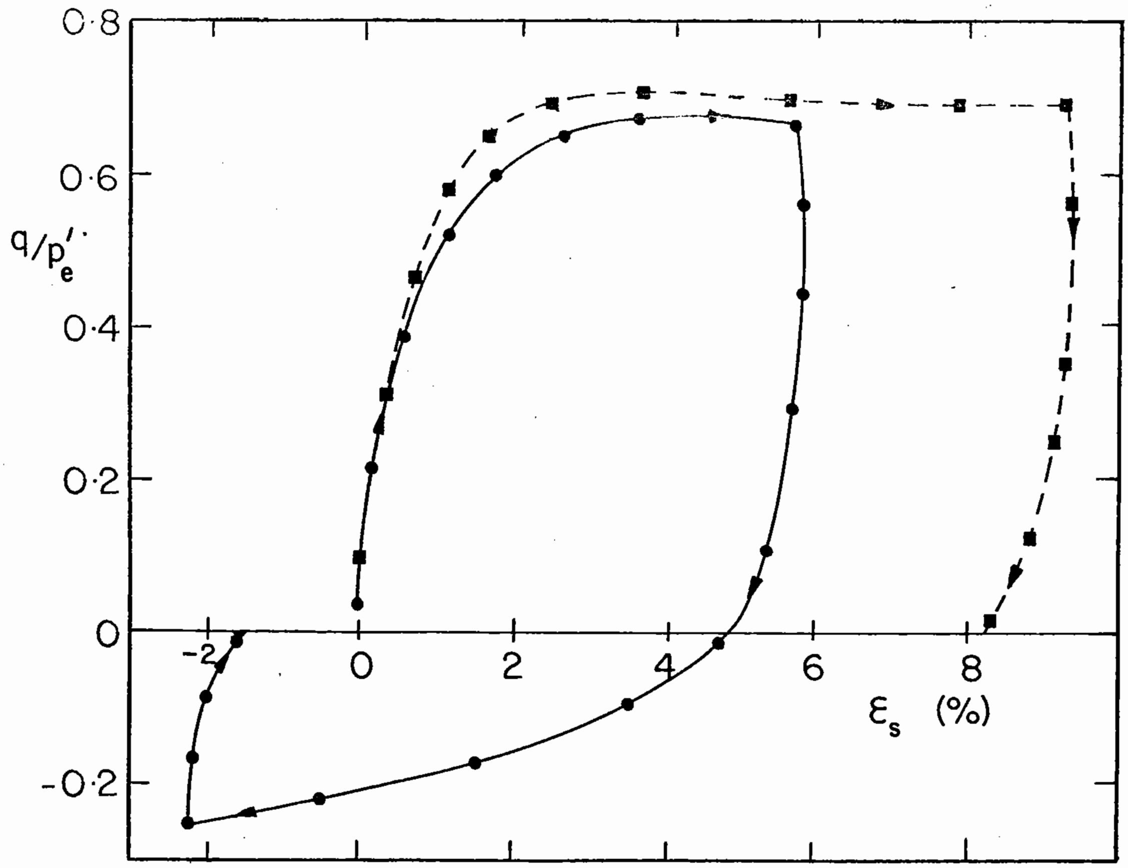
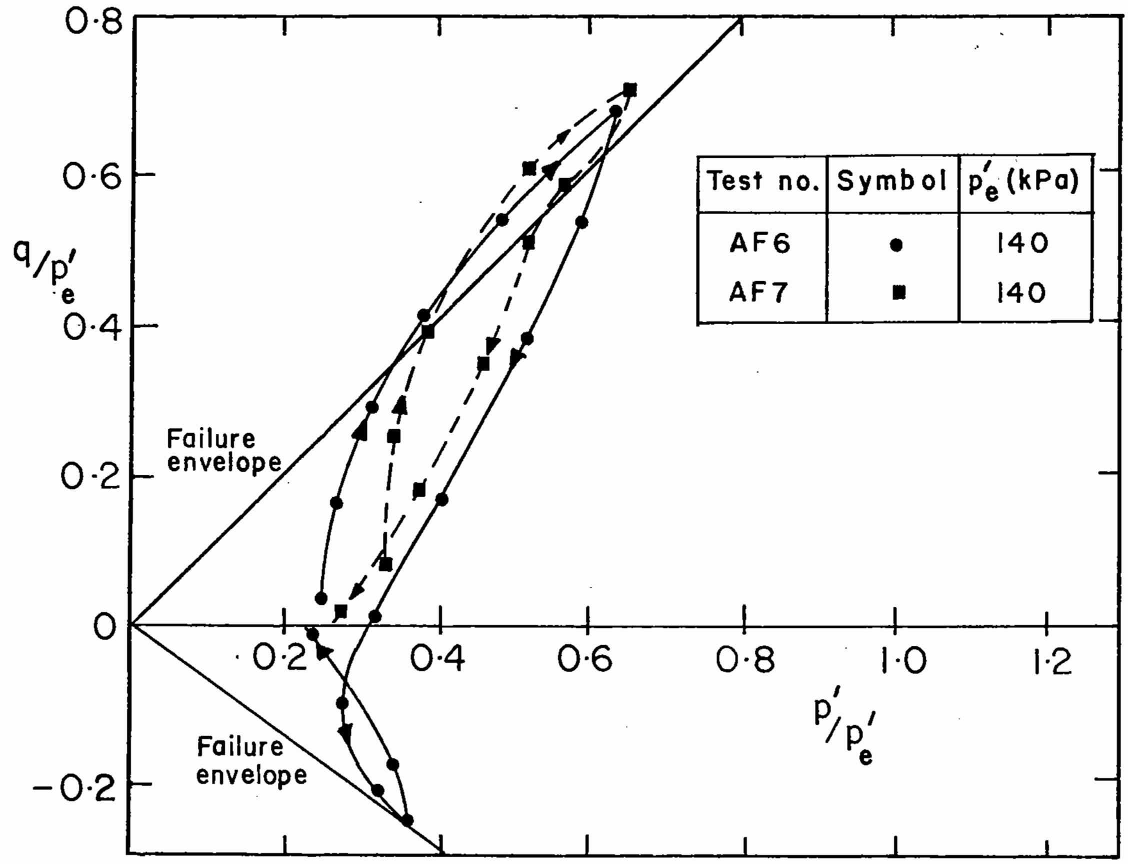


Figure 10.7 STRESS-STRAIN CURVES FOR OVERCONSOLIDATED SPECIMENS



Test no.	Symbol	p'_e (kPa)
AF6	●	140
AF7	■	140

Figure 10.8 STRESS PATHS FOR OVERCONSOLIDATED SPECIMENS

10.2 NEW CAM CLAY MODEL FOR CYCLIC LOADING

The concepts of critical state soil mechanics were set out by Schofield and Wroth (1968). They developed models which successfully described the general behaviour of soil under monotonic loading. Roscoe and Burland (1968) extended this work by introducing the Modified Cam Clay model, which provided a better fit to the experimental data.

The Modified Cam Clay is an elasto-plastic work hardening material which, as it stands, does not work well for cyclic loading. For example, if an undrained normally consolidated clay is considered, on the first application of load the soil strains and work hardens, developing permanent pore pressures, as shown in Figure 10.9. On unloading, the soil moves inside the yield surface. If the soil is then reloaded to the same peak stress, it will remain inside the surface behaving elastically and no further plastic strain or pore pressure will occur. Soil tests show that plastic strain and pore pressure develop with each successive cycle of load until equilibrium is reached or failure occurs (France and Sangrey, 1977; Wilson and Greenwood, 1974; Brown et al., 1975; Andersen, 1976).

This research project involved some liaison with Cambridge University to assist in the development of a model which would predict soil behaviour under cyclic loading. Carter et al., (1979) suggested a procedure which allowed plastic strain increments to develop with each cycle of load. The model is based on the Modified Cam Clay and requires only one additional parameter. A brief resumé of the way in which the model works is given here, full details being available in Carter et al., (1979).

The model defines a parameter p'_c as the non-zero intercept of the current elliptical yield surface and the p' axis. Figure 10.10 illustrates this. A variable, p'_y, is defined as the non-zero intercept of an ellipse, through the current stress point (p',q), with the p' axis. If $p'_y = p'_c$ the behaviour is plastic. During plastic behaviour, the yield locus changes

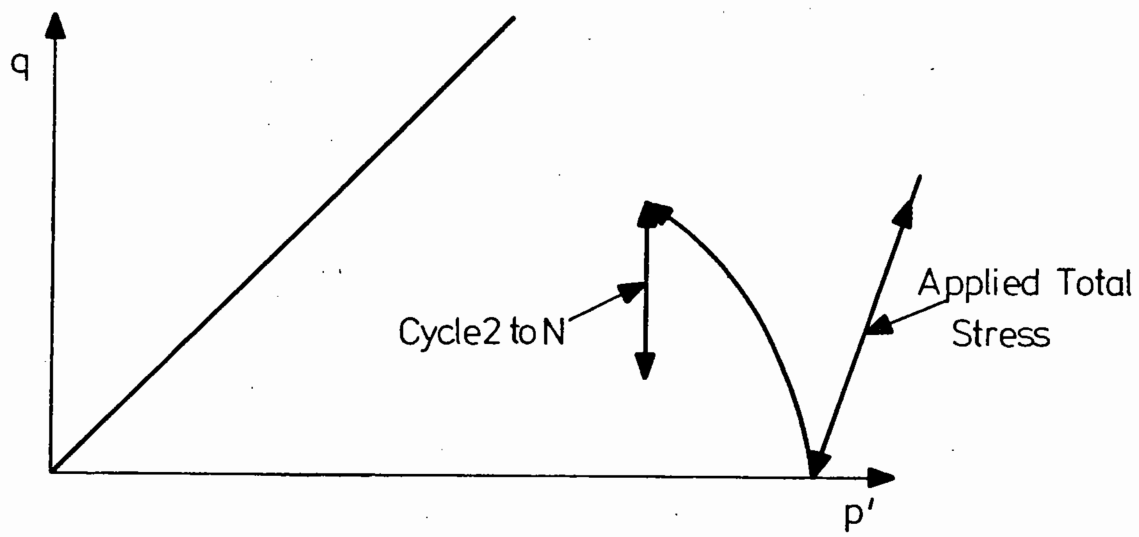


Figure 10.9 PREDICTED STRESS PATH FOR CYCLIC LOADING FROM CAM CLAY MODEL

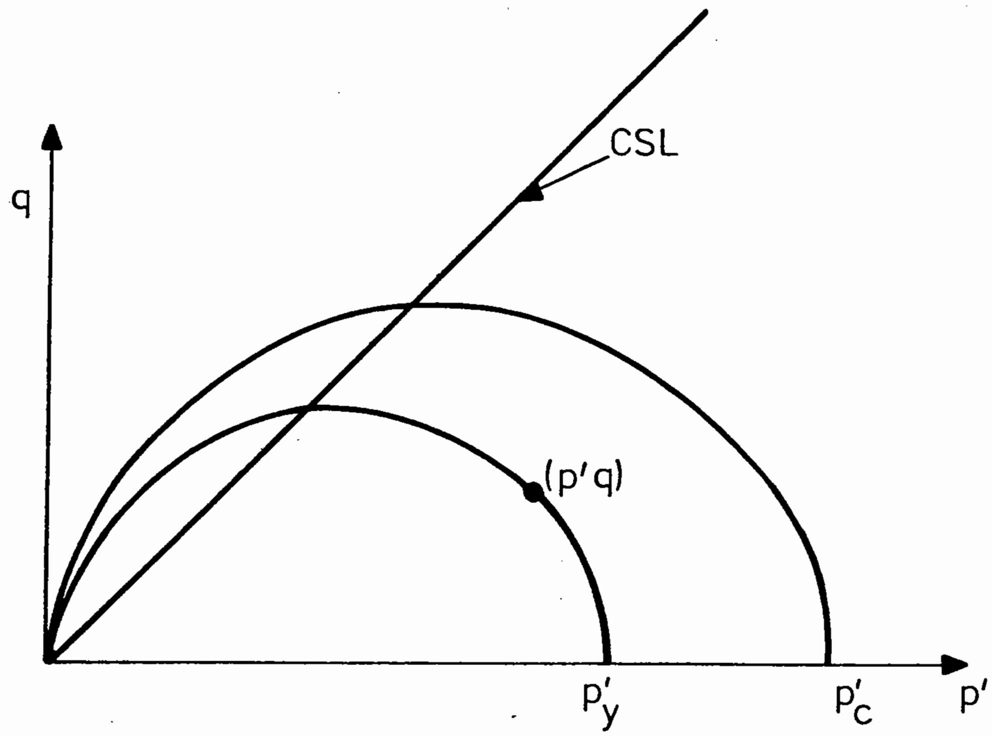


Figure 10.10 RELATIVE POSITIONS OF p'_y AND p'_c FOR NEW CAM CLAY MODEL

according to the law:

$$\frac{dp_c'}{p_c'} = \frac{dp_y'}{p_y'} \tag{10.1}$$

Permanent strains can occur in each cycle of repeated loading by assuming that the yield surface is contracted slightly by the elastic unloading in a cycle ($dp_y' < 0$), so that when the stress state is inside the yield surface and p_y' is decreasing, equation 10.1 becomes:

$$\frac{dp_c'}{p_c'} = \theta . \frac{dp_y'}{p_y'} \tag{10.2}$$

Hence the yield surface contracts by an amount dependent on the size of the unloading and the new parameter θ. This parameter has to be chosen with a knowledge of the material response, but it is usually small. On reloading ($dp_y' \geq 0$) there is no change in the yield surface (i.e. $dp_c' = 0$) until $p_y' = p_c'$.

In Modified Cam Clay, the position of the "λ lines" (normal consolidation) are assumed to be unique for a particular $\eta (\eta = q/p')$. However, the new model will cause these lines to migrate with each cycle of drained loading. In particular, the position of the "critical state line" in p',q,V space is not uniquely defined. In undrained loading, the contraction of the yield surface with each cycle will allow the build-up of plastic shear strain and pore pressure.

10.3 APPLICATION OF THE MODEL TO THE TEST PROGRAMME

Schofield and Wroth (1968) suggested that soil is an elasto-plastic, work hardening viscous material and stated that, for their model, they would only consider slow application of load so that the viscous component need not be considered. The model proposed by Carter et al., (1979) is also a non-viscous, elasto-plastic work hardening model developed for an isotropic material.

In trying to use this model, the fact that it is isotropic does not prevent its use for anisotropic work as it is possible to pick a relevant stress ratio on the state boundary surface as the initial position for anisotropic tests. However, the model in its present form cannot be applied to the work of this research project since viscous rate effects were noted in the recorded behaviour. In addition, the peak q values used in the test programme were far in excess of the maximum q predicted by the model.

The Modified Cam Clay equation for the state boundary surface is:

$$\frac{p'}{p'_e} = \left[\frac{M^2}{M^2 + \eta^2}\right]^{\left(\frac{\lambda - \kappa}{\lambda}\right)} \qquad (10.3)$$

where M, λ and κ are as given in Chapter Six

η = q/p'

p'_e = the non-zero intercept of the state boundary surface and the p' axis

For the state boundary surface through the initial anisotropic stresses used in the cyclic loading (p'_o q_o) of (183.3, 130 kPa) as shown in Figure 10.11, equation 10.3 can be used to give a p'_e of 263.6 kPa.

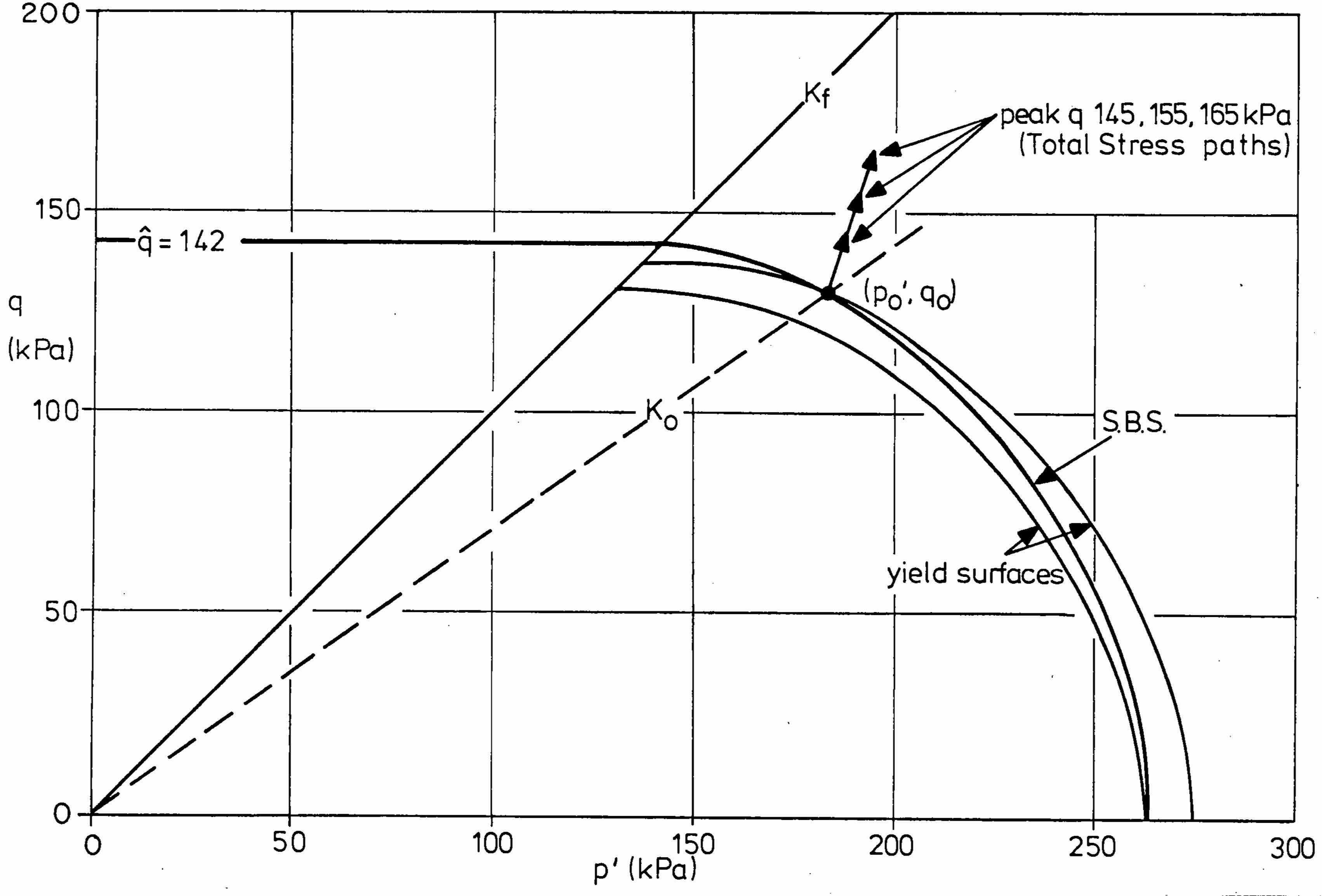


Figure 10.11 MAXIMUM DEVIATOR STRESS PREDICTED BY MODIFIED CAM CLAY MODEL

As η = M at the critical state, this gives a maximum q of 142 kPa and all specimens would be expected to fail in cycle 1 (the peak q values used in cyclic loading were 145, 155 and 165 kPa).

As the predominant feature of the strength tests was a rate effect, an attempt was made to introduce a viscosity effect into the model.

10.4 "VISCOUS PLASTICITY"

The general pattern of the stress-strain relationships for monotonic tests as evidenced by this research is given in Figure 10.12. The portion AB is linear, followed by a curved portion (BC) to the peak q, which is in turn followed by a decrease in q (CD) to a residual value. A model conceptually similar to a spring and dash pot was postulated by Murayama and Shibata (1964) to describe soil creep behaviour, as in Figure 10.13. If the dash pot response is influenced by the size of the load as well as the rate at which it is applied, then on application of the load, the elastic portion responds immediately, but the plastic part depends on the rate at which the load is applied. With reference to Figure 10.12, the portion AB could be thought of as elastic with the viscosity effects controlling the subsequent plastic behaviour. At B the load is sufficient for plastic strain to occur and the soil deforms and work hardens. If the shape of the corresponding stress path is examined as illustrated in Figure 10.14, the stress path rises along AB at a constant p' as though inside a yield surface, then, at B the soil appears to yield and strains to failure at D.

As the soil was normally consolidated and, therefore, on a yield surface at A, the portion AB of Figures 10.12 and 10.14 seems to result from an expansion of the yield locus which depends on the strain rate. The variation in AB with rate of loading can be investigated. Since the failure tests were performed at a constant rate of strain, the abscissa

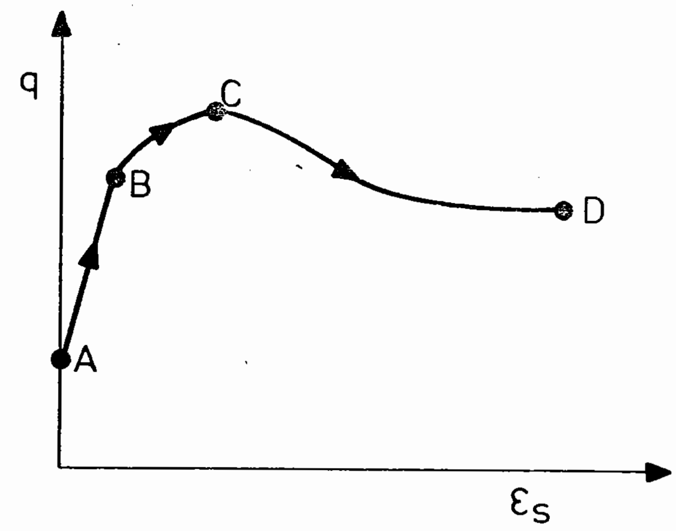


Figure 10.12 IDEALISED STRESS-STRAIN PLOT

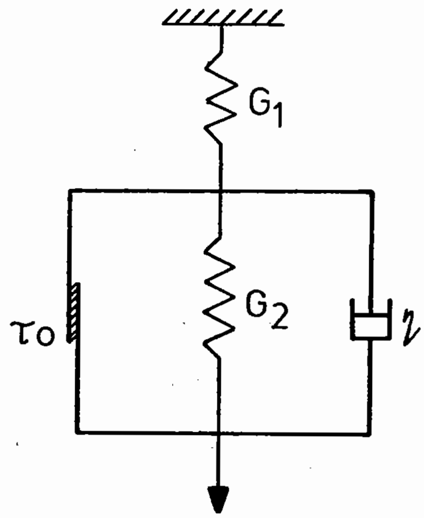


Figure 10.13 SOIL MODEL

(after Murayama and Shibata, 1964)

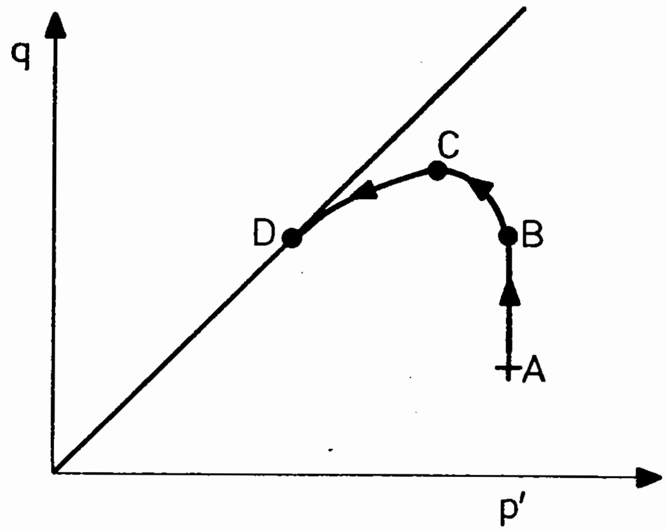


Figure 10.14 IDEALISED STRESS PATH

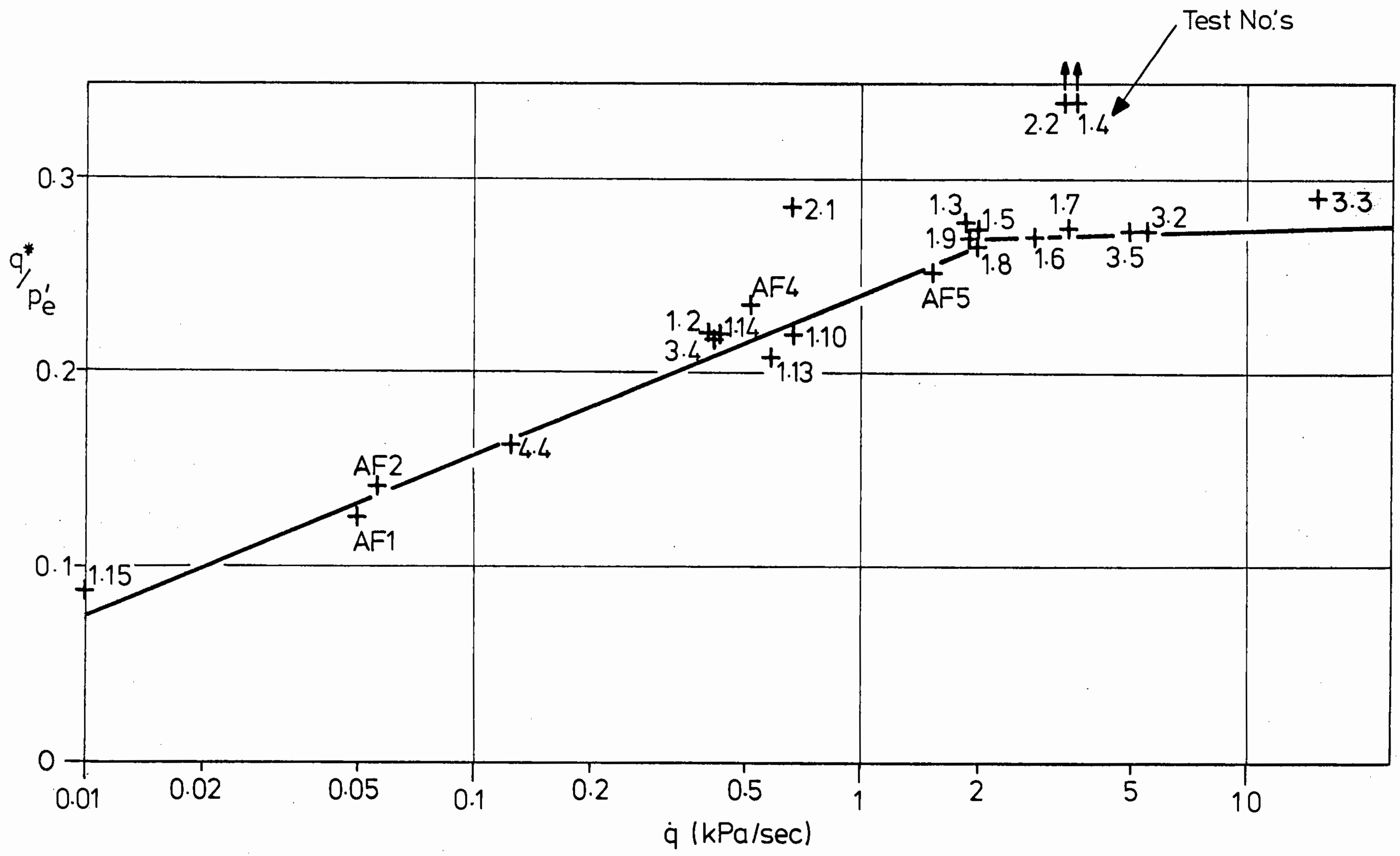


Figure 10.15 VARIATION OF "APPARENT YIELD" POINT IN FAILURE TESTS WITH RATE OF LOADING

in Figures 10.1, 10.3 and 10.5 can be "time" instead of "strain". This gives a constant stress rate ($\dot{q}$) for the linear section AB. At point B, the soil response changes from being predominantly elastic to elasto-plastic and a particular value of q can be defined (at B) (Figures 10.12 and 10.14) as q*, (the value of q greater than q_o, see Figure 10.11) for each value of stress rate. The result is plotted in Figure 10.15. As the failure tests started at different stresses, the deviator stress ordinate (q*) is normalised with respect to p'_e (the p' value of the normal consolidation line for a given specific volume). The abscissa is $\dot{q}$ on a log scale. The graph shows that the extent of the linear portion of the stress-strain or p' - q stress path (AB) varies with the rate at which q is applied. The suggested line in Figure 10.15 has the equation:

$$\frac{q^*}{p'_e} = 0.24 + 0.0825 \log \dot{q} \qquad (10.4)$$

Extrapolation suggests that if the stress was applied at a very slow rate ($\dot{q} < 0.001$ kPa/sec) then no viscous effect would be seen ($q^* = 0$) and the soil would behave as an elasto-plastic material. At high rates of stress application, the graph has a cut-off at q^*/p'_e of 0.275. This indicates that the elastic portion will not allow the soil to exist beyond the failure envelope, because if $q^* > 0.275\ p'_e$ the stress path in p' - q space would have risen vertically to a stress ratio in excess of M = 1 (where $M = q_f/p'_f$). Three tests did not fit the pattern; significantly two of these were the initially overconsolidated specimens.

To extend these ideas to cyclic loading, it is necessary to examine the applied wave form to obtain $\dot{q}$. The three levels of cyclic loading were applied as sine waves of the same period (10 secs) but different amplitudes. If one cycle of load is considered (as shown in Figure 10.16), then, as the loading oscillates about the K_0 line, the loading portion is a quarter cycle and occurs in 2.5 secs (0 to $\pi/2$). For this portion, the Cam Clay Model predicts that the soil will develop permanent strain and pore pressure. For the rest of a cycle ($\pi/2$ to 2π) the soil would be inside the yield curve and only elastic behaviour would occur.

During the period 0 to $\pi/2$, the stress is applied to the sample at a continuously decreasing rate from a maximum at time 0 to zero at 2.5 secs ($\pi/2$). It is possible to calculate instantaneous values of $\dot{q}$ at values of time between 0 to 2.5 seconds from the slope of the sine wave, and also the value of q at this time. The equation of the loading is:

$$q = q_c \sin \omega t \tag{10.5}$$

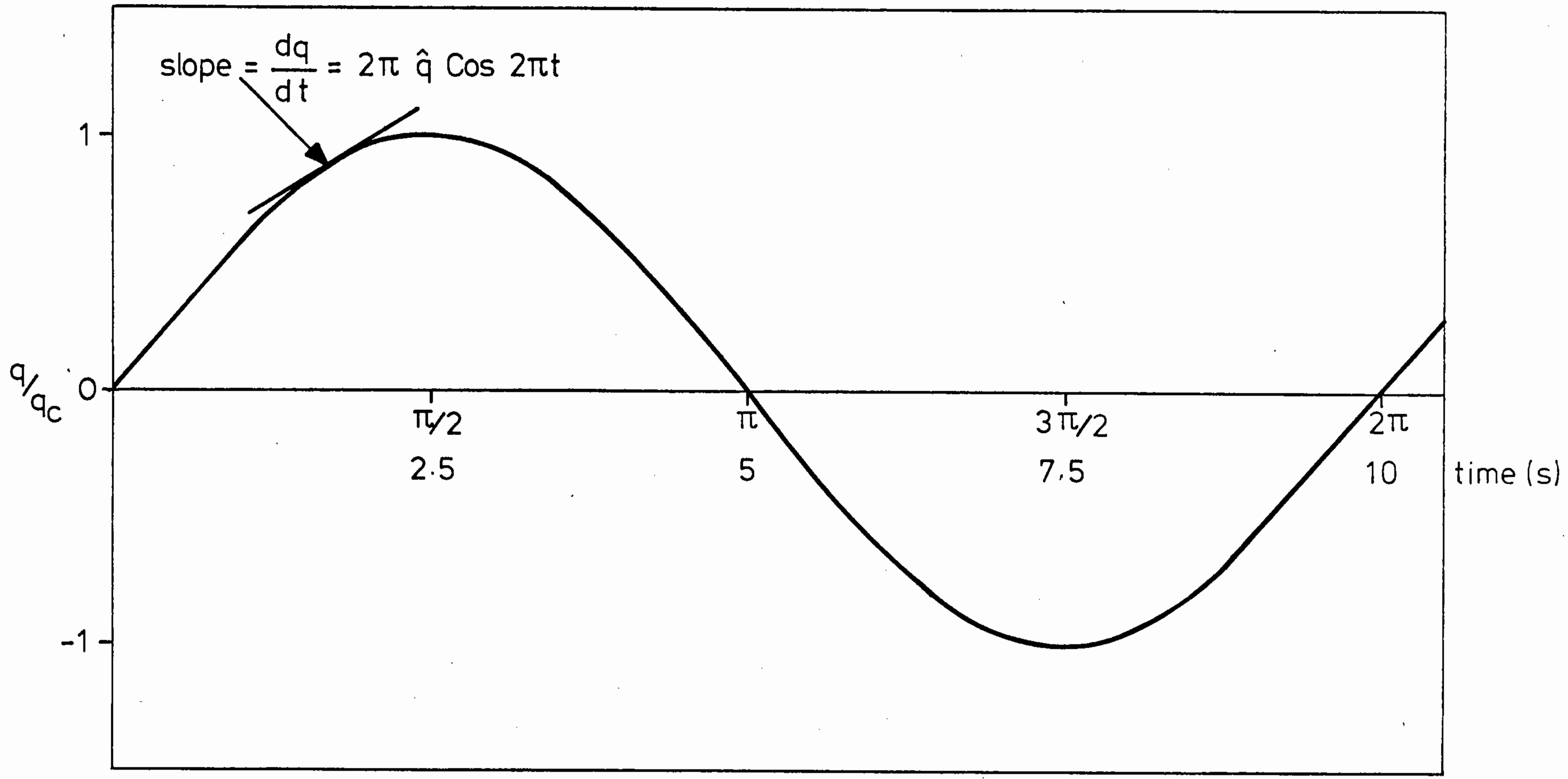
where q_c is the amplitude

and $\omega = 2\pi/10$

The stress rate $\dot{q}$ is obtained by differentiating equation 10.5 with respect to time, i.e.

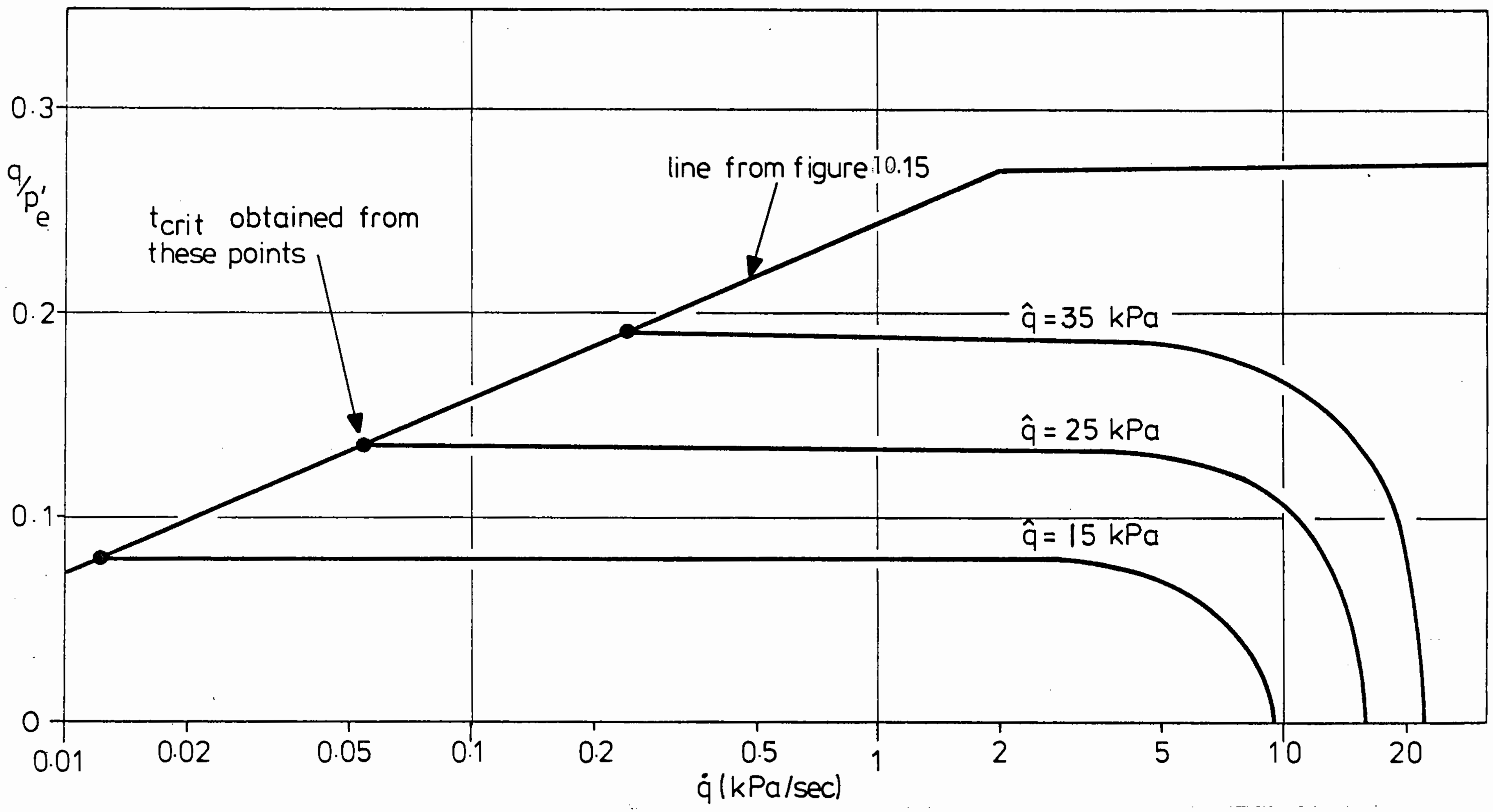
$$\dot{q} = \omega q_c \cos \omega t \tag{10.6}$$

If the values of q and $\dot{q}$ are plotted on a graph of q/p'_e against $\dot{q}$ as on Figure 10.17 and a line drawn through them, a time from the start of the cycle can be obtained when the stress rate is sufficiently slow for the viscous effect to give way to the plastic portion. This occurs at the intersection of the relationship and the line from equation 10.4, giving a q* and a critical time (t_{crit}), which is close to 2.5 seconds for all three stress levels used in this research. This corresponds to the value of q during cyclic loading where the viscous effects no longer predominate.



SINE WAVE CYCLIC LOADING CURVE

Figure 10.16



VARIATION OF STRESS RATE DURING CYCLIC LOADING

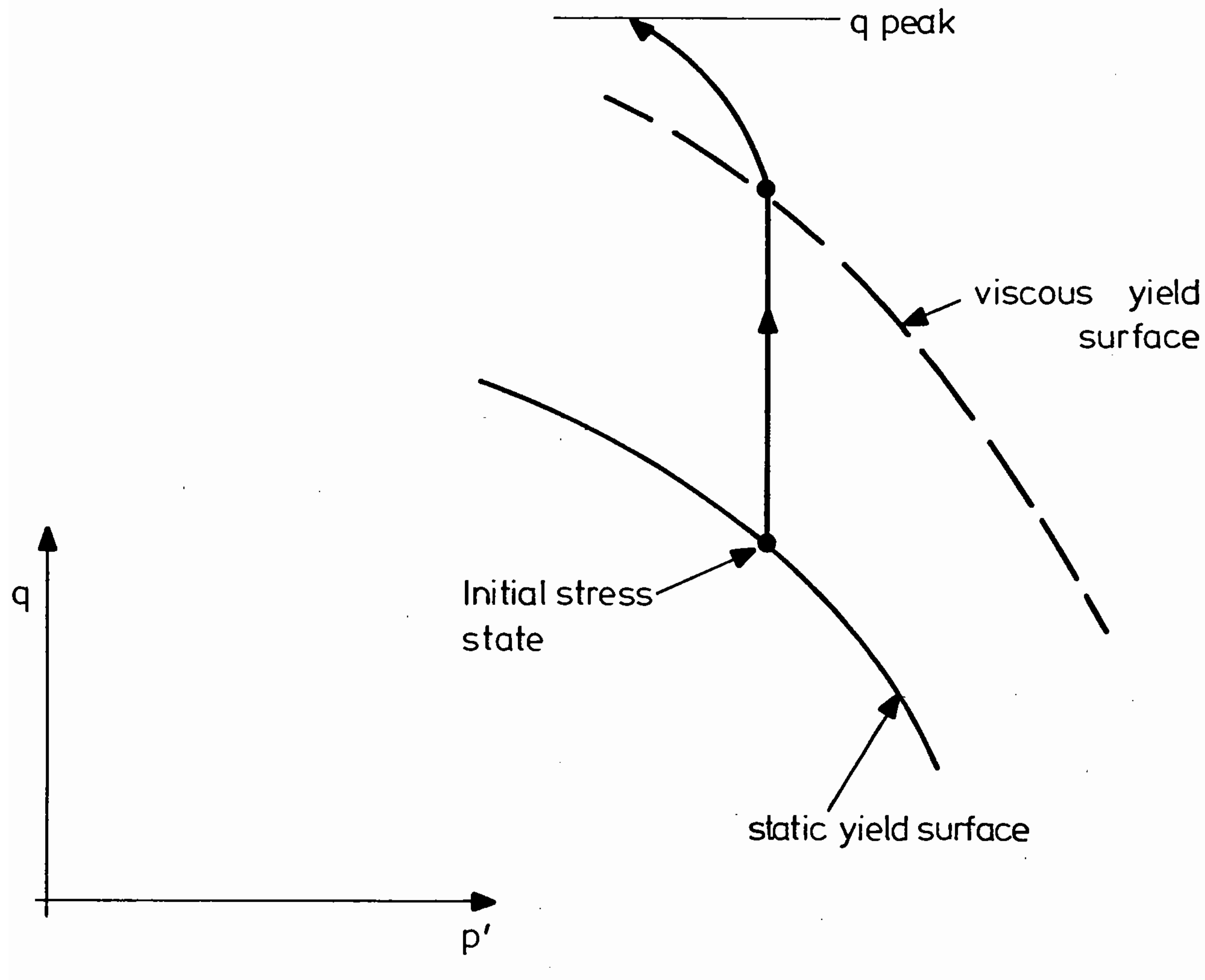
Figure 10.17

10.5 MODIFICATIONS TO THE MODEL

In applying the Carter et al. model, certain modifications were necessary. It was assumed that in a load cycle from time t = 0 to time $t = t_{crit}$ the soil response was controlled by the rate effects which enlarged the yield locus so that it behaved in an essentially elastic manner until the stress reached q*. At this point a "viscous" yield surface was reached and the soil followed the state boundary surface to the peak q as shown in Figure 10.18. On unloading, this "viscous" yield surface contracted as the model predicted. On reloading, there were now two criteria for yield, one was q* and the other the q_{yield} for the new "viscous" yield locus. The larger of the two was used as illustrated in Figure 10.19.

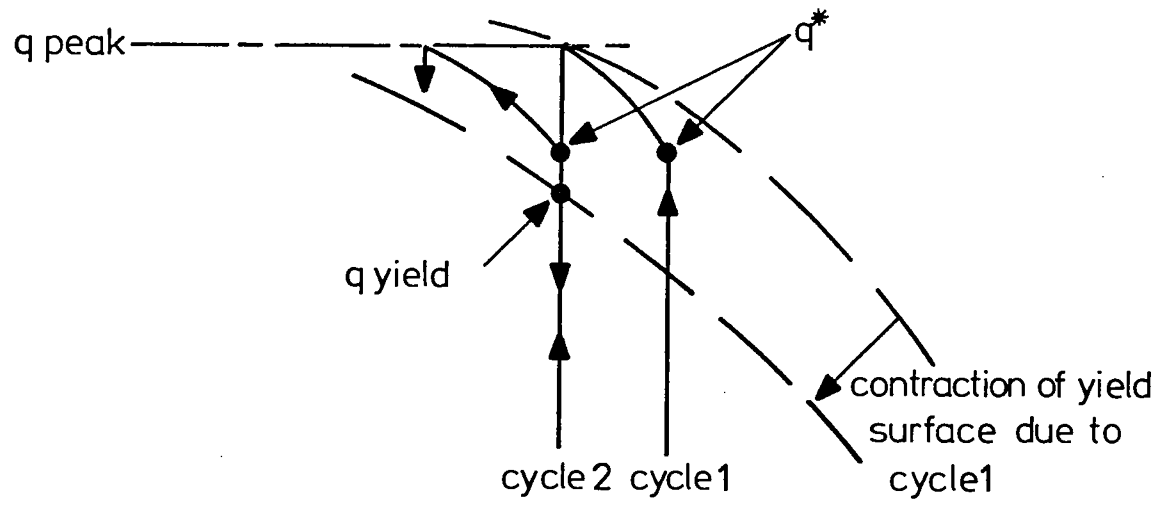
One further modification was allowed. It has already been shown (Figure 10.15) that the value of q* has a cut off which prevents the rate effects taking the soil beyond the critical state line. As the model predicts a build up of pore pressure with number of cycles then unless q* decreases at the same time, it is possible for the soil state to go beyond the critical state line during cyclic loading as shown in Figure 10.20(a). A simple linear variation of q* with pore pressure was used as illustrated in Figure 10.20(b).

It is possible to apply the model to the prediction of the movement of the yield surfaces in stress space and hence the change in pore pressure fairly easily, whereas the strain prediction equations must be applied incrementally and involve longer computation. It was felt that a first application of the model should be restricted to the stress space predictions to see if the model could be of use and a computer program was written for this purpose.

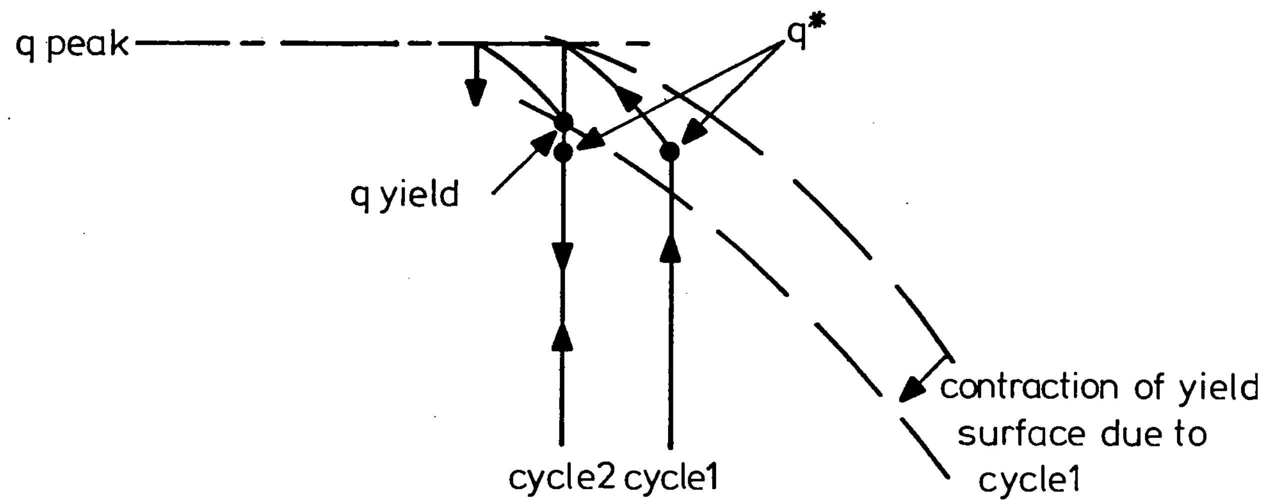


"VISCOUS ELASTIC" EXPANSION OF YIELD SURFACE

Figure 10.18

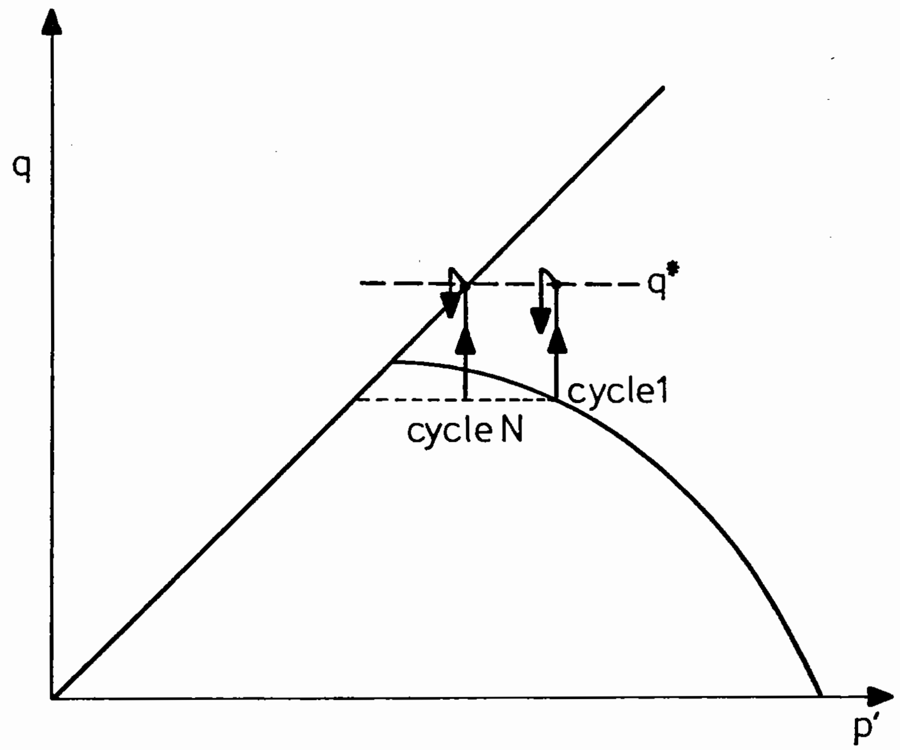


(a) $q^* > q_{yield}$

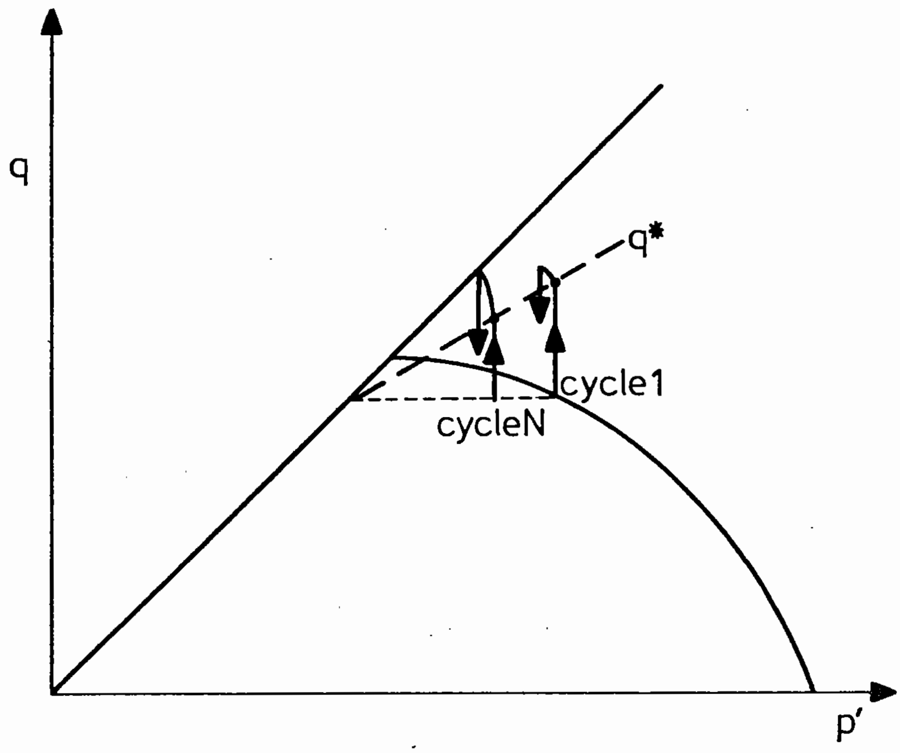


(b) $q^* < q_{yield}$

Figure 10.19 SOIL BEHAVIOUR DURING CYCLIC LOADING



(a) q* constant

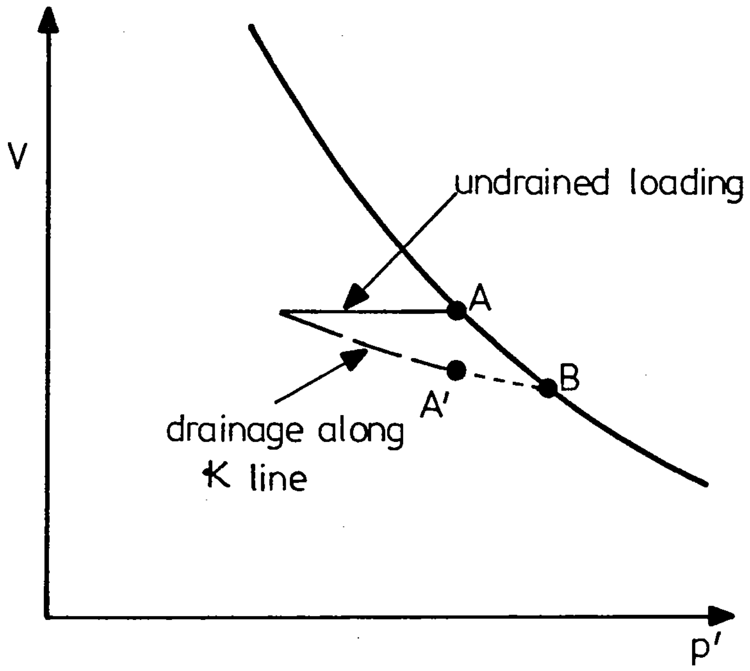


(b) q* varying

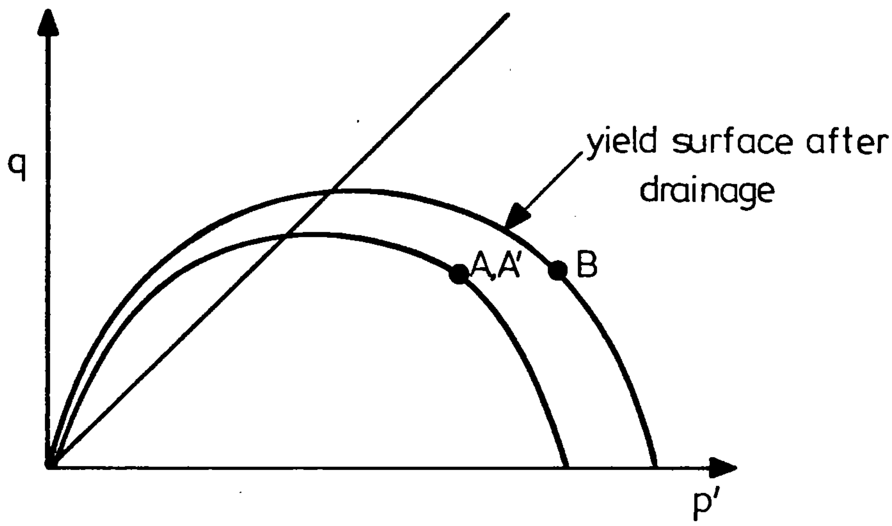
Figure 10.20 CYCLIC LOADING STRESS PATHS

. The program was run using different values of θ for each stress level and the best prediction for all stress levels when compared with the test programme was obtained with a θ of 0.0004. The predictions for the three levels of loading are given in Table 10.1. The table shows the initial p' and q for cycle 0, then the peak values of each cycle of load. The soil survives 184 cycles of the largest loading, 543 cycles of the middle loading and 2085 of the smallest loading. These figures compared with approximately 100, 500 and 2160 cycles to failure in day 1 of the experiments and hence represent reasonable modelling.

If drainage is allowed to take place in an ideal clay that contains pore pressures, the soil will move along a κ line. The tests in the programme were allowed to drain under the initial p' and q before the loading was repeated as shown in Figure 10.21(a). This leaves the soil on a κ line which is, therefore, inside the current yield surface as in Figure 10.21(b). On reloading, the soil might be expected to be stronger as it is yielding for a smaller part of the load cycle. To allow this in the model, an expansion of the "viscous" yield curve was allowed. This expansion meant that, for the first few cycles of loading, the soil state remained completely inside the expanded yield surface and the behaviour was elastic. The unloading part of each cycle still contracted the yield surface as the model in Carter et al., (1979) suggested so that eventually plastic strains began to develop. This effect allowed the soil to survive for more cycles of load before reaching the critical state. Unfortunately, because of the contraction of the yield surface inherent in the model, at the end of the loading it was no larger than at the end of the first period of cyclic loading. Hence, further drainage along a κ line can only expand the yield locus by an amount equal to that obtained from the first drainage period and no further increase in resistance occurs. This is at



(a) Volume change



(b) Change in yield surface

Figure 10.21 SOIL BEHAVIOUR DURING DRAINAGE variance with the observed results where the soil continued to gain strength with each drainage period provided significant pore pressures existed in the soil.

70% level			50% level			30% level		
Cycle No.	q (kPa)	p' (kPa)	Cycle No.	q (kPa)	p' (kPa)	Cycle No.	q (kPa)	p' (kPa)
0	130	183.3	0	130	183.3	0	130	183.3
1	165	183.3	1	155	183.3	1	145	183.3
25	165	181.7	25	155	182.6	25	145	183.1
50	165	179.5	50	155	181.6	50	145	182.7
75	165	177.2	75	155	180.7	100	145	181.8
100	165	174.9	100	155	179.7	200	145	180.1
125	165	172.2	150	155	177.6	300	145	178.4
150	165	169.4	200	155	175.2	400	145	176.6
175	165	166.2	250	155	172.7	500	145	174.9
183	165	165.1	300	155	170.2	600	145	173.1
Soil at critical state on cycle 184			350	155	167.6	700	145	171.3
			400	155	164.9	800	145	169.5
			450	155	161.7	1000	145	165.9
			500	155	158.3	1200	145	162.2
			542	155	155.0	1400	145	158.4
			Soil at critical state on cycle 543			1600	145	154.6
						1800	145	150.7
						2000	145	146.7
						2084	145	145.0
						Soil at critical state on cycle 2085		

MODEL PREDICTIONS FOR CYCLIC LOADING

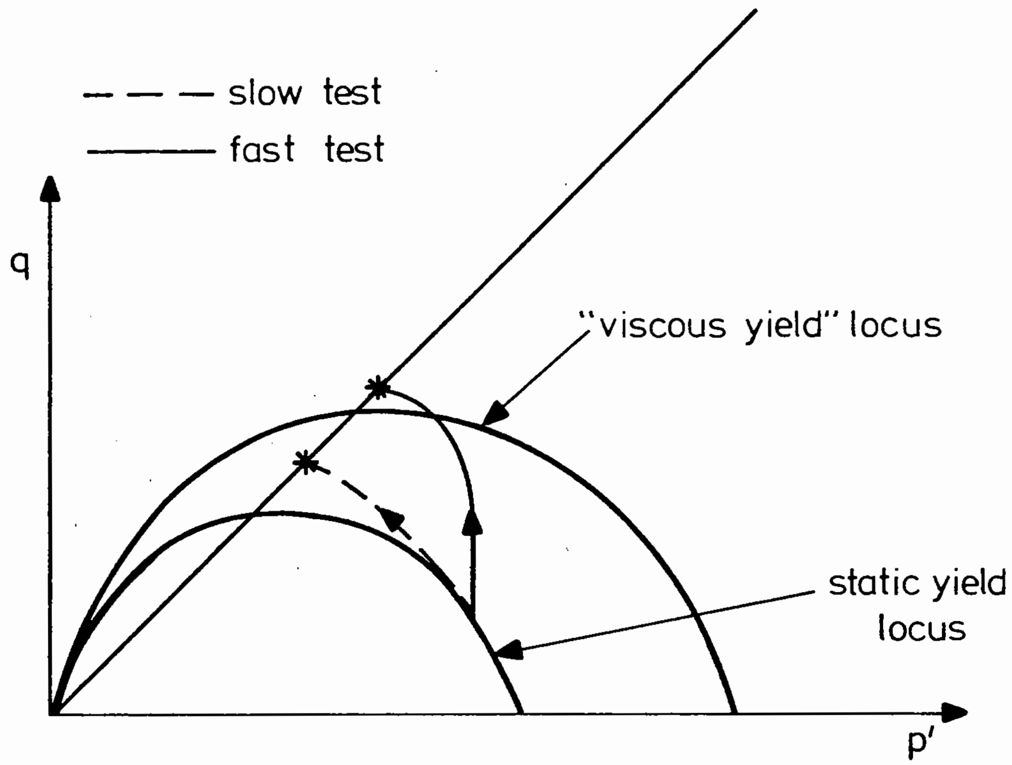
Table 10.1

10.6 FURTHER DEVELOPMENT OF THE MODEL

The model of Carter et al., (1979) was modified as described previously to allow it to be applied to the test results. Even so, the contraction of the yield surface with cyclic loading would not allow the soil to gain strength during each drainage period. It had also become apparent that the cyclic load Cam Clay model could only be realistically applied if viscous rate effects were included. Rate effects were explored, in a preliminary way, in conjunction with Houlsby, (1981).

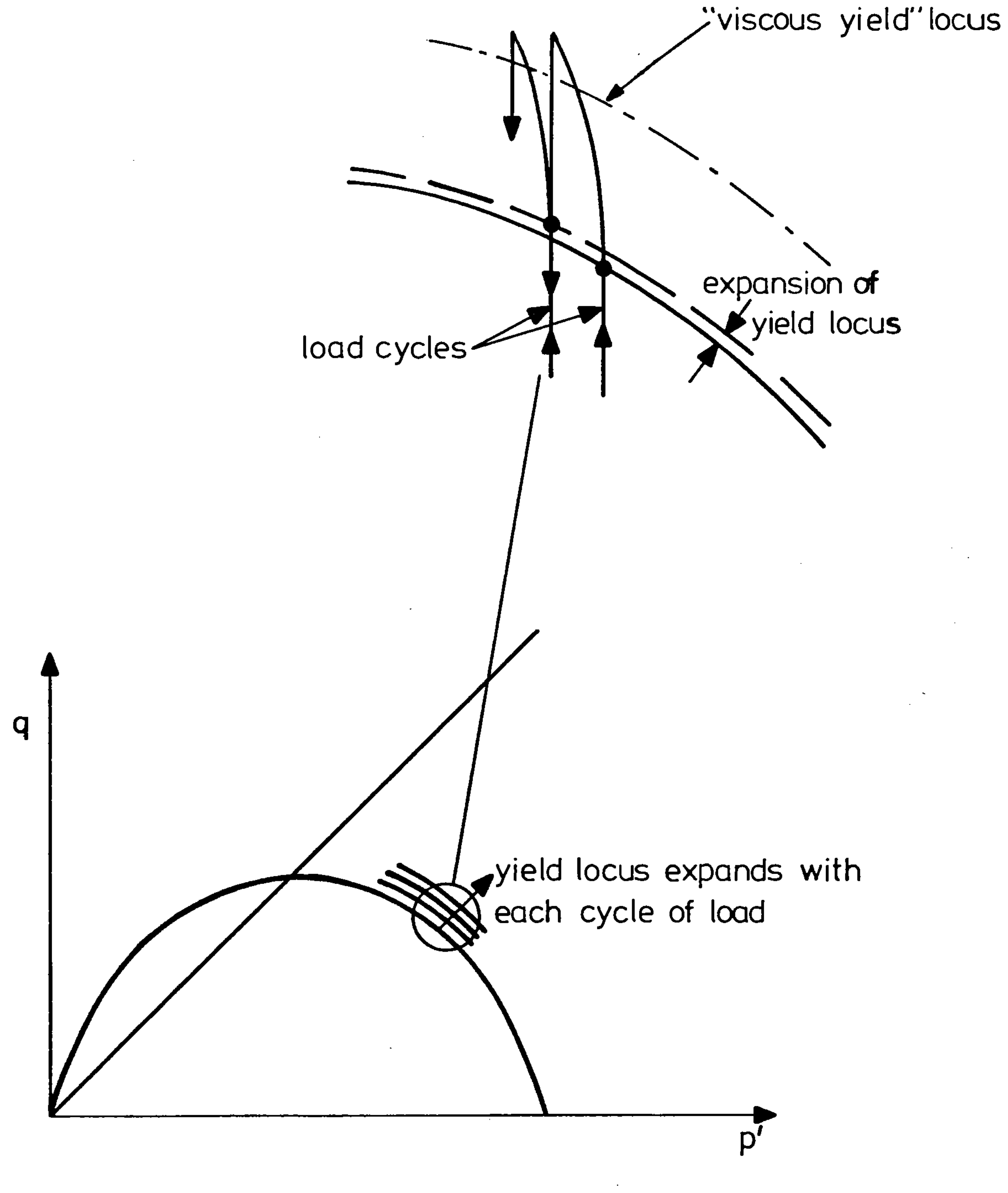
If the failure test is considered first, then the expanded elastic region can only exist if the soil is allowed to develop a small portion of permanent strain. On the basis of work by Been and Sills (1981), and other sources, it was proposed that the yield locus be enlarged from the "static" one by viscous effects as plastic straining occurs. The result, during a shear test, is a smooth transition from zero plastic strain rate as the "static" yield locus is crossed to the full plastic strain rate as an expanded "viscous" yield locus, appropriate to the particular strain rate, is approached as shown in Figure 10.22.

During cyclic loading, each load cycle will cause a small permanent strain whilst the "viscous" yield locus is active, causing the "static" yield surface to expand as in Figure 10.23. If the soil is drained to its initial stresses at the end of loading, the yield surface is further expanded (Figure 10.21). On reloading, the yield surface is larger, due not only to the drainage but also to the incremental increases obtained from cyclic loading already undergone. Given sufficient periods of load and drainage, the yield locus will eventually be as large as the loading and the soil behaviour will degenerate to elastic behaviour with no further permanent deformation.



SUGGESTED STRESS PATH TO FAILURE FOR TEST WITH VISCOUS EFFECTS

Figure 10.22



SUGGESTED YIELD SURFACE BEHAVIOUR WITH CYCLIC LOADING

Figure 10.23

Houlsby has adapted his Modified Cam Clay computer model and states that:-

"The model involves a viscosity which is proportional to preconsolidation pressure and a new constant is introduced which has the dimensions of time. The effect is that, as plastic straining occurs, the yield locus is expanded from the "static locus" with the expansion being proportional to the plastic strain rate". (Houlsby, 1981).

Houlsby's preliminary computer studies are very encouraging. Monotonic loading on isotropically consolidated materials to a level of about the undrained strength at different rates gives less strain and pore pressure development for fast tests than for slow ones, allowing higher q values to be reached at the critical state.

For cyclic loading, the model gives increments of pore pressure and strain with each cycle at a decreasing rate suggesting the soil is tending to equilibrium. On allowing drainage, the strain and pore pressure development on subsequent loading are reduced.

In summary, it should be noted that in contrast with the model developed by Carter et al., (1979) which reduces the size of the yield locus on unloading, the new model proposal expands it on loading. The expansion is proportional to strain rate, whilst the contraction in Carter et al.'s model was independent of strain rate.

CHAPTER ELEVEN

DISCUSSION OF THE RESULTS

The research carried out in this project had four main areas of interest:

(i) To develop a sophisticated triaxial test facility with the ability and techniques to obtain accurate readings.

(ii) To investigate the behaviour of a clay under cyclic loading with particular emphasis on allowing drained rest periods.

(iii) To correlate complex loading patterns with simple load patterns.

(iv) To provide data to help the development of the critical state soil models originally developed at Cambridge.

11.1 EQUIPMENT

The existing equipment at Nottingham already formed a stiff system able to apply well controlled stresses. Improved methods of measuring deformations and loads inside the triaxial cell causing minimum disturbance to the soil, in the restricted space available, were successfully developed.

The problem of measuring deformations was overcome by using miniature LVDT's to monitor axial movements with the soil carrying only the LVDT cores and with non-contact displacement transducers measuring the radial movements. After some modifications to the LVDT connections, this produced good information giving the expected undrained Poisson's ratio of 0.5, based on the permanent strain readings, provided the permanent deformations did not become excessive. The measured resilient strains also gave a Poisson's ratio of 0.5, which was achieved even at high permanent strains, until failure was approached when it became impossible to measure accurate resilient deformations.

A special unit was designed to apply a stress difference to the soil during consolidation so as to maintain K_o conditions. This formed part of a novel system whereby the radial deformation transducers provided the automatic control in a servo-loop with pressure regulators which controlled the deviator stress. The system performed well as a centrally positioned pore pressure probe, able to read values even with the drainage line open showed that a constant effective stress ratio gave the normally consolidated value of K_o. The system enabled the complete consolidation characteristics of the soil to be obtained from one specimen without the time wasting process of applying load increments and waiting for equilibrium. The consolidation results were also free from any large scatter in the plotted points.

Lubricated loading platens were used for all tests to give reduced end restraint. A sandwich of two rubber membranes, glued together by their rims provided a grease reservoir for each end platen. The inclusion of small bleed holes near the centre of each reservoir provided a continuous supply of grease to each platen. Unfortunately, the reservoirs were difficult to manufacture and de-air when filling them with grease. Visual inspection of the platens at the end of a test showed grease to still be present in appreciable quantities but the larger amounts of grease needed tended to reach the filter paper drains and sintered bronze drainage ring which impeded their effective operation.

Pore pressures were previously only measured at the base of the test specimens. To increase the amount of data obtained and to try to accurately measure the rapid cyclic variations, a facility to measure pore pressures in the soil was developed. This involved placement of a transducer in the soil slurry prior to consolidation. This central pore pressure probe gave valuable information during consolidation because it was possible to record the pore pressures in the soil with the drainage line open. During cyclic load testing, the permanent pore pressures measured by the two transducers were usually in close agreement but, like the theoretical and measured values of Poisson's ratio, the difference became significant at high strains, reinforcing the suggestion that the soil was ceasing to act as an element. During failure tests, the central probe consistently indicated that the effective stress state of the soil reached, but did not exceed, the failure envelope obtained for the soil from the isotropic test series. The base probe readings, however, showed inconsistencies between tests with some stress paths exceeding the failure envelope, some reaching it (as did those from the central probe) whilst others fell short.

The cyclic pore pressures were difficult to analyse. If a saturated, undrained soil is subjected to a change in stress, such that it responds elastically, there should be no change in the mean normal effective stress (p'). That is, the pore pressures would mirror a change in confining stress and vary by a third of a change in deviator stress, since $p' = q/3 + \sigma_3'$. However, during tests with cyclic q when the soil was not developing large permanent strains (a predominantly elastic response), it was noted that the cyclic response of the centre probe was not the expected value. To investigate this, some tests were performed where the confining stress was cycled over a frequency range of 0.001 Hz to 1.0 Hz. If gas was present despite the stringent de-airing procedure, the pore pressure response at all frequencies should be affected. It was found that both probes responded well at very low frequencies with the base probe response dropping off at frequencies greater than 0.01 Hz, whereas the centre probe responded well up to 0.1 Hz in all tests. This would discount the presence of gas and indicate that the soil was restrained at the base at frequencies greater than 0.01 Hz. Tests were then performed over the same frequency range by cycling the deviator stress. The cyclic stress level was kept small to avoid large permanent strains developing in a cycle. The base probe showed a large pore pressure response, in some cases abnormally large, whilst the centre probe generally had a reduced response. Changing the rate of loading did not have a significant effect on this behaviour. Finally, the position of the centre probe in the soil was compared with its response. This indicated that the measured cyclic pore pressure was largest when the probe position was closest to the specimen axis. Although there were not enough tests performed to draw a firm conclusion, it does appear that either the soil was not behaving uniformly or that the position and fixity of the transducers influenced their response.

11.2 TEST RESULTS

The preliminary isotropic failure tests established that the slope of the virgin consolidation and critical state lines was the same as that of the anisotropic normally consolidated soil when plotted in V - ln p' space. The failure envelope in p' - q stress space was obtained for both triaxial compression and extension, the slopes of the two lines being related by the expression $(6 \sin \Phi')/(3 \pm \sin \Phi')$. It was found that the failure envelope in compression was also applicable to the anisotropically consolidated soil.

The results of the main test programme showed that anisotropic normally consolidated Keuper marl is extremely sensitive to the rate at which it is loaded. The predominance of the rate dependence of the soil only became apparent as the test programme developed. The peak loads used in the cyclic tests were chosen as proportions of the peak strength of a monotonic test, but this strength was subsequently found to vary considerably with the strain rate. No lower bound to the viscous effects was found for the range of tests performed, however, the soil response during failure tests did suggest a rate of test at which a lower bound on the strength would be obtained. An upper bound was indicated as the value of q on the failure envelope corresponding to the initial p' value of the test, i.e. a vertical effective stress path. As this upper bound was close to the value originally used and would also be correct for a test performed at a rate comparable to the cyclic loading, it is felt that the cyclic stresses used in the programme were realistic. However, the calculated peak strength using the modified Cam Clay model was such that even the lowest cyclic stress level should cause failure in cycle one. Hence, the rate effect allowed significant numbers of load cycles to be applied before failure was approached.

11.2.1 Permanent Response

The major series of tests was performed with one cyclic stress level in each test, the mean stress level being on the K_0 line. At first, the soil showed development of pore pressure and strain in each cycle of load although the amounts were often small, suggesting that for much of a cycle the soil was responding elastically. The slow development of permanent strain and pore pressure meant that the soil typically survived for anything between 100 and 2000 cycles depending on the severity of load. The inclusion of drainage periods had the effect that the soil drained small amounts of water whilst dissipating its pore pressures but showed a large increase in resistance to subsequent loading such that every test, after a sufficient number of drainage periods, survived the loading. The slope of the drainage lines when plotted as specific volume change against mean normal stress showed an average slope that varied between the slope of the over-consolidation line and the normally consolidated line. Generally, the closer the soil was to failure when the testing was halted, the greater the water outflow. However, the change in water content of all specimens was small and the actual water content did not appear to control the amount of increased resistance after drainage. Rather, it was the magnitude of the change in water content that was important. It is possible that at the end of consolidation, before any cyclic loading was applied, the soil achieved a stable structure which could exist over a small range of moisture contents (i.e. a sensitivity). The loading and drainage then caused an expansion of the yield surface, some of which was related to an outflow of water. The drainage occurred under the original consolidation stresses so the soil stress state moved inside the yield surface and the soil developed a small overconsolidation ratio. When the soil behaviour was predominantly an elastic response, the water content was comparable with that of a specimen with an overconsolidation ratio of 1.3 built into it. Further expansion of the yield surface was small as the soil had essentially come to equilibrium under the applied load. A subsequent strength test could then show the same rate effects as a specimen without cyclic loading once the new yield locus had been exceeded.

A series of tests were performed in which the cyclic stress level was applied at three levels, building to a maximum and then waning (storm loading). The soil behaviour was initially similar to that of the first test series but on increasing the stress level, failure was soon reached. After drainage, the soil again survived the imposed loading and, when the stress level was reduced from the maximum, the response appeared to be elastic. Whilst it was possible to relate the three storm load tests with each other, it proved difficult to compare them with the simple load tests.

Some tests were performed about different mean stress levels such that either the maximum or minimum cyclic deviator stress lay on the K_0 line. The low mean test showed a slight elongation due to the stress relief but the development of permanent strain and pore pressure was small. Results from tests with a high mean deviator stress were difficult to interpret. Some showed, at first, that failure occurred earlier if drainage was allowed while eventually gaining strength to survive subsequent loading. There was greater scope for error in these tests as the mean level was first increased before the cyclic load was imposed, leaving the soil at a high stress for short periods that nevertheless were not constant. A possible improvement would be to apply the cyclic stress before slowly increasing the mean level.

One test was performed at 0.01 Hz rather than 0.1 Hz. It was expected that this test would show less resistance to the loading than the faster tests at this stress level. However, this was not the case. A possible explanation could be that the viscous effects were still controlling the soil behaviour for most of the loading portion of a cycle. If the load curve was plotted on Figure 10.17, it would be similar to those shown, being the same size as the smallest illustrated, but shifted towards the origin by one log cycle. It can be seen that for most of the loading, the soil would still be controlled by its viscous response. Of more interest would be a test at this speed at a higher stress level when a significant proportion of the loading would not be controlled by the viscous response.

11.2.2 Resilient Response

The stress path tests of series 4, showed that for elastic response, the effective stress path of undrained, saturated Keuper marl is independent of the applied total stress path for a constant level of cyclic deviator stress. The cyclic pore pressure response indicated that the effective stress path produced a constant p' during a cycle, although there were discrepancies in the pore pressure probes readings. The size and shape of the stress-strain hysteresis loops obtained during these tests were identical for any one set of total stress paths with the same mean and cyclic deviator stress.

The hysteresis loops of specimens tested about the K_0 line showed that permanent strain developed with each cycle of load. Often, the increase in a cycle was too small to record with the plotter and the loops appeared closed. When permanent strain was increasing noticeably with each cycle it developed from just prior to the load peak until the stress was reversed. The resilient response of the test specimens did not conform to the pattern reported by other researchers. Earlier tests on clays have shown a large fall in shear modulus under cyclic loading (Hyde, 1974; Andersen, 1976). These tests were either on isotropic specimens or performed using a simple shear apparatus. This research did not show such a definite pattern of behaviour. Some tests showed high modulus values at cycle 1 but the shear modulus was often constant until failure, at which point it was difficult to measure resilient strains due to the rapid development of permanent strain. Hence, no consistent large strain softening was seen although it must be noted that the range of permanent strains before failure was small and there was scatter in the results during each test which was due to fluctuations in the peak load applied.

11.2.3 Model Developments

Part of this project involved a dialogue with the developers of the Cam Clay soil model. To this end, a model was developed at Cambridge to predict cyclic loading and an attempt was made at Nottingham to apply it to the data obtained in the tests. The model did not perform well as it could neither predict the reduced development of permanent strain and pore pressure at the rate of loading used nor did it give a satisfactory increase in the soil resistance after drainage. However, it may be that this model would better predict the behaviour of slow tests.

An attempt was made by the author to include a rate effect which, following further discussion with the model developers, resulted in a preliminary prediction of soil behaviour under cyclic loading which included viscosity effects. Although the new model still needs developing, it can predict different amounts of strain and pore pressure development depending on the rate of loading. To do this, the model material has to exceed the Cam Clay state boundary surface. Thus, for cyclic loading, the model is able to predict permanent strains and pore pressures with each cycle and give a corresponding expansion of the yield surface. This expansion of the yield surface, coupled with the expansion that occurs with drainage will allow significant strengthening to occur. This process continues with further cyclic loading. In addition, if the cyclic stress level is varied during undrained loading and the soil survives the maximum level, then when the stress level is decreased, the model will show elastic behaviour if sufficient yield surface expansion has occurred. This development has the potential for predicting soil behaviour at the rates of loading encountered in the field.

CHAPTER TWELVE

CONCLUSIONS

The work set out in this thesis was designed to develop a sophisticated triaxial test facility, to investigate the behaviour of Keuper marl subjected to undrained loading and drained rest periods and to help in the development of a model for cyclic loading. The main conclusions of the work are listed below.

12.1 Equipment

(a) The deformation measuring system described in Chapter Three worked well giving accurate readings of small strains which showed that the saturated undrained soil had a Poisson's ratio of 0.5.

(b) A novel system to apply K_o conditions to the soil was developed. This has application to site samples as they could be correctly reconsolidated to their pre-consolidation pressure.

(c) Lubricated ends were provided by grease reservoirs. These supplied grease to the end platens throughout the test but were difficult to use.

(d) The soil specimen in a triaxial cell only acted as an element at small values of permanent strain.

(e) Pore pressures were measured in the soil specimen using a centre probe whilst the drainage line was open, providing useful information during consolidation. The technique also has application if drained tests are desired.

(f) At small strains and a loading frequency of 0.1 Hz, permanent pore pressures could be measured at either the centre or base with little error. During a subsequent strength test to failure base pore pressure measurements were inadequate.

(g) Due to end restraint, the base reading of cyclic pore pressures contained errors. The base readings were small when the confining pressure was cycled and tended to be overlarge when the deviator stress was cycled.

(h) The centre readings of cyclic pore pressure were sensitive to changes in confining stress. The response to changes in deviator stress seemed to depend on the transducer position.

(i) The slurry preparation technique employed produced consistent, saturated soil specimens.

12.2 TEST RESULTS

12.2.1 Permanent Response to Cyclic Loading Tests

(a) The response of Keuper marl to cyclic deviator stress at 0.1 Hz was dominated by viscous effects.

(b) There was a small increase in permanent strain and pore pressure in each load cycle until failure was approached or an equilibrium state was achieved. The increment in cycle one was not significantly different from that of subsequent cycles.

(c) It required one drainage period for a specimen loaded at the lowest stress level to survive. Specimens loaded at the higher levels generally required three drainage periods.

(d) After drainage, the number of cycles required to produce the same permanent shear strain and pore pressure were significantly increased from what was needed before.

(e) The change in water content of a specimen during a drainage period was small, but the assoicated change in soil response was large.

(f) It was not possible to predict the storm load response from the simple cyclic load tests, although the initial response at the low stress level was similar for both types of test.

(g) The soil response after five loading periods was similar to that of soil overconsolidated to a ratio of 1.33, provided the K_0 normally consolidated stress ratio was preserved during the swell back phase.

(h) Permanent strain only developed over the portion of a load cycle from just prior to the peak load until the stress was reversed.

12.2.2 Resilient Response

(a) The resilient response of Keuper marl during cyclic loading did not show a viscous component.

(b) The resilient shear modulus of anisotropic normally consolidated Keuper marl showed little variation with the development of permanent pore pressure, it tended to a value of 100 MPa.

(c) The stress-strain loops obtained did not vary greatly during non-failure loading. The energy lost per cycle was approximately constant for a given cyclic deviator stress.

(d) When the response was predominantly elastic, the application of a range of total stress paths produced a unique effective stress path. The effective stress path was such that the mean normal effective stress was constant during a cycle.

12.2.3 Strength Tests

(a) The viscous response of Keuper marl showed an upper bound of strength characterised by the equation:

$$q_{max} = Mp'_o$$

where q is the maximum deviator stress and p'_o the initial mean normal effective stress.

(b) A lower bound for viscous behaviour is described by the equation:

$$q^*/p'_e = 0.24 + 0.0825 \log \dot{q}$$

when $q^*/p'_e = 0$. That is $\dot{q} = 0.0012$ kPa/sec.

(c) The failure envelope established from isotropic tests proved to be applicable to the anisotropic specimens.

(d) Keuper marl can survive transient loads in excess of the static strength obtained from slow monotonic tests.

(e) The strain to failure of anisotropic normally consolidated Keuper marl was small. The peak deviator stress was reached within 0.5% strain.

(f) The strain required to develop the peak shearing resistance was independent of the rate of strain.

12.3 MODEL DEVELOPMENTS

(a) The model developed by Carter et al., (1979) used a contracting yield surface to permit plastic behaviour during cyclic loading. It was incapable of predicting the behaviour of Keuper marl under cyclic load at 0.1 Hz.

(b) A new model based on the Cam Clay critical state concept has been developed in conjunction with Houlsby (1981). It can deal with viscous effects and will predict the behaviour of Keuper marl under cyclic loading at 0.1 Hz. The model involves allowing an expansion of the yield surface with each load cycle.

CHAPTER THIRTEEN

RECOMMENDATIONS FOR FURTHER WORK

This research dealt almost exclusively with normally consolidated soil. Lightly and heavily overconsolidated soil are also encountered in practice and it is desirable that they be investigated under similar loading regimes.

The behaviour of Keuper marl was discussed qualitatively rather than quantitatively as due to the time consuming nature of the test procedure, the number of specimens was not large. A continuation of the testing programme would result in a clearer distinction of the soil's elastic, plastic and viscous response.

Repeated loading of isotropically consolidated specimens is rarely considered in relation to time effects, possibly because it is less obvious due to the higher strains and pore pressures developed before failure compared with anisotropic tests. As much laboratory testing is done with isotropic specimens, greater knowledge of the behaviour with time of loading is required.

The rate effect seen to influence the behaviour of normally consolidated anisotropic soil was very great. Further research is necessary to investigate whether the soil can ever by considered as purely elasto-plastic.

The stress-strain response of anisotropic soil during strength tests is very different from its isotropic response. This has been described as a soil sensitivity. Further work is required to discover whether it is a time effect or whether other factors such as voids ratio are important. The equipment is capable of applying negative deviator stress and the triaxial extension region of stress space is still largely unexplored by research into clay behaviour.

It was difficult to investigate the soil response to different stress paths. More information on the relative importance of the total stress path and effective stress path would be obtained for a saturated clay if the speed of test was slower and a means of controlling the effective stress was used. This could be achieved by cycling the pore pressures through the back pressuring system.

Cyclic pore pressure measurement proved difficult to resolve. The relative responses of the centre and base probes still requires explanation. Further effort to determine correct transient values is required.

In view of the good agreement between the observed behaviour and the new model, further effort is needed to develop the model to see if it can be used for other soils.

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APPENDIX A

CALIBRATIONS

A.1 Transducers

Date	Load Cells		Cell Pressure Transducer		Base Pore Pressure Transducer	
	Volts/100 kPa*		Volts/100 kPa		Volts/100 kPa	
	1	2	1	2		
31. 7.79	1.578	1.779	1.842	1.831	1.092	1.089
22.11.79	1.552	1.739	-	-	-	-
16. 6.80	1.592	1.748	1.850	1.845	1.095	1.092
4. 1.81	1.576	1.752	-	-	-	-
2. 6.81	1.584	1.760	1.848	1.841	1.093	1.090

Date	Centre Pore Pressure Transducer				Axial Strain LVDT		Radial Strain Transducer	
	Volts/50 kPa				mm/Div		mm/Div	
	1	2	3	4	1	2	1	2
31. 7.79	.714	.720	.712	.715	.847	.849	.169	.171
22.11.79	-	-	-	-				
16. 6.80	.718	.718	.714	.716	.848	.846	.170	.169
4. 1.81	-	-	-	-				
2. 6.81	.716	.717	.712	.718	.849	.847	.168	.170

Load cells calibrated with a proving ring.

Cell pressure and pore pressure transducers were calibrated by applying known air pressure to them in the triaxial cell.

The LVDTs and radial transducers were calibrated in a non-rotating head micrometer.

*Assumes an area of 47.78 cm^2 (diameter of specimen 78 mm).

A.2 THE LOAD SYSTEM

The system stiffness was approximately 0.6 mm per 100 kPa change in deviator stress provided the cell pressure was 150 kPa or more. If the deviator was cycled at low stresses with a low confining stress, large deformations occurred in the silicone grease of the lubricated ends. This correction was applied to all tests using the external LVDT to measure axial deformation.

A.3 THE CONSOLIDATION UNIT

The consolidation top used air pressure acting over the area of a bellofram to counter the upthrust from the cell pressure and provide the vertical stress during consolidation. The effective areas of the bellofram were supplied by the manufacturer. Thus, for an applied air pressure, the resultant force F is given by:

$$F = \sigma_{con} A_{B1}$$

where σ_{con} is the air pressure

A_{B1} is the area of the bellofram on which the air acts

The force imparted to the soil (P) is the consolidation force minus the upthrust from the cell pressure:

$$P = F - \sigma_{cell} A_{B2}$$

$$= \sigma_{con} A_{B1} - \sigma_{cell} A_{B2}$$

where σ_{cell} = cell pressure

A_{B2} = area of bellofram over which the cell pressure acts

The vertical force on the soil, V, is given by:

$$V = P + \sigma_{cell} A_s$$

where A_s = area of soil sample

The effective vertical stress on the soil (σ_v')

$$= \sigma_{con} \frac{A_{B1}}{A_s} + \sigma_{cell} \left(1 - \frac{A_{B2}}{A_s}\right) - \sigma_{BP}$$

where σ_{BP} is the back pressure in the soil pore water.

Similarly, the effective horizontal stress $\sigma_H' = \sigma_{cell} - \sigma_{BP}$.

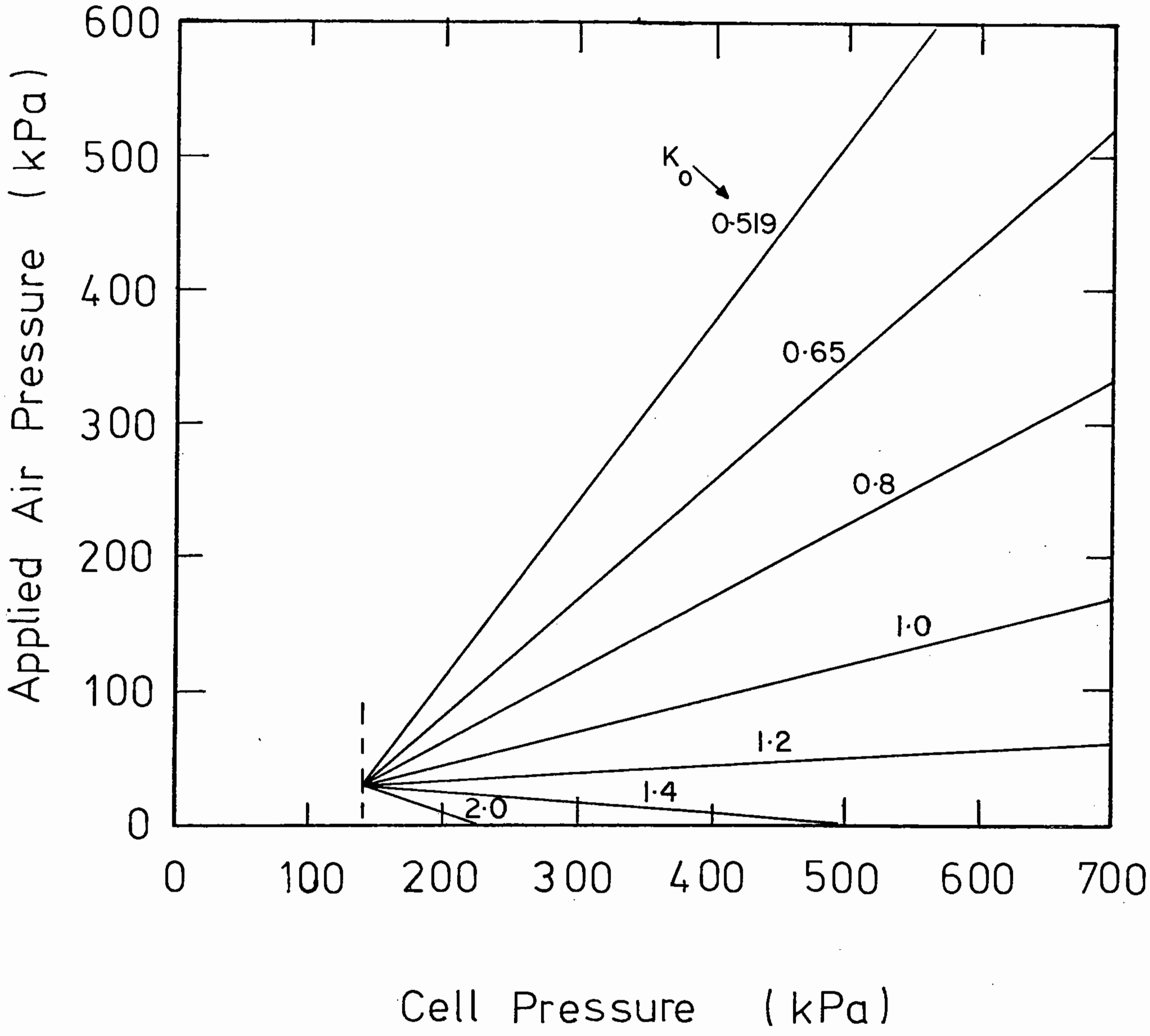
K is the ratio σ_3'/σ_1'

$$K = \frac{\sigma_{cell} - \sigma_{BP}}{\sigma_{con} \frac{A_{B1}}{A_s} + \sigma_{cell} \left(1 - \frac{A_{B2}}{A_s}\right) - \sigma_{BP}}$$

Rearranging gives:

$$\sigma_{con} = \frac{A_s}{A_{B1}} \left[\frac{\sigma_{cell} - \sigma_{BP}}{K} - \sigma_{cell} \left(1 - \frac{A_{B2}}{A_s}\right) + \sigma_{BP} \right]$$

Given that A_{B1} = 4097 mm^2, A_{B2} = 1000 mm^2 and σ_{BP} = 140 kPa, then taking consolidation under K_o conditions, gives a constant A_s = 4778 mm^2. The value of K_o for the Keuper marl is 0.52 when normally consolidated. Figure A.1 shows the air pressure required for consolidation at different cell pressures with contours of K plotted on it. When K = 1.0, the sample



AIR PRESSURE REQUIRED FOR CONSOLIDATION UNDER VARIOUS K_0 CONDITIONS

Figure A.1

is under isotropic conditions and the air pressure is sufficient to balance the cell pressure only.

APPENDIX B

MATERIAL PROPERTIES

The Keuper marl used in this project was reconstituted as a slurry from all material passing the 150 μm BS sieve. The grain size curve is given in Figure B.1. The grading was obtained by the pipette method.

A series of standard tests were performed to obtain the basic classification data listed below:

Liquid Limit	30%	(Cone penetrometer)
Plastic Limit	17%	
Plasticity Index	13%	
Specific Gravity	2.65	(Gas Jar test)
Permeability	2.5×10^{-7} mm/sec	(Falling head permeameter)

The permeability of the filter paper drains was measured in the triaxial cell. The equipment was arranged as shown in Figure B.2. A standpipe was connected to the specimen using a tube to the pore pressure transducer lead exit in the top cap. Three layers of filter paper were put between the top cap and the soil so that water could flow to the side drains. The soil was first consolidated isotropically under a back pressure. When the soil came to equilibrium, the standpipe and collection reservoir were pressurised to the same back pressure as the drainage line and the cocks were opened. Measurements of the change in head of water with time were taken. It was assumed that the flow was predominantly through the filter paper and a permeability of about 4×10^{-5} mm/sec was calculated. This is 160 times more permeable than the clay. When the test was repeated without the side drains, no flow occurred as the bottom platen formed a barrier between the drainage line and the soil.

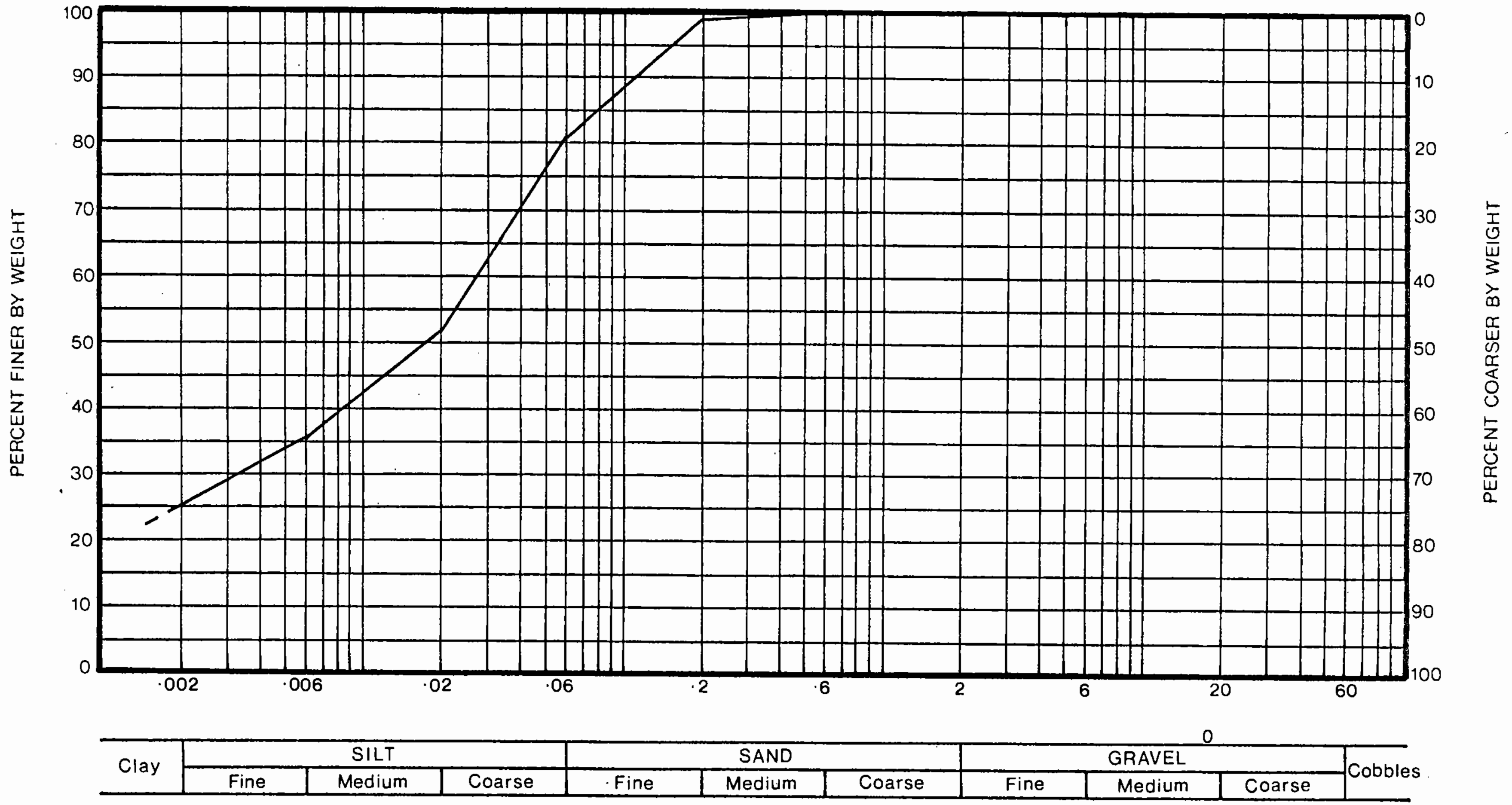
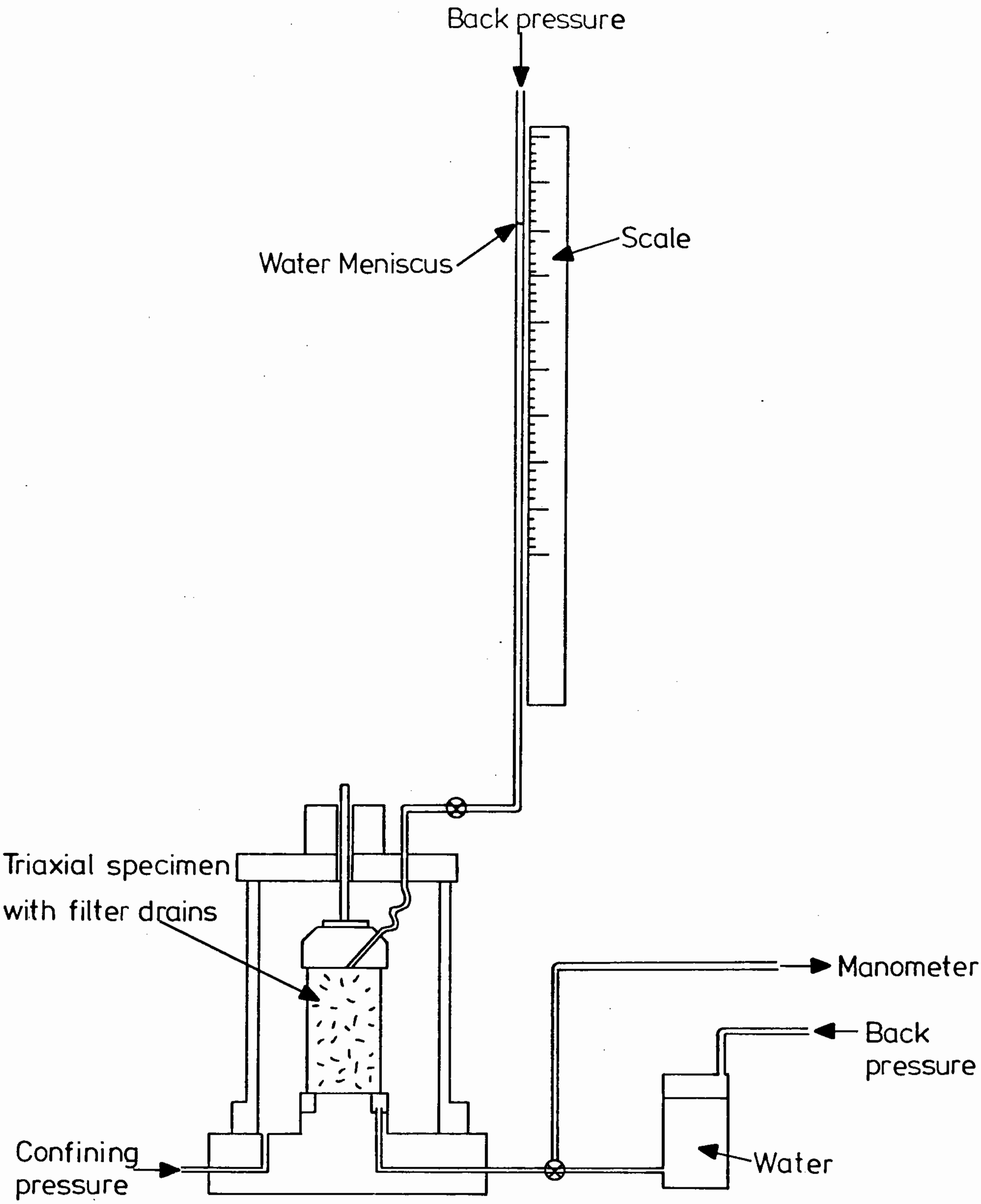


FIGURE BI: GRAIN SIZE CURVE - KEUPER MARL



APPARATUS FOR MEASUREMENT OF PERMEABILITY OF FILTER PAPER DRAINS

Figure B.2

APPENDIX C

ONE DIMENSIONAL CONSOLIDATION WITH RADIAL FLOW

An element of soil from a triaxial specimen is shown in Figure C.1. The flow through the soil is controlled by Darcy's equation:

$$v = ki \tag{C.1}$$

where k is the coefficient of permeability

and i is the hydraulic gradient

The flow into the element is a function of r and θ:

$$v_r = f_n(r,\theta) \tag{C.2}$$

where r and θ are defined in Figure C.1.

If the element is δr thick, then the flow out of the element is given by:

$$v_{r+\delta r} = f_n(r+\delta r,\theta) \tag{C.3}$$

Expanding this:

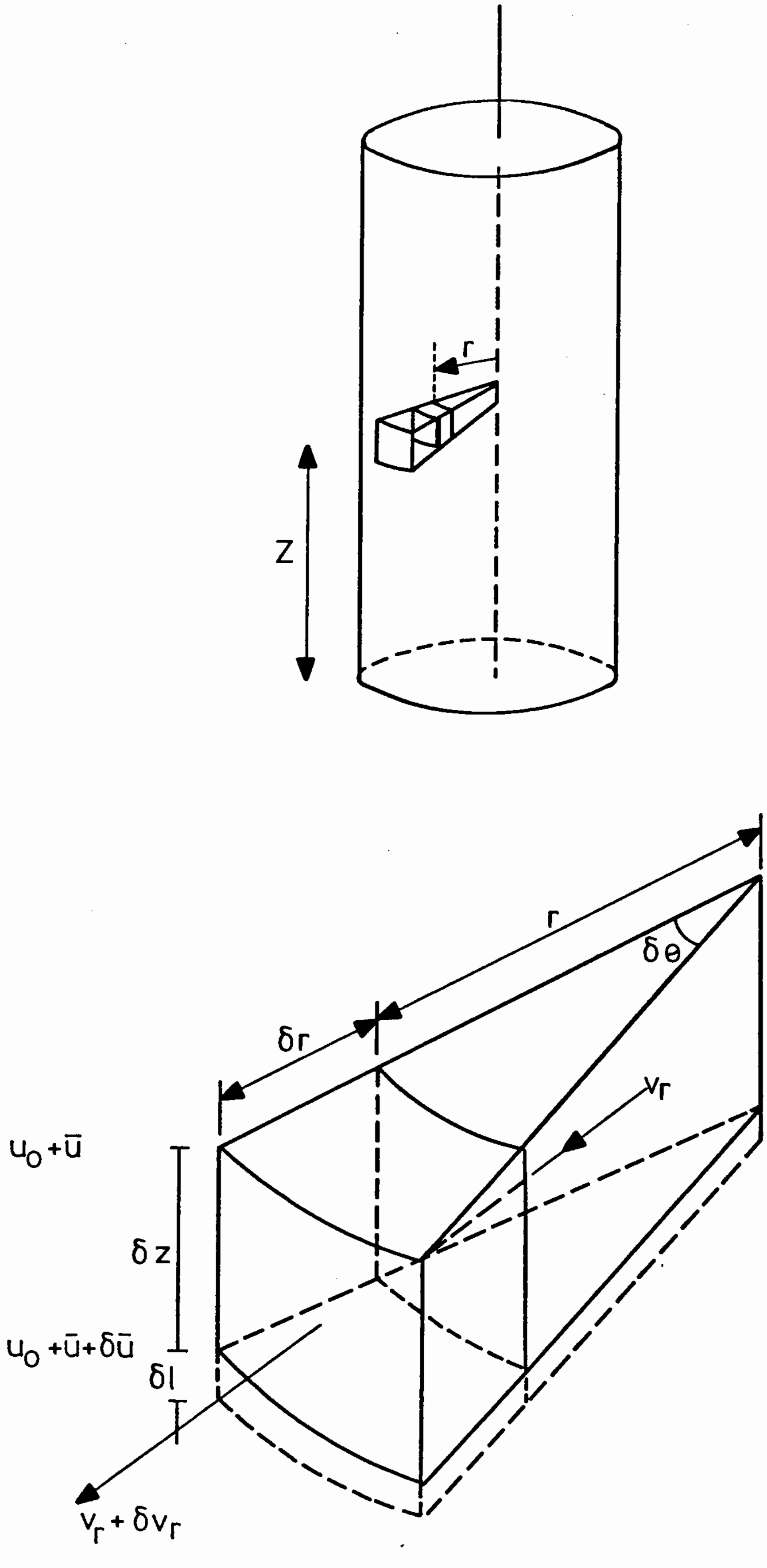
$$v_{r+\delta r} = v_r(r,\theta) + \frac{\partial v_r}{\partial r}(r,\theta)\delta r + \frac{1}{2!}\frac{\partial^2 v_r}{\partial r^2}(r,\theta)\delta r^2 + 0(\delta r^3)$$

As δr is small, δr^2 and higher terms tend to zero:

$$v_{r+\delta r} = v_r(r,\theta) + \frac{\partial v_r}{\partial r}(r,\theta)\ \delta r \ \Big| \underbrace{+ \frac{1}{2!}\ \frac{\partial^2 v_r}{\partial r^2}(r+\mu\delta r,\theta)\delta r^2}_{\longrightarrow 0} \qquad 0 \leq \mu < 1$$

The mass flow into the element:

$$\dot{M}_{in} = v_r\ r\delta\theta\delta z = -k\frac{\partial h}{\partial r}\ .\ r\delta\theta\delta z \tag{C.4}$$



WATER FLOW THROUGH AN ELEMENT OF SOIL

Figure C.1

The mass flow out:

$$\dot{M}_{out} = \left(v_r + \frac{\partial v_r}{\partial r}\delta r\right) r\delta\theta\delta z$$

$$= \left[-k\frac{\partial h}{\partial r} + \frac{\partial}{\partial r}\left(-k\frac{\partial h}{\partial r}\right)\delta r\right] r\delta\theta\delta z \qquad (C.5)$$

Therefore, the net flow of water from the element is:

$$\dot{M}_{out} - \dot{M}_{in} = -k\frac{\partial^2 h}{\partial r^2} r\delta r\delta\theta\delta z \qquad (C.6)$$

The head of water:

$$h = z + \frac{u_{(r,z)}}{\gamma_\omega} \qquad (C.7)$$

For a given z, differentiating C.7 gives:

$$\frac{\partial h}{\partial r} = \frac{1}{\gamma_\omega}\frac{\partial u}{\partial r}$$

and

$$\frac{\partial^2 h}{\partial r^2} = \frac{1}{\gamma_\omega}\frac{\partial^2 u}{\partial r^2} \qquad (C.8)$$

From C.6 and C.8 the net rate of flow from the element

$$= -\frac{k}{\gamma_\omega}\frac{\partial^2 u}{\partial r^2} r\delta r\delta\theta\delta z \qquad (C.9)$$

The rate of change of voids:

$$= \frac{\partial}{\partial t}\left(\frac{e}{1+e}\right) r\delta r\delta\theta\delta z$$

$$= \frac{r\delta r\delta\theta\delta z}{1+e}\frac{\partial e}{\partial t} \qquad (C.10)$$

During consolidation, if the soil particles are incompressible, equation C.9 equals C.10:

$$\therefore \quad -\frac{k}{\gamma_\omega}\frac{\partial^2 u}{\partial r^2} = \frac{1}{1+e}\frac{\partial e}{\partial t} \tag{C.11}$$

$$\text{But} \quad m_v = \frac{1}{1+e}\frac{\partial e}{\partial \sigma'} \tag{C.12}$$

Therefore;

$$\frac{k}{m_v \gamma_\omega}\frac{\partial^2 u}{\partial r^2} = -\frac{\partial \sigma'}{\partial e} \cdot \frac{\partial e}{\partial t} \tag{C.13}$$

$$\text{Let} \quad c_v = \frac{k}{m_v \gamma_\omega} \qquad c_v \frac{\partial^2 u}{\partial r^2} = -\frac{\partial \sigma'}{\partial e} \cdot \frac{\partial e}{\partial t} \tag{C.14}$$

This is the same equation that Terzaghi developed for one-dimensional consolidation but with flow radially instead of vertical.

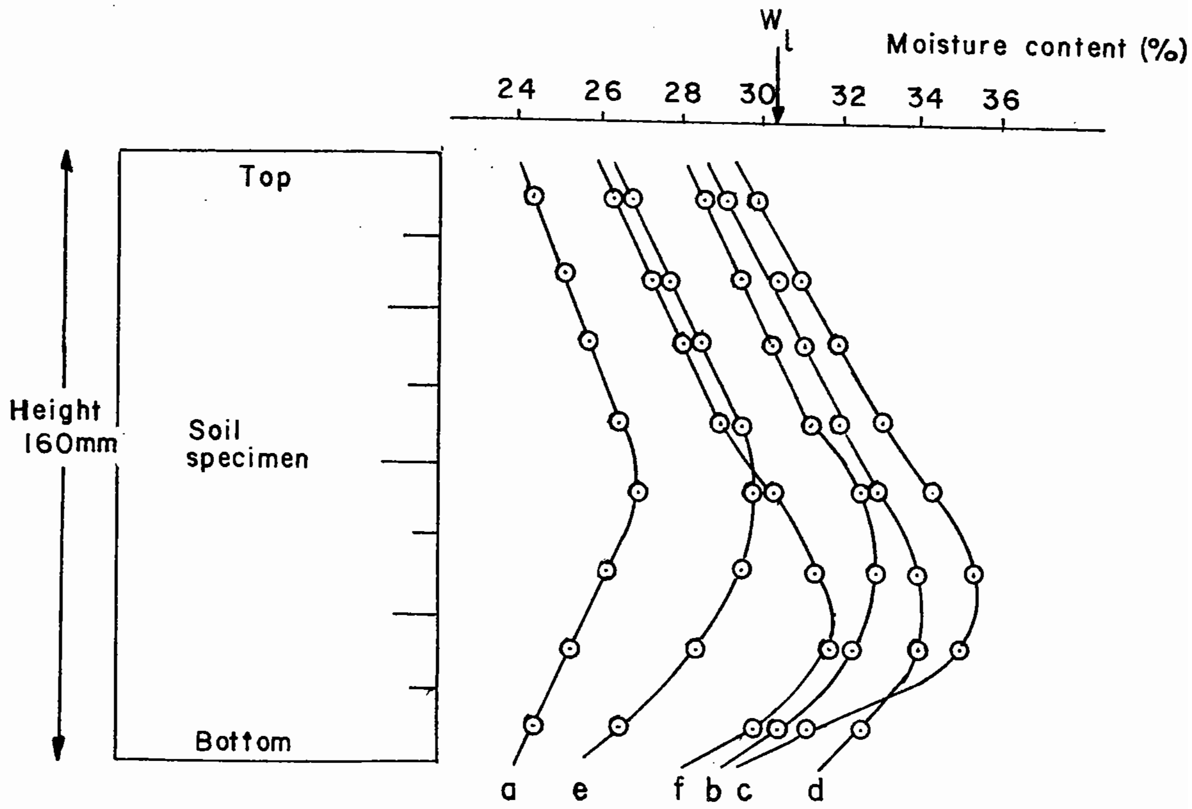
The solution of this equation is a Fourier series and, with appropriate boundary conditions, factors relating time with amount of consolidation can be obtained.

APPENDIX D

MINIMUM PRESSURE REQUIRED TO PRODUCE SOIL SPECIMENS

The pressure required to produce a specimen which could be built into the triaxial cells was determined. Six specimens were subjected to various vertical pressures in the slurry moulds and left for either 8 or 13 days. They were then extruded, cut into eight horizontal sections and the moisture contents found.

The results are plotted in Figure D.1 and a vertical pressure of 70 kPa applied for 14 days was chosen to produce specimens for the research programme.



Specimen	Vertical pressure (kPa)	Time (Days)
a	125	13
b	60	8
c	45	13
d	35	8
e	70	13
f	70	8

MOISTURE CONTENT VARIATION IN SOIL SPECIMENS

Figure D.1

APPENDIX E

DETAILED TEST DATA

The following pages give a concise listing of the results of the repeated load tests performed. All stresses are quoted in Kilopascals (kPa) and all strains in percent (%).

A key to the column headings is given below:-

N	cycle number
P_m	total mean normal stress
P_r	total cyclic normal stress
q_m	mean deviator stress level
q_r	cyclic deviator stress
U_B^p	permanent pore pressure measured by base probe
U_C^p	permanent pore pressure measured by centre probe
U_B^r	cyclic pore pressure measured by base probe
U_C^r	cyclic pore pressure measured by central probe
ε_s^p	permanent shear strain
ε_v^p	apparent permanent volumetric strain
ε_s^r	resilient shear strain
ε_v^r	apparent resilient volumetric strain
A.G.L.	axial gauge length
R.G.L.	radial gauge length

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
					TEST NO 1.1 & 4.2		U.C.R. 1					
					A.G.L. 42.74		R.G.L. 39.02					
1	184.37	16.64	133.12	49.92	0.42	2.30	0.79	6.69	0.0013	0.0020	0.0162	-0.0011
50	184.36	16.59	133.08	49.77	0.39	2.89	0.83	6.56	0.0387	0.0118	0.0190	-0.0016
100	184.49	16.60	133.48	49.81	0.37	4.19	0.64	6.45	0.0697	-0.0100	0.0178	0.0010
200	184.36	16.39	133.07	49.16	-0.19	5.71	0.84	6.46	0.0845	-0.0008	0.0183	-0.0010
300	184.34	16.25	133.01	48.75	0.25	7.03	0.53	6.33	0.1000	0.0061	0.0236	-0.0013
400	184.36	16.62	133.06	49.85	4.11	8.12	24.88	6.32	0.1072	0.0170	0.0250	0.0030
500	184.44	16.56	133.33	49.67	6.94	9.23	25.56	6.18	0.1280	0.0351	0.0225	-0.0006
700	184.55	16.80	133.65	50.41	10.72	11.37	25.06	6.04	0.1372	0.0191	0.0278	0.0003
1000	184.53	15.84	133.53	47.52	15.50	14.15	25.45	5.99	0.1711	0.0008	0.0314	-0.0024
1200	184.60	15.54	133.81	46.61	18.02	15.92	23.17	5.57	0.1917	0.0044	0.0342	0.0036
1500	184.02	16.43	132.06	49.44	22.11	19.31	24.51	5.79	0.2676	0.0885	0.0376	0.0078
1700	184.24	16.34	132.73	49.03	25.54	21.56	25.44	5.36	0.3403	0.1467	0.0321	0.0062
1800	184.23	15.74	132.68	47.21	28.23	24.03	22.43	5.24	0.4068	0.1820	0.0325	0.0037
						DRAINED REST PERIOD						
					A.G.L. 42.53		R.G.L. 39.06					
1	184.34	16.73	133.03	50.19	4.93	9.29	25.72	6.17	0.0062	0.0054	0.0229	0.0066
50	183.92	16.53	131.76	49.53	5.66	9.73	25.16	6.05	0.0177	0.0065	0.0280	0.0044
100	184.64	16.40	133.91	49.20	8.56	10.85	24.26	5.86	0.0359	0.0116	0.0273	0.0047
200	184.60	16.44	133.79	49.32	11.75	11.90	24.36	5.84	0.0390	0.0084	0.0280	0.0038
230	184.18	16.62	132.54	49.85	11.38	12.11	21.20	5.74	0.0404	0.0073	0.0294	0.0050
300	184.17	16.43	132.51	49.29	13.54	13.61	24.82	5.73	0.0532	0.0017	0.0320	0.0053
500	184.10	16.63	132.29	49.88	16.53	15.22	23.95	5.49	0.0570	0.0023	0.0311	0.0031
700	184.06	16.47	132.19	49.40	17.76	16.13	24.23	5.52	0.0667	-0.0059	0.0312	0.0005
1000	184.28	16.55	132.84	49.64	20.71	17.72	24.01	5.42	0.0922	0.0011	0.0343	0.0069
1200	184.06	16.41	132.19	49.24	21.21	18.72	23.00	5.49	0.1068	0.0140	0.0329	0.0069
1500	184.17	16.10	132.51	48.30	22.70	19.89	22.44	5.31	0.1156	0.0084	0.0353	0.0082
1700	184.06	16.32	132.17	48.95	23.76	20.86	23.09	5.36	0.1261	0.0129	0.0378	0.0071
2000	183.72	16.18	131.17	48.55	24.74	22.04	22.30	5.39	0.1453	0.0060	0.0364	0.0166
2160	184.17	16.29	132.52	48.88	25.90	22.69	22.27	5.23	0.1559	-0.0048	0.0395	0.0105
						DRAINED REST PERIOD						
					A.G.L. 42.43		R.G.L. 39.07					
1	184.23	16.37	132.70	49.11	-1.13	3.44	26.67	6.36	0.0044	-0.0012	0.0249	0.0055
50	184.12	16.94	132.37	50.82	-1.61	3.79	26.50	6.48	0.0209	0.0002	0.0258	0.0067
100	183.99	16.91	131.98	50.74	-0.29	4.31	26.66	6.33	0.0259	0.0031	0.0297	0.0051
300	184.47	16.35	133.40	49.04	2.53	5.85	26.10	6.15	0.0312	-0.0039	0.0294	0.0031
500	184.41	16.07	133.22	48.21	3.67	6.55	25.31	6.09	0.0367	-0.0022	0.0304	0.0064
700	184.46	16.13	133.39	48.40	4.02	7.09	25.47	6.04	0.0443	-0.0012	0.0290	0.0102
1000	184.49	15.94	133.47	47.83	5.47	7.85	24.68	5.95	0.0515	0.0012	0.0299	0.0052
1200	184.50	16.27	133.51	48.81	5.52	8.03	24.00	5.88	0.0519	-0.0001	0.0297	0.0034
1500	184.21	16.26	132.63	48.78	6.74	8.66	24.58	5.90	0.0525	-0.0019	0.0295	0.0001
1700	184.37	16.78	133.12	50.34	6.59	9.01	24.43	6.00	0.0543	-0.0043	0.0329	0.0076
2000	184.29	15.92	132.87	47.77	7.29	9.84	23.91	5.91	0.0576	0.0007	0.0331	0.0044
2160	184.22	16.18	132.65	48.55	7.38	10.13	23.88	5.96	0.0660	-0.0004	0.0324	0.0062
						DRAINED REST PERIOD						
					A.G.L. 42.40		R.G.L. 39.08					
1	184.53	16.37	133.59	49.11	0.06	4.19	26.22	6.24	0.0063	-0.0009	0.0260	0.0034
50	183.97	16.52	131.91	49.57	0.59	4.38	25.16	6.22	0.0053	0.0021	0.0275	0.0022
100	184.42	16.27	133.25	48.80	1.57	4.93	25.61	6.38	0.0087	0.0039	0.0274	0.0044
200	184.11	16.34	132.33	49.01	1.06	5.23	25.30	6.16	0.0097	0.0009	0.0310	-0.0021
230	184.08	16.47	132.23	49.41	1.96	5.82	23.45	6.98	0.0131	-0.0004	0.0307	0.0041
300	184.16	16.35	132.47	49.05	2.80	6.34	25.09	6.18	0.0149	0.0002	0.0273	0.0071

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
500	184.25	15.99	132.76	47.97	3.63	6.76	24.39	6.25	0.0167	-0.0022	0.0297	0.0072
700	184.71	16.40	134.12	49.21	4.57	7.46	24.23	6.08	0.0234	0.0078	0.0276	0.0071
1000	184.36	16.52	133.09	49.55	4.97	7.79	25.26	6.13	0.0307	0.0097	0.0302	0.0035
1200	184.33	16.05	132.98	48.16	5.45	8.14	24.12	5.95	0.0326	0.0100	0.0342	0.0078
1500	184.25	15.95	132.74	47.85	6.17	8.68	23.86	6.08	0.0427	0.0186	0.0295	0.0052
1700	184.20	15.85	132.60	47.54	7.06	8.92	22.88	6.06	0.0493	0.0200	0.0303	0.0032
2000	184.42	16.07	133.26	48.20	7.06	9.29	23.62	5.93	0.0530	0.0146	0.0272	0.0119
2160	184.41	16.29	133.22	48.87	7.06	9.40	23.18	6.19	0.0552	0.0113	0.0299	0.0090
						DRAINED REST PERIOD						
					A.G.L. 42.39		R.G.L. 39.08					
1	183.99	16.77	131.98	50.32	0.57	1.77	26.45	6.60	0.0010	0.0001	0.0213	0.0125
50	184.26	16.54	132.79	49.63	-0.32	2.20	25.75	6.34	0.0101	-0.0004	0.0206	0.0097
100	184.21	16.23	132.63	48.85	-0.04	2.48	28.50	6.28	0.0133	-0.0009	0.0257	0.0048
300	184.34	16.11	133.03	48.32	1.56	3.27	25.66	6.07	0.0167	-0.0022	0.0271	0.0035
500	184.33	16.36	133.14	49.09	1.42	3.51	26.52	6.06	0.0252	-0.0038	0.0237	0.0030
1000	184.59	16.30	133.76	43.90	2.30	4.08	24.82	5.99	0.0282	-0.0006	0.0256	0.0045
1500	184.31	16.34	132.93	49.02	2.41	4.46	26.66	6.11	0.0301	-0.0004	0.0280	0.0038
2000	184.13	16.53	132.39	49.59	2.25	4.66	25.44	6.15	0.0327	0.0036	0.0259	0.0018
2160	184.09	16.59	132.28	49.77	2.16	4.65	23.79	6.45	0.0332	0.0082	0.0292	0.0061
						DRAINED REST PERIOD						
					A.G.L. 42.38		R.G.L. 39.07					
						** STRESS PATH TESTS **						
0	132.32	20.64	47.17	0.00	17.20	18.35	29.22	22.61	-0.1356	-0.0247	-0.0000	-0.0002
0	176.89	34.41	46.86	-0.07	58.92	50.95	32.72	28.00	-0.1469	-0.0149	0.0005	-0.0025
0	233.31	34.76	47.36	-0.02	108.76	94.74	34.03	28.66	-0.1270	-0.0235	-0.0003	-0.0006
0	230.64	82.47	45.57	0.00	108.90	94.04	74.61	64.62	-0.1296	-0.0157	0.0007	-0.0025
0	185.29	85.03	47.26	0.09	63.86	56.25	82.59	67.93	-0.1306	-0.0217	0.0011	-0.0040
0	144.05	92.91	46.70	-0.07	24.69	22.74	86.56	69.72	-0.1265	-0.0280	0.0005	0.0001
0	134.12	16.62	46.71	49.87	13.89	16.89	28.62	9.24	-0.1294	-0.0374	0.0351	0.0075
0	186.12	17.20	45.82	50.97	66.22	63.91	30.31	10.23	-0.1461	0.0097	0.0404	0.0077
0	225.70	16.78	46.38	50.17	103.45	95.34	30.80	10.41	-0.1465	0.0110	0.0399	0.0035
0	227.72	-47.48	44.89	48.89	109.61	97.96	-37.58	-41.93	-0.1695	-0.0339	0.0387	0.0026
0	185.51	-46.71	46.19	49.18	69.31	64.39	-38.57	-44.20	-0.1769	-0.0177	0.0363	0.0080
0	136.25	-39.44	45.58	49.85	21.58	25.53	-33.81	-37.49	-0.1794	-0.0131	0.0391	0.0096
0	140.30	-12.92	46.40	50.35	27.26	28.31	-22.67	-21.72	-0.1805	-0.0069	0.0403	0.0114
0	185.96	-4.66	46.82	47.60	72.55	66.52	-32.26	-19.42	-0.1504	0.0136	0.0426	-0.0011
0	225.96	-5.62	43.64	50.94	110.32	99.96	-34.45	-19.19	-0.1704	-0.0163	0.0395	0.0091
0	234.57	50.07	48.26	45.09	117.90	103.59	65.13	37.77	-0.1836	-0.0304	0.0366	0.0182
0	177.35	59.00	46.64	49.46	64.98	58.70	67.84	40.99	-0.1899	-0.0118	0.0420	0.0067
0	135.02	65.19	34.95	72.06	26.26	27.29	66.49	41.06	-0.1921	-0.0080	0.0425	0.0049
0	181.69	31.07	45.65	91.76	76.02	68.61	67.05	16.05	-0.2170	0.0067	0.1095	0.0133
0	233.03	30.56	44.83	91.76	126.71	119.10	60.77	16.84	-0.2608	0.0183	0.1225	0.0074
0	132.04	30.08	45.11	90.59	28.65	35.79	54.04	16.41	-0.2599	0.0007	0.1253	0.0029
0	224.75	-102.02	45.09	89.95	117.33	112.99	-75.95	-88.43	-0.2573	0.0106	0.1240	0.0178
0	231.26	-13.07	45.49	91.44	128.69	119.41	-24.91	-27.77	-0.2488	0.0032	0.1299	0.0085
0	185.15	-3.09	45.42	90.29	84.93	85.50	26.28	-23.10	-0.2414	0.0169	0.1316	0.0157
0	137.44	-1.73	45.26	90.80	43.56	47.29	23.04	-22.56	-0.2443	0.0138	0.1295	0.0221
0	142.82	86.52	45.71	91.55	41.52	46.69	105.63	60.10	-0.2810	-0.0022	0.1387	0.0138
0	182.17	86.93	45.65	90.34	82.35	83.59	105.20	58.01	-0.2866	-0.0152	0.1352	0.0162
0	231.02	95.38	45.47	92.08	120.37	123.07	91.85	60.30	-0.2610	-0.0022	0.1374	0.0132
0	231.99	25.54	0.24	0.02	128.54	126.15	21.45	18.99	-0.3692	-0.0013	0.0010	-0.0022
0	185.38	30.08	-0.15	0.48	85.78	88.85	25.58	23.15	-0.3729	0.0100	-0.0003	-0.0005

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
0	122.03	18.90	-0.22	0.25	23.99	36.34	15.12	14.29	-0.3732	0.0109	-0.0007	-0.0008
0	137.04	31.84	-0.54	0.43	39.43	50.10	74.33	63.95	-0.3670	-0.0078	0.0010	-0.0024
0	184.53	37.31	0.46	0.05	87.07	88.50	83.36	68.75	-0.3888	0.0005	0.0004	-0.0047
0	229.91	37.65	0.40	0.25	126.37	122.61	80.39	66.38	-0.3830	0.0013	0.0014	-0.0019
0	135.85	28.11	90.88	0.16	58.39	47.06	26.38	22.71	-0.2592	-0.0015	-0.0009	-0.0018
0	189.32	26.98	91.16	0.05	107.38	89.38	24.70	21.11	-0.2619	0.0004	-0.0008	-0.0039
0	228.42	27.37	90.36	-0.14	144.10	121.76	21.88	20.72	-0.2545	-0.0035	-0.0001	-0.0017
0	232.72	73.26	91.07	0.00	140.13	124.24	42.49	55.86	-0.2346	-0.0035	-0.0009	-0.0010
0	189.82	65.95	90.88	0.11	106.65	90.17	63.35	51.98	-0.2128	0.0122	0.0001	-0.0010
0	180.82	16.34	94.19	48.29	97.02	81.13	27.94	6.58	-0.1998	0.0149	0.0477	0.0120
0	235.87	15.39	94.75	48.36	147.62	124.28	26.77	6.94	-0.1754	0.0346	0.0462	0.0173
0	136.91	16.67	95.37	49.00	51.24	42.01	25.93	7.66	-0.1573	0.0163	0.0473	0.0112
0	181.47	-39.08	94.01	47.93	95.90	79.79	-34.51	-40.65	-0.1502	0.0431	0.0458	0.0118
0	227.75	-38.19	93.04	47.67	138.66	118.40	-32.52	-36.52	-0.1478	0.0448	0.0424	0.0120
0	234.30	-0.65	94.30	43.09	144.60	121.59	16.83	-14.62	-0.1592	0.0401	0.0465	0.0067
0	135.78	3.47	94.54	47.01	98.76	82.84	-17.50	-11.84	-0.1608	0.0389	0.0479	0.0036
0	141.57	4.52	94.44	47.15	54.59	46.13	20.55	-8.80	-0.1469	0.0481	0.0479	0.0085
0	139.04	41.65	95.74	46.71	50.62	42.27	47.33	25.14	-0.1447	0.0475	0.0453	0.0109
0	186.90	42.14	93.64	46.74	98.37	84.06	50.57	25.98	-0.1478	0.0357	0.0398	0.0024
0	223.47	41.66	94.15	48.11	137.34	118.68	34.37	24.27	-0.1513	0.0584	0.0479	0.0091
0	183.15	27.41	90.17	83.25	94.79	82.49	43.85	8.96	-0.1194	0.0406	0.1044	0.0103
0	235.35	28.23	90.15	84.32	140.71	123.48	38.37	11.71	-0.1207	0.0413	0.1038	0.0026
0	231.43	2.04	91.26	85.99	141.47	122.29	23.23	-17.15	-0.1151	0.0185	0.1052	0.0135
0	186.05	0.37	91.19	83.38	95.06	73.03	25.10	-44.07	-0.1133	0.0102	0.1024	0.0099
0	184.83	81.57	89.66	83.29	97.57	84.97	91.43	50.15	-0.1038	0.0146	0.0975	0.0077
0	235.48	86.22	90.05	83.43	143.18	125.56	95.94	51.70	-0.1076	-0.0009	0.1027	0.0110
0	139.62	81.92	90.75	84.55	52.92	48.69	90.86	53.80	-0.1025	0.0198	0.1014	-0.0035
0	132.21	30.58	0.14	0.05	61.45	61.46	30.30	24.58	-0.3440	0.0462	0.1019	-0.0060
0	179.15	32.16	-0.66	0.05	83.62	96.33	31.12	25.34	-0.3500	0.0372	-0.0007	-0.0027
0	229.10	38.80	0.00	0.09	132.12	136.14	38.46	30.50	-0.3630	0.0132	-0.0003	0.0001
0	236.26	99.71	0.47	0.11	134.87	140.74	81.90	77.84	-0.3518	0.0274	-0.0003	0.0026
0	177.08	96.93	-0.59	0.27	85.79	94.44	89.25	73.57	-0.3578	0.0216	0.0003	0.0037
0	136.95	97.75	-0.66	0.18	47.24	61.72	92.37	76.02	-0.3448	0.0425	-0.0005	0.0015
0	119.02	16.01	0.03	46.56	109.47	51.98	31.75	10.26	-0.5214	0.0298	0.0759	0.0091
0	184.15	15.57	1.12	46.08	97.02	106.64	31.07	10.85	-0.5161	0.0319	0.0802	0.0099
0	223.89	13.83	0.64	46.90	135.80	138.17	31.86	10.05	-0.5327	0.0278	0.0724	0.0202
0	232.52	-47.50	1.12	48.09	140.15	144.15	-34.01	-36.37	-0.5318	0.0311	0.0774	0.0126
0	189.02	-44.24	0.39	48.27	104.08	110.44	-31.84	-36.98	-0.5350	0.0283	0.0795	0.0198
0	133.06	-42.83	0.09	48.00	90.35	66.03	-35.13	-38.51	-0.5542	0.0234	0.0771	0.0132
0	135.10	-1.19	-0.22	46.92	56.29	68.24	11.09	-7.96	-0.5810	-0.0011	0.0772	0.0174
0	183.27	-8.78	0.89	46.12	103.24	108.98	7.57	-9.42	-0.5756	0.0127	0.0779	0.0156
0	231.46	-9.43	-0.10	46.01	150.09	146.15	8.25	-9.34	-0.5740	0.0139	0.0800	0.0191
0	232.44	41.82	0.92	45.67	144.15	145.30	53.86	29.12	-0.5497	0.0730	0.0799	0.0201
0	182.36	40.75	0.50	47.86	106.01	107.20	52.40	29.63	-0.5872	0.0265	0.0848	0.0128
0	138.47	46.19	1.45	47.43	62.17	70.84	55.10	32.56	-0.5876	0.0306	0.0764	0.0213
0	141.84	29.22	1.29	87.56	65.55	78.60	54.08	18.48	-0.7502	0.0779	0.3134	-0.0155
0	185.92	23.50	2.62	84.77	107.30	116.35	58.84	24.70	-0.8104	0.0849	0.3769	-0.0347
0	224.27	29.97	1.80	88.34	138.84	146.04	71.96	28.45	-0.9014	0.0583	0.3860	-0.0210

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
					TEST NO	AR 1.2	O.C.R.	1				
					**********	**********	**********	*****				
					A.G.L.130.00		R.G.L. 38.97					
1	183.04	9.33	129.12	27.99	1.35	0.00	12.79	0.00	0.0104	0.0026	0.0173	0.0075
50	183.28	10.05	129.83	30.16	4.49	0.00	14.71	0.00	0.0157	0.0039	0.0241	0.0024
100	184.19	9.84	132.57	29.53	6.12	0.00	14.65	0.00	0.0209	0.0052	0.0175	0.0089
200	183.59	10.10	130.77	30.31	7.09	0.00	14.31	0.00	0.0268	0.0062	0.0205	0.0052
300	184.31	10.94	132.92	32.81	8.46	0.00	15.83	0.00	0.0380	0.0048	0.0238	-0.0001
500	184.56	9.34	133.68	28.03	8.70	0.00	13.15	0.00	0.0459	0.0115	0.0223	-0.0046
700	185.29	10.37	135.86	31.12	9.65	0.00	14.78	0.00	0.0630	0.0215	0.0203	0.0061
1000	184.67	9.85	134.01	29.55	10.69	0.00	13.92	0.00	0.0852	0.0430	0.0159	0.0085
1200	182.77	10.58	128.31	31.75	10.72	0.00	15.02	0.00	0.0958	0.0485	0.0179	0.0105
1500	183.73	10.70	131.20	32.11	13.13	0.00	15.19	0.00	0.1206	0.0623	0.0220	0.0032
1700	185.93	10.62	137.95	31.85	14.38	0.00	14.80	0.00	0.1438	0.0502	0.0239	-0.0005
2000	185.77	10.67	137.30	32.01	15.94	0.00	14.88	0.00	0.1653	0.0537	0.0251	0.0000
2160	185.40	10.30	136.21	30.90	17.29	0.00	14.41	0.00	0.1723	0.0343	0.0238	0.0018
						DRAINED REST PERIOD						
					A.G.L.129.43		R.G.L. 38.98					
1	184.64	10.08	133.93	30.23	-0.52	0.00	12.68	0.00	0.0084	0.0003	0.0187	0.0018
100	183.19	10.60	129.56	31.79	0.60	0.00	14.36	0.00	0.0160	-0.0020	0.0195	-0.0040
300	182.89	9.92	128.67	29.75	2.02	0.00	14.43	0.00	0.0227	0.0001	0.0196	-0.0042
500	183.27	10.40	129.82	31.20	3.75	0.00	14.19	0.00	0.0318	0.0034	0.0226	-0.0019
700	183.82	9.99	131.46	29.97	5.82	0.00	13.92	0.00	0.0396	0.0021	0.0206	-0.0031
1000	182.57	11.35	127.71	34.05	5.91	0.00	15.50	0.00	0.0562	-0.0017	0.0250	-0.0009
1200	183.70	11.99	131.09	35.97	7.95	0.00	17.06	0.00	0.0710	0.0101	0.0266	0.0054
1500	184.25	11.45	132.76	34.36	10.35	0.00	16.49	0.00	0.0854	0.0199	0.0258	0.0067
1700	184.41	11.02	133.23	33.06	10.66	0.00	15.65	0.00	0.0935	0.0192	0.0248	-0.0016
2000	182.91	11.01	128.73	33.04	11.76	0.00	15.75	0.00	0.1078	0.0275	0.0221	0.0020
2160	183.38	10.60	130.14	31.80	12.60	0.00	15.45	0.00	0.1174	0.0243	0.0221	0.0045
						DRAINED REST PERIOD						
					A.G.L.129.30		R.G.L. 38.99					
1	184.49	10.31	133.47	30.92	1.45	0.00	14.35	0.00	0.0063	-0.0003	0.0134	0.0045
100	183.50	10.07	130.50	30.22	3.25	0.00	14.03	0.00	0.0221	0.0019	0.0239	-0.0012
300	183.63	10.13	130.90	30.40	5.48	0.00	14.24	0.00	0.0289	0.0088	0.0217	-0.0001
500	182.73	10.02	128.18	30.05	5.64	0.00	14.04	0.00	0.0298	0.0095	0.0226	-0.0015
700	182.91	10.27	128.73	30.82	6.63	0.00	14.82	0.00	0.0283	0.0072	0.0220	0.0018
1000	183.51	9.98	130.52	29.93	7.34	0.00	14.33	0.00	0.0310	0.0009	0.0224	0.0003
1200	183.52	10.33	130.57	31.00	7.76	0.00	13.96	0.00	0.0313	0.0014	0.0211	-0.0012
1500	183.56	10.35	130.68	31.05	8.51	0.00	15.00	0.00	0.0397	0.0036	0.0243	0.0021
1700	183.87	10.66	131.61	31.99	8.74	0.00	14.83	0.00	0.0469	0.0078	0.0233	0.0007
2000	183.02	10.28	129.05	30.83	8.62	0.00	14.31	0.00	0.0542	0.0097	0.0229	0.0023
2160	183.98	10.66	131.94	31.99	9.35	0.00	14.68	0.00	0.0542	0.0097	0.0220	0.0035
						DRAINED REST PERIOD						
					A.G.L.129.29		R.G.L. 39.00					
1	182.98	11.18	128.94	33.53	2.14	0.00	15.87	0.00	0.0115	-0.0022	0.0219	0.0050
100	183.34	10.47	130.01	31.41	4.40	0.00	14.72	0.00	0.0172	-0.0055	0.0207	0.0062
300	183.84	10.46	131.51	31.38	5.35	0.00	12.48	0.00	0.0457	0.0009	0.0187	0.0006
500	182.71	8.84	128.12	26.51	6.94	0.00	12.54	0.00	0.0522	0.0087	0.0172	0.0012
700	183.36	8.76	130.08	26.27	7.42	0.00	12.53	0.00	0.0524	0.0031	0.0138	0.0019
1000	183.38	9.65	130.14	28.94	7.27	0.00	13.57	0.00	0.0573	0.0105	0.0209	0.0043
1200	183.58	8.35	130.74	25.05	7.76	0.00	13.04	0.00	0.0551	0.0085	0.0187	0.0053
1500	183.57	8.41	130.72	25.22	8.08	0.00	11.89	0.00	0.0520	0.0044	0.0139	0.0028
1700	183.25	9.80	129.76	29.39	8.17	0.00	13.64	0.00	0.0520	0.0025	0.0223	0.0091
2000	182.79	9.80	128.37	29.40	8.16	0.00	13.46	0.00	0.0562	0.0088	0.0226	0.0080

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
2160	182.87	9.87	128.62	29.61	8.99	0.00	13.44	0.00	0.0597	0.0101	0.0221	0.0074
						DRAINED REST PERIOD						
					A.G.L.129.16		R.G.L. 39.00					
1	182.60	11.44	127.99	34.31	-0.10	0.00	15.83	0.00	0.0042	0.0011	0.0193	0.0095
100	183.25	10.36	129.76	31.09	0.97	0.00	13.93	0.00	0.0146	0.0023	0.0198	0.0040
300	182.53	10.13	127.74	30.38	1.28	0.00	13.74	0.00	0.0173	0.0026	0.0174	0.0107
500	183.00	9.90	129.00	29.69	1.85	0.00	13.98	0.00	0.0196	0.0060	0.0175	-0.0004
1000	182.99	8.80	128.96	26.39	3.46	0.00	12.93	0.00	0.0210	0.0054	0.0134	0.0017
1500	183.13	10.15	129.39	30.46	4.00	0.00	13.88	0.00	0.0270	0.0112	0.0224	0.0067
2000	183.28	10.51	129.83	31.52	4.22	0.00	14.20	0.00	0.0274	0.0118	0.0189	0.0135
2160	182.86	8.29	128.58	24.86	4.21	0.00	11.49	0.00	0.0275	0.0113	0.0187	-0.0015
					STRAIN CONTROL FAILURE TEST							
1	183.73	-0.01	131.19	0.00	5.20	0.00	0.00	0.00	0.0006	0.0049	0.0000	0.0000
1	189.30	0.00	148.09	0.00	9.23	0.00	0.00	0.00	0.0171	0.0308	0.0000	0.0000
1	194.05	0.01	162.15	0.00	12.03	0.00	0.00	0.00	0.0520	0.0558	0.0000	0.0000
1	195.58	0.00	166.75	0.00	14.32	0.00	0.00	0.00	0.0732	0.0349	0.0000	0.0000
1	200.95	0.00	182.86	0.00	17.51	0.00	0.00	0.00	0.1658	0.0267	0.0000	0.0000
1	193.84	0.00	161.51	0.00	13.65	0.00	0.00	0.00	1.3673	-0.1347	0.0000	0.0000
1	186.23	0.01	138.68	0.00	5.66	0.00	0.00	0.00	1.4996	-0.3524	0.0000	0.0000
1	177.26	0.00	111.78	0.00	1.74	0.00	0.00	0.00	1.4883	-0.3543	0.0000	0.0000
1	166.89	0.00	80.67	0.00	-5.33	0.00	0.00	0.00	1.4213	-0.3480	0.0000	0.0000
1	156.17	0.00	43.51	0.00	-10.81	0.00	0.00	0.00	1.2377	-0.4731	0.0000	0.0000
1	144.28	0.00	12.83	0.00	-12.44	0.00	0.00	0.00	0.8792	-0.5277	0.0000	0.0000
					TEST NO	AR 1.3		O.C.R. 1				
					************************************							
					A.G.L. 43.43		R.G.L. 39.00					
1	184.64	17.95	133.92	53.85	0.30	-0.00	20.77	2.74	0.0022	0.0021	0.0147	0.0022
15	183.12	22.59	129.35	67.77	0.99	2.04	27.01	2.99	0.0860	0.0111	0.0241	-0.0221
50	183.02	22.68	129.05	68.03	16.56	11.98	25.87	2.17	0.6603	0.4872	0.0830	0.0031
83	183.28	16.09	129.83	48.26	21.99	26.93	15.72	0.95	4.0623	2.2613	0.3877	0.2834
						DRAINED REST PERIOD						
					A.G.L. 40.39		R.G.L. 39.48					
1	183.60	23.07	130.79	69.22	6.59	3.23	23.67	2.48	0.0456	0.0015	0.0744	0.0428
15	183.52	22.72	130.57	68.16	7.99	5.44	26.84	2.38	0.0876	0.0138	0.0819	0.0672
30	183.53	22.46	130.60	67.38	10.62	7.79	27.05	2.16	0.1490	0.0467	0.0855	0.0694
50	183.43	22.98	130.43	68.94	12.40	9.93	25.44	2.03	0.1637	0.0655	0.0851	0.0630
75	183.79	23.54	131.36	70.63	16.23	12.67	26.67	2.15	0.1891	0.0617	0.0875	0.0714
100	183.70	23.38	131.10	70.15	18.47	15.45	27.37	1.76	0.2041	0.0669	0.0920	0.0583
125	183.58	23.07	130.75	69.20	21.08	18.28	25.79	1.51	0.2471	0.0542	0.0955	0.0754
150	183.55	23.66	130.64	70.97	23.07	20.72	26.63	1.27	0.2792	0.0335	0.1058	0.0815
175	183.45	23.08	130.34	69.25	26.03	23.50	25.70	1.26	0.3911	0.1004	0.1065	0.0799
200	183.60	22.68	130.80	68.03	27.46	26.06	26.40	1.14	0.4371	0.1070	0.1032	0.0737
225	183.34	23.31	130.01	69.94	29.42	29.30	27.48	1.07	0.5565	0.1448	0.1107	0.0863
250	183.49	22.78	130.47	68.33	31.44	33.17	26.26	0.16	0.6889	0.1407	0.1099	0.0764
275	182.95	22.25	128.84	66.75	31.95	37.69	25.84	0.02	0.9521	0.2191	0.0910	0.0404
300	183.35	22.39	130.05	67.18	34.19	42.13	25.56	1.75	1.4860	0.3563	0.0912	0.0230
						DRAINED REST PERIOD						
					A.G.L. 39.74		R.G.L. 39.68					
1	184.98	21.29	134.94	63.88	13.29	9.04	24.63	2.30	0.0213	0.0032	0.0626	0.0366
10	184.30	22.40	132.89	67.19	13.33	11.18	26.26	1.94	0.0483	0.0085	0.0735	0.0521
25	184.30	22.99	132.89	68.97	13.68	14.19	26.22	2.03	0.0718	0.0148	0.0556	0.0220
50	183.96	23.51	131.87	70.53	15.32	17.22	26.98	1.80	0.0968	0.0389	0.0573	0.0166
75	183.89	23.43	131.66	70.29	16.54	19.27	25.52	1.86	0.1060	0.0432	0.0591	0.0103

N	p_m	p_r	q_m	q_r	u_B^p	u_C^p	u_B^r	u_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
100	184.39	23.48	133.16	70.45	17.90	20.81	26.45	1.55	0.1189	0.0267	0.0563	0.0143
125	184.41	23.39	133.22	70.18	19.23	22.17	25.90	1.55	0.1290	0.0348	0.0573	0.0153
150	184.42	23.20	133.26	69.59	20.17	23.09	26.05	1.62	0.1360	0.0395	0.0577	0.0168
200	184.26	22.82	132.79	68.47	22.21	24.96	25.97	1.44	0.1613	0.0339	0.0610	0.0067
250	184.31	23.80	132.92	71.39	23.66	26.33	27.17	1.32	0.1574	0.0327	0.0595	0.0131
300	184.33	23.20	132.99	69.59	25.20	27.44	26.57	1.53	0.1745	0.0166	0.0577	0.0165
400	184.71	23.48	134.14	70.44	28.54	29.42	26.38	1.60	0.2306	0.0272	0.0633	0.0083
500	184.74	23.66	134.23	70.99	31.44	30.98	27.45	1.46	0.2768	0.0037	0.0616	0.0245
600	184.80	23.25	134.39	69.76	33.08	32.37	27.55	1.29	0.3129	0.0009	0.0611	0.0130
700	184.57	23.97	133.71	71.90	34.69	32.80	41.51	1.45	0.3297	0.0081	0.0636	0.0055
800	185.06	23.66	135.17	70.98	37.31	33.65	26.77	1.25	0.3616	0.0145	0.0668	0.0147
1000	185.26	23.66	135.77	70.97	40.66	34.70	26.88	1.55	0.4320	-0.0592	0.0627	0.0143
1300	184.82	22.80	134.47	68.39	42.83	34.91	26.38	1.33	0.4958	-0.0172	0.0628	0.0091
1500	184.97	23.26	134.91	69.78	45.30	35.59	24.36	1.62	0.5635	-0.0128	0.0606	0.0078
1800	184.84	23.33	134.51	69.93	47.56	36.64	25.06	1.63	0.6573	-0.0065	0.0653	0.0051
2000	184.55	22.83	133.64	68.50	48.81	37.17	22.83	1.14	0.7133	-0.0211	0.0595	0.0087
2160	184.76	23.86	134.27	71.57	50.02	37.59	24.02	1.23	0.7267	-0.0484	0.0665	0.0125
						DRAINED REST PERIOD						
					A.G.L. 39.47		R.G.L. 39.78					
1	184.73	23.78	134.20	71.34	7.61	6.14	27.80	2.69	0.0365	-0.0065	0.0467	0.0183
25	184.18	24.01	132.53	72.02	9.73	8.50	28.31	2.46	0.0779	0.0013	0.0553	0.0137
50	184.20	23.85	132.59	71.56	11.71	9.65	28.21	2.59	0.0886	0.0078	0.0542	0.0185
75	184.03	24.17	132.10	72.50	13.48	10.50	28.22	2.24	0.0943	0.0163	0.0560	0.0097
100	183.93	24.07	131.95	72.20	14.99	11.20	27.79	2.48	0.0912	0.0225	0.0570	0.0114
150	184.93	23.99	134.79	71.97	18.12	11.33	28.32	-0.24	0.1060	0.0230	0.0538	0.0203
200	184.61	24.27	133.82	72.81	19.06	13.46	27.93	2.31	0.1084	0.0318	0.0578	0.0076
300	184.82	24.00	134.47	72.00	21.29	14.64	27.96	2.29	0.1096	0.0284	0.0568	0.0112
400	184.64	23.91	133.92	71.73	22.76	15.49	27.57	2.23	0.1086	0.0282	0.0578	0.0114
500	184.45	23.58	133.35	70.73	23.88	16.39	28.07	2.16	0.1196	0.0434	0.0505	0.0064
600	184.44	24.34	133.32	73.03	24.18	16.98	28.22	2.25	0.1213	0.0415	0.0577	0.0080
700	184.53	24.21	133.60	72.63	25.24	17.66	28.38	2.19	0.1283	0.0431	0.0585	0.0086
1000	184.55	24.42	133.66	73.27	27.50	18.91	29.01	2.11	0.1287	0.0290	0.0600	0.0150
1200	184.53	24.18	133.59	72.55	28.57	19.41	30.27	1.99	0.1367	0.0468	0.0530	0.0158
1500	184.54	24.47	133.63	73.40	29.42	19.67	29.44	1.88	0.1384	0.0545	0.0571	0.0152
1800	184.36	24.34	133.67	73.01	29.98	20.38	29.30	1.75	0.1407	0.0573	0.0593	0.0159
2000	184.71	24.44	134.13	73.32	30.66	21.16	28.97	1.84	0.1425	0.0389	0.0574	0.0171
2160	184.64	24.11	133.93	72.33	31.19	21.67	27.17	1.91	0.1435	0.0391	0.0581	0.0199
						DRAINED REST PERIOD						
					A.G.L. 39.43		R.G.L. 39.78					
1	184.69	24.05	134.08	72.14	0.27	0.16	-3.08	3.31	0.0246	0.0036	0.0335	0.0153
25	184.56	24.47	133.67	73.41	0.48	1.82	4.47	3.00	0.0296	0.0080	0.0426	0.0211
100	184.55	24.62	133.66	73.85	5.32	3.65	30.55	2.89	0.0348	0.0050	0.0421	0.0223
150	184.33	24.62	133.00	73.85	5.38	4.25	28.99	2.74	0.0363	0.0072	0.0475	0.0112
200	184.35	24.54	133.05	73.62	5.82	4.79	30.41	2.72	0.0343	0.0003	0.0478	0.0130
300	184.92	24.50	134.76	73.50	7.20	4.48	29.62	2.82	0.0421	0.0057	0.0434	0.0134
500	184.88	23.74	134.63	71.22	8.67	5.50	28.92	2.78	0.0418	0.0066	0.0430	0.0151
700	184.87	24.34	134.61	73.02	9.49	6.57	29.60	2.76	0.0434	0.0083	0.0514	0.0075
1000	184.94	23.93	134.83	71.80	11.30	7.90	29.55	2.61	0.0462	0.0030	0.0491	0.0111
1200	184.94	24.02	134.82	72.06	11.89	8.30	29.06	2.47	0.0587	0.0204	0.0483	0.0125
1500	185.19	24.43	135.57	73.29	12.66	8.75	29.95	2.59	0.0671	0.0241	0.0493	0.0130
1800	185.18	24.13	135.54	72.39	13.15	9.28	30.30	2.39	0.0674	0.0296	0.0485	0.0070
2000	184.98	24.31	134.94	72.93	13.17	9.58	30.66	2.44	0.0741	0.0353	0.0469	0.0091
2160	185.02	24.13	135.07	72.40	13.62	9.74	29.76	2.46	0.0859	0.0484	0.0491	0.0156

N	P_m	P_r	q_m	q_r	$U_B{}^p$	$U_C{}^p$	$U_B{}^r$	$U_C{}^r$	$\varepsilon_s{}^p$	$\varepsilon_v{}^p$	$\varepsilon_s{}^r$	$\varepsilon_v{}^r$
					STRAIN CONTROL FAILURE TEST							
1	185.47	0.01	136.40	0.00	15.29	7.98	0.00	0.00	0.0475	-0.0169	0.0000	0.0000
1	187.72	0.03	143.16	0.00	17.99	8.54	0.00	0.00	0.0453	-0.0201	0.0000	0.0000
1	190.59	-0.00	151.78	0.00	20.38	9.25	0.00	0.00	0.0489	-0.0019	0.0000	0.0000
1	196.43	-0.01	169.28	0.00	24.28	10.77	0.00	0.00	0.0553	-0.0147	0.0000	0.0000
1	193.11	0.00	174.34	0.00	27.98	11.23	0.00	0.00	0.1063	0.0644	0.0000	0.0000
1	203.24	-0.01	139.73	0.00	32.31	12.16	0.00	0.00	0.1189	0.0749	0.0000	0.0000
1	207.43	0.00	202.29	0.00	35.90	12.98	0.00	0.00	0.1423	0.0967	0.0000	0.0000
1	211.56	0.00	214.68	0.00	38.72	13.37	0.00	0.00	0.1749	0.1226	0.0000	0.0000
1	215.24	0.01	225.73	0.00	39.27	13.37	0.00	0.00	0.3435	0.1775	0.0000	0.0000
1	213.96	0.01	218.87	0.00	37.49	14.44	0.00	0.00	0.5700	0.3418	0.0000	0.0000
1	209.93	-0.03	209.80	0.00	39.33	16.04	0.00	0.00	0.8859	0.8629	0.0000	0.0000
1	203.25	0.02	204.74	0.00	41.84	16.66	0.00	0.00	1.1441	1.3671	0.0000	0.0000
1	205.25	-0.02	195.76	0.00	47.35	17.44	0.00	0.00	1.4475	1.8191	0.0000	0.0000
1	173.92	0.00	116.77	0.00	26.63	14.32	0.00	0.00	1.5594	1.8669	0.0000	0.0000
1	174.64	0.00	103.92	0.00	24.34	14.24	0.00	0.00	1.3870	1.7270	0.0000	0.0000
1	167.61	-0.00	82.83	0.00	16.97	14.38	0.00	0.00	1.2530	1.5815	0.0000	0.0000
1	150.72	0.00	59.17	0.00	9.53	15.12	0.00	0.00	1.2027	1.4391	0.0000	0.0000
1	144.24	0.00	12.72	0.00	-10.51	17.71	0.00	0.00	0.6710	0.9568	0.0000	0.0000
					TEST NO	AR 1.4	O.C.R. 1					
					***********************************							
					A.G.L.130.01		R.G.L. 38.95					
1	182.17	23.58	126.50	70.75	2.91	0.00	29.18	0.00	0.0143	0.0025	0.0437	0.0030
25	182.94	23.81	128.83	71.43	8.54	0.00	28.67	0.00	0.1085	0.0017	0.0582	-0.0008
50	183.16	23.44	129.47	70.33	20.03	0.00	23.84	0.00	0.3434	0.0118	0.0830	-0.0003
70	182.91	22.00	128.74	66.00	34.80	0.00	22.32	0.00	0.9850	0.1822	0.1390	0.0243
					DRAINED REST PERIOD							
					A.G.L.125.28		R.G.L. 39.19					
1	183.13	24.09	129.39	72.27	3.54	0.00	28.63	0.00	0.0250	0.0058	0.0482	0.0060
50	182.75	24.01	128.25	72.02	16.57	0.00	26.28	0.00	0.1467	-0.0106	0.0558	0.0024
75	183.47	24.60	130.42	73.79	20.62	0.00	25.59	0.00	0.1978	-0.0143	0.0655	0.0041
100	183.94	24.77	131.81	74.32	25.02	0.00	25.76	0.00	0.4304	-0.0134	0.0814	-0.0044
115	183.70	24.27	131.11	72.80	26.17	0.00	25.16	0.00	0.7044	-0.0525	0.1029	0.0069
					DRAINED REST PERIOD							
					A.G.L.124.31		R.G.L. 39.32					
1	184.25	24.26	132.76	72.77	0.71	0.00	29.88	0.00	0.0422	-0.0025	0.0428	0.0057
50	183.93	24.01	131.80	72.04	5.26	0.00	30.37	0.00	0.0709	-0.0053	0.0434	-0.0027
100	183.96	23.99	131.89	71.97	8.19	0.00	30.24	0.00	0.0954	-0.0113	0.0436	-0.0058
200	184.31	24.05	132.93	72.16	13.50	0.00	30.07	0.00	0.1665	0.0361	0.0526	-0.0015
300	184.20	23.90	132.60	71.71	17.53	0.00	28.78	0.00	0.2969	0.0741	0.0551	0.0048
400	184.58	23.93	133.73	71.80	21.61	0.00	28.38	0.00	0.6668	0.2576	0.0649	0.0164
450	184.54	22.07	133.61	66.21	22.73	0.00	26.50	0.00	1.8159	1.3686	0.1206	0.0693
					DRAINED REST PERIOD							
					A.G.L.121.42		R.G.L. 39.45					
1	184.61	23.01	133.83	69.04	5.29	0.00	29.08	0.00	0.0169	0.0021	0.0366	0.0049
50	184.29	24.14	132.86	72.41	6.30	0.00	29.83	0.00	0.0702	0.0127	0.0392	0.0009
100	184.22	23.48	132.67	70.44	7.30	0.00	30.88	0.00	0.0736	0.0190	0.0381	-0.0023
300	184.61	23.43	133.82	70.28	12.24	0.00	29.11	0.00	0.0930	0.0171	0.0394	-0.0023
500	184.77	23.51	134.31	70.54	14.67	0.00	27.80	0.00	0.0971	0.0066	0.0424	-0.0057
700	184.84	22.39	134.53	67.18	17.35	0.00	25.61	0.00	0.0879	0.0141	0.0415	-0.0028
1000	184.97	22.72	134.91	68.15	20.29	0.00	25.97	0.00	0.0920	0.0035	0.0431	0.0029
1200	185.07	22.88	135.22	68.65	20.04	0.00	26.07	0.00	0.1089	0.0147	0.0440	0.0049
1500	185.02	24.00	135.06	72.00	23.41	0.00	28.73	0.00	0.1176	-0.0058	0.0422	-0.0066
1700	185.47	24.01	136.41	72.02	24.62	0.00	28.50	0.00	0.1464	0.0130	0.0415	-0.0021

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
2000	183.33	24.57	135.96	73.72	25.35	0.00	28.20	0.00	0.1557	0.0069	0.0506	-0.0033
2160	186.10	24.60	138.31	73.81	26.92	0.00	26.21	0.00	0.1572	0.0041	0.0459	-0.0007
						DRAINED REST PERIOD						
						A.G.L.121.23	R.G.L. 39.46					
1	184.74	21.31	134.21	63.92	-0.43	0.00	32.17	0.00	0.0173	-0.0010	0.0422	0.0047
50	184.39	24.01	133.16	72.02	3.85	0.00	29.20	0.00	0.0293	0.0104	0.0337	-0.0027
100	184.80	23.69	134.39	71.06	4.93	0.00	27.72	0.00	0.0355	0.0044	0.0375	0.0028
300	184.77	24.10	134.30	72.31	6.48	0.00	27.23	0.00	0.0349	0.0061	0.0371	-0.0011
500	184.89	23.75	134.67	71.26	7.65	0.00	27.37	0.00	0.0363	0.0056	0.0359	-0.0043
700	184.57	24.65	133.70	73.94	8.53	0.00	29.90	0.00	0.0363	0.0056	0.0388	-0.0059
1000	184.43	24.72	133.43	74.15	10.74	0.00	29.40	0.00	0.0390	0.0031	0.0406	0.0029
1200	184.16	23.22	132.48	69.67	10.34	0.00	28.81	0.00	0.0391	0.0065	0.0403	0.0015
1500	183.74	23.69	131.22	71.07	10.47	0.00	28.80	0.00	0.0400	0.0073	0.0415	0.0016
1700	184.23	23.40	132.63	70.20	12.37	0.00	28.00	0.00	0.0417	0.0078	0.0393	0.0007
2000	183.97	23.84	131.91	71.52	12.30	0.00	27.51	0.00	0.0411	0.0076	0.0392	0.0050
2160	183.71	23.33	131.13	69.93	12.42	0.00	29.71	0.00	0.0394	0.0037	0.0393	0.0011
					STRAIN CONTROL FAILURE TEST							
1	183.54	0.00	130.62	0.00	17.77	0.00	0.00	0.00	0.0498	0.0252	0.0000	0.0000
1	196.65	0.00	169.94	0.00	25.20	0.00	0.00	0.00	0.0659	0.0242	0.0000	0.0000
1	201.20	-0.02	183.59	0.00	26.19	0.00	0.00	0.00	0.0814	0.0012	0.0000	0.0000
1	204.45	0.00	193.34	0.00	28.33	0.00	0.00	0.00	0.0849	-0.0038	0.0000	0.0000
1	203.69	0.00	206.07	0.00	29.81	0.00	0.00	0.00	0.1195	-0.0711	0.0000	0.0000
1	203.02	0.00	189.06	0.00	24.75	0.00	0.00	0.00	0.1562	-0.0977	0.0000	0.0000
1	183.97	0.00	128.90	0.00	10.47	0.00	0.00	0.00	0.1457	-0.0460	0.0000	0.0000
1	171.13	0.00	93.33	0.00	0.16	0.00	0.00	0.00	0.0683	-0.0211	0.0000	0.0000
					TEST NO	AR 1.5		O.C.R. 1				
					***********************************							
						A.G.L. 43.65	R.G.L. 38.94		EX.G.L.129.90			
1	133.72		131.16	26.22	1.92	0.77	9.03	8.68	0.1315	0.0420	0.0170	0.0000
50	133.74		131.22	30.57	5.75	10.13	10.34	9.83	0.3458	0.0217	0.0272	0.0000
100	133.01		129.02	31.16	7.99	12.50	10.42	9.03	0.4636	0.0929	0.0291	0.0000
150	133.07		129.20	29.31	10.79	16.09	10.28	9.22	0.5860	0.1884	0.0354	0.0000
200	132.99		128.97	30.10	18.05	20.51	9.69	9.89	0.7754	0.4609	0.0300	0.0000
250	132.54		127.63	27.53	26.84	23.87	8.89	10.58	1.3101	1.0856	0.0372	0.0000
						DRAINED REST PERIOD						
					A.G.L. 42.47		R.G.L. 39.07		EX.G.L.124.59			
1	133.93		131.80	39.66	3.10	4.52	13.03	8.82	0.0152	-0.0038	0.0295	0.0000
50	133.49		130.47	28.88	7.77	8.17	10.21	6.71	0.0551	0.0080	0.0329	0.0000
100	133.51		130.52	28.67	8.82	9.19	9.17	6.44	0.0645	0.0038	0.0409	0.0000
300	133.14		129.43	30.12	12.47	11.86	9.30	7.35	0.0831	0.0168	0.0396	0.0000
500	134.15		132.45	28.31	17.15	14.40	9.19	6.65	0.0991	0.0108	0.0329	0.0000
741	134.10		132.30	29.08	18.26	16.90	8.93	7.07	0.1386	0.0298	0.0383	0.0000
748	133.64		130.91	55.78	17.74	15.79	16.62	13.94	0.2495	0.0409	0.0318	0.0000
800	132.88		128.64	54.44	22.57	20.02	17.65	14.92	0.3197	0.0305	0.0494	0.0000
840	132.51		127.52	52.91	25.77	20.98	17.00	14.86	0.9919	-0.0484	0.0871	0.0000
						DRAINED REST PERIOD						
					A.G.L. 42.00		R.G.L. 39.24		EX.G.L.123.21			
1	132.61		127.84	29.31	3.86	5.97	11.27	7.42	0.0179	-0.0054	0.0147	0.0000
50	132.84		128.53	25.61	5.49	6.99	9.46	7.19	0.0398	0.0377	0.0157	0.0000
100	132.80		128.40	26.12	8.05	8.01	9.16	7.18	0.0373	0.0211	0.0209	0.0000
300	134.04		132.12	28.48	10.77	11.55	9.49	7.46	0.0609	0.0260	0.0214	0.0000
500	133.60		130.81	24.57	13.78	13.93	8.00	7.07	0.0637	0.0296	0.0274	0.0000
741	132.44		127.32	33.43	16.05	14.90	9.29	7.59	0.0756	0.0423	0.0321	0.0000
745	133.83		131.49	51.10	16.63	14.25	15.53	11.90	0.1042	0.0321	0.0446	0.0000

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_y^p	ε_s^r	ε_v^r
870	183.48	130.45	49.79	18.17	17.17	15.53	12.04	0.1260	0.0059	0.0436	0.0000
1000	183.29	129.88	47.19	21.14	20.10	16.08	11.57	0.1905	-0.0514	0.0438	0.0000
1053	183.41	130.24	48.56	22.04	20.59	15.77	12.38	0.2051	-0.0256	0.0431	0.0000
1056	183.61	130.82	64.28	22.17	19.95	20.28	18.39	0.2554	0.0291	0.0589	0.0000
1086	183.67	131.02	65.60	22.89	20.97	20.97	19.38	0.4058	0.0043	0.0632	0.0000
1107	183.85	131.55	69.01	25.02	21.80	20.78	20.21	0.5870	-0.0345	0.0835	0.0000
1109	183.87	131.60	50.94	25.40	22.02	16.37	15.58	0.6615	0.0294	0.0449	0.0000
1150	183.41	130.23	46.16	26.16	27.16	15.44	10.53	0.8987	0.0403	0.0446	0.0000
1200	183.99	131.98	48.61	28.36	26.71	15.85	14.45	1.2783	0.0234	0.0565	0.0000
				DRAINED REST PERIOD							
				A.G.L. 41.47		R.G.L. 39.43		EX.G.L.121.53			
1	184.33	132.99	33.50	3.08	1.10	12.42	7.90	0.0190	0.0041	0.0185	0.0000
100	183.58	130.74	29.29	2.00	2.06	10.28	6.74	0.0360	-0.0008	0.0213	0.0000
400	182.84	128.53	27.83	5.23	3.27	9.45	7.26	0.0432	-0.0132	0.0219	0.0000
600	183.35	130.06	30.45	4.91	3.54	9.65	7.16	0.0391	-0.0071	0.0234	0.0000
741	181.99	125.96	37.56	4.87	4.23	12.68	7.15	0.0472	0.0206	0.0204	0.0000
745	185.02	135.06	50.67	4.16	3.50	15.64	11.53	0.0615	0.0176	0.0167	0.0000
900	183.90	131.69	51.23	6.69	5.31	15.30	12.11	0.0682	0.0219	0.0215	0.0000
1053	183.43	130.30	50.75	9.56	7.01	15.42	12.32	0.0806	0.0217	0.0270	0.0000
1056	183.88	131.64	68.91	9.89	6.91	20.54	16.81	0.0913	0.0049	0.0449	0.0000
1075	184.37	133.12	69.49	9.97	6.35	21.36	20.91	0.1064	0.0115	0.0412	0.0000
1103	184.20	132.61	68.54	11.41	9.23	21.18	18.79	0.1107	0.0199	0.0397	0.0000
1107	184.59	133.77	50.31	12.28	9.82	15.61	12.77	0.1192	0.0281	0.0382	0.0000
1200	184.05	132.14	51.71	12.61	10.03	15.46	13.10	0.1071	0.0216	0.0283	0.0000
1418	183.71	131.13	49.70	13.02	11.34	16.12	13.42	0.1223	0.0282	0.0333	0.0000
1422	183.64	130.93	31.53	12.79	11.79	10.37	7.14	0.1164	0.0426	0.0221	0.0000
1700	183.46	130.37	28.89	14.59	11.99	11.24	6.95	0.1139	0.0504	0.0223	0.0000
2000	183.53	130.60	23.46	16.05	12.60	10.23	6.39	0.1120	0.0437	0.0208	0.0000
2160	183.76	131.27	29.90	15.76	12.90	10.44	7.30	0.1174	0.0306	0.0206	0.0000
				DRAINED REST PERIOD							
				A.G.L. 41.42		R.G.L. 39.43		EX.G.L.121.43			
1	183.31	129.94	31.48	2.77	3.77	10.04	8.00	0.0131	-0.0118	0.0155	0.0000
50	184.17	132.50	29.88	4.37	3.92	9.25	6.89	0.0463	0.0051	0.0152	0.0000
100	183.70	131.10	28.25	4.76	3.22	10.16	6.20	0.0463	0.0051	0.0109	0.0000
300	183.37	130.10	29.39	5.70	4.63	9.95	6.32	0.0456	0.0041	0.0140	0.0000
500	183.31	129.93	27.00	7.09	5.06	9.84	6.14	0.0494	0.0052	0.0135	0.0000
741	183.65	130.96	28.68	9.41	5.41	10.23	6.59	0.0513	0.0087	0.0120	0.0000
746	184.60	133.81	52.86	8.35	6.33	17.05	12.56	0.0487	0.0132	0.0223	0.0000
900	184.62	133.85	51.85	9.12	6.69	16.70	12.51	0.0518	0.0069	0.0230	0.0000
1053	184.59	133.78	51.19	10.37	7.05	16.45	12.85	0.0568	0.0196	0.0236	0.0000
1056	184.43	133.29	73.77	9.34	7.05	22.81	19.17	0.0641	0.0008	0.0487	0.0000
1060	184.44	133.31	72.63	11.65	7.81	23.21	19.64	0.0643	0.0063	0.0425	0.0000
1107	184.48	133.43	52.61	11.17	8.62	17.04	15.12	0.0602	0.0188	0.0378	0.0000
1200	184.15	132.45	49.42	13.12	9.19	16.05	12.63	0.0603	0.0183	0.0292	0.0000
1418	183.90	131.70	51.35	13.14	9.64	15.64	12.09	0.0610	0.0162	0.0215	0.0000
1420	184.06	132.19	29.44	12.98	10.15	9.84	7.88	0.0607	0.0171	0.0129	0.0000
1700	184.44	133.31	27.72	14.95	10.83	9.14	7.93	0.0615	0.0149	0.0155	0.0000
2000	184.51	133.52	28.06	13.29	10.68	8.95	7.84	0.0618	0.0168	0.0157	0.0000
2160	184.60	133.79	28.45	14.51	10.43	8.88	7.99	0.0624	0.0182	0.0127	0.0000
				STRAIN CONTROL FAILURE TEST							
1	183.43	130.28	0.00	14.24	10.20	0.00	0.00	0.0635	0.0211	0.0000	0.0000
1	200.93	182.93	0.00	23.97	14.28	0.00	0.00	0.1371	0.0331	0.0000	0.0000
1	202.99	183.98	0.00	23.48	13.31	0.00	0.00	0.1289	0.0027	0.0000	0.0000
1	203.80	191.41	0.00	27.18	13.33	0.00	0.00	0.5492	0.2042	0.0000	0.0000

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	193.91		176.74	0.00	36.47	23.77	0.00	0.00	1.1771	0.8281	0.0000	0.0000
1	195.45		166.36	0.00	38.73	32.50	0.00	0.00	1.3838	1.0603	0.0000	0.0000
1	191.95		155.34	0.00	32.32	37.42	0.00	0.00	1.5828	1.4199	0.0000	0.0000
					TEST NO	AR 1.6	O.C.R.	1				
					********	********	********	********				
					A.G.L.129.01		R.G.L. 38.95					
1	184.85	10.24	134.56	30.73	3.10	0.00	15.03	0.00	0.1629	-0.0048	0.0224	0.0032
50	184.70	9.75	134.37	29.24	7.09	0.00	15.48	0.00	0.1689	-0.0009	0.0221	-0.0035
100	185.59	9.84	136.77	29.53	8.00	0.00	13.92	0.00	0.1761	-0.0018	0.0217	-0.0022
200	186.19	10.49	138.57	31.46	11.34	0.00	14.42	0.00	0.1995	-0.0248	0.0210	-0.0037
500	184.08	9.60	132.25	28.80	16.09	0.00	12.64	0.00	0.2100	0.0001	0.0195	-0.0054
700	183.95	9.53	131.85	28.53	18.48	0.00	11.76	0.00	0.2237	0.0043	0.0202	-0.0012
870	184.06	9.66	132.18	28.99	18.74	0.00	11.73	0.00	0.2251	0.0118	0.0217	-0.0043
875	183.94	16.40	131.83	49.20	18.50	0.00	21.65	0.00	0.2458	-0.0160	0.0343	-0.0039
900	184.46	16.55	133.39	49.64	19.13	0.00	20.31	0.00	0.2591	0.0119	0.0348	-0.0107
950	184.20	16.27	132.61	48.80	25.93	0.00	20.98	0.00	0.3545	0.0201	0.0490	-0.0081
1000	183.76	15.15	131.29	45.46	37.19	0.00	28.85	0.00	0.6009	0.1882	0.0461	-0.0248
1025	183.82	15.29	131.46	45.87	45.65	0.00	19.74	0.00	1.2672	0.7130	0.0956	0.0661
						DRAINED	REST PERIOD					
					A.G.L.124.40		R.G.L. 39.10					
1	183.61	8.81	130.84	26.44	12.48	0.00	13.30	0.00	0.0034	-0.0014	0.0172	-0.0054
50	183.66	9.62	130.97	28.85	15.25	0.00	14.47	0.00	0.0084	-0.0004	0.0216	-0.0028
100	183.14	8.40	129.42	25.19	15.74	0.00	13.96	0.00	0.0094	0.0011	0.0208	-0.0043
200	183.93	9.67	131.93	29.02	18.36	0.00	14.79	0.00	0.0119	0.0010	0.0230	-0.0052
300	183.75	9.89	131.26	29.68	19.44	0.00	13.18	0.00	0.0228	-0.0021	0.0205	-0.0019
500	183.43	9.06	130.45	27.18	20.77	0.00	14.29	0.00	0.0245	-0.0081	0.0207	-0.0108
700	183.81	9.78	131.44	29.34	22.29	0.00	13.74	0.00	0.0299	-0.0019	0.0195	0.0067
741	183.75	9.84	131.24	29.52	22.44	0.00	13.88	0.00	0.0304	-0.0012	0.0201	-0.0028
745	184.04	17.19	132.11	51.57	22.69	0.00	23.31	0.00	0.0393	-0.0054	0.0344	-0.0055
800	184.66	16.70	133.97	50.09	24.95	0.00	23.44	0.00	0.0601	-0.0034	0.0356	0.0015
900	184.08	15.98	132.25	47.94	28.11	0.00	23.11	0.00	0.1061	-0.0032	0.0345	0.0036
1000	184.27	16.57	132.82	49.71	30.82	0.00	23.11	0.00	0.1840	-0.0143	0.0394	-0.0006
1053	184.16	16.87	132.47	50.60	32.14	0.00	23.64	0.00	0.2478	-0.0141	0.0355	-0.0077
1060	184.35	23.32	133.04	69.96	32.76	0.00	31.70	0.00	0.2814	-0.0176	0.0653	-0.0040
1080	183.95	23.19	131.95	69.57	32.98	0.00	31.21	0.00	0.6308	-0.0870	0.0945	-0.0209
						DRAINED	REST PERIOD					
					A.G.L.123.39		R.G.L. 39.22					
1	184.03	9.76	132.08	29.33	3.70	0.00	15.02	0.00	0.0060	0.0026	0.0147	0.0077
50	183.82	10.18	131.45	30.54	4.58	0.00	14.57	0.00	0.0192	-0.0016	0.0139	0.0071
100	183.44	9.96	130.33	29.89	5.43	0.00	15.85	0.00	0.0213	0.0008	0.0219	-0.0056
300	183.50	10.52	130.49	31.56	7.41	0.00	16.33	0.00	0.0194	0.0032	0.0181	-0.0042
500	182.39	10.74	127.17	32.21	7.49	0.00	14.95	0.00	0.0198	0.0011	0.0240	-0.0016
700	183.27	11.96	126.80	35.87	8.22	0.00	17.65	0.00	0.0198	-0.0008	0.0213	-0.0024
820	183.61	17.60	130.82	52.79	8.72	0.00	26.67	0.00	0.0245	0.0096	0.0239	-0.0073
825	184.45	17.13	133.36	51.39	10.30	0.00	26.29	0.00	0.0243	0.0047	0.0278	-0.0012
900	184.28	16.70	132.83	50.10	10.79	0.00	26.79	0.00	0.0232	0.0127	0.0317	-0.0067
1000	184.17	16.91	132.52	50.72	11.03	0.00	25.76	0.00	0.0254	0.0084	0.0296	-0.0091
1130	184.21	23.34	132.63	70.02	11.30	0.00	35.24	0.00	0.0339	0.0011	0.0403	-0.0055
1135	184.37	23.60	133.12	70.79	12.07	0.00	36.28	0.00	0.0387	0.0069	0.0426	0.0003
1160	184.25	23.46	132.76	70.39	12.44	0.00	35.86	0.00	0.0426	0.0120	0.0437	0.0006
1186	184.23	17.54	132.69	52.61	13.10	0.00	27.61	0.00	0.0416	0.0081	0.0328	0.0002
1190	184.31	17.57	132.94	52.70	13.98	0.00	26.43	0.00	0.0464	0.0113	0.0330	0.0003
1200	184.27	17.12	132.80	51.35	15.53	0.00	25.79	0.00	0.0551	0.0076	0.0349	-0.0052

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1498	184.05	10.73	132.16	32.35	17.87	0.00	16.28	0.00	0.0580	0.0125	0.0259	-0.0005
1503	184.04	9.95	132.13	29.86	17.81	0.00	14.89	0.00	0.0546	0.0094	0.0190	-0.0051
1700	183.91	9.84	131.73	29.53	19.25	0.00	14.76	0.00	0.0584	0.0021	0.0183	-0.0051
2000	183.95	10.07	131.85	30.22	20.13	0.00	15.40	0.00	0.0596	0.0007	0.0217	-0.0021
						DRAINED REST PERIOD						
					A.G.L.123.32		R.G.L. 39.21					
1	184.77	11.13	134.31	33.55	3.66	0.00	17.79	0.00	0.0163	0.0050	0.0208	-0.0051
50	184.10	10.57	132.30	31.72	4.04	0.00	17.31	0.00	0.0155	0.0039	0.0194	-0.0061
100	183.74	9.78	131.22	29.35	4.96	0.00	16.17	0.00	0.0163	0.0037	0.0197	-0.0039
300	184.31	10.30	132.92	30.90	6.73	0.00	15.29	0.00	0.0169	0.0033	0.0130	-0.0074
500	183.86	10.13	131.58	30.33	7.46	0.00	15.63	0.00	0.0180	0.0043	0.0195	0.0001
700	183.73	9.92	131.35	29.75	8.13	0.00	15.33	0.00	0.0174	0.0028	0.0195	-0.0025
778	183.93	9.45	131.73	28.35	8.33	0.00	15.39	0.00	0.0171	0.0011	0.0201	-0.0066
784	184.09	16.88	132.27	50.63	8.62	0.00	24.16	0.00	0.0179	0.0023	0.0257	-0.0125
900	183.81	16.66	131.44	49.97	9.17	0.00	25.05	0.00	0.0186	0.0020	0.0289	-0.0047
1093	183.41	16.18	130.23	48.54	9.34	0.00	25.32	0.00	0.0182	0.0013	0.0286	-0.0043
1096	184.20	24.48	132.60	73.44	9.41	0.00	34.37	0.00	0.0207	-0.0001	0.0374	-0.0110
1135	184.12	24.45	132.35	73.35	9.75	0.00	35.68	0.00	0.0163	-0.0002	0.0400	-0.0034
1149	183.83	24.78	131.48	74.34	10.00	0.00	35.94	0.00	0.0165	-0.0012	0.0438	-0.0029
1153	183.42	16.36	130.27	49.07	10.46	0.00	26.36	0.00	0.0176	-0.0014	0.0314	-0.0023
1300	183.60	17.47	130.80	52.42	12.19	0.00	26.10	0.00	0.0166	-0.0023	0.0315	0.0022
1470	184.09	16.96	132.26	50.89	12.44	0.00	26.64	0.00	0.0178	0.0007	0.0334	-0.0037
1475	183.63	9.71	130.88	29.13	12.38	0.00	16.23	0.00	0.0182	-0.0031	0.0202	-0.0046
1700	183.54	9.79	130.63	29.37	12.65	0.00	16.08	0.00	0.0179	-0.0016	0.0208	-0.0043
2000	183.19	9.26	129.56	27.79	12.93	0.00	14.92	0.00	0.0171	0.0010	0.0219	-0.0050
2160	183.10	9.56	129.29	28.67	13.22	0.00	14.64	0.00	0.0187	0.0002	0.0139	-0.0033
						DRAINED REST PERIOD						
					A.G.L.123.29		R.G.L. 39.21					
1	185.30	10.28	135.90	30.83	1.41	0.00	17.19	0.00	0.0100	-0.0006	0.0207	-0.0071
100	183.93	9.55	131.94	28.66	1.58	0.00	15.24	0.00	0.0088	-0.0024	0.0165	-0.0045
300	183.69	8.95	131.07	26.84	4.18	0.00	14.18	0.00	0.0097	-0.0009	0.0174	-0.0074
500	184.08	9.63	132.24	28.90	4.95	0.00	15.14	0.00	0.0110	-0.0016	0.0206	-0.0028
754	183.60	9.63	130.81	28.90	5.16	0.00	14.92	0.00	0.0143	0.0021	0.0195	-0.0016
758	184.50	16.60	133.51	49.81	5.35	0.00	26.07	0.00	0.0154	-0.0002	0.0230	0.0067
900	183.81	17.28	131.43	51.83	5.30	0.00	26.47	0.00	0.0150	-0.0014	0.0313	-0.0053
1068	183.80	17.38	131.39	52.14	5.51	0.00	26.21	0.00	0.0166	-0.0036	0.0310	-0.0029
1071	183.58	24.60	130.73	73.80	5.59	0.00	37.14	0.00	0.0185	0.0011	0.0336	0.0100
1100	183.64	24.12	130.93	72.37	5.80	0.00	36.58	0.00	0.0186	0.0000	0.0398	-0.0007
1122	183.67	23.57	131.01	70.72	6.12	0.00	35.58	0.00	0.0195	-0.0044	0.0389	0.0069
1125	184.07	16.64	132.20	49.91	7.27	0.00	25.42	0.00	0.0220	0.0019	0.0332	-0.0031
1300	183.94	16.94	131.81	50.81	7.10	0.00	26.35	0.00	0.0214	0.0042	0.0348	-0.0016
1440	184.21	16.68	132.63	50.04	7.39	0.00	25.44	0.00	0.0231	0.0082	0.0311	0.0021
1444	183.74	10.21	131.23	30.64	8.37	0.00	17.14	0.00	0.0193	0.0023	0.0216	0.0108
1700	184.62	10.46	133.87	31.39	8.41	0.00	17.36	0.00	0.0203	0.0045	0.0218	-0.0000
2000	184.02	9.83	132.05	29.64	8.44	0.00	16.16	0.00	0.0167	0.0036	0.0232	0.0029
2160	183.79	9.75	131.38	29.24	8.35	0.00	16.37	0.00	0.0212	0.0046	0.0252	0.0051
					STRAIN CONTROL FAILURE TEST							
1	183.29	0.00	129.87	0.00	8.83	0.00	0.00	0.00	0.0183	-0.0049	0.0000	0.0000
1	200.79	0.00	182.37	0.00	31.77	0.00	0.00	0.00	0.0759	0.0426	0.0000	0.0000
1	204.67	-0.05	194.01	0.00	35.43	0.00	0.00	0.00	0.1381	0.0400	0.0000	0.0000
1	203.36	0.00	205.07	0.00	42.25	0.00	0.00	0.00	0.2542	0.0446	0.0000	0.0000
1	201.68	0.02	185.03	0.00	29.01	0.00	0.00	0.00	0.8695	0.3465	0.0000	0.0000
1	196.06	0.00	168.19	0.00	23.25	0.00	0.00	0.00	1.5470	1.0844	0.0000	0.0000

TEST NO AR 1.7 O.C.R. 1

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A.G.L. 43.04 R.G.L. 38.97 EX.G.L.128.30

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	133.34	130.02	22.10	1.41	4.86	7.13	3.28	0.0165	0.0013	0.0165	0.0010
50	132.50	127.51	27.51	0.68	4.96	9.76	4.27	0.0210	-0.0011	0.0208	-0.0021
100	132.33	128.48	26.69	2.11	8.26	10.71	4.46	0.0440	0.0015	0.0242	0.0035
200	133.91	131.72	29.20	2.91	9.04	10.10	4.37	0.0462	0.0015	0.0237	-0.0007
300	133.90	131.69	29.04	4.15	9.76	10.18	4.20	0.0696	0.0014	0.0242	0.0006
400	133.67	131.01	30.71	4.26	10.23	10.42	4.41	0.0734	0.0026	0.0245	-0.0033
500	133.50	130.73	30.25	5.10	10.84	10.61	4.35	0.0770	0.0021	0.0259	-0.0033
700	133.63	131.03	30.90	6.83	12.22	10.30	4.41	0.1007	0.0312	0.0252	-0.0056
740	133.61	130.33	31.16	7.47	12.52	10.53	4.37	0.1151	0.0443	0.0266	-0.0022
743	134.17	132.52	47.18	7.73	12.45	16.15	5.79	0.1161	0.0347	0.0335	0.0101
775	133.77	131.31	47.16	8.25	14.03	17.17	5.72	0.1428	0.0526	0.0354	0.0030
825	133.70	131.09	43.39	12.40	17.22	16.17	5.32	0.2293	0.0513	0.0365	0.0097
875	133.90	131.69	47.04	18.33	20.55	15.13	4.62	0.3837	0.1051	0.0387	-0.0023
930	134.43	133.30	42.39	26.01	24.89	14.91	4.05	0.7374	0.2721	0.0404	0.0057

DRAINED REST PERIOD

A.G.L. 42.58 R.G.L. 39.07 EX.G.L.127.24

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	133.57	130.71	29.13	-2.00	3.68	10.79	4.29	0.0162	0.0035	0.0265	0.0072
50	133.04	129.11	29.11	-0.38	4.39	10.94	4.12	0.0274	0.0021	0.0187	-0.0014
100	133.43	130.30	28.29	1.08	5.02	9.94	3.85	0.0303	0.0032	0.0211	-0.0002
200	133.40	130.19	27.81	2.30	5.98	9.60	3.83	0.0404	0.0047	0.0212	0.0001
300	133.45	130.36	26.56	3.69	6.52	9.35	3.87	0.0403	0.0020	0.0217	0.0022
500	133.62	130.85	31.25	6.03	7.97	10.71	4.20	0.0511	0.0064	0.0264	0.0080
700	133.14	129.41	28.52	6.83	8.94	9.02	3.83	0.0611	0.0129	0.0249	0.0007
740	133.41	130.23	29.75	7.01	9.19	9.11	3.97	0.0675	0.0136	0.0219	-0.0047
743	134.64	133.93	48.39	8.51	9.27	15.51	5.65	0.0896	-0.0041	0.0349	0.0152
800	133.76	131.29	48.18	9.01	12.35	15.48	5.34	0.1126	0.0110	0.0377	0.0074
900	133.41	130.23	47.20	13.98	16.06	16.07	4.80	0.1938	0.0144	0.0365	0.0015
1050	132.80	128.41	45.58	17.75	20.10	16.58	3.91	0.3068	0.0280	0.0440	0.0232
1054	133.58	130.75	67.53	18.49	19.77	22.74	4.55	0.3214	0.0214	0.0675	0.0305
1075	133.65	130.95	68.29	19.52	22.70	22.80	3.88	0.5547	0.0040	0.0701	-0.0064
1086	133.35	130.04	67.98	20.17	25.57	21.60	3.66	0.7788	-0.0368	0.0840	0.0024

DRAINED REST PERIOD

A.G.L. 42.12 R.G.L. 39.20 EX.G.L.126.17

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	133.30	131.40	33.69	0.17	-0.01	14.10	5.58	0.0088	0.0008	0.0199	0.0123
50	133.63	130.89	26.03	0.79	0.61	10.08	4.31	0.0227	0.0004	0.0245	0.0111
100	133.58	130.75	32.88	1.35	0.84	12.96	5.12	0.0245	0.0018	0.0323	0.0072
300	133.36	130.09	31.97	1.92	0.98	12.67	4.86	0.0296	0.0055	0.0282	0.0034
500	133.27	129.81	30.89	2.25	1.66	12.35	4.68	0.0324	0.0059	0.0238	-0.0035
700	133.97	131.90	28.53	2.65	2.25	10.90	4.43	0.0314	0.0030	0.0254	-0.0006
744	133.85	131.56	28.41	3.20	2.34	10.88	4.15	0.0323	0.0025	0.0259	0.0006
746	134.12	132.36	51.15	2.30	2.05	19.31	6.77	0.0355	0.0027	0.0402	0.0220
800	133.99	131.97	53.90	3.42	3.53	21.19	6.63	0.0357	-0.0002	0.0411	0.0145
900	133.92	131.75	53.83	5.17	5.41	20.73	6.16	0.0352	0.0036	0.0467	0.0222
1060	134.52	133.55	56.75	7.55	7.22	21.66	6.25	0.0476	-0.0070	0.0524	0.0154
1064	133.59	130.76	68.20	6.22	7.08	26.24	7.24	0.0495	-0.0074	0.0624	0.0245
1090	133.82	131.45	70.14	7.69	9.17	27.36	6.82	0.0732	-0.0139	0.0654	0.0317
1117	133.77	131.30	70.38	9.03	10.73	26.87	6.61	0.0857	-0.0114	0.0625	0.0307
1122	133.86	131.57	50.11	10.21	11.12	18.37	5.16	0.0914	-0.0223	0.0423	0.0024
1200	133.80	131.40	50.50	10.83	11.71	18.54	5.44	0.0843	0.0124	0.0462	0.0165
1400	133.71	131.14	49.89	13.04	12.65	18.55	5.38	0.0988	-0.0002	0.0295	-0.0018
1430	133.58	130.73	50.94	12.91	12.75	18.32	5.36	0.0978	0.0081	0.0454	0.0133
1432	133.43	130.29	30.95	13.40	12.87	10.48	3.60	0.1047	-0.0036	0.0244	0.0008

N	p_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1700	134.01	132.02	30.34	15.08	12.74	10.63	3.71	0.1104	0.0056	0.0200	-0.0014
2000	133.98	131.95	28.20	15.74	12.79	9.91	3.55	0.1089	0.0111	0.0209	-0.0054
2160	133.23	129.84	28.62	15.86	12.60	10.60	3.77	0.1078	-0.0029	0.0242	0.0023
DRAINED REST PERIOD											
A.G.L. 42.08					R.G.L. 39.20		EX.G.L.126.05				
1	132.86	128.59	29.62	-0.08	0.05	12.44	4.78	0.0241	-0.0014	0.0217	0.0005
50	133.07	129.20	29.08	1.99	0.39	11.25	4.63	0.0247	0.0007	0.0137	-0.0000
200	132.47	127.40	25.11	2.27	0.64	11.18	4.43	0.0285	0.0013	0.0190	-0.0003
400	132.62	127.85	26.58	2.81	0.73	9.99	4.24	0.0325	0.0021	0.0238	0.0055
700	132.93	128.78	26.99	3.14	0.96	9.92	4.40	0.0349	0.0018	0.0218	-0.0024
808	133.22	129.66	25.87	2.86	1.16	9.60	4.11	0.0346	-0.0012	0.0196	-0.0056
812	132.88	128.64	42.09	2.36	1.62	15.27	5.28	0.0348	-0.0034	0.0262	-0.0051
1090	134.01	132.03	51.13	4.36	3.16	19.31	6.46	0.0381	-0.0025	0.0415	0.0063
1119	134.05	132.14	50.03	6.00	3.72	18.82	6.24	0.0381	-0.0025	0.0373	0.0114
1122	134.46	133.38	65.15	5.26	3.74	22.55	8.00	0.0384	-0.0020	0.0537	0.0166
1174	134.08	132.24	68.56	6.00	5.80	26.85	7.19	0.0509	0.0026	0.0511	0.0168
1176	133.90	131.71	48.18	7.09	5.98	18.68	5.45	0.0498	0.0008	0.0347	0.0016
1300	133.97	131.90	47.89	7.64	6.25	19.47	5.52	0.0527	-0.0026	0.0352	0.0029
1544	133.95	131.85	47.40	8.83	6.68	19.13	5.47	0.0632	0.0087	0.0327	-0.0007
1546	133.91	131.73	31.90	9.44	6.79	11.93	3.83	0.0590	0.0049	0.0232	-0.0018
1700	133.32	129.95	28.33	9.16	6.61	10.86	3.56	0.0614	0.0053	0.0253	0.0005
2000	133.42	130.26	23.69	9.67	6.65	11.03	3.75	0.0613	0.0077	0.0228	0.0008
2160	133.25	129.75	27.46	9.77	6.62	10.85	3.78	0.0585	0.0048	0.0183	-0.0066
DRAINED REST PERIOD											
A.G.L. 42.06					R.G.L. 39.20		EX.G.L.126.01				
1	134.25	132.76	30.51	2.21	0.66	14.11	5.16	0.0122	-0.0011	0.0255	0.0082
50	132.61	127.82	28.96	1.11	0.30	12.94	4.93	0.0133	-0.0007	0.0254	0.0016
100	132.99	128.96	28.57	1.28	0.20	11.72	4.55	0.0132	-0.0010	0.0237	0.0023
300	133.38	130.13	26.92	2.14	0.66	10.59	4.24	0.0187	0.0021	0.0244	0.0081
500	133.13	129.39	26.03	1.84	0.73	10.68	4.36	0.0249	0.0069	0.0217	0.0168
745	133.19	129.57	26.60	2.11	0.69	10.86	4.51	0.0233	0.0026	0.0277	0.0052
748	132.96	128.87	50.35	0.18	0.62	20.51	7.52	0.0251	0.0040	0.0230	-0.0089
900	133.70	131.36	54.27	2.42	1.97	22.59	6.90	0.0229	0.0000	0.0288	0.0031
1054	133.81	131.44	53.48	2.98	2.64	22.40	6.94	0.0256	-0.0012	0.0362	0.0132
1058	133.90	131.70	67.85	2.52	2.45	28.42	8.36	0.0252	-0.0010	0.0373	-0.0042
1085	133.84	131.53	68.57	2.93	3.22	28.42	8.08	0.0427	0.0070	0.0412	-0.0039
1112	133.76	131.28	67.94	3.35	3.56	28.32	8.02	0.0433	0.0060	0.0459	-0.0012
1116	133.75	131.25	47.29	3.89	3.70	19.90	5.75	0.0388	0.0058	0.0421	0.0150
1300	133.73	131.18	44.70	4.55	3.74	17.54	5.76	0.0415	0.0001	0.0423	0.0145
1425	133.66	130.99	44.72	5.29	4.04	14.66	5.84	0.0412	0.0048	0.0427	0.0146
1429	133.20	129.59	29.15	5.26	3.92	11.29	3.91	0.0423	0.0083	0.0250	0.0035
1700	133.93	131.80	29.42	5.96	4.02	10.30	3.77	0.0397	0.0046	0.0259	-0.0007
2000	134.22	132.67	30.13	5.34	4.17	10.57	4.01	0.0431	0.0057	0.0246	-0.0002
2160	134.25	132.76	29.91	5.97	4.00	10.70	3.84	0.0462	0.0085	0.0265	0.0044
STRAIN CONTROL FAILURE TEST											
1	133.48	130.43	0.00	5.21	3.69	0.00	0.00	0.0396	0.0005	0.0000	0.0000
1	194.24	162.71	0.00	12.29	6.11	0.00	0.00	0.0617	-0.0266	0.0000	0.0000
1	200.62	181.85	0.00	17.50	8.45	0.00	0.00	0.1121	-0.0132	0.0000	0.0000
1	203.66	190.98	0.00	19.48	8.69	0.00	0.00	0.1312	0.0162	0.0000	0.0000
1	205.73	197.33	0.00	21.69	10.51	0.00	0.00	0.4597	0.1073	0.0000	0.0000
1	204.32	192.97	0.00	20.59	13.18	0.00	0.00	0.6440	0.1719	0.0000	0.0000
1	200.96	182.88	0.00	18.16	14.74	0.00	0.00	0.7021	0.2059	0.0000	0.0000
1	197.18	171.53	0.00	16.35	18.63	0.00	0.00	0.7798	0.1923	0.0000	0.0000
1	190.60	151.80	0.00	10.73	18.71	0.00	0.00	0.7476	0.1660	0.0000	0.0000

N	P_m	P_r	q_m	q_r	$u_B^{\,p}$	$u_C^{\,p}$	$u_B^{\,r}$	$u_C^{\,r}$	$\varepsilon_s^{\,p}$	$\varepsilon_v^{\,p}$	$\varepsilon_s^{\,r}$	$\varepsilon_v^{\,r}$
					TEST NO	AR 1.8	O.C.R.	1				
					********	********	********	********				
					A.G.L.128.50		R.G.L. 39.00					
1	183.47	10.08	130.41	30.24	-0.45	0.00	14.16	0.00	0.0079	0.0014	0.0208	0.0055
50	183.77	10.07	131.31	30.22	1.64	0.00	13.11	0.00	0.0167	0.0029	0.0181	0.0007
100	183.92	9.76	131.75	29.29	1.40	0.00	12.10	0.00	0.0181	-0.0002	0.0193	-0.0028
200	183.29	9.68	129.86	29.03	2.91	0.00	12.51	0.00	0.0192	-0.0018	0.0208	0.0034
300	184.01	9.78	132.02	29.34	3.66	0.00	13.12	0.00	0.0230	-0.0058	0.0208	0.0029
500	183.50	10.08	130.50	30.24	5.79	0.00	13.00	0.00	0.0211	-0.0022	0.0217	-0.0022
700	184.00	9.33	131.99	28.14	9.10	0.00	12.75	0.00	0.0291	-0.0098	0.0226	0.0013
1000	183.96	9.81	131.89	29.44	11.80	0.00	12.23	0.00	0.0580	-0.0055	0.0196	0.0007
1200	183.76	9.20	131.28	27.61	13.89	0.00	12.05	0.00	0.0705	-0.0011	0.0215	0.0009
1500	183.76	9.71	131.29	29.13	22.23	0.00	12.84	0.00	0.1551	0.0028	0.0235	0.0010
1700	183.80	9.39	131.41	28.17	42.93	0.00	11.23	0.00	0.3610	0.0557	0.0307	0.0077
1730	183.68	8.83	131.04	26.48	47.98	0.00	9.91	0.00	0.6157	0.1331	0.0505	0.0424
						DRAINED	REST	PERIOD				
					A.G.L.125.72		R.G.L. 38.99					
1	183.47	10.20	130.42	30.59	8.48	0.00	15.02	0.00	0.0093	0.0022	0.0222	0.0049
50	183.61	9.34	130.82	28.03	12.56	0.00	12.41	0.00	0.0201	0.0028	0.0179	-0.0009
100	183.57	9.44	130.72	28.31	15.60	0.00	12.45	0.00	0.0339	0.0027	0.0172	0.0018
300	184.02	8.92	132.07	26.76	19.73	0.00	11.58	0.00	0.0381	0.0044	0.0193	0.0011
500	184.02	9.99	132.07	29.98	21.61	0.00	12.20	0.00	0.0522	0.0054	0.0197	0.0010
700	183.98	9.58	131.93	28.75	24.39	0.00	11.62	0.00	0.0769	0.0014	0.0199	0.0006
1100	183.35	10.82	130.05	32.46	26.43	0.00	12.87	0.00	0.1016	-0.0032	0.0256	0.0030
1500	183.93	9.76	131.80	29.28	27.94	0.00	11.39	0.00	0.1117	0.0009	0.0237	0.0041
1700	183.66	9.57	130.99	28.70	28.52	0.00	11.35	0.00	0.1282	0.0021	0.0225	0.0033
2000	184.00	9.84	132.00	29.53	30.06	0.00	11.67	0.00	0.1500	0.0017	0.0215	0.0047
2160	183.74	9.40	131.22	28.21	30.23	0.00	11.96	0.00	0.1729	-0.0004	0.0232	0.0026
						DRAINED	REST	PERIOD				
					A.G.L.125.47		R.G.L. 39.02					
1	184.20	10.63	132.61	31.88	1.72	0.00	14.87	0.00	0.0082	-0.0034	0.0210	0.0051
50	184.04	8.76	132.11	26.28	5.29	0.00	12.58	0.00	0.0212	0.0005	0.0186	0.0054
100	183.81	9.28	131.43	27.85	6.34	0.00	11.97	0.00	0.0210	-0.0024	0.0208	0.0008
300	183.68	8.57	131.03	25.71	9.40	0.00	12.10	0.00	0.0286	0.0064	0.0183	0.0057
500	183.72	8.95	131.15	26.84	11.06	0.00	11.94	0.00	0.0346	0.0109	0.0187	0.0020
700	184.03	9.50	132.08	28.50	12.42	0.00	12.25	0.00	0.0340	0.0041	0.0130	-0.0002
1000	183.53	9.34	130.60	28.01	13.66	0.00	12.12	0.00	0.0377	-0.0000	0.0206	0.0028
1400	183.10	9.04	129.29	27.12	15.14	0.00	12.19	0.00	0.0502	0.0076	0.0211	0.0018
1700	183.50	9.22	130.50	27.67	16.12	0.00	12.16	0.00	0.0595	0.0170	0.0208	0.0032
2160	183.77	9.37	131.31	28.10	17.32	0.00	10.82	0.00	0.0728	0.0051	0.0185	0.0025
						DRAINED	REST	PERIOD				
					A.G.L.125.40		R.G.L. 39.00					
1	182.20	7.73	126.59	23.18	-1.22	0.00	0.91	0.00	0.0302	0.0121	0.0121	0.0036
300	183.67	9.51	131.00	28.52	4.63	0.00	1.05	0.00	0.0560	0.0065	0.0194	0.0081
800	183.81	9.55	131.44	28.64	10.59	0.00	0.74	0.00	0.0611	-0.0060	-0.0050	-0.0246
						DRAINED	REST	PERIOD				
					A.G.L.125.32		R.G.L. 39.01					
					STRAIN	CONTROL	FAILURE	TEST				
1	183.77	-0.00	146.31	0.00	0.13	0.00	0.00	0.00	0.0034	0.0038	0.0000	0.0000
1	195.82	0.00	167.45	0.00	-0.08	0.00	0.00	0.00	0.0285	0.0342	0.0000	0.0000
1	201.66	-0.04	181.99	0.00	1.32	0.00	0.00	0.00	0.0899	0.0581	0.0000	0.0000
1	198.71	-0.01	176.12	0.00	1.42	0.00	0.00	0.00	0.3665	0.0258	0.0000	0.0000
1	194.34	0.00	163.01	0.00	1.01	0.00	0.00	0.00	0.7114	0.1872	0.0000	0.0000
1	191.32	-0.02	153.97	0.00	0.97	0.00	0.00	0.00	0.8348	0.1829	0.0000	0.0000
1	173.43	-0.01	115.29	0.00	1.35	0.00	0.00	0.00	1.0467	0.3699	0.0000	0.0000

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_y^p	ε_s^r	ε_v^r
				TEST NO	AR 1.9	O.C.R.	1				
				**********	**********	**********	**********				
				A.G.L. 42.57		R.G.L. 38.95		EX.G.L.128.30			
1	130.72	122.15	39.20	2.49	1.17	16.80	3.11	0.0028	0.0023	0.0182	-0.0222
50	133.22	129.67	48.29	4.84	4.15	15.09	2.53	0.0322	0.0026	0.0389	0.0114
100	133.39	130.16	47.24	7.15	5.60	14.64	2.32	0.0438	0.0005	0.0400	0.0160
200	133.54	130.62	47.72	10.65	7.77	15.14	2.48	0.0676	0.0023	0.0401	0.0184
300	133.43	130.44	48.24	11.42	10.06	15.17	2.21	0.0827	-0.0012	0.0397	0.0221
500	133.60	130.79	47.64	14.64	15.77	15.39	2.12	0.1528	0.0017	0.0412	0.0145
700	133.94	131.82	47.86	22.91	19.85	15.09	2.12	0.3632	-0.0041	0.0476	0.0003
745	133.95	131.86	46.95	26.82	25.54	14.63	1.48	0.5463	-0.0933	0.0458	0.0142
				DRAINED REST PERIOD							
				A.G.L. 42.25		R.G.L. 39.05		EX.G.L.127.32			
1	133.30	129.89	48.33	-1.92	1.80	14.93	2.42	0.0046	0.0011	0.0342	0.0100
50	133.30	131.39	49.18	3.51	5.84	15.60	2.29	0.0283	0.0034	0.0416	0.0182
100	133.70	131.09	49.56	5.85	6.74	15.28	2.33	0.0292	-0.0004	0.0392	0.0205
300	133.45	130.34	48.29	8.81	8.95	15.04	2.22	0.0329	-0.0027	0.0426	0.0138
500	133.49	130.46	47.94	9.49	10.32	15.21	2.17	0.0381	0.0038	0.0415	0.0174
700	133.64	130.91	48.33	11.56	11.42	14.88	2.15	0.0492	-0.0042	0.0427	0.0150
1000	134.03	132.08	47.59	15.04	12.87	14.95	2.15	0.0560	0.0002	0.0433	0.0155
1400	134.03	132.08	47.71	16.48	14.18	15.04	2.12	0.0665	-0.0044	0.0449	0.0108
1800	134.19	132.56	48.14	17.54	15.48	14.92	1.97	0.0820	-0.0058	0.0432	0.0157
2160	134.10	132.31	47.82	19.19	16.81	15.15	1.87	0.0811	0.0006	0.0431	0.0158
				DRAINED REST PERIOD							
				A.G.L. 42.21		R.G.L. 39.04		EX.G.L.127.19			
1	133.47	130.40	51.16	-0.63	0.47	16.06	2.81	0.0029	-0.0003	0.0344	0.0096
50	133.92	131.75	48.37	2.64	1.94	15.09	2.52	0.0185	-0.0074	0.0377	0.0072
200	133.58	130.75	47.20	2.77	2.51	14.70	2.35	0.0209	-0.0037	0.0377	0.0035
500	133.72	131.15	46.77	5.31	3.14	14.31	2.35	0.0222	-0.0019	0.0333	0.0047
700	133.75	131.26	46.96	6.23	3.56	14.70	2.24	0.0215	0.0024	0.0368	0.0107
1000	133.74	131.22	46.67	6.45	4.03	15.30	2.30	0.0211	0.0024	0.0364	0.0035
1400	133.82	131.47	46.89	6.94	4.40	14.52	2.35	0.0233	0.0043	0.0342	0.0081
1800	133.93	131.94	46.57	7.91	4.68	14.53	2.31	0.0244	0.0061	0.0368	0.0055
2160	133.90	131.70	46.48	6.92	4.89	14.52	2.25	0.0280	0.0095	0.0390	0.0039
				DRAINED REST PERIOD							
				A.G.L. 42.21		R.G.L. 39.04		EX.G.L.127.17			
1	134.56	133.67	47.43	3.19	1.29	16.02	2.68	0.0008	0.0011	0.0349	0.0162
50	134.35	133.06	45.59	3.33	1.81	14.30	2.26	0.0191	0.0013	0.0334	0.0123
100	134.39	133.18	45.79	3.31	1.99	14.02	2.42	0.0255	0.0058	0.0339	0.0057
400	134.25	132.76	46.29	3.61	2.57	13.90	2.34	0.0229	-0.0002	0.0340	0.0015
800	134.26	132.78	45.55	5.33	3.15	17.34	2.33	0.0245	-0.0004	0.0337	0.0057
1000	134.33	133.14	46.24	5.33	3.40	12.73	2.42	0.0248	-0.0031	0.0332	0.0065
1400	134.11	132.33	45.54	4.97	3.76	14.69	2.32	0.0251	0.0019	0.0344	0.0054
1800	134.22	132.65	46.20	6.78	4.29	14.15	2.30	0.0255	-0.0027	0.0335	0.0100
2160	134.16	132.47	46.04	6.69	4.55	14.48	2.29	0.0223	0.0016	0.0354	0.0007
				DRAINED REST PERIOD							
				A.G.L. 42.20		R.G.L. 39.04		EX.G.L.127.14			
1	134.53	133.58	45.28	3.68	0.01	15.95	2.93	0.0078	-0.0000	0.0358	0.0147
200	133.79	131.37	48.17	2.97	1.15	14.69	2.58	0.0090	0.0005	0.0363	0.0096
400	133.64	130.92	47.29	2.96	1.55	14.21	2.50	0.0091	-0.0006	0.0364	0.0077
800	133.76	131.28	46.70	3.97	2.24	14.29	2.47	0.0084	-0.0004	0.0384	0.0016
1200	134.03	132.24	47.23	4.63	2.81	14.45	2.54	0.0105	-0.0006	0.0319	0.0069
1600	133.78	131.34	46.41	4.54	2.95	14.62	2.61	0.0116	-0.0035	0.0328	0.0095
2160	133.57	130.70	46.04	5.73	3.10	14.02	2.46	0.0091	-0.0026	0.0346	0.0029

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_y^p	ε_s^r	ε_v^r
				STRAIN CONTROL FAILURE TEST							
1	183.75	131.26	0.00	3.30	-0.11	0.00	0.00	0.0022	-0.0045	0.0000	0.0000
1	193.57	160.71	0.00	11.89	4.31	0.00	0.00	0.0241	-0.0016	0.0000	0.0000
1	198.17	174.52	0.00	17.77	7.20	0.00	0.00	0.0340	-0.0135	0.0000	0.0000
1	202.19	186.57	0.00	22.60	9.95	0.00	0.00	0.0718	-0.0250	0.0000	0.0000
1	203.35	190.04	0.00	23.56	12.03	0.00	0.00	0.1657	-0.0409	0.0000	0.0000
1	198.89	176.67	0.00	27.28	13.85	0.00	0.00	0.2691	-0.0094	0.0000	0.0000
1	198.30	174.89	0.00	42.79	15.95	0.00	0.00	0.3928	0.0669	0.0000	0.0000
1	195.58	166.74	0.00	56.71	17.97	0.00	0.00	0.5607	0.1815	0.0000	0.0000
1	193.50	160.50	0.00	60.30	20.29	0.00	0.00	1.2732	1.0227	0.0000	0.0000
				TEST NO AR 1.10 O.C.R. 1							
				************************************							
				A.G.L.133.51 R.G.L. 38.94							
1	133.10	129.30	47.39	2.53	-0.17	16.72	14.71	-0.0022	0.0020	0.0209	-0.0037
50	133.18	129.53	48.75	5.16	4.11	18.69	17.11	0.0152	0.0058	0.0243	0.0017
100	133.19	129.57	50.53	6.53	6.30	19.84	16.82	0.0379	0.0060	0.0260	0.0063
200	133.55	130.66	48.85	9.11	9.54	19.03	16.01	0.0755	0.0116	0.0260	0.0040
300	133.43	130.43	49.02	12.21	13.07	19.21	16.50	0.1274	0.0373	0.0285	0.0029
400	133.28	129.83	50.72	15.43	19.02	18.66	16.50	0.2319	0.0426	0.0292	0.0045
500	133.42	130.25	48.43	21.77	21.74	18.73	13.13	0.5785	-0.0361	0.0400	0.0068
				DRAINED REST PERIOD							
				A.G.L.132.48 R.G.L. 39.05							
1	133.34	130.01	50.98	5.01	5.88	21.36	17.10	0.0078	0.0013	0.0230	0.0024
50	133.57	130.70	48.89	9.15	9.75	20.23	16.24	0.0253	0.0061	0.0248	0.0051
100	133.61	130.84	49.09	10.71	11.13	19.21	15.84	0.0411	-0.0086	0.0237	0.0042
300	133.55	130.64	49.64	17.33	15.23	19.35	16.29	0.0801	0.0069	0.0259	0.0024
500	133.44	130.31	48.53	23.67	23.11	19.54	18.35	0.1899	0.0111	0.0327	0.0063
700	133.47	130.41	49.52	35.28	32.56	19.46	16.78	0.6025	0.1455	0.0401	0.0088
				DRAINED REST PERIOD							
				A.G.L.131.32 R.G.L. 39.10							
1	133.38	130.15	46.34	7.84	7.21	15.68	14.34	0.0105	-0.0012	0.0217	0.0008
100	133.48	130.44	50.35	10.56	10.11	20.96	14.99	0.0399	0.0008	0.0239	0.0026
400	133.37	130.10	50.11	19.11	15.70	21.45	16.68	0.1000	0.0019	0.0247	0.0060
600	133.41	130.23	50.78	24.15	18.84	19.80	16.29	0.1375	0.0120	0.0289	0.0008
1000	133.29	129.87	49.20	29.74	27.20	19.32	14.65	0.3389	0.1505	0.0307	0.0011
1400	134.72	134.15	57.21	36.40	30.78	16.77	13.81	1.0269	0.8474	0.0526	0.0120
				DRAINED REST PERIOD							
				A.G.L.129.17 R.G.L. 39.18							
1	133.48	130.44	48.76	5.83	9.88	24.12	14.97	0.0010	-0.0004	0.0242	-0.0068
100	133.33	130.14	49.09	10.59	12.61	22.86	14.70	0.0373	0.0054	0.0253	0.0003
300	133.40	130.19	49.66	17.09	15.36	22.36	15.38	0.0459	0.0022	0.0275	-0.0046
500	133.48	130.44	49.92	20.56	16.75	22.47	16.20	0.0474	-0.0015	0.0292	-0.0079
700	133.32	129.97	49.01	23.51	18.47	20.54	16.14	0.0506	-0.0044	0.0272	-0.0044
1000	133.54	130.61	48.98	26.30	19.97	22.13	16.27	0.0690	-0.0125	0.0258	-0.0048
1200	133.39	130.16	49.32	28.26	21.32	20.37	16.56	0.0702	0.0030	0.0259	-0.0129
1500	133.24	129.72	50.81	29.97	22.39	20.23	16.50	0.0773	0.0031	0.0294	-0.0092
1800	133.64	130.93	49.59	30.30	23.01	21.13	16.60	0.0823	0.0023	0.0290	-0.0098
2160	133.53	130.60	49.50	32.58	24.14	20.44	17.33	0.1092	-0.0047	0.0385	0.0089
				DRAINED REST PERIOD							
				A.G.L.129.03 R.G.L. 39.19							
1	133.81	131.43	46.52	7.80	11.06	23.74	15.89	0.0106	-0.0010	0.0251	-0.0064
100	133.46	130.37	49.19	10.91	11.61	23.34	17.16	0.0322	0.0017	0.0227	-0.0040
400	133.48	130.43	49.79	16.01	13.70	23.25	17.05	0.0396	0.0063	0.0251	-0.0035
800	134.14	132.41	50.45	21.00	15.20	20.97	15.25	0.0414	0.0050	0.0255	-0.0039
1200	133.54	130.63	47.91	22.36	16.41	20.69	16.53	0.0420	0.0033	0.0256	-0.0020

N	p_m	p_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1600	183.63		130.89	48.33	23.53	16.21	20.37	16.55	0.0435	-0.0014	0.0255	-0.0004
2160	183.59		130.76	49.28	23.88	17.02	21.01	16.24	0.0433	-0.0006	0.0254	-0.0080
					STRAIN CONTROL FAILURE TEST							
1	182.76		128.27	0.00	24.15	17.32	0.00	0.00	0.0416	-0.0174	0.0000	0.0000
1	197.78		173.35	0.00	39.06	21.80	0.00	0.00	0.0857	0.0204	0.0000	0.0000
1	200.95		182.85	0.00	40.59	21.24	0.00	0.00	0.2716	-0.0191	0.0000	0.0000
1	199.44		178.32	0.00	37.93	24.39	0.00	0.00	0.5944	-0.1361	0.0000	0.0000
1	197.05		171.15	0.00	34.56	27.42	0.00	0.00	0.7550	-0.2283	0.0000	0.0000
1	194.31		162.92	0.00	32.40	30.95	0.00	0.00	1.0472	-0.2682	0.0000	0.0000
1	191.97		155.91	0.00	27.89	37.54	0.00	0.00	1.6482	-0.2202	0.0000	0.0000
1	189.37		148.10	0.00	28.42	38.16	0.00	0.00	2.1935	0.0043	0.0000	0.0000
					TEST NOS I.II & 4.I O.C.R. 1							
					A.G.L. 42.60		R.G.L. 38.97					
1	184.12	10.62	132.36	31.86	1.32	4.81	5.07	2.55	0.0200	-0.0037	0.0293	0.0074
50	183.78	11.50	131.35	34.50	1.38	5.86	5.55	2.00	0.0480	-0.0031	0.0329	0.0065
100	183.75	11.20	131.24	33.61	1.10	5.90	5.44	2.17	0.0484	-0.0044	0.0314	0.0079
200	183.74	11.12	131.23	33.37	1.49	6.65	5.54	1.97	0.0492	-0.0032	0.0330	0.0065
300	183.84	11.47	131.53	34.40	2.37	6.95	5.49	2.19	0.0504	-0.0033	0.0306	0.0082
400	184.21	11.30	132.63	33.90	2.48	7.94	5.04	4.08	0.0552	-0.0037	0.0394	0.0018
500	183.34	11.35	130.01	34.04	2.87	8.55	5.06	3.48	0.0557	-0.0050	0.0403	-0.0009
700	183.18	10.87	129.53	32.60	2.86	9.63	4.68	3.38	0.0643	-0.0027	0.0379	-0.0004
1000	183.55	11.66	130.64	34.99	3.93	11.44	4.91	3.43	0.0742	-0.0080	0.0412	0.0006
1300	183.42	11.92	130.25	35.76	5.30	14.00	4.93	3.41	0.0772	-0.0132	0.0427	0.0020
1500	183.73	11.39	131.18	34.13	6.63	14.71	4.77	3.18	0.1074	-0.0159	0.0395	0.0055
1700	183.55	11.07	130.66	33.22	6.72	15.08	4.59	3.18	0.1223	-0.0254	0.0396	-0.0019
2000	183.62	12.20	130.86	36.59	6.72	15.39	4.80	3.41	0.1291	-0.0247	0.0450	0.0044
2160	183.32	11.96	129.97	35.89	6.55	15.63	4.79	3.18	0.1325	-0.0313	0.0396	0.0024
					DRAINED REST PERIOD							
					A.G.L. 42.55		R.G.L. 38.98					
1	182.99	11.73	128.96	35.18	1.76	7.96	4.92	3.54	0.0203	0.0026	0.0334	-0.0006
50	183.24	11.48	129.72	34.45	1.93	8.56	5.31	3.10	0.0221	0.0043	0.0338	0.0019
100	183.11	11.76	129.33	35.28	1.69	8.43	5.31	3.86	0.0228	0.0092	0.0350	0.0048
200	183.13	11.64	129.40	34.91	1.72	8.85	5.03	3.65	0.0239	0.0060	0.0379	0.0042
300	183.29	11.86	129.87	35.58	2.36	9.15	4.99	3.73	0.0259	0.0033	0.0394	0.0043
400	183.41	11.72	130.24	35.17	3.00	9.51	5.01	3.54	0.0271	0.0032	0.0389	0.0024
500	183.42	10.92	130.26	32.75	3.11	9.51	4.66	3.42	0.0284	0.0099	0.0343	-0.0017
700	182.60	13.92	127.79	41.75	3.18	10.16	4.83	3.56	0.0327	0.0077	0.0391	0.0040
1000	183.50	12.09	130.51	36.26	3.16	10.43	4.88	3.63	0.0329	0.0070	0.0409	-0.0005
1200	183.26	11.76	129.79	35.29	3.53	10.37	4.95	3.60	0.0352	0.0037	0.0380	-0.0002
1500	182.48	13.80	127.43	41.40	3.18	10.64	4.60	3.53	0.0350	0.0044	0.0399	-0.0050
1700	183.17	11.67	129.52	35.00	3.05	10.66	4.89	3.28	0.0354	0.0031	0.0367	0.0036
2000	183.57	11.38	130.71	34.15	3.30	10.95	4.67	3.50	0.0368	0.0023	0.0393	-0.0004
2160	183.64	11.64	130.91	34.91	3.43	11.09	4.81	3.36	0.0393	0.0090	0.0365	0.0001
					DRAINED REST PERIOD							
					A.G.L. 42.54		R.G.L. 38.97					
1	183.17	11.76	129.52	35.29	-0.18	2.80	5.75	3.60	0.0164	-0.0033	0.0295	0.0024
50	182.98	11.77	128.94	35.32	0.33	3.91	5.36	3.48	0.0140	0.0037	0.0374	0.0034
100	183.35	12.11	130.04	36.33	0.61	4.24	5.45	3.60	0.0209	0.0006	0.0357	0.0078
200	183.50	11.57	130.49	34.72	0.62	4.55	5.34	3.62	0.0286	-0.0013	0.0333	-0.0048
300	182.36	13.54	127.08	40.63	0.67	5.24	5.30	3.60	0.0432	-0.0026	0.0345	0.0072
500	182.90	11.57	128.70	34.72	0.90	5.31	5.23	3.52	0.0419	0.0013	0.0348	0.0037
700	183.36	11.43	130.09	34.29	0.81	6.02	5.30	3.61	0.0457	-0.0065	0.0336	-0.0009
1000	183.49	11.73	130.46	35.19	1.46	6.31	5.25	3.60	0.0467	-0.0098	0.0351	0.0021
1200	182.38	13.44	127.15	40.33	1.25	6.30	5.33	3.70	0.0484	-0.0111	0.0341	0.0038

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1500	183.38	11.90	130.14	35.71	1.31	6.56	5.52	3.64	0.0499	-0.0156	0.0359	0.0046
1700	183.49	11.53	130.47	34.58	1.69	6.88	5.42	3.76	0.0499	-0.0156	0.0335	0.0008
2000	183.46	11.67	130.37	35.02	1.74	7.08	5.46	3.69	0.0489	-0.0162	0.0336	0.0023
2160	183.72	11.77	131.16	35.30	2.22	7.38	5.49	3.76	0.0503	-0.0169	0.0332	-0.0036
					DRAINED REST PERIOD							
					A.G.L. 42.51		R.G.L. 38.94					
1	183.53	11.16	130.60	33.49	0.06	0.94	5.75	3.47	0.0049	0.0064	0.0328	0.0004
50	183.27	11.93	129.81	35.80	0.51	0.97	5.88	3.84	0.0101	0.0016	0.0345	-0.0060
100	182.45	13.64	127.36	40.92	0.69	1.48	5.80	3.68	0.0117	0.0002	0.0329	-0.0009
300	183.89	11.24	131.68	33.73	0.35	2.01	5.48	3.70	0.0129	0.0001	0.0290	-0.0024
500	183.62	11.67	130.86	35.02	0.31	2.11	5.49	3.47	0.0151	0.0005	0.0333	-0.0117
700	183.55	11.21	130.66	33.63	0.87	3.55	5.35	3.55	0.0171	0.0016	0.0309	0.0004
1000	183.33	11.64	129.99	34.92	1.03	3.57	4.94	3.23	0.0203	0.0026	0.0293	0.0031
1200	183.16	11.71	129.43	35.13	1.43	4.12	5.57	3.49	0.0209	0.0044	0.0322	0.0030
1500	183.55	11.89	130.64	35.67	1.63	4.46	5.46	3.57	0.0236	-0.0002	0.0339	-0.0022
1700	183.52	11.45	130.55	34.35	1.90	4.64	5.49	3.49	0.0235	0.0035	0.0330	0.0127
2000	183.18	11.82	129.55	35.46	2.16	4.65	5.26	3.26	0.0256	0.0008	0.0350	0.0115
2160	183.41	11.36	130.23	34.09	2.09	4.75	5.27	3.48	0.0278	0.0013	0.0320	0.0025
					DRAINED REST PERIOD							
					A.G.L. 42.50		R.G.L. 38.95					
1	183.80	11.08	131.40	33.25	1.15	0.30	9.14	3.29	0.0141	-0.0000	0.0319	-0.0038
50	183.27	11.72	129.80	35.17	0.43	0.15	5.52	3.53	0.0137	0.0013	0.0328	0.0012
100	183.45	11.58	130.35	34.75	0.63	0.20	5.46	3.51	0.0143	0.0031	0.0352	-0.0051
200	183.48	11.76	130.45	35.29	0.38	0.30	5.60	3.35	0.0155	0.0030	0.0333	-0.0018
500	183.43	11.63	130.30	34.89	1.17	1.83	5.47	3.32	0.0188	-0.0035	0.0357	0.0011
1000	183.43	11.48	130.43	34.44	0.65	2.10	5.18	3.50	0.0198	-0.0030	0.0314	0.0006
1500	183.47	11.91	130.41	35.73	1.63	2.35	5.32	3.34	0.0219	-0.0057	0.0353	-0.0060
1700	182.35	13.58	127.06	40.75	1.13	2.46	5.26	3.51	0.0258	0.0002	0.0335	-0.0031
2000	183.67	11.25	131.00	33.76	1.79	2.45	5.38	3.60	0.0269	-0.0030	0.0312	0.0023

** STRESS PATH TESTS **

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N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
					DRAINED REST PERIOD							
					A.G.L. 42.48		R.G.L. 38.96					
					FREQUENCY	0.0500	HZ					
0	185.55	95.61	46.13	-0.02	-18.60	-22.85	29.49	55.64	-0.0728	0.0207	-0.0004	0.0051
					FREQUENCY	0.0100	HZ					
0	185.11	66.32	45.96	0.05	-17.74	-22.86	34.56	41.11	-0.0788	-0.0037	-0.0003	0.0017
					FREQUENCY	0.1000	HZ					
0	185.26	97.84	46.04	-0.02	-17.92	-22.94	26.45	47.01	-0.0713	-0.0050	0.0005	0.0002
					FREQUENCY	0.0400	HZ					
0	188.15	87.54	46.21	0.00	-16.99	-23.65	22.14	47.63	-0.0791	-0.0099	0.0008	-0.0017
					FREQUENCY	0.0500	HZ					
0	187.62	93.51	45.08	-0.02	-16.79	-21.48	29.99	53.66	-0.0944	0.0008	0.0005	-0.0019
					FREQUENCY	0.0400	HZ					
0	186.22	88.24	46.80	0.09	-16.86	-22.93	30.53	50.66	-0.1009	-0.0080	0.0029	-0.0060
					FREQUENCY	0.0300	HZ					
0	185.92	94.44	46.81	0.02	-17.82	-23.10	34.58	57.46	-0.0896	0.0041	-0.0012	-0.0053
					FREQUENCY	0.0200	HZ					
0	185.20	86.15	46.37	-0.05	-17.45	-22.33	36.51	54.17	-0.0755	-0.0065	0.0017	0.0002
					FREQUENCY	0.0100	HZ					
0	186.38	88.53	45.87	-0.05	-17.98	-22.02	44.78	54.95	-0.0742	-0.0035	0.0018	0.0001
					FREQUENCY	1.0000	HZ					
0	183.63	14.98	47.13	44.95	-15.73	-21.49	6.00	2.83	-0.0972	0.0303	0.0495	0.0059

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ϵ_s^p	ϵ_v^p	ϵ_s^r	ϵ_v^r
					FREQUENCY 0.5000 HZ							
0	184.25	14.63	45.83	44.45	-16.43	-18.97	5.73	2.96	-0.1066	0.0374	0.0472	0.0015
					FREQUENCY 0.1000 HZ							
0	184.58	13.60	48.20	37.88	-15.64	-18.84	5.58	4.50	-0.1070	0.0349	0.0464	0.0065
					FREQUENCY 0.0500 HZ							
0	186.12	13.21	49.33	37.45	-14.96	-17.97	6.39	4.93	-0.1307	0.0320	0.0479	-0.0061
					FREQUENCY 0.0100 HZ							
0	186.89	10.30	48.58	32.64	-13.73	-16.58	8.84	6.24	-0.1207	0.0162	0.0498	0.0033
					FREQUENCY 0.1000 HZ							
0	183.76	79.54	46.67	0.00	-14.65	-17.29	22.39	41.17	-0.1441	0.0369	0.0035	-0.0033
0	233.45	30.89	46.80	0.09	1.86	13.42	20.95	40.76	-0.1476	0.0404	0.0021	-0.0029
0	196.22	97.26	46.15	0.07	-4.96	12.97	11.83	24.74	-0.1381	0.0190	0.0018	-0.0002
0	185.79	29.94	46.85	0.05	-13.30	-16.89	7.63	14.84	-0.1465	0.0440	0.0018	-0.0030
0	136.37	33.74	45.99	-0.07	-29.74	-46.76	9.91	19.95	-0.1214	0.0431	0.0012	-0.0039
0	186.19	14.27	48.01	43.72	-12.42	-15.27	6.92	5.63	-0.1310	0.1000	0.0655	-0.0013
0	215.03	15.12	48.19	45.27	-3.46	3.14	7.14	5.38	-0.1423	0.0916	0.0665	0.0050
0	132.81	14.94	46.98	44.45	-30.16	-48.15	7.27	5.18	-0.1445	0.0874	0.0668	0.0073
0	133.28	30.15	45.14	89.63	-29.72	-29.39	13.37	14.01	-0.1841	0.1146	0.0750	0.0097
0	184.76	66.31	48.04	49.51	-10.63	-3.21	20.10	29.25	-0.2313	0.1960	0.0853	-0.0001
0	220.60	67.52	46.43	46.19	-2.44	26.46	23.35	29.95	-0.2787	0.1441	0.0860	-0.0007
0	136.90	75.30	45.49	45.91	-24.74	-38.83	28.86	45.95	-0.2684	0.1201	0.0823	0.0066
0	174.57	-40.58	34.45	70.23	-11.88	-0.80	12.32	28.66	-0.2639	0.1316	0.0866	-0.0046
0	219.83	-42.96	33.93	68.68	3.65	27.62	-13.02	-28.41	-0.2647	0.1833	0.0822	-0.0015
0	122.69	-11.69	47.66	45.00	-27.66	-31.33	-7.03	-11.73	-0.2651	0.1423	0.0831	0.0014
0	177.41	-11.82	34.84	70.69	-11.19	-3.31	8.93	-13.18	-0.2728	0.1404	0.0842	-0.0044
0	222.00	-18.13	45.03	41.32	-0.78	19.43	-7.40	-12.09	-0.2682	0.1656	0.0832	0.0027
0	183.87	46.53	46.49	46.72	-7.05	-4.59	15.74	32.50	-0.2626	0.1557	0.0840	0.0011
0	223.87	57.41	33.76	63.11	4.98	26.73	15.40	-28.61	-0.2830	0.1675	0.0889	-0.0027
0	134.75	51.68	46.73	45.50	-24.42	-32.15	19.27	21.02	-0.3004	0.1105	0.0846	0.0027
0	222.01	-28.99	46.06	91.35	-9.53	29.43	25.15	58.62	-0.2765	0.1551	0.2328	-0.0175
0	234.03	-33.54	45.32	92.24	3.79	32.86	20.56	52.39	-0.2675	0.1599	0.2360	-0.0120
0	227.43	-17.82	45.46	92.75	5.58	32.00	-14.93	-35.87	-0.3084	0.2650	0.2399	-0.0066
0	186.76	-13.81	44.91	90.41	-8.50	6.42	-15.04	-15.04	-0.2790	0.2120	0.2372	-0.0117
0	186.15	34.60	45.24	90.21	-5.17	4.49	25.88	34.39	-0.2732	0.2476	0.2427	-0.0036
0	222.22	32.19	46.43	90.82	4.91	25.11	24.43	30.98	-0.3190	0.2261	0.2405	-0.0062
0	136.56	85.93	44.73	90.34	-21.40	-19.08	24.95	38.38	-0.3370	0.2165	0.2460	-0.0073
					TEST NO 1.12 O.C.R. 1							
					************************************							
					A.G.L. 44.50 R.G.L. 38.88							
1	134.21		132.64	27.07	0.00	0.02	0.00	6.40	0.0081	0.0043	0.0158	0.0010
50	135.17		135.51	29.33	0.00	1.27	0.00	6.96	0.0269	0.0050	0.0177	0.0027
100	135.06		135.17	31.30	0.00	2.05	0.00	7.06	0.0305	-0.0000	0.0221	-0.0011
200	134.73		134.33	29.38	0.00	4.03	0.00	6.46	0.0290	-0.0042	0.0174	0.0007
300	134.27		132.82	30.92	0.00	5.44	0.00	6.86	0.0305	-0.0032	0.0248	0.0022
500	134.53		133.59	30.99	0.00	5.86	0.00	7.18	0.0307	0.0022	0.0245	0.0040
700	134.96		134.89	29.18	0.00	6.85	0.00	5.99	0.0381	0.0226	0.0233	0.0010
1000	133.99		131.96	27.83	0.00	17.43	0.00	5.74	0.1399	0.0798	0.0254	0.0023
1200	134.69		134.06	25.06	0.00	20.74	0.00	5.67	0.2113	0.0739	0.0247	-0.0018
1500	133.37		131.60	26.77	0.00	22.89	0.00	6.33	0.3004	0.1803	0.0265	0.0030
1700	133.19		129.58	28.61	0.00	27.98	0.00	6.21	0.3219	0.1329	0.0281	-0.0026
2000	134.46		133.46	32.12	0.00	29.30	0.00	6.48	0.5227	0.2099	0.0345	0.0065
2160	134.02		132.06	30.86	0.00	31.74	0.00	6.20	0.6111	0.2642	0.0326	0.0014
					DRAINED REST PERIOD							
					A.G.L. 44.13 R.G.L. 38.96							
1	134.02		132.07	31.91	0.00	23.36	0.00	6.32	0.0111	0.0011	0.0234	0.0067

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_y^p	ε_s^r	ε_v^r
50	134.36	133.08	32.54	0.00	24.48	0.00	6.83	0.0163	-0.0056	0.0267	0.0088
100	134.69	134.06	29.95	0.00	25.13	0.00	6.03	0.0201	-0.0057	0.0239	0.0077
200	134.28	132.85	30.43	0.00	25.24	0.00	5.90	0.0215	-0.0011	0.0247	-0.0007
300	134.00	131.99	28.43	0.00	25.47	0.00	5.71	0.0274	0.0040	0.0236	0.0061
500	133.66	130.97	29.35	0.00	25.67	0.00	6.00	0.0275	0.0067	0.0236	0.0081
700	134.74	134.21	31.99	0.00	27.94	0.00	5.96	0.0374	0.0086	0.0245	0.0050
1000	134.25	132.75	28.80	0.00	28.26	0.00	5.73	0.1248	-0.0004	0.0206	0.0148
1200	134.45	133.36	25.73	0.00	33.87	0.00	5.61	0.2938	-0.0755	0.0244	0.0050
1500	134.31	132.92	28.55	0.00	35.94	0.00	5.48	0.4835	0.0372	0.0232	0.0046
1700	134.55	133.66	28.24	0.00	37.86	0.00	5.69	0.5864	0.0480	0.0277	0.0019
2000	134.18	132.55	28.60	0.00	41.82	0.00	5.79	0.8481	-0.0351	0.0270	0.0074
2160	134.05	132.16	23.02	0.00	43.84	0.00	5.82	1.1601	0.0074	0.0287	0.0123
DRAINED REST PERIOD											
A.G.L. 43.53 R.G.L. 39.16											
1	135.42	136.27	28.95	0.00	23.03	0.00	5.72	0.0200	0.0041	0.0249	0.0093
50	134.10	132.31	28.90	0.00	23.04	0.00	6.19	0.0329	-0.0025	0.0227	0.0084
100	133.36	131.57	28.03	0.00	23.10	0.00	5.57	0.0354	-0.0013	0.0207	0.0058
200	135.22	129.67	27.44	0.00	22.64	0.00	5.97	0.0504	0.0004	0.0208	0.0041
300	133.16	129.47	28.49	0.00	23.21	0.00	6.25	0.0585	0.0054	0.0229	0.0047
500	133.93	131.78	27.77	0.00	24.11	0.00	5.99	0.0661	0.0058	0.0212	0.0075
700	134.51	133.54	26.62	0.00	25.18	0.00	5.68	0.1014	-0.0269	0.0194	0.0082
1000	135.84	137.52	31.05	0.00	27.40	0.00	6.10	0.1912	0.0476	0.0245	0.0118
1200	133.31	129.92	29.06	0.00	34.22	0.00	5.57	0.3797	0.0891	0.0285	0.0105
1500	135.00	135.01	30.32	0.00	40.11	0.00	5.81	0.5541	0.1056	0.0267	0.0128
1700	133.80	131.40	31.86	0.00	42.60	0.00	6.19	0.7340	0.1084	0.0279	0.0033
2000	135.22	135.66	29.78	0.00	47.18	0.00	5.41	1.1787	0.0403	0.0268	0.0091
2160	135.12	135.35	27.63	0.00	50.42	0.00	4.95	1.4435	-0.0132	0.0279	0.0103
DRAINED REST PERIOD											
A.G.L. 42.83 R.G.L. 39.43											
300	134.21	132.63	30.76	0.00	26.58	0.00	5.75	0.1000	-0.0007	0.0255	0.0113
700	133.33	130.00	34.83	0.00	29.25	0.00	5.66	0.1191	-0.0016	0.0254	0.0043
1000	133.65	130.95	24.66	0.00	30.71	0.00	4.69	0.1248	-0.0215	0.0224	0.0029
1200	134.14	132.41	27.69	0.00	33.88	0.00	5.60	0.1241	-0.0077	0.0235	0.0111
1500	134.64	133.93	32.22	0.00	35.26	0.00	6.23	0.1394	-0.0119	0.0290	0.0117
1700	134.02	132.07	29.16	0.00	35.23	0.00	5.89	0.1444	-0.0063	0.0274	0.0106
2000	133.53	130.74	29.36	0.00	35.69	0.00	5.60	0.1620	0.0092	0.0262	0.0084
2160	134.08	132.24	31.36	0.00	35.58	0.00	5.93	0.1638	0.0067	0.0261	0.0069
DRAINED REST PERIOD											
A.G.L. 42.74 R.G.L. 39.44											
1	133.94	131.83	26.44	0.00	9.73	0.00	5.72	0.0050	-0.0002	0.0134	0.0114
100	134.78	134.34	28.84	0.00	11.88	0.00	6.14	0.0117	0.0066	0.0208	0.0160
500	133.48	130.43	27.67	0.00	11.90	0.00	5.82	0.0119	0.0088	0.0197	0.0148
700	133.15	129.45	28.03	0.00	11.82	0.00	5.54	0.0136	0.0068	0.0189	0.0190
1000	135.69	137.08	31.45	0.00	14.29	0.00	6.10	0.0131	0.0054	0.0229	0.0146
1200	134.40	133.20	30.18	0.00	13.59	0.00	5.92	0.0132	0.0050	0.0231	0.0099
1500	134.46	133.39	32.06	0.00	14.27	0.00	6.53	0.0140	0.0055	0.0251	0.0127
1700	136.13	138.54	30.54	0.00	15.64	0.00	5.99	0.0140	0.0055	0.0236	0.0059
2160	133.71	131.14	28.95	0.00	14.49	0.00	5.58	0.0183	0.0165	0.0190	0.0160
STRAIN CONTROL FAILURE TEST											
0	138.56	145.67	0.00	0.00	15.21	0.00	0.00	0.0345	-0.0055	0.0000	0.0000
0	198.63	175.90	0.00	0.00	18.31	0.00	0.00	0.0431	-0.0016	0.0000	0.0000
0	199.36	179.57	0.00	0.00	18.83	0.00	0.00	0.1010	0.0446	0.0000	0.0000
0	202.33	187.00	0.00	0.00	19.75	0.00	0.00	0.1134	0.0311	0.0000	0.0000
0	202.29	186.36	0.00	0.00	20.70	0.00	0.00	0.2214	0.1171	0.0000	0.0000
0	201.72	185.15	0.00	0.00	22.40	0.00	0.00	0.4717	0.4269	0.0000	0.0000

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
					TEST NO	1.13		O.C.R.	1			
					A.G.L.	44.17	R.G.L. 39.24					
3	185.94	18.04	127.48	53.94	0.20	-0.76	21.21	10.60	0.0118	0.0004	0.0337	-0.0050
50	186.13	16.77	129.11	50.60	1.74	0.94	19.59	9.27	0.0129	-0.0007	0.0324	-0.0022
100	185.42	17.06	128.53	50.74	2.22	1.92	19.92	9.28	0.0147	-0.0031	0.0303	-0.0089
200	185.22	17.23	127.71	51.70	4.12	2.59	20.78	9.36	0.0226	-0.0060	0.0333	-0.0065
400	184.28	17.07	125.37	51.40	4.13	3.60	20.44	9.26	0.0232	-0.0055	0.0340	-0.0066
600	182.99	16.76	121.95	49.00	4.27	4.33	18.93	9.32	0.0266	0.0056	0.0394	0.0042
1200	186.15	17.58	128.13	53.46	11.41	11.66	21.20	8.46	0.0678	-0.0052	0.0341	-0.0030
1400	187.05	18.02	128.63	53.32	14.34	14.43	20.17	7.74	0.1146	-0.0248	0.0374	0.0049
1800	186.47	17.50	129.27	52.86	17.83	17.59	19.70	7.04	0.1694	-0.0231	0.0425	-0.0035
2000	185.64	17.77	128.97	53.32	21.33	21.81	21.24	6.86	0.2531	-0.0319	0.0377	-0.0142
2160	187.49	17.41	127.52	52.13	25.93	28.24	21.60	6.32	0.4609	-0.0603	0.0439	-0.0121
						DRAINED REST PERIOD						
					A.G.L.	43.92	R.G.L. 39.63					
3	184.99	16.29	126.99	48.79	6.92	9.45	19.95	7.93	0.0105	0.0026	0.0340	0.0051
50	186.14	16.33	126.90	48.79	9.66	11.91	19.99	8.13	0.0243	0.0030	0.0286	-0.0041
100	186.22	16.60	127.70	50.16	11.43	13.39	18.91	8.03	0.0424	0.0051	0.0295	0.0034
200	186.83	16.47	127.25	49.23	13.71	15.74	19.91	7.14	0.0550	0.0014	0.0313	-0.0042
400	183.01	15.89	128.30	47.49	18.79	19.23	19.63	6.38	0.1032	0.0041	0.0329	0.0024
600	186.44	16.66	128.54	49.80	21.60	22.31	20.19	5.95	0.1323	-0.0066	0.0349	0.0058
1000	187.62	16.31	127.64	48.10	27.40	28.45	20.72	6.17	0.2690	-0.0176	0.0497	-0.0016
1200	186.67	16.49	127.34	49.57	28.44	32.15	19.75	5.62	0.3563	-0.0597	0.0406	0.0063
1330	185.82	16.22	125.67	48.65	30.97	35.04	20.72	4.52	0.4594	-0.0806	0.0379	-0.0188
						DRAINED REST PERIOD						
					A.G.L.	43.68	R.G.L. 40.40					
2	186.49	16.56	126.96	49.68	4.07	4.59	19.75	8.56	0.0028	0.0003	0.0278	-0.0002
50	185.54	16.33	124.45	48.98	7.01	6.42	19.32	7.95	0.0089	0.0075	0.0311	0.0057
100	186.47	15.82	127.45	50.94	8.43	7.91	21.42	7.73	0.0124	0.0070	0.0280	0.0081
200	187.04	16.42	126.85	49.25	10.41	9.04	18.91	7.33	0.0188	0.0046	0.0303	0.0035
400	186.04	16.84	126.43	50.32	13.46	10.55	20.09	7.67	0.0241	0.0046	0.0319	0.0012
600	186.13	16.46	126.55	49.48	14.87	11.93	19.81	7.50	0.0358	0.0081	0.0309	0.0024
1000	187.31	16.68	127.26	49.75	17.68	14.13	20.38	7.18	0.0378	0.0057	0.0317	-0.0006
1400	185.79	15.20	127.06	48.79	18.75	15.56	19.26	6.50	0.0394	0.0032	0.0335	0.0004
1800	186.65	15.41	127.51	46.60	20.05	16.73	19.08	6.16	0.0555	0.0064	0.0278	-0.0033
2160	185.85	16.40	127.29	49.29	20.76	17.57	19.24	5.80	0.0544	0.0032	0.0302	0.0005
						DRAINED REST PERIOD						
					A.G.L.	43.65	R.G.L. 41.13					
3	186.67	16.31	129.74	49.94	1.66	4.93	19.50	8.34	0.0039	0.0051	0.0295	0.0063
50	186.42	17.20	127.48	51.42	1.39	5.68	18.38	7.67	0.0045	0.0032	0.0285	0.0003
100	183.12	16.38	128.47	49.32	3.19	6.06	19.60	7.48	0.0052	0.0055	0.0295	0.0034
200	187.17	16.67	129.13	49.55	4.08	6.92	18.44	7.22	0.0083	-0.0001	0.0314	0.0015
400	186.80	16.11	129.25	49.25	5.86	8.26	20.26	7.33	0.0067	0.0045	0.0238	0.0002
800	186.46	16.57	128.00	49.43	7.46	9.71	19.52	7.17	0.0149	0.0005	0.0280	0.0001
1200	187.35	17.02	128.30	50.42	8.08	10.58	19.96	7.33	0.0251	0.0004	0.0295	0.0003
1600	186.80	16.61	128.02	49.20	9.38	11.22	19.07	7.37	0.0277	0.0005	0.0318	0.0041
2000	188.07	17.00	128.09	49.93	10.20	12.08	19.22	7.39	0.0315	0.0031	0.0295	-0.0028
						STRAIN CONTROL FAILURE TEST						
	189.60	1.10	133.15	0.00	9.79	11.88	0.00	0.00	0.0316	0.0033	0.0000	0.0000
	190.77	0.43	140.33	0.00	11.26	12.93	0.00	0.00	0.0359	0.0051	0.0000	0.0000
	194.52	0.77	149.61	0.00	12.02	15.45	0.00	0.00	0.0367	-0.0046	0.0000	0.0000
	199.38	0.40	168.20	0.00	16.39	18.71	0.00	0.00	0.0877	0.0032	0.0000	0.0000
	209.53	0.45	171.43	0.00	19.65	20.41	0.00	0.00	0.1612	0.0052	0.0000	0.0000
	199.83	0.06	168.53	0.00	20.30	24.52	0.00	0.00	0.2589	0.0226	0.0000	0.0000

N	P_m	P_r	q_m	q_r	u_B^p	u_C^p	u_B^r	u_C^r	ϵ_s^p	ϵ_v^p	ϵ_s^r	ϵ_v^r
	198.59	-0.08	165.03	0.00	21.22	30.13	0.00	0.00	0.3837	0.0339	0.0000	0.0000
	197.62	-0.02	159.85	0.00	45.77	38.30	0.00	0.00	0.5931	0.0258	0.0000	0.0000
	196.60	0.85	154.43	0.00	46.02	45.62	0.00	0.00	0.9055	0.0453	0.0000	0.0000
	193.99	0.01	149.37	0.00	45.28	46.79	0.00	0.00	0.9940	0.0416	0.0000	0.0000
	193.31	-0.02	149.23	0.00	45.65	46.94	0.00	0.00	1.0032	0.0218	0.0000	0.0000
	192.48	-0.05	146.62	0.00	45.94	51.07	0.00	0.00	1.3777	-0.0135	0.0000	0.0000
	192.20	0.00	143.89	0.00	45.84	54.54	0.00	0.00	2.0010	-0.3153	0.0000	0.0000
	190.95	0.12	141.41	0.00	45.60	55.20	0.00	0.00	2.2104	-0.4489	0.0000	0.0000
	191.01	0.02	140.45	0.00	49.07	56.57	0.00	0.00	2.5881	-0.5115	0.0000	0.0000
	191.00	0.07	139.62	0.00	52.09	57.27	0.00	0.00	2.9372	-0.4737	0.0000	0.0000
	189.36	0.00	137.38	0.00	56.27	58.31	0.00	0.00	3.3148	-0.3932	0.0000	0.0000
	189.89	-0.02	136.31	0.00	59.49	60.84	0.00	0.00	3.8310	-0.0276	0.0000	0.0000
	190.82	-0.02	135.33	0.00	58.89	62.18	0.00	0.00	4.3116	0.4334	0.0000	0.0000
	189.28	0.03	135.54	0.00	62.69	60.76	0.00	0.00	5.5056	1.6083	0.0000	0.0000
	188.85	-0.03	132.94	0.00	64.80	61.07	0.00	0.00	6.4689	2.2792	0.0000	0.0000
	188.58	-0.02	131.99	0.00	64.30	62.24	0.00	0.00	7.0120	2.6807	0.0000	0.0000
					TEST NOS	1.14 & 4.5	O.C.R.		1			
					******	**********	**********	******				
					A.G.L.	43.25	R.G.L.	39.03				
0	207.09	-34.28	124.62	0.00	16.74	17.77	-32.09	-34.12	0.0035	-0.0040	-0.0005	-0.0011
0	206.95	34.42	125.06	0.32	17.57	16.61	31.00	34.76	0.0026	0.0033	-0.0007	-0.0043
						DRAINED	REST PERIOD					
					A.G.L.	43.21	R.G.L. 39.19					
4	189.13	13.51	130.83	55.33	1.26	2.03	25.84	9.95	0.0145	0.0080	0.0332	-0.0023
25	189.58	17.82	131.34	54.10	2.44	3.96	24.92	9.64	0.0394	0.0016	0.0366	0.0015
50	183.25	17.16	127.79	51.40	2.18	5.98	23.59	9.19	0.0632	-0.0087	0.0377	0.0036
100	189.23	17.25	127.87	51.65	4.28	10.53	24.11	8.48	0.1497	0.0137	0.0337	0.0022
150	183.65	17.12	128.20	51.37	7.59	16.27	23.46	9.20	0.3298	0.0637	0.0426	-0.0022
175	189.41	17.48	128.62	52.54	9.11	18.56	24.78	8.61	0.4521	0.0898	0.0430	-0.0013
						DRAINED	REST PERIOD					
					A.G.L.	42.92	R.G.L. 39.48					
8	183.75	16.67	126.82	49.91	2.45	1.43	21.76	8.65	0.0189	-0.0012	0.0257	-0.0033
100	188.72	16.97	128.78	50.00	5.52	5.36	22.64	9.33	0.0376	-0.0050	0.0297	-0.0042
200	189.26	17.19	129.02	51.03	7.46	7.49	22.86	9.23	0.0413	-0.0041	0.0263	-0.0070
400	188.21	16.71	126.71	50.30	9.23	10.02	23.77	9.13	0.0646	0.0074	0.0277	-0.0093
600	187.64	15.33	126.08	49.82	11.30	10.44	23.35	11.22	0.0803	0.0195	0.0234	0.0044
800	186.57	16.40	122.94	49.29	12.25	13.08	23.52	8.42	0.0830	0.0157	0.0315	-0.0024
1000	187.51	15.39	123.27	48.81	14.14	14.30	23.27	8.24	0.0912	0.0164	0.0307	0.0001
1200	185.15	15.81	118.95	47.53	13.17	15.29	23.25	8.20	0.0997	0.0306	0.0331	-0.0020
1400	185.36	16.02	120.67	49.43	15.18	16.28	23.16	7.86	0.1114	0.0059	0.0298	-0.0047
1600	183.36	16.36	125.60	49.09	18.29	19.30	23.65	8.52	0.1424	0.0159	0.0345	-0.0039
1800	187.08	16.24	124.91	48.45	19.68	21.25	23.20	8.73	0.1868	0.0158	0.0306	-0.0079
2000	183.38	16.63	126.21	49.89	22.81	25.83	23.16	7.80	0.2418	0.0039	0.0303	-0.0025
2160	187.48	16.30	125.48	48.99	24.56	30.01	24.63	7.44	0.3273	0.0231	0.0370	-0.0025
						DRAINED	REST PERIOD					
					A.G.L.	42.76	R.G.L. 40.06					
10	186.83	16.26	124.69	49.41	6.42	6.03	22.41	8.06	0.0033	-0.0002	0.0251	-0.0018
100	186.82	17.16	124.22	51.40	7.75	7.81	24.32	9.48	0.0119	-0.0007	0.0304	-0.0042
200	186.91	16.81	124.13	50.35	8.33	8.30	23.72	9.21	0.0116	0.0008	0.0294	-0.0031
400	186.60	17.08	124.21	51.51	8.80	8.86	24.09	9.12	0.0127	0.0013	0.0272	-0.0054
800	187.24	16.63	124.36	49.89	10.89	9.61	24.18	8.93	0.0218	-0.0053	0.0293	-0.0015
1200	185.58	16.68	123.58	50.03	11.65	10.24	24.19	8.70	0.0271	-0.0025	0.0340	0.0041
1600	187.80	17.24	123.88	51.99	14.14	11.82	23.72	8.45	0.0467	-0.0019	0.0282	-0.0025
2000	188.08	17.13	126.15	51.74	14.71	13.25	24.23	8.28	0.0780	-0.0047	0.0307	0.0043
2160	187.98	16.79	125.28	50.37	15.57	13.85	23.65	8.50	0.0892	0.0048	0.0312	0.0091

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
						DRAINED REST PERIOD A.G.L. 42.72 R.G.L. 40.12						
1	185.38	-0.02	130.17	0.02	3.61	6.50	0.00	-0.01	0.0014	-0.0036	0.0039	-0.0002
1	155.03	0.03	47.49	0.09	-3.93	0.17	-0.07	-0.00	-0.1146	0.0041	0.0020	-0.0005
1	164.06	39.55	44.21	0.98	3.63	6.94	27.72	40.02	-0.1424	0.0156	-0.0006	-0.0050
1	184.47	39.99	45.00	0.00	7.82	26.35	27.96	40.04	-0.1421	0.0152	-0.0006	-0.0055
1	206.97	46.22	47.90	0.05	13.19	50.57	31.33	45.25	-0.1472	0.0121	-0.0017	-0.0076
1	223.67	43.97	46.58	0.05	17.33	73.75	29.39	45.68	-0.1419	0.0198	-0.0019	-0.0054
1	253.92	44.35	44.49	0.00	22.48	100.88	25.31	41.80	-0.1424	0.0228	-0.0037	-0.0071
1	140.80	44.34	46.61	-0.02	4.29	-18.00	35.04	42.95	-0.1552	0.0128	-0.0027	-0.0066
1	115.71	43.52	45.97	0.16	-2.62	-45.11	35.90	44.79	-0.1527	0.0197	-0.0005	-0.0054
1	134.80	83.26	45.48	-0.09	4.43	-23.95	62.43	86.13	-0.1538	0.0176	-0.0027	-0.0066
1	184.62	86.99	45.61	0.09	13.22	26.36	47.81	85.49	-0.1494	0.0217	-0.0001	-0.0030
1	229.54	85.83	45.65	0.02	20.40	74.33	49.83	86.28	-0.1556	0.0200	-0.0025	-0.0073
1	222.78	14.98	46.63	45.04	19.45	74.08	23.45	13.02	-0.1593	0.0091	0.0358	-0.0012
1	252.00	1.64	45.65	44.36	24.05	108.69	6.96	-1.02	-0.1744	-0.0000	0.0367	0.0043
1	232.60	1.82	47.69	43.53	14.97	83.00	-4.41	-0.69	-0.1760	0.0048	0.0377	0.0025
1	206.21	1.00	47.25	43.90	-55.94	57.78	0.22	-1.28	-0.1760	0.0019	0.0371	0.0023
1	185.22	1.05	47.04	44.04	17.91	32.13	11.59	-1.02	-0.1729	0.0095	0.0354	0.0079
1	162.27	1.46	47.80	43.90	11.53	11.74	12.78	-1.07	-0.1715	0.0157	0.0355	0.0038
1	142.07	1.05	46.66	45.23	5.47	-13.78	14.98	-1.07	-0.1692	0.0157	0.0381	0.0008
1	116.67	2.91	46.77	43.67	2.04	-36.74	16.35	-1.10	-0.1826	0.0017	0.0378	0.0002
1	137.83	-37.20	47.46	44.77	4.75	-15.26	-16.14	-47.88	-0.1825	0.0108	0.0348	0.0011
1	182.26	-42.65	46.54	46.10	13.23	31.93	-18.34	-49.41	-0.1689	0.0161	0.0363	0.0036
1	227.81	-44.09	45.26	44.59	23.03	81.98	-23.46	-50.30	-0.1784	0.0133	0.0354	0.0020
1	224.80	91.68	33.44	68.63	21.55	81.60	47.12	78.17	-0.1778	0.0200	0.0372	0.0039
1	223.89	49.37	46.91	44.17	24.92	81.60	36.09	43.31	-0.1829	0.0159	0.0377	-0.0010
1	182.67	49.86	45.86	44.54	18.16	34.63	35.53	44.40	-0.1938	0.0031	0.0377	0.0037
1	137.83	50.23	46.83	45.29	10.94	-12.20	33.00	41.55	-0.1813	0.0267	0.0372	-0.0004
1	129.86	29.58	48.51	84.44	5.84	-18.07	35.06	25.01	-0.2021	0.0215	0.1121	-0.0004
1	140.70	-1.00	48.24	85.76	6.48	14.43	22.48	-0.94	-0.2440	0.0340	0.1237	0.0045
1	161.96	-2.03	46.87	83.96	10.14	50.85	25.00	-1.30	-0.2411	0.0486	0.1321	0.0092
1	184.82	-1.22	47.29	82.54	16.74	70.81	21.20	-1.15	-0.2443	0.0493	0.1331	0.0032
1	203.06	0.46	46.51	84.00	18.15	89.84	22.11	-0.69	-0.2470	0.0431	0.1355	0.0050
1	225.50	-2.21	46.16	84.32	21.70	114.07	17.36	-0.87	-0.2533	0.0323	0.1350	0.0024
1	251.61	-4.57	47.32	84.12	28.22	141.71	16.30	-0.15	-0.2487	0.0438	0.1333	-0.0003
1	232.83	-91.11	47.05	84.35	26.80	120.10	-29.47	-93.61	-0.2520	0.0479	0.1350	0.0046
1	187.71	-90.69	48.52	84.78	21.52	73.79	-29.89	-101.19	-0.2548	0.0547	0.1330	0.0018
1	133.92	84.44	47.70	84.69	9.63	23.08	47.17	75.67	-0.2680	0.0468	0.1415	0.0021
1	184.93	87.83	45.87	84.32	18.24	74.80	47.15	80.44	-0.2703	0.0611	0.1457	0.0078
1	223.93	91.53	45.84	84.83	25.82	120.79	41.57	71.61	-0.2587	0.0588	0.1506	0.0113
1	168.46	0.10	50.91	-0.07	17.79	58.13	0.11	0.20	-0.2604	0.0512	-0.0001	-0.0001
1	172.52	0.61	69.96	0.00	18.72	58.47	-0.08	0.00	-0.2255	0.0633	-0.0020	-0.0029
1	186.42	37.49	69.73	0.02	21.64	72.76	23.97	41.70	-0.2257	0.0619	-0.0008	-0.0051
1	206.44	44.04	68.90	-0.27	26.47	94.31	23.59	43.21	-0.2317	0.0603	-0.0010	-0.0030
1	232.75	44.67	70.37	-0.14	32.04	120.24	22.83	42.39	-0.2384	0.0420	-0.0003	-0.0036
1	254.49	46.47	70.08	-0.21	28.42	139.88	35.76	37.97	-0.2298	0.0585	0.0006	-0.0017
1	161.48	41.01	69.53	-0.21	19.31	45.17	20.93	41.60	-0.2332	0.0546	0.0002	-0.0031
1	139.03	42.03	70.62	-1.37	13.49	21.48	21.60	42.24	-0.2286	0.0624	-0.0018	-0.0043
1	162.41	57.94	69.76	-0.11	17.05	44.83	30.17	59.74	-0.2278	0.0548	-0.0008	-0.0056
1	206.04	58.85	71.24	0.32	26.65	92.84	31.29	61.61	-0.2254	0.0550	0.0007	-0.0026
1	253.03	64.13	70.70	-1.21	35.31	139.71	28.49	53.31	-0.2344	0.0796	-0.0010	-0.0054
1	164.80	12.34	70.62	32.16	19.22	47.91	19.74	10.03	-0.2262	0.0944	0.0308	0.0034
1	161.11	-47.74	68.32	37.86	17.02	45.95	-18.75	-56.94	-0.2216	0.0941	0.0414	0.0005
1	206.86	-42.28	69.14	37.04	28.68	92.64	-13.48	-53.18	-0.2306	0.0817	0.0362	0.0074

N	P_m	P_r	q_m	q_r	$U_B{}^p$	$U_C{}^p$	$U_B{}^r$	$U_C{}^r$	$\varepsilon_s{}^p$	$\varepsilon_v{}^p$	$\varepsilon_s{}^r$	$\varepsilon_v{}^r$
1	254.04	-46.92	67.50	39.00	40.28	138.60	-14.95	-46.80	-0.2267	0.0870	0.0385	-0.0004
1	250.37	0.92	63.74	37.24	39.15	137.41	5.70	-1.66	-0.2248	0.0909	0.0373	0.0019
1	223.28	0.04	67.34	37.91	36.12	119.08	-6.33	-0.41	-0.2250	0.0855	0.0386	-0.0017
1	205.64	-3.90	66.26	39.19	25.10	95.98	-22.46	-0.15	-0.2248	0.0858	0.0385	-0.0006
1	184.44	-2.85	66.48	38.02	26.61	68.55	-8.96	-1.43	-0.2181	0.0938	0.0353	-0.0018
1	157.35	-2.42	66.80	37.20	20.08	43.46	12.17	-0.82	-0.2349	0.0835	0.0334	0.0004
1	136.42	-1.44	66.93	38.73	15.22	19.25	10.95	-0.13	-0.2245	0.0885	0.0404	0.0031
1	114.21	42.30	68.32	37.77	9.35	-2.65	31.95	35.37	-0.2374	0.0657	0.0379	0.0012
1	162.17	43.30	68.48	36.67	19.80	43.28	29.01	39.20	-0.2283	0.0838	0.0423	0.0016
1	206.69	45.67	68.47	37.01	28.59	92.64	28.46	38.38	-0.2309	0.0809	0.0388	-0.0026
1	254.22	46.58	69.21	36.81	39.05	139.22	29.76	35.40	-0.2184	0.0875	0.0366	-0.0044
1	166.29	0.34	70.79	0.02	23.58	46.82	-0.17	0.03	-0.2173	0.0976	-0.0025	-0.0062
1	150.60	0.38	25.74	-0.05	18.35	38.20	-0.01	0.00	-0.2829	0.0959	-0.0011	-0.0042
1	117.41	49.92	25.34	-0.39	8.98	1.74	29.89	49.97	-0.3027	0.0943	-0.0014	-0.0025
1	137.19	46.54	24.11	-1.01	12.49	25.41	30.30	48.87	-0.3024	0.0905	-0.0019	-0.0059
1	158.07	48.49	23.36	-1.01	17.58	47.02	25.20	48.16	-0.3009	0.0881	-0.0025	-0.0050
1	184.00	44.74	23.78	0.25	22.43	75.26	23.94	46.75	-0.2999	0.0956	-0.0017	-0.0045
1	204.48	50.75	24.41	0.64	27.60	97.60	26.75	51.98	-0.2958	0.0997	-0.0011	-0.0025
1	223.35	48.88	25.71	0.23	33.77	120.38	25.24	45.78	-0.2901	0.0989	0.0006	-0.0022
1	253.16	50.75	23.63	0.09	31.98	145.41	36.99	40.58	-0.3091	0.0821	-0.0006	-0.0042
1	242.63	14.12	25.50	43.99	41.56	137.78	15.61	10.31	-0.3026	0.1015	0.0470	0.0074
1	252.62	-50.60	27.41	40.72	44.08	143.37	-15.13	-45.53	-0.3099	0.0965	0.0416	0.0037
1	207.83	-45.15	25.02	40.70	35.97	101.07	-17.11	-51.78	-0.3152	0.0917	0.0404	0.0001
1	162.83	-44.75	25.50	41.43	26.02	53.39	-17.74	-53.08	-0.3164	0.0969	0.0441	0.0005
1	115.24	-45.25	26.42	41.13	14.04	3.59	-18.63	-55.66	-0.3145	0.0999	0.0429	-0.0000
1	117.29	2.59	26.17	39.90	15.57	4.45	-17.01	-1.15	-0.3164	0.1051	0.0428	0.0062
1	141.75	-2.23	26.16	41.89	18.65	29.40	-12.32	-0.10	-0.3242	0.0809	0.0444	0.0030
1	161.67	-2.80	27.92	39.10	24.04	50.11	-12.47	-0.33	-0.3289	0.0910	0.0434	0.0046
1	171.01	30.53	26.47	42.09	29.65	75.35	9.13	-0.13	-0.3165	0.1031	0.0430	0.0070
1	204.45	-11.73	15.72	46.70	34.82	99.39	8.46	-0.64	-0.3226	0.0967	0.0426	0.0033
1	190.73	3.57	15.00	47.09	32.70	126.96	-8.04	-1.12	-0.3109	0.1034	0.0451	0.0050
1	254.25	1.34	24.90	45.18	45.74	146.98	7.97	-0.03	-0.3085	0.1139	0.0456	-0.0029
1	251.59	44.40	25.89	42.07	44.09	145.78	31.00	38.56	-0.3146	0.1017	0.0454	0.0061
1	201.83	43.97	21.77	42.80	31.30	98.38	42.36	40.63	-0.3250	0.0845	0.0430	0.0100
1	160.43	46.73	21.05	42.73	18.91	50.66	19.80	43.03	-0.3298	0.0938	0.0510	0.0089
1	112.56	46.01	21.85	39.49	15.46	4.08	36.47	41.34	-0.3338	0.0904	0.0414	0.0031
1	152.90	-0.06	20.22	0.00	19.53	43.91	-13.62	-0.03	-0.3441	0.0899	0.0001	-0.0018
1	175.63	0.05	87.19	-0.11	30.61	56.09	-0.13	0.10	-0.2154	0.0939	-0.0014	-0.0076
1	177.16	11.74	88.89	34.66	29.98	58.26	17.82	9.95	-0.1880	0.1093	0.0198	0.0251
1	176.56	34.10	88.92	92.60	29.97	53.68	35.17	22.48	-0.1419	0.1202	0.1232	-0.0028
1	171.64	30.91	90.69	87.50	21.07	50.66	15.23	22.76	-0.0990	0.0992	0.1203	-0.0021
					DRAINED REST PERIOD							
					A.G.L. 42.68	R.G.L. 40.61						
					STRAIN CONTROL FAILURE TEST							
0	191.70	0.01	131.93	0.00	0.92	3.32	0.00	0.00	0.0002	0.0053	0.0000	0.0000
0	191.09	-0.05	135.99	0.00	1.59	5.32	0.00	0.00	0.0024	0.0078	0.0000	0.0000
0	197.02	0.08	149.76	0.00	1.71	8.52	0.00	0.00	0.0175	0.0032	0.0000	0.0000
0	197.74	0.04	156.64	0.00	1.98	10.59	0.00	0.00	0.0200	0.0039	0.0000	0.0000
0	202.94	-0.10	167.11	0.00	3.12	13.36	0.00	0.00	0.0636	-0.0019	0.0000	0.0000
0	203.92	-0.03	172.61	0.00	3.88	14.72	0.00	0.00	0.0813	-0.0005	0.0000	0.0000
0	204.89	0.10	175.16	0.00	4.57	15.82	0.00	0.00	0.1193	0.0082	0.0000	0.0000
0	204.96	0.85	174.99	0.00	5.10	17.15	0.00	0.00	0.1684	-0.0015	0.0000	0.0000
0	206.14	0.41	176.06	0.00	4.61	20.05	0.00	0.00	0.2741	-0.0175	0.0000	0.0000
0	205.34	0.77	174.41	0.00	4.05	24.77	0.00	0.00	0.4411	-0.1286	0.0000	0.0000

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
0	205.31	1.09	175.03	0.00	4.72	26.98	0.00	0.00	0.4975	-0.1171	0.0000	0.0000
0	205.74	0.18	175.05	0.00	4.65	28.70	0.00	0.00	0.5150	-0.0839	0.0000	0.0000
0	202.44	0.21	164.79	0.00	5.57	32.72	0.00	0.00	0.7125	-0.1879	0.0000	0.0000
0	199.16	0.85	160.34	0.00	4.74	39.70	0.00	0.00	1.0227	-0.3015	0.0000	0.0000
0	199.60	0.72	157.18	0.00	5.62	44.11	0.00	0.00	1.3153	-0.4555	0.0000	0.0000
0	193.10	-0.67	156.74	0.00	5.45	43.92	0.00	0.00	1.3150	-0.4548	0.0000	0.0000
0	197.81	-0.97	153.87	0.00	6.36	49.27	0.00	0.00	1.7460	-0.7122	0.0000	0.0000
0	195.58	-0.73	151.12	0.00	5.98	52.09	0.00	0.00	2.1662	-0.9783	0.0000	0.0000
0	196.26	0.53	150.13	0.00	7.65	54.11	0.00	0.00	2.4333	-1.0937	0.0000	0.0000
0	197.23	0.00	149.82	0.00	7.52	56.75	0.00	0.00	2.4309	-1.0977	0.0000	0.0000
0	195.39	0.37	144.91	0.00	9.56	60.68	0.00	0.00	3.1579	-1.0677	0.0000	0.0000
					TEST NO	1.15		O.C.R.	1			
					************************************							
					A.G.L. 44.00		R.G.L. 38.82					
1	202.75	-33.09	132.73	0.02	17.95	17.60	-36.68	-38.27	0.0022	-0.0045	0.0006	-0.0018
0	203.03	37.10	132.10	-0.14	17.57	17.38	37.55	38.18	-0.0032	-0.0011	-0.0005	-0.0013
0	188.20	10.48	134.17	31.45	11.00	11.86	10.04	7.22	0.0526	0.0168	0.0148	0.0027
0	187.76	16.07	134.15	48.38	10.99	11.79	14.62	10.12	0.0512	0.0087	0.0264	0.0044
0	186.73	16.29	132.05	49.23	13.64	14.37	15.12	10.36	0.0796	0.0000	0.0320	0.0040
0	187.19	16.66	132.80	49.25	17.51	19.81	15.51	10.69	0.1268	0.0137	0.0370	-0.0043
0	183.39	16.89	133.05	49.48	19.24	22.46	15.81	10.17	0.1623	-0.0020	0.0362	0.0006
						DRAINED REST PERIOD						
					A.G.L. 43.91		R.G.L. 39.06					
1	185.46	15.45	134.12	46.71	2.23	3.20	14.99	12.26	0.0062	0.0017	0.0243	0.0069
50	185.25	16.07	133.69	48.47	5.45	7.21	15.04	12.39	0.0191	0.0040	0.0276	0.0047
100	185.34	16.26	131.93	48.98	6.14	8.80	14.94	11.97	0.0240	-0.0005	0.0289	0.0049
200	184.19	15.74	131.53	47.49	8.60	11.55	15.18	11.27	0.0337	0.0095	0.0290	0.0004
400	184.17	15.75	131.64	48.27	12.62	17.69	14.38	10.89	0.0746	0.0003	0.0329	0.0060
500	184.16	15.63	131.99	46.80	15.81	20.72	14.90	11.15	0.1074	0.0045	0.0317	0.0037
500	185.33	16.20	133.16	48.61	16.38	21.38	15.40	11.48	0.1171	0.0147	0.0306	0.0026
600	185.58	16.48	134.43	49.18	19.13	26.28	14.88	9.75	0.1971	-0.0165	0.0432	0.0012
650	185.39	17.67	133.43	52.08	20.94	31.18	15.96	8.60	0.3181	-0.0317	0.0437	-0.0020
700	185.81	17.15	132.88	50.73	23.41	37.72	15.43	7.88	0.5952	-0.1046	0.0559	-0.0116
						DRAINED REST PERIOD						
					A.G.L. 43.57		R.G.L. 39.70					
1	185.53	17.38	131.58	52.34	7.42	8.44	16.41	11.88	0.0184	0.0089	0.0346	0.0051
10	185.33	17.85	133.49	53.09	9.81	11.49	16.03	11.14	0.0237	0.0010	0.0341	0.0019
50	186.19	17.27	132.78	51.17	13.22	15.31	15.82	10.28	0.0549	0.0093	0.0333	-0.0073
100	187.19	17.00	132.83	51.47	15.72	18.25	14.85	10.09	0.0777	-0.0101	0.0333	0.0038
200	185.27	17.10	131.90	50.39	20.94	23.76	14.39	9.30	0.1651	-0.0182	0.0332	0.0048
400	185.93	17.95	134.79	50.75	28.46	32.92	13.90	6.11	0.5519	-0.1636	0.0547	-0.0084
						DRAINED REST PERIOD						
					A.G.L. 43.28		R.G.L. 40.72					
1	184.22	17.45	130.54	49.71	5.88	7.95	15.51	11.40	0.0025	-0.0000	0.0273	0.0023
50	184.38	16.98	132.18	50.85	7.68	10.16	15.13	10.74	0.0053	0.0030	0.0303	0.0026
100	182.73	16.18	130.23	49.64	9.34	11.30	15.30	10.31	0.0106	-0.0016	0.0313	0.0038
200	184.19	16.95	129.78	49.84	8.83	11.85	15.25	10.24	0.0100	-0.0020	0.0316	0.0046
400	183.82	16.52	130.23	48.82	11.09	14.80	14.95	10.08	0.0114	-0.0005	0.0301	0.0006
600	183.62	16.57	130.97	49.71	14.08	18.01	14.50	10.00	0.0120	-0.0008	0.0324	0.0075
600	183.54	16.40	130.86	49.30	15.82	18.62	15.01	10.02	0.0220	0.0030	0.0327	0.0047
1000	184.19	16.43	130.58	49.11	16.26	19.31	14.35	9.92	0.0277	0.0092	0.0328	0.0029
1200	184.93	16.12	131.00	47.17	16.62	19.86	14.91	10.17	0.0354	0.0126	0.0348	0.0078
1400	183.68	16.03	130.13	46.98	16.93	20.04	14.60	10.24	0.0364	0.0134	0.0353	0.0050
1600	184.82	17.61	130.95	49.07	18.70	20.70	14.57	10.74	0.0385	0.0157	0.0348	0.0012

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1800	182.84	16.19	129.99	48.01	17.58	20.61	15.09	10.60	0.0393	0.0156	0.0345	-0.0015
2000	184.24	16.33	131.96	49.46	19.34	21.87	15.08	11.08	0.0406	0.0168	0.0364	-0.0015
2160	183.46	16.44	130.52	48.86	19.15	21.91	15.22	11.01	0.0393	0.0119	0.0348	0.0078
						DRAINED REST PERIOD						
					A.G.L. 43.26		R.G.L. 41.57					
1	183.67	19.27	130.22	57.07	8.22	10.13	18.05	13.11	0.0189	-0.0003	0.0331	0.0089
10	183.61	17.58	130.66	52.93	9.52	11.92	15.51	11.62	0.0202	0.0010	0.0298	0.0039
50	185.03	17.72	131.30	49.96	10.84	13.14	15.25	10.97	0.0229	0.0068	0.0305	0.0025
100	184.58	17.35	131.56	50.03	11.91	13.91	15.61	10.70	0.0250	0.0007	0.0313	0.0042
200	183.91	17.05	130.63	49.78	11.54	14.48	15.16	10.45	0.0226	0.0012	0.0296	0.0009
400	183.24	16.50	129.56	49.87	12.57	15.23	14.50	10.46	0.0259	0.0031	0.0318	0.0002
800	184.22	18.06	130.70	50.81	13.26	16.83	15.01	10.29	0.0261	0.0024	0.0345	-0.0022
1200	183.22	17.13	129.81	50.55	13.87	17.47	15.16	10.47	0.0353	-0.0003	0.0305	0.0022
1600	183.13	17.58	129.32	51.26	15.44	17.98	15.04	10.59	0.0340	0.0016	0.0347	0.0056
2000	183.69	17.80	128.56	50.92	14.34	18.59	15.09	10.76	0.0347	-0.0007	0.0353	0.0035
2400	182.51	16.22	129.19	49.94	15.41	18.96	15.01	10.76	0.0370	0.0035	0.0365	0.0001
					STRAIN CONTROL FAILURE TEST							
0	189.06	0.01	130.99	0.00	1.69	-0.14	0.00	0.00	0.0149	0.0046	0.0000	0.0000
0	189.69	0.02	132.88	0.00	1.89	0.50	0.00	0.00	0.0162	0.0026	0.0000	0.0000
0	190.42	0.01	135.55	0.00	2.60	1.24	0.00	0.00	0.0158	0.0026	0.0000	0.0000
0	191.31	0.05	138.75	0.00	3.91	1.68	0.00	0.00	0.0225	0.0022	0.0000	0.0000
0	192.28	-0.02	140.66	0.00	3.69	2.28	0.00	0.00	0.0258	0.0043	0.0000	0.0000
0	192.36	0.00	142.03	0.00	4.62	2.42	0.00	0.00	0.0229	0.0018	0.0000	0.0000
0	193.30	-0.14	143.46	0.00	4.87	2.95	0.00	0.00	0.0273	0.0078	0.0000	0.0000
0	194.61	0.05	146.23	0.00	5.68	3.80	0.00	0.00	0.0319	0.0110	0.0000	0.0000
0	195.67	0.01	149.22	0.00	6.91	4.64	0.00	0.00	0.0446	0.0213	0.0000	0.0000
0	194.81	0.04	149.18	0.00	7.34	5.76	0.00	0.00	0.0392	0.0060	0.0000	0.0000
0	195.37	0.01	150.02	0.00	8.92	7.50	0.00	0.00	0.0598	0.0161	0.0000	0.0000
0	194.99	-0.05	149.17	0.00	9.97	8.60	0.00	0.00	0.0620	0.0052	0.0000	0.0000
0	195.34	0.06	149.30	0.00	12.35	10.39	0.00	0.00	0.0771	0.0099	0.0000	0.0000
0	194.92	0.02	147.95	0.00	13.81	12.01	0.00	0.00	0.0946	0.0154	0.0000	0.0000
0	194.46	0.05	147.55	0.00	14.38	13.68	0.00	0.00	0.1093	0.0006	0.0000	0.0000
0	194.95	0.03	147.22	0.00	16.11	14.94	0.00	0.00	0.1206	0.0041	0.0000	0.0000
0	194.47	0.05	145.87	0.00	16.81	16.20	0.00	0.00	0.1317	0.0047	0.0000	0.0000
0	194.25	0.03	145.04	0.00	17.92	17.36	0.00	0.00	0.1490	0.0058	0.0000	0.0000
0	193.22	0.01	143.61	0.00	19.42	18.95	0.00	0.00	0.1629	-0.0072	0.0000	0.0000
0	193.47	0.05	144.41	0.00	20.87	20.99	0.00	0.00	0.1924	-0.0069	0.0000	0.0000
0	193.33	0.04	144.16	0.00	21.64	20.55	0.00	0.00	0.1994	0.0003	0.0000	0.0000
0	192.74	-0.02	142.77	0.00	23.45	22.61	0.00	0.00	0.2361	0.0105	0.0000	0.0000
0	192.50	0.02	141.31	0.00	26.79	25.78	0.00	0.00	0.3175	-0.0012	0.0000	0.0000
0	192.07	-0.11	141.03	0.00	28.11	28.50	0.00	0.00	0.3808	-0.0162	0.0000	0.0000
0	192.18	0.00	139.91	0.00	30.79	30.47	0.00	0.00	0.4644	-0.0304	0.0000	0.0000
0	191.76	-0.02	138.78	0.00	31.79	33.32	0.00	0.00	0.5648	-0.0509	0.0000	0.0000
0	192.16	0.00	138.12	0.00	34.45	36.04	0.00	0.00	0.6932	-0.0965	0.0000	0.0000
0	191.17	-0.04	136.32	0.00	36.57	38.01	0.00	0.00	0.7836	-0.1634	0.0000	0.0000
0	190.61	0.01	135.19	0.00	38.09	39.40	0.00	0.00	0.8760	-0.1862	0.0000	0.0000
0	190.76	0.05	134.99	0.00	37.93	38.66	0.00	0.00	0.8641	-0.1165	0.0000	0.0000
0	189.68	0.02	133.49	0.00	40.35	41.08	0.00	0.00	1.0133	-0.2137	0.0000	0.0000
0	189.29	0.00	132.05	0.00	42.69	43.65	0.00	0.00	1.2436	-0.3326	0.0000	0.0000
0	189.74	-0.02	131.30	0.00	43.33	44.32	0.00	0.00	1.2549	-0.3158	0.0000	0.0000
0	183.87	-1.06	130.80	0.00	44.91	45.68	0.00	0.00	1.4027	-0.2941	0.0000	0.0000
0	187.04	-0.02	125.58	0.00	49.54	51.60	0.00	0.00	1.8543	-0.0412	0.0000	0.0000
0	186.70	0.02	124.56	0.00	50.08	51.86	0.00	0.00	1.8946	-0.0386	0.0000	0.0000
0	186.52	0.07	122.28	0.00	53.10	54.73	0.00	0.00	2.2422	0.1206	0.0000	0.0000

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
0	185.11	-0.03	120.39	0.00	55.03	57.26	0.00	0.00	2.5611	0.2995	0.0000	0.0000
0	184.36	0.02	118.24	0.00	55.98	59.48	0.00	0.00	3.0033	0.4526	0.0000	0.0000
0	183.96	-0.43	118.55	0.00	57.99	61.55	0.00	0.00	3.3796	0.5402	0.0000	0.0000
0	184.56	-0.62	113.23	0.00	58.06	61.44	0.00	0.00	3.5298	0.7657	0.0000	0.0000
0	184.30	-1.57	116.53	0.00	57.77	61.57	0.00	0.00	4.0774	0.5063	0.0000	0.0000
0	184.21	0.00	116.27	0.00	59.77	63.59	0.00	0.00	4.9917	0.3611	0.0000	0.0000
0	179.43	-0.02	100.65	0.00	59.42	63.47	0.00	0.00	4.9948	0.3651	0.0000	0.0000
					TEST NO	2.1		U.C.R.	13			
					************************************							
					A.G.L.127.50		R.G.L. 38.97					
5	133.35		130.05	46.73	-0.05	0.00	20.23	0.00	0.0001	-0.0019	0.0170	-0.0086
50	133.96		131.98	43.15	1.45	0.00	21.13	0.00	0.0053	0.0041	0.0195	-0.0014
100	133.52		130.55	45.39	1.95	0.00	21.27	0.00	0.0039	-0.0033	0.0215	-0.0058
200	133.67		131.02	46.45	2.69	0.00	19.96	0.00	0.0038	0.0031	0.0220	0.0021
300	133.73		131.20	46.50	2.49	0.00	20.05	0.00	0.0017	-0.0013	0.0217	0.0001
600	133.76		131.29	45.93	2.14	0.00	21.04	0.00	0.0021	-0.0007	0.0217	-0.0018
1000	133.78		131.35	45.65	2.00	0.00	20.48	0.00	0.0006	-0.0017	0.0213	-0.0001
1400	133.69		131.08	45.22	2.29	0.00	20.26	0.00	0.0039	-0.0033	0.0198	-0.0020
1800	133.92		131.77	44.37	2.65	0.00	20.01	0.00	0.0023	0.0008	0.0239	-0.0019
2160	133.52		130.56	45.81	2.04	0.00	19.35	0.00	0.0024	0.0003	0.0244	-0.0025
						DRAINED REST PERIOD						
					A.G.L.127.45		R.G.L. 38.96					
2	133.36		131.58	44.93	0.97	0.00	21.48	0.00	0.0022	-0.0013	0.0226	-0.0033
50	133.43		130.43	46.81	-0.40	0.00	21.41	0.00	0.0040	-0.0044	0.0228	-0.0053
100	132.93		128.93	46.29	-1.02	0.00	20.48	0.00	0.0019	-0.0030	0.0217	-0.0037
400	132.97		128.91	47.60	-0.71	0.00	20.76	0.00	0.0037	0.0016	0.0224	-0.0012
800	132.25		126.74	45.85	-0.14	0.00	19.88	0.00	0.0051	0.0037	0.0209	-0.0069
1200	132.27		126.81	44.99	-0.62	0.00	19.84	0.00	0.0062	0.0048	0.0215	-0.0043
1600	131.61		124.84	43.51	-0.04	0.00	21.28	0.00	0.0045	-0.0037	0.0225	-0.0037
2000	132.06		126.17	41.34	0.12	0.00	19.92	0.00	0.0041	-0.0029	0.0227	-0.0040
2160	132.20		126.60	44.03	0.76	0.00	21.14	0.00	0.0017	-0.0027	0.0217	-0.0023
						DRAINED REST PERIOD						
					A.G.L.127.47		R.G.L. 38.96					
4	133.76		131.28	42.36	-0.28	0.00	21.00	0.00	0.0048	0.0045	0.0187	-0.0031
100	133.76		131.29	46.70	-0.23	0.00	20.99	0.00	0.0082	0.0005	0.0204	-0.0079
400	133.42		130.25	46.20	-0.93	0.00	22.47	0.00	0.0075	-0.0005	0.0205	-0.0030
800	133.54		130.63	46.34	0.92	0.00	20.36	0.00	0.0063	-0.0023	0.0221	-0.0036
1200	133.96		131.89	44.91	0.78	0.00	19.63	0.00	0.0070	-0.0012	0.0202	-0.0102
1600	133.22		129.66	45.43	0.34	0.00	20.37	0.00	0.0092	0.0021	0.0202	-0.0079
2160	133.22		129.67	69.99	0.00	0.00	30.21	0.00	0.0054	-0.0024	0.0244	-0.0117
					STRAIN CONTROL FAILURE TEST							
1	133.44		130.33	0.00	0.63	0.00	0.00	0.00	0.0080	0.0016	0.0000	0.0000
1	138.79		146.37	0.00	4.79	0.00	0.00	0.00	0.0216	0.0207	0.0000	0.0000
1	193.30		161.41	0.00	8.38	0.00	0.00	0.00	0.0243	0.0273	0.0000	0.0000
1	197.78		173.35	0.00	11.49	0.00	0.00	0.00	0.0347	0.0338	0.0000	0.0000
1	204.21		192.63	0.00	14.95	0.00	0.00	0.00	0.0610	0.0655	0.0000	0.0000
1	203.76		206.28	0.00	17.34	0.00	0.00	0.00	0.2254	0.0643	0.0000	0.0000
1	203.69		191.06	0.00	18.09	0.00	0.00	0.00	1.0068	-0.2548	0.0000	0.0000
1	200.23		180.69	0.00	27.26	0.00	0.00	0.00	2.1359	-0.2582	0.0000	0.0000
1	197.17		171.50	0.00	36.19	0.00	0.00	0.00	2.2451	-0.2253	0.0000	0.0000
1	193.49		160.48	0.00	40.41	0.00	0.00	0.00	2.2352	-0.2271	0.0000	0.0000

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_y^p	ε_s^r	ε_v^r
				TEST NO	2.2		O.C.R. 1.3				
				***********************************							
				A.G.L. 42.89		R.G.L. 38.96					
10	132.88	128.63	42.59	-0.27	0.59	13.62	4.81	0.0078	0.0072	0.0111	-0.0033
100	133.55	130.66	46.83	-0.18	1.30	15.12	5.05	0.0081	0.0017	0.0242	0.0039
300	134.25	132.74	50.25	-0.33	1.39	15.17	4.92	0.0088	0.0021	0.0263	0.0066
500	133.38	130.14	44.48	-0.27	2.21	15.25	4.81	0.0083	0.0007	0.0281	0.0096
700	133.00	129.00	43.64	-0.86	2.51	14.42	4.85	0.0094	0.0037	0.0279	0.0080
1000	132.84	128.52	44.33	-0.19	2.82	15.25	4.79	0.0087	0.0025	0.0282	0.0087
1200	132.82	128.47	43.93	-0.28	2.72	14.89	4.64	0.0059	0.0044	0.0272	0.0062
1600	133.30	129.91	42.12	-0.23	2.90	13.76	4.50	0.0064	0.0129	0.0297	0.0126
2000	132.96	128.96	46.00	-0.31	3.07	14.59	4.48	0.0101	0.0020	0.0288	0.0072
					DRAINED REST PERIOD						
				A.G.L. 42.89		R.G.L. 38.97					
3	132.77	128.32	47.90	0.92	0.27	15.40	5.21	0.0029	0.0005	0.0205	-0.0002
50	132.37	127.10	47.25	0.29	0.20	15.18	5.15	0.0065	0.0033	0.0239	0.0033
100	133.51	130.52	47.03	0.38	0.97	14.76	4.86	0.0085	0.0037	0.0217	-0.0006
400	133.75	131.26	43.02	0.33	1.98	14.70	4.74	0.0081	0.0056	0.0250	0.0005
800	133.43	130.30	41.98	-0.10	2.40	14.54	4.55	0.0091	-0.0014	0.0219	-0.0029
1200	133.35	130.06	42.83	-0.08	2.77	13.90	4.65	0.0117	0.0033	0.0216	0.0001
1600	133.56	130.68	43.39	-0.12	2.86	14.40	4.85	0.0120	-0.0002	0.0231	0.0020
2000	133.20	129.87	41.56	-0.33	2.95	14.06	4.77	0.0103	-0.0047	0.0172	-0.0071
					DRAINED REST PERIOD						
				A.G.L. 42.89		R.G.L. 38.96					
3	133.08	129.23	45.27	1.13	-0.56	15.72	5.08	0.0041	-0.0004	0.0176	-0.0048
50	133.15	129.44	45.16	0.68	-0.33	15.55	4.86	0.0035	0.0027	0.0211	-0.0025
200	132.50	127.51	44.50	-0.83	-0.39	15.39	4.64	0.0061	-0.0000	0.0255	0.0044
400	132.68	128.05	45.18	-1.31	0.07	14.79	4.77	0.0049	0.0080	0.0218	-0.0014
800	132.46	127.37	43.80	-1.27	0.70	14.85	4.75	0.0065	0.0085	0.0188	-0.0054
1200	133.05	129.14	45.28	-1.04	1.52	15.46	4.98	0.0052	0.0059	0.0249	-0.0011
1600	133.23	129.69	45.98	-1.06	1.46	15.36	4.80	0.0057	0.0007	0.0217	-0.0025
2000	132.93	128.78	45.83	-1.09	1.60	15.59	4.93	0.0075	0.0021	0.0226	0.0009
					DRAINED REST PERIOD						
				A.G.L. 42.88		R.G.L. 38.96					
3	133.20	129.59	47.11	0.77	0.08	16.94	5.33	0.0013	-0.0020	0.0309	0.0164
50	133.19	129.56	47.17	0.16	-0.17	16.03	5.14	0.0012	-0.0021	0.0270	0.0042
100	132.83	128.50	46.82	-0.66	-0.41	16.18	5.09	-0.0014	-0.0059	0.0218	-0.0011
350	133.54	130.63	46.95	-1.36	0.05	15.28	5.12	0.0014	-0.0017	0.0240	-0.0027
800	133.40	130.21	44.14	-1.80	0.50	14.97	4.88	0.0006	-0.0043	0.0271	-0.0022
1200	133.53	130.58	43.81	-2.10	0.59	15.32	4.85	0.0026	-0.0065	0.0191	-0.0078
1600	133.23	129.68	42.89	-2.21	0.43	14.45	4.70	0.0007	-0.0035	0.0203	-0.0055
2000	133.49	130.48	44.72	-2.36	0.31	14.93	4.75	0.0021	-0.0034	0.0251	0.0053
					DRAINED REST PERIOD						
				A.G.L. 42.88		R.G.L. 38.96					
3	134.92	134.75	47.66	0.84	0.13	15.83	5.35	0.0017	-0.0027	0.0171	-0.0086
200	132.83	128.48	46.59	-0.80	-0.72	15.68	5.16	-0.0001	-0.0041	0.0211	-0.0036
400	133.39	130.17	44.95	-0.93	-0.08	14.60	4.93	0.0018	-0.0039	0.0196	-0.0028
800	133.63	131.04	45.97	-1.23	0.28	14.66	5.02	0.0023	-0.0031	0.0208	-0.0045
1200	133.75	131.26	44.91	-1.55	0.42	13.82	4.58	-0.0012	-0.0057	0.0226	0.0008
1600	133.05	129.15	46.24	-1.84	0.63	14.30	4.86	-0.0027	0.0018	0.0243	-0.0049
2000	132.80	128.68	47.25	-1.46	0.94	14.28	4.88	0.0026	-0.0130	0.0236	-0.0009
2160	132.96	128.87	47.55	-1.41	0.92	14.36	4.67	0.0004	-0.0086	0.0192	-0.0054
					STRAIN CONTROL FAILURE TEST						
1	134.34	133.03	0.00	-0.74	0.71	0.00	0.00	0.0013	0.0006	0.0000	0.0000
1	[illegible]	143.87	0.00	1.69	2.05	0.00	0.00	0.0057	0.0007	0.0000	0.0000

N	P_m	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_y^p	ε_s^r	ε_v^r
1	193.79	161.37	0.00	4.39	4.44	0.00	0.00	0.0080	-0.0010	0.0000	0.0000
1	198.63	175.88	0.00	7.32	5.37	0.00	0.00	0.0099	-0.0041	0.0000	0.0000
1	204.53	193.74	0.00	10.29	6.21	0.00	0.00	0.0094	0.0076	0.0000	0.0000
1	209.48	208.45	0.00	12.94	4.85	0.00	0.00	0.0377	-0.0035	0.0000	0.0000
1	212.11	216.33	0.00	14.47	2.16	0.00	0.00	0.0775	-0.0174	0.0000	0.0000
1	212.46	217.39	0.00	14.77	0.83	0.00	0.00	0.1077	-0.0385	0.0000	0.0000
1	211.99	215.96	0.00	14.26	-1.13	0.00	0.00	0.2013	-0.0598	0.0000	0.0000
1	210.75	212.26	0.00	13.45	-1.21	0.00	0.00	0.2763	-0.1005	0.0000	0.0000
1	208.32	204.97	0.00	12.74	-0.11	0.00	0.00	0.4041	-0.0998	0.0000	0.0000
1	205.56	190.67	0.00	11.90	1.00	0.00	0.00	0.5453	-0.0150	0.0000	0.0000
1	202.24	186.72	0.00	13.09	1.80	0.00	0.00	0.8113	0.1806	0.0000	0.0000
1	199.57	173.70	0.00	16.80	2.43	0.00	0.00	1.1410	0.7730	0.0000	0.0000
TEST NO 3.1 U.C.R. 1											
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A.G.L.132.50 R.G.L. 38.89											
1	134.51	133.52	63.45	0.52	0.00	17.47	0.00	0.0070	-0.0013	0.0295	0.0149
50	134.34	133.02	50.58	0.62	0.00	17.66	0.00	0.0070	0.0000	0.0335	0.0123
100	134.09	132.27	49.01	3.05	0.00	17.38	0.00	0.0074	0.0019	0.0300	0.0138
200	134.74	134.21	47.40	5.07	0.00	17.02	0.00	0.0089	0.0003	0.0320	0.0179
400	135.19	135.56	46.14	5.64	0.00	17.98	0.00	0.0076	-0.0023	0.0364	0.0200
1	191.52	154.57	31.93	13.34	0.00	10.88	0.00	0.0250	0.0081	0.0219	0.0077
100	191.74	155.21	28.07	13.27	0.00	9.12	0.00	0.0378	-0.0034	0.0162	0.0110
300	192.16	156.49	27.32	13.47	0.00	9.07	0.00	0.0395	-0.0021	0.0174	0.0128
500	191.90	155.71	26.66	14.07	0.00	9.18	0.00	0.0424	-0.0011	0.0210	0.0127
700	191.98	155.93	27.27	14.49	0.00	8.96	0.00	0.0446	-0.0030	0.0179	0.0119
1000	192.25	156.75	26.12	15.08	0.00	8.92	0.00	0.0469	-0.0002	0.0195	0.0087
1200	192.56	157.67	26.06	14.91	0.00	8.63	0.00	0.0477	0.0011	0.0134	0.0119
DRAINED REST PERIOD											
A.G.L.132.34 R.G.L. 38.89											
1	191.13	153.38	48.96	8.18	0.00	18.04	0.00	0.0071	-0.0024	0.0248	0.0068
50	192.47	157.41	40.02	9.75	0.00	15.08	0.00	0.0181	0.0010	0.0193	0.0069
100	191.93	155.80	39.40	10.49	0.00	12.98	0.00	0.0222	0.0007	0.0182	0.0005
200	190.75	152.26	38.33	10.84	0.00	13.11	0.00	0.0319	-0.0051	0.0203	0.0054
500	192.00	155.99	41.06	11.96	0.00	13.60	0.00	0.0383	0.0052	0.0204	0.0080
700	191.54	154.63	39.45	12.28	0.00	12.54	0.00	0.0528	-0.0109	0.0203	0.0036
1000	191.89	155.67	40.65	13.28	0.00	13.06	0.00	0.0791	-0.0152	0.0206	0.0029
1200	192.13	156.38	41.69	14.45	0.00	13.31	0.00	0.1049	0.0176	0.0229	0.0052
1500	192.19	156.58	38.32	16.74	0.00	13.14	0.00	0.1648	0.0304	0.0221	0.0036
1700	192.31	156.94	39.46	19.24	0.00	14.30	0.00	0.2480	0.0175	0.0220	0.0071
1900	192.65	157.95	39.94	21.18	0.00	13.98	0.00	0.4213	-0.0033	0.0207	0.0085
DRAINED REST PERIOD											
A.G.L.131.56 R.G.L. 38.98											
1	192.20	156.59	39.99	9.12	0.00	15.80	0.00	0.0057	0.0034	0.0209	0.0073
50	191.76	155.28	40.39	9.78	0.00	15.76	0.00	0.0069	0.0044	0.0227	0.0101
100	192.02	156.06	38.34	11.38	0.00	15.05	0.00	0.0128	0.0010	0.0225	0.0113
300	192.01	156.03	39.70	16.37	0.00	15.02	0.00	0.0396	-0.0038	0.0230	0.0105
500	192.11	156.33	39.46	19.84	0.00	14.50	0.00	0.0704	0.0026	0.0230	0.0071
700	192.15	156.44	40.29	23.30	0.00	14.23	0.00	0.1414	-0.0068	0.0264	0.0043
900	191.94	155.81	40.80	28.26	0.00	13.37	0.00	0.3769	-0.0351	0.0283	0.0048
DRAINED REST PERIOD											
A.G.L.130.44 R.G.L. 39.19											
1	191.64	154.92	44.18	7.79	0.00	17.41	0.00	0.0267	0.0109	0.0236	0.0073
50	192.36	157.07	38.72	11.87	0.00	14.34	0.00	0.0650	-0.0010	0.0250	0.0050
100	192.38	157.14	40.96	14.37	0.00	17.10	0.00	0.1112	-0.0003	0.0271	0.0049

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
200	154.65		191.55	38.69	18.49	0.00	13.48	0.00	0.2779	-0.0206	0.0280	0.0083
250	156.02		192.01	35.94	20.57	0.00	13.67	0.00	0.5239	-0.1615	0.0235	-0.0011

DRAINED REST PERIOD

A.G.L.129.40 R.G.L. 39.31

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	155.71		191.90	43.50	8.35	0.00	13.85	0.00	0.0036	0.0028	0.0224	0.0173
50	156.40		192.13	42.04	8.95	0.00	13.07	0.00	0.0131	-0.0010	0.0233	0.0126
100	153.73		191.24	41.90	8.52	0.00	16.65	0.00	0.0130	0.0015	0.0254	0.0052
300	151.55		190.52	40.87	8.38	0.00	12.58	0.00	0.0192	-0.0003	0.0220	0.0124
500	153.67		191.22	41.23	9.39	0.00	12.63	0.00	0.0206	-0.0047	0.0231	0.0095
700	151.26		190.42	40.44	9.65	0.00	12.40	0.00	0.0359	0.0054	0.0204	0.0073
1000	149.92		189.97	40.30	9.04	0.00	12.89	0.00	0.0323	-0.0039	0.0242	0.0132
1200	150.87		190.26	39.95	9.29	0.00	12.90	0.00	0.0595	-0.0012	0.0232	0.0126
1500	154.88		191.63	40.53	12.15	0.00	13.05	0.00	0.0724	0.0020	0.0238	0.0116
1700	156.44		192.15	39.46	13.10	0.00	12.53	0.00	0.0845	0.0066	0.0249	0.0131
2000	154.93		191.64	37.75	13.61	0.00	12.28	0.00	0.1050	-0.0014	0.0229	0.0117
2160	157.40		192.47	39.35	14.31	0.00	12.26	0.00	0.1091	-0.0030	0.0229	0.0098

DRAINED REST PERIOD

A.G.L.129.25 R.G.L. 39.30

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	158.28		192.76	38.14	8.07	0.00	13.27	0.00	0.0135	0.0003	0.0222	0.0108
100	156.26		192.09	35.42	8.15	0.00	12.48	0.00	0.0175	-0.0034	0.0215	0.0155
300	154.97		191.66	41.41	8.27	0.00	11.17	0.00	0.0214	0.0075	0.0178	0.0069
500	155.35		191.78	39.91	9.73	0.00	13.11	0.00	0.0241	0.0103	0.0234	0.0096
700	156.82		192.27	36.86	12.19	0.00	12.82	0.00	0.0283	0.0011	0.0235	0.0155
1000	155.80		191.93	35.34	12.84	0.00	13.14	0.00	0.0420	0.0075	0.0243	0.0120
1500	156.15		192.05	35.23	15.60	0.00	12.21	0.00	0.0641	-0.0091	0.0239	0.0093
1700	157.20		192.40	38.54	17.23	0.00	12.13	0.00	0.0752	-0.0081	0.0226	0.0143
2160	157.92		192.64	39.46	19.73	0.00	12.84	0.00	0.0894	0.0088	0.0267	0.0202

STRAIN CONTROL FAILURE TEST

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
0	171.58		197.19	0.00	18.01	0.00	0.00	0.00	0.1011	-0.0176	0.0000	0.0000
0	176.28		196.76	0.00	19.68	0.00	0.00	0.00	0.1137	0.0013	0.0000	0.0000
0	181.72		200.57	0.00	22.57	0.00	0.00	0.00	0.1173	0.0105	0.0000	0.0000
0	188.02		202.67	0.00	24.52	0.00	0.00	0.00	0.1291	0.0153	0.0000	0.0000
0	190.48		205.49	0.00	27.04	0.00	0.00	0.00	0.2024	0.0736	0.0000	0.0000
0	185.74		201.91	0.00	30.12	0.00	0.00	0.00	0.5567	0.3796	0.0000	0.0000

TEST NO 3.2 O.C.R. 1

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A.G.L.128.01 R.G.L. 38.96

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
0	183.16	0.00	129.48	0.00	-0.52	0.03	-0.01	-0.00	0.0008	-0.0001	-0.0000	0.0001
2	183.53	11.00	145.60	32.99	4.57	7.34	11.97	2.65	0.0152	0.0019	0.0285	0.0050
50	183.52	10.57	145.55	31.72	8.04	9.99	9.25	2.18	0.0398	0.0057	0.0254	-0.0024
100	183.63	10.71	145.88	32.12	9.48	10.83	11.16	2.22	0.0485	-0.0009	0.0258	0.0057
200	183.48	10.85	145.43	32.56	11.64	12.60	9.79	2.08	0.0761	-0.0006	0.0249	0.0046
300	183.65	10.62	145.96	31.85	15.32	14.74	9.97	2.04	0.0881	-0.0022	0.0248	0.0045
400	183.59	10.44	145.78	31.32	16.49	15.52	10.56	1.91	0.0994	-0.0048	0.0231	0.0033
600	183.66	10.21	145.98	30.63	17.58	16.35	10.00	2.06	0.1123	0.0016	0.0222	0.0075
800	183.71	10.84	146.14	32.53	20.66	17.64	11.65	1.85	0.1633	0.0247	0.0228	0.0100
1000	183.61	10.36	145.83	31.07	22.48	19.42	10.32	1.81	0.1878	0.0392	0.0254	0.0006
1200	183.83	10.09	146.49	30.28	24.66	20.66	10.18	2.03	0.2106	0.0421	0.0245	0.0017
1400	183.50	10.30	145.50	30.90	26.61	21.80	9.98	1.72	0.2345	0.0650	0.0242	0.0057
1600	183.59	10.82	145.78	32.47	28.01	22.66	10.64	1.76	0.2596	0.0844	0.0256	0.0039
1800	182.49	11.00	145.46	33.01	31.50	23.95	10.92	1.40	0.2910	0.1263	0.0226	-0.0017
2000	180.19	10.60	147.56	31.79	32.95	24.80	10.43	1.31	0.3387	0.1431	0.0226	0.0015
2160	183.43	10.66	145.29	31.99	34.57	25.51	11.21	1.39	0.3668	0.1787	0.0239	0.0022
0	183.34	-0.01	130.01	-0.03	29.63	23.23	0.00	-0.01	0.3750	0.1864	0.0000	0.0001

N	p_m	p_r	q_m	q_r	u_B^p	u_C^p	u_B^r	u_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
DRAINED REST PERIOD A.G.L.127.44 R.G.L. 38.98												
0	183.33	-0.00	129.99	-0.01	4.21	6.64	-0.01	-0.01	0.0000	0.0000	-0.0000	0.0001
1	183.24	10.63	144.73	31.90	9.86	10.52	10.85	2.31	0.0153	-0.0050	0.0251	0.0068
50	183.52	11.02	145.57	33.06	13.01	12.16	10.84	2.07	0.0225	0.0012	0.0238	0.0079
100	183.59	10.70	145.76	32.11	13.45	12.43	9.42	1.67	0.0259	-0.0002	0.0217	0.0029
300	183.32	10.42	144.96	31.26	17.21	13.88	10.49	1.92	0.0332	-0.0023	0.0239	0.0032
600	183.46	10.73	145.37	32.19	17.77	15.05	10.43	1.93	0.0405	0.0047	0.0228	0.0034
1000	183.42	10.62	145.26	31.85	20.07	16.70	9.65	1.98	0.0573	0.0045	0.0225	0.0013
1400	183.62	10.87	145.87	32.62	21.44	17.86	9.98	1.84	0.0700	-0.0025	0.0229	-0.0001
1800	183.36	10.77	145.08	32.32	22.34	18.86	9.28	1.85	0.0724	0.0005	0.0241	0.0034
2160	183.53	10.61	145.60	31.83	23.15	19.07	9.11	2.00	0.0798	0.0109	0.0221	-0.0012
0	183.34	-0.01	130.01	-0.04	18.63	16.39	0.01	0.00	0.0788	0.0088	0.0000	0.0001
DRAINED REST PERIOD A.G.L.127.34 R.G.L. 38.98												
0	183.34	-0.00	130.01	-0.01	1.41	2.55	-0.01	0.00	0.0000	0.0000	0.0000	0.0001
1	183.40	10.72	145.21	32.15	6.85	7.35	9.72	2.34	0.0130	-0.0000	0.0212	0.0021
50	183.70	10.72	146.09	32.17	10.33	9.27	10.33	2.18	0.0265	-0.0013	0.0243	0.0014
100	183.46	10.61	145.37	31.84	10.70	9.52	10.54	2.16	0.0286	-0.0027	0.0230	0.0014
200	183.78	10.51	146.35	31.52	11.53	9.87	9.65	2.15	0.0304	-0.0000	0.0237	0.0022
640	183.45	10.40	145.34	31.20	12.47	11.05	10.12	1.85	0.0285	-0.0015	0.0215	0.0028
1080	183.40	10.84	145.10	32.52	13.38	11.75	10.05	1.86	0.0359	0.0095	0.0233	0.0007
1520	183.36	10.53	145.08	31.59	14.78	12.50	9.04	1.80	0.0368	0.0096	0.0230	0.0045
1740	183.71	10.73	146.12	32.19	14.62	12.82	11.27	1.71	0.0386	0.0071	0.0217	0.0027
2160	183.38	10.25	145.15	30.74	15.06	13.28	11.84	1.76	0.0436	0.0067	0.0212	-0.0012
0	183.33	0.00	129.99	0.01	10.80	10.76	0.01	-0.00	0.0434	0.0065	-0.0000	0.0001
DRAINED REST PERIOD A.G.L.127.28 R.G.L. 38.98												
0	183.34	-0.00	130.01	-0.01	0.17	0.89	0.00	0.00	0.0000	0.0000	0.0000	0.0001
3	183.51	10.76	145.54	32.29	6.21	6.79	10.43	2.37	0.0083	0.0007	0.0230	0.0016
50	183.58	10.92	145.75	32.75	7.06	7.23	9.98	2.19	0.0112	0.0005	0.0188	-0.0009
100	183.41	10.64	145.24	31.93	7.49	7.01	10.47	2.36	0.0124	0.0024	0.0224	0.0038
200	183.59	10.78	145.78	32.33	7.37	7.10	9.73	2.61	0.0144	-0.0032	0.0181	0.0012
600	183.52	10.78	145.55	32.34	9.81	9.01	11.76	2.34	0.0182	0.0013	0.0208	-0.0017
1000	183.41	10.75	145.23	32.24	11.80	9.89	8.83	1.70	0.0180	-0.0016	0.0214	-0.0007
1400	183.49	10.71	145.48	32.14	12.61	8.58	10.65	2.58	0.0193	-0.0024	0.0175	0.0026
1800	183.50	10.83	145.50	32.50	12.44	10.62	8.92	1.83	0.0202	-0.0022	0.0202	0.0024
2160	183.54	10.51	145.62	31.53	13.78	10.96	10.56	1.86	0.0199	-0.0001	0.0230	0.0027
0	183.33	0.00	130.00	0.00	9.52	8.43	0.00	-0.00	0.0195	-0.0007	0.0000	0.0001
DRAINED REST PERIOD A.G.L.127.26 R.G.L. 38.98												
0	183.33	0.00	130.00	0.00	0.07	0.00	0.00	0.00	0.0000	0.0000	-0.0000	0.0001
1	183.65	10.39	145.95	31.18	7.37	5.89	11.49	2.49	0.0011	-0.0010	0.0182	0.0010
50	183.53	10.66	145.58	31.97	9.35	7.26	11.47	2.63	0.0050	-0.0016	0.0265	0.0055
100	183.49	10.94	145.48	32.83	9.02	7.46	10.22	2.44	0.0062	-0.0038	0.0264	-0.0010
200	183.72	11.26	146.15	33.77	9.82	8.14	11.58	2.25	0.0095	-0.0021	0.0263	-0.0006
600	183.55	10.62	145.64	31.86	10.70	8.86	10.29	2.15	0.0119	-0.0017	0.0212	-0.0010
1000	183.36	10.89	145.07	32.66	11.80	9.29	11.63	2.45	0.0139	-0.0014	0.0227	0.0057
1400	183.62	10.96	145.86	32.88	12.07	9.75	11.93	2.44	0.0183	0.0001	0.0279	-0.0033
1800	183.70	10.81	146.09	32.42	12.47	10.11	11.52	2.54	0.0198	0.0010	0.0269	0.0043
2160	180.00	11.44	147.01	34.31	11.59	10.36	13.03	2.36	0.0203	-0.0009	0.0272	-0.0083
0	183.33	0.00	130.00	0.00	7.42	5.42	0.00	0.00	0.0206	-0.0004	-0.0000	0.0001
STRAIN CONTROL FAILURE TEST												
1	183.78	0.00	131.35	0.00	8.71	6.81	0.00	0.00	0.0004	0.0000	0.0000	0.0000
1	191.45	-0.00	154.36	0.00	13.36	8.38	0.00	0.00	0.0043	0.0000	0.0000	0.0000
1	198.77	0.01	176.31	0.00	19.26	11.68	0.00	0.00	0.0122	0.0000	0.0000	0.0000

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	204.48	0.02	193.45	0.00	20.53	8.50	0.00	0.00	0.1025	0.0000	0.0000	0.0000
1	206.60	-0.04	199.81	0.00	23.02	7.94	0.00	0.00	0.1594	0.0000	0.0000	0.0000
1	204.97	0.00	194.92	0.00	21.50	8.20	0.00	0.00	0.3466	0.0000	0.0000	0.0000
1	203.41	-0.02	190.24	0.00	19.35	12.37	0.00	0.00	0.6875	0.0000	0.0000	0.0000
1	202.01	-0.07	186.04	0.00	18.20	16.88	0.00	0.00	1.1518	0.0000	0.0000	0.0000
1	200.20	0.00	180.61	0.00	17.53	20.62	0.00	0.00	1.6860	0.0000	0.0000	0.0000
1	198.58	0.01	175.73	0.00	19.64	25.61	0.00	0.00	2.6654	0.0000	0.0000	0.0000
1	194.47	0.02	163.41	0.00	20.41	29.79	0.00	0.00	3.7516	0.0000	0.0000	0.0000
1	194.15	0.00	162.46	0.00	21.38	29.77	0.00	0.00	3.8510	0.0000	0.0000	0.0000
					TEST NO		3.3	O.C.R.	1			
					*********************************							
					A.G.L. 43.62		R.G.L. 39.04					
0	133.33		130.00	0.00	0.00	0.00	-0.01	0.00	0.0022	-0.0007	0.0001	-0.0000
0	137.38		142.15	0.00	7.37	0.00	0.08	0.00	0.0075	-0.0005	-0.0000	-0.0002
1	136.33		144.98	27.44	7.30	0.00	11.96	0.00	0.0503	0.0033	0.0147	-0.0105
50	137.25		141.75	29.42	8.43	0.00	12.45	0.00	0.0951	0.0008	0.0176	-0.0092
100	137.62		142.86	30.14	14.06	0.00	11.49	0.00	0.1896	0.0061	0.0196	-0.0000
150	137.19		141.58	29.30	23.96	0.00	10.65	0.00	0.3836	0.0005	0.0195	0.0033
170	137.32		141.95	28.32	28.18	0.00	10.70	0.00	0.5347	-0.0013	0.0278	0.0055
0	132.85		128.55	0.01	24.33	0.00	0.02	0.00	0.5920	0.0073	0.0000	0.0002
						DRAINED REST PERIOD						
					A.G.L. 43.20		R.G.L. 39.13					
0	133.33		130.00	0.00	7.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0002
0	137.07		141.20	0.05	13.09	0.00	0.00	0.00	0.0069	0.0078	-0.0000	-0.0002
1	137.49		142.46	28.76	14.57	0.00	11.17	0.00	0.0405	-0.0063	0.0132	0.0001
50	136.86		140.57	33.21	14.79	0.00	14.12	0.00	0.0845	-0.0030	0.0181	-0.0061
100	137.51		142.52	30.91	21.29	0.00	12.62	0.00	0.1964	-0.0285	0.0211	-0.0046
150	137.49		142.46	30.39	25.57	0.00	11.73	0.00	0.3726	-0.0292	0.0220	-0.0032
185	137.74		143.22	30.19	28.96	0.00	12.66	0.00	0.6117	-0.0507	0.0268	-0.0034
0	132.41		127.22	0.00	20.99	0.00	0.36	0.00	0.6341	-0.0912	0.0045	0.0005
						DRAINED REST PERIOD						
					A.G.L. 42.90		R.G.L. 39.24					
0	133.33		130.00	0.00	2.80	0.00	-0.01	0.00	0.0000	0.0000	-0.0000	-0.0002
0	136.92		140.77	0.01	10.92	0.00	0.50	0.00	0.0182	0.0046	-0.0003	-0.0010
1	137.51		142.53	30.97	14.83	0.00	12.04	0.00	0.0430	0.0191	0.0139	-0.0095
50	137.95		143.84	29.51	17.71	0.00	10.51	0.00	0.1009	-0.0266	0.0207	0.0009
100	137.78		143.33	29.37	19.61	0.00	10.71	0.00	0.1504	-0.0152	0.0210	-0.0065
200	138.17		144.52	30.20	23.15	0.00	11.07	0.00	0.2144	-0.0111	0.0237	-0.0026
300	137.94		143.81	29.66	26.17	0.00	12.22	0.00	0.3274	-0.0239	0.0230	-0.0008
400	137.41		142.22	30.43	29.18	0.00	12.67	0.00	0.5079	-0.0296	0.0258	-0.0009
500	138.14		144.42	29.87	32.47	0.00	12.89	0.00	0.8462	-0.1156	0.0189	0.0007
0	132.27		126.82	0.01	24.68	0.00	-0.10	0.00	0.8721	-0.1169	-0.0009	-0.0031
						DRAINED REST PERIOD						
					A.G.L. 42.51		R.G.L. 39.40					
0	133.33		130.00	0.00	3.16	0.00	-0.02	0.00	0.0000	0.0000	0.0000	-0.0004
0	137.00		141.01	-0.07	10.93	0.00	-0.06	0.00	0.0074	-0.0082	-0.0008	-0.0034
1	138.04		144.12	32.76	15.69	0.00	13.72	0.00	0.0389	-0.0048	0.0143	-0.0035
50	138.22		144.65	32.27	16.77	0.00	13.83	0.00	0.0596	0.0133	0.0181	0.0006
100	138.06		144.19	29.18	18.29	0.00	10.28	0.00	0.0768	-0.0027	0.0162	-0.0044
200	138.01		144.04	29.73	20.54	0.00	11.63	0.00	0.1015	0.0105	0.0160	-0.0037
400	138.05		144.14	29.57	24.34	0.00	10.22	0.00	0.1346	-0.0005	0.0160	-0.0042
600	138.14		144.41	29.67	26.42	0.00	11.37	0.00	0.2043	0.0093	0.0224	0.0036
300	137.91		143.72	29.33	32.59	0.00	13.17	0.00	0.3553	-0.0419	0.0181	-0.0065
1000	137.90		143.71	31.63	37.30	0.00	10.18	0.00	0.5583	-0.0783	0.0212	-0.0059
0	133.33		130.00	0.00	32.90	0.00	0.01	0.00	0.5579	-0.0770	-0.0001	0.0000

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
						DRAINED REST PERIOD						
					A.G.L. 42.25		R.G.L. 39.53					
0	133.33		130.00	0.00	3.05	0.00	-0.04	0.00	0.0000	0.0000	-0.0000	-0.0002
0	135.27		135.80	0.01	9.86	0.00	-0.97	0.00	0.0044	0.0047	-0.0006	0.0008
3	135.90		137.69	31.43	13.97	0.00	13.44	0.00	0.0163	0.0000	0.0196	-0.0008
50	137.20		141.84	32.84	15.11	0.00	14.38	0.00	0.0192	-0.0027	0.0159	-0.0020
100	137.02		141.25	31.19	16.15	0.00	13.94	0.00	0.0288	0.0021	0.0161	-0.0016
200	137.21		141.63	33.29	17.08	0.00	13.02	0.00	0.0269	-0.0085	0.0156	-0.0034
400	137.75		143.26	29.79	19.68	0.00	12.36	0.00	0.0338	0.0007	0.0133	0.0006
600	138.04		144.13	30.17	20.95	0.00	11.13	0.00	0.0544	0.0103	0.0160	0.0013
1000	137.77		143.31	31.75	23.46	0.00	10.43	0.00	0.0434	0.0014	0.0159	-0.0007
1400	138.04		144.13	30.81	24.69	0.00	11.07	0.00	0.0592	0.0072	0.0153	-0.0023
1800	138.00		144.01	30.26	25.18	0.00	11.59	0.00	0.0678	0.0047	0.0173	-0.0014
2160	138.05		144.15	30.31	25.97	0.00	12.93	0.00	0.0647	-0.0039	0.0188	-0.0033
0	132.53		127.58	0.10	17.34	0.00	-0.01	0.00	0.0655	-0.0071	0.0075	0.0076
					STRAIN CONTROL FAILURE TEST							
1	133.34		130.03	0.00	15.90	0.00	0.00	0.00	0.0594	0.0000	0.0000	0.0000
1	136.56		139.67	0.00	20.66	0.00	0.00	0.00	0.0686	0.0000	0.0000	0.0000
1	193.84		161.53	0.00	29.65	0.00	0.00	0.00	0.0754	0.0000	0.0000	0.0000
1	198.92		176.76	0.00	34.50	0.00	0.00	0.00	0.0749	0.0000	0.0000	0.0000
1	203.13		189.39	0.00	38.61	0.00	0.00	0.00	0.1288	0.0000	0.0000	0.0000
1	204.31		192.93	0.00	37.74	0.00	0.00	0.00	0.2127	0.0000	0.0000	0.0000
1	202.86		188.58	0.00	32.45	0.00	0.00	0.00	0.4774	0.0000	0.0000	0.0000
1	200.51		181.53	0.00	30.05	0.00	0.00	0.00	0.7996	0.0000	0.0000	0.0000
1	198.34		175.02	0.00	30.91	0.00	0.00	0.00	1.1475	0.0000	0.0000	0.0000
1	196.78		170.34	0.00	33.21	0.00	0.00	0.00	1.6315	0.0000	0.0000	0.0000
					TEST NO	3.4		O.C.R.	1			
					************************************							
					A.G.L.132.02		R.G.L. 39.19					
0	173.79	0.00	116.37	0.00	-4.23	0.00	0.00	0.00	0.0049	-0.0017	-0.0052	-0.0079
4	170.02	9.30	117.07	27.89	-4.59	0.00	15.51	0.00	0.0002	-0.0022	0.0223	0.0012
50	173.03	10.27	114.10	30.80	0.15	0.00	14.73	0.00	0.0009	-0.0019	0.0207	-0.0020
100	177.70	10.14	113.11	30.41	0.74	0.00	14.63	0.00	0.0026	-0.0052	0.0210	-0.0039
200	172.29	9.66	114.87	28.98	1.88	0.00	14.08	0.00	0.0013	-0.0032	0.0229	-0.0127
600	176.96	9.33	110.89	27.99	2.39	0.00	12.00	0.00	0.0036	-0.0011	0.0190	-0.0054
1000	176.16	9.62	108.43	28.86	3.32	0.00	11.51	0.00	0.0009	-0.0051	0.0188	-0.0066
1400	175.58	10.42	106.75	31.27	4.21	0.00	13.45	0.00	0.0005	-0.0032	0.0191	-0.0008
1800	176.29	5.03	108.87	27.09	4.59	0.00	12.15	0.00	-0.0006	-0.0041	0.0136	-0.0021
2160	177.46	8.56	112.39	25.67	5.75	0.00	10.73	0.00	-0.0031	0.0045	0.0150	-0.0021
0	182.95	-0.00	128.86	-0.01	12.54	0.00	0.00	0.00	-0.0035	0.0149	-0.0049	-0.0075
						DRAINED REST PERIOD						
					A.G.L.132.01		R.G.L. 39.17					
0	173.77	0.00	116.32	0.01	-5.77	0.00	-0.17	0.00	0.0019	-0.0010	-0.0042	-0.0106
2	173.65	8.54	115.95	25.63	-4.51	0.00	14.91	0.00	-0.0003	0.0009	0.0172	0.0033
50	173.37	9.60	115.10	28.80	-1.54	0.00	14.55	0.00	-0.0015	-0.0016	0.0169	0.0029
100	173.05	10.41	114.14	31.23	-1.67	0.00	15.03	0.00	-0.0019	-0.0009	0.0183	0.0024
200	177.71	10.45	113.13	31.36	-1.10	0.00	14.05	0.00	-0.0005	0.0011	0.0173	0.0050
600	177.53	9.74	112.58	29.22	-0.49	0.00	13.29	0.00	-0.0011	-0.0043	0.0171	0.0016
1000	177.94	9.14	113.81	27.41	0.74	0.00	11.77	0.00	-0.0021	-0.0018	0.0154	0.0034
1000	173.51	9.93	115.52	29.79	0.74	0.00	11.78	0.00	-0.0021	0.0008	0.0152	0.0057
1800	177.84	9.38	113.53	28.13	1.01	0.00	12.18	0.00	0.0002	0.0016	0.0156	0.0010
2160	177.65	9.93	112.94	29.95	0.37	0.00	13.02	0.00	-0.0011	0.0004	0.0164	0.0014
0	183.33	0.00	130.00	0.00	5.60	0.00	0.01	0.00	-0.0012	0.0041	-0.0050	-0.0077
						DRAINED REST PERIOD						
					A.G.L.132.01		R.G.L. 39.15					
0	173.87	0.00	116.62	0.01	-5.25	0.00	-0.34	0.00	0.0061	-0.0051	-0.0039	-0.0125

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	173.63	11.97	119.05	35.90	-3.09	0.00	16.95	0.00	0.0053	-0.0056	0.0138	0.0065
100	173.01	9.04	114.04	27.13	-1.73	0.00	12.57	0.00	0.0091	-0.0110	0.0158	0.0003
200	173.81	9.51	113.42	28.52	-1.07	0.00	12.15	0.00	0.0071	-0.0010	0.0168	0.0015
600	173.63	9.45	112.90	28.34	-1.31	0.00	12.87	0.00	0.0036	0.0002	0.0171	0.0003
1000	173.69	9.01	116.06	27.02	0.76	0.00	14.90	0.00	0.0053	0.0015	0.0185	0.0018
1400	173.29	9.45	114.83	28.36	0.99	0.00	14.16	0.00	0.0059	-0.0041	0.0166	0.0021
1800	173.84	9.56	116.51	28.67	1.94	0.00	14.90	0.00	0.0043	0.0052	0.0133	0.0014
2160	173.64	9.38	115.92	28.14	1.31	0.00	14.72	0.00	0.0030	0.0032	0.0161	0.0034
0	183.33	0.00	130.00	0.00	7.00	0.00	0.01	0.00	0.0033	0.0023	-0.0059	-0.0078
DRAINED REST PERIOD												
A.G.L.132.01 R.G.L. 39.15												
0	183.33	0.00	130.00	0.00	-4.20	0.00	-0.01	0.00	0.0000	0.0000	-0.0050	-0.0077
2	173.95	9.88	116.84	29.65	-1.32	0.00	16.18	0.00	0.0017	0.0038	0.0165	0.0016
100	173.60	10.12	112.79	30.36	-1.62	0.00	16.13	0.00	0.0027	0.0066	0.0177	0.0013
200	173.23	9.36	117.68	28.07	0.32	0.00	15.04	0.00	0.0022	0.0045	0.0177	0.0013
600	173.97	9.16	116.90	27.49	1.32	0.00	13.92	0.00	0.0003	0.0070	0.0170	0.0002
1000	173.99	9.67	116.97	29.02	1.10	0.00	13.94	0.00	0.0040	0.0034	0.0189	0.0016
1400	173.74	10.08	116.23	30.24	1.79	0.00	13.38	0.00	0.0040	0.0111	0.0139	0.0015
1800	173.84	9.57	117.12	28.70	1.94	0.00	13.28	0.00	0.0014	0.0040	0.0175	0.0002
2160	173.37	9.87	115.10	29.62	1.22	0.00	14.48	0.00	0.0007	0.0082	0.0138	0.0008
0	183.33	0.00	130.00	0.00	2.80	0.00	-0.01	0.00	-0.0000	0.0104	-0.0051	-0.0075
STRAIN CONTROL FAILURE TEST												
0	183.57	0.00	130.70	0.00	3.53	0.00	0.00	0.00	0.0026	0.0000	0.0000	0.0000
0	186.95	0.00	140.84	0.00	7.03	0.00	0.00	0.00	0.0065	0.0000	0.0000	0.0000
0	191.87	0.00	155.62	0.00	12.89	0.00	0.00	0.00	0.0095	0.0000	0.0000	0.0000
0	197.25	-0.00	171.76	0.00	18.62	0.00	0.00	0.00	0.0510	0.0000	0.0000	0.0000
0	199.45	-0.04	178.36	0.00	21.31	0.00	0.00	0.00	0.1955	0.0000	0.0000	0.0000
0	193.19	0.00	174.57	0.00	22.89	0.00	0.00	0.00	0.3191	0.0000	0.0000	0.0000
0	196.07	-0.04	168.20	0.00	28.24	0.00	0.00	0.00	0.6050	0.0000	0.0000	0.0000
0	189.86	-0.00	149.53	0.00	43.69	0.00	0.00	0.00	1.1754	0.0000	0.0000	0.0000
0	187.43	-0.02	142.29	0.00	57.78	0.00	0.00	0.00	1.7030	0.0000	0.0000	0.0000
TEST NO 3.5 O.C.R. 1												
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A.G.L. 44.29 R.G.L. 38.97												
1	184.17	8.46	132.51	25.39	1.67	1.86	11.69	4.85	0.0138	-0.0014	0.0195	0.0154
25	182.66	8.44	127.99	25.33	2.94	2.26	13.48	4.83	0.0180	-0.0003	0.0192	0.0106
50	182.30	7.39	126.91	22.16	6.90	4.13	11.74	4.45	0.0232	0.0028	0.0160	0.0063
100	183.72	7.10	131.17	21.29	8.49	8.12	10.99	4.00	0.0259	-0.0016	0.0139	0.0084
150	183.82	7.22	131.47	21.66	4.18	10.29	18.17	4.39	0.0303	-0.0054	0.0159	0.0048
175	184.41	9.52	133.23	28.56	14.49	13.27	11.01	4.20	0.0473	0.0044	0.0202	0.0067
200	183.97	9.04	131.92	27.13	16.62	15.66	10.44	4.12	0.0654	0.0003	0.0215	0.0058
DRAINED REST PERIOD												
A.G.L. 44.22 R.G.L. 38.96												
2	182.81	9.54	128.43	28.62	3.26	3.82	13.57	4.64	0.0075	-0.0089	0.0199	-0.0028
25	182.85	8.53	128.56	25.58	5.45	5.62	12.96	4.25	0.0190	-0.0060	0.0195	-0.0035
50	182.94	8.69	128.81	26.08	10.70	7.17	11.59	4.11	0.0192	-0.0044	0.0153	-0.0083
75	182.86	8.59	128.57	25.77	11.49	9.14	11.44	4.13	0.0239	0.0007	0.0218	-0.0003
100	183.25	8.32	129.76	24.97	12.75	10.16	12.53	4.18	0.0245	-0.0010	0.0173	-0.0012
150	182.94	8.71	128.83	26.13	13.90	11.49	11.52	4.16	0.0325	0.0056	0.0130	-0.0067
200	182.71	9.28	128.14	27.85	14.94	12.73	13.44	4.38	0.0425	0.0090	0.0175	-0.0020
216	182.36	8.69	127.09	26.06	15.04	12.86	13.43	3.99	0.0507	0.0037	0.0220	-0.0070
DRAINED REST PERIOD												
A.G.L. 44.20 R.G.L. 38.96												
1	184.17	7.87	132.52	23.60	4.05	2.65	12.06	4.64	0.0129	-0.0035	0.0147	-0.0027
25	183.01	8.83	129.03	26.64	4.92	2.93	11.73	4.60	0.0273	0.0044	0.0177	-0.0051

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
50	133.79	8.87	131.38	26.62	5.98	4.33	10.89	4.36	0.0325	-0.0054	0.0133	-0.0089
75	134.43	8.23	133.29	24.70	7.15	5.59	9.83	4.10	0.0463	-0.0095	0.0146	0.0015
100	134.14	7.77	132.41	23.30	8.20	6.20	9.10	4.09	0.0455	-0.0073	0.0145	-0.0018
125	132.80	8.25	128.68	24.75	8.33	6.71	10.02	3.88	0.0449	-0.0083	0.0168	-0.0081
150	133.54	6.75	130.62	20.24	8.31	7.23	11.14	4.07	0.0475	-0.0038	0.0147	-0.0014
175	134.46	7.84	133.39	23.52	9.55	7.19	11.24	4.01	0.0501	-0.0037	0.0170	-0.0076
200	134.15	7.70	132.45	23.11	11.77	8.93	11.93	3.86	0.0726	-0.0059	0.0130	-0.0103
216	133.99	7.87	131.98	23.61	11.75	10.13	10.72	3.89	0.0729	-0.0054	0.0121	-0.0034
DRAINED REST PERIOD												
A.G.L. 44.17 R.G.L. 38.97												
1	133.35	7.54	130.06	22.61	3.21	1.70	13.89	5.27	0.0028	-0.0011	0.0174	-0.0023
10	133.79	8.19	131.36	24.56	4.25	1.83	12.26	4.96	0.0143	0.0032	0.0150	-0.0063
25	133.93	8.43	131.93	25.29	4.85	2.28	13.71	5.17	0.0211	-0.0022	0.0191	0.0001
50	133.71	8.40	131.12	25.19	5.20	2.95	13.03	4.90	0.0186	0.0011	0.0145	-0.0099
75	133.94	8.86	131.83	26.57	6.13	3.63	12.29	5.06	0.0174	0.0026	0.0150	-0.0042
100	133.87	8.74	131.61	26.21	6.49	4.01	11.93	4.89	0.0177	0.0024	0.0155	-0.0013
125	134.41	9.69	133.22	29.06	6.95	4.86	10.37	4.62	0.0183	0.0033	0.0184	-0.0006
150	134.09	7.00	132.28	21.01	7.66	5.58	8.66	4.09	0.0176	0.0048	0.0172	-0.0045
175	134.66	8.09	133.98	24.27	8.08	6.10	9.58	4.19	0.0186	0.0031	0.0165	-0.0140
200	134.56	6.63	133.67	19.89	8.43	6.68	8.83	3.90	0.0182	0.0006	0.0123	0.0018
216	134.53	7.90	133.60	23.70	8.92	6.79	9.97	4.11	0.0180	0.0022	0.0151	-0.0043
FREQUENCY 0.1000 HZ												
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0	134.56	8.81	133.69	26.42	9.17	6.91	12.56	1.76	0.0088	-0.0063	0.0159	-0.0004
FREQUENCY 0.0010 HZ												
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0	134.69	10.56	134.08	31.68	8.97	6.65	12.59	7.83	-0.0042	0.0041	0.0270	-0.0083
DRAINED REST PERIOD												
A.G.L. 44.16 R.G.L. 38.96												
1	134.32	9.83	132.96	29.49	3.80	1.79	13.61	5.61	0.0065	-0.0000	0.0164	-0.0026
25	133.23	9.30	129.69	27.89	4.00	2.10	13.45	5.41	0.0061	-0.0019	0.0160	-0.0008
50	133.63	9.94	130.90	29.82	4.26	2.30	14.41	5.43	0.0115	-0.0043	0.0176	-0.0071
75	133.63	9.50	130.89	28.50	4.76	2.75	13.61	5.21	0.0117	-0.0072	0.0152	0.0029
100	134.12	8.76	132.37	26.27	4.72	2.26	11.63	5.13	0.0154	-0.0068	0.0160	-0.0018
125	133.99	7.83	131.98	23.50	5.32	2.67	10.74	4.71	0.0177	-0.0086	0.0137	0.0045
150	134.07	7.74	132.20	23.21	5.95	2.89	8.90	4.43	0.0208	-0.0041	0.0139	-0.0058
175	133.67	8.10	131.01	24.31	5.03	3.03	11.19	4.86	0.0294	0.0024	0.0128	-0.0010
200	133.31	7.38	129.93	22.14	5.02	3.00	11.46	4.99	0.0308	0.0018	0.0148	-0.0059
216	133.63	8.20	130.90	24.59	5.99	3.08	13.18	5.05	0.0340	0.0028	0.0155	-0.0000
STRAIN CONTROL FAILURE TEST												
0	133.17	0.00	129.51	0.00	3.50	-1.32	0.00	0.00	0.0123	0.0054	0.0000	0.0000
0	136.52	0.00	139.56	0.00	5.82	0.15	0.00	0.00	0.0193	-0.0264	0.0000	0.0000
0	195.62	0.00	166.85	0.00	12.89	2.84	0.00	0.00	0.0342	-0.0321	0.0000	0.0000
0	200.61	-0.04	181.83	0.00	14.46	6.18	0.00	0.00	0.0694	-0.0140	0.0000	0.0000
0	201.86	-0.01	185.57	0.00	15.95	7.92	0.00	0.00	0.2416	-0.0456	0.0000	0.0000
0	200.33	-0.03	181.00	0.00	13.43	14.09	0.00	0.00	0.4616	-0.0930	0.0000	0.0000
0	198.86	0.05	176.58	0.00	11.57	18.92	0.00	0.00	0.6328	-0.1407	0.0000	0.0000
0	194.05	-0.00	162.16	0.00	10.62	13.65	0.00	0.00	1.5605	-0.4810	0.0000	0.0000
0	191.17	-0.02	153.50	0.00	11.62	21.00	0.00	0.00	2.4758	-0.8725	0.0000	0.0000
0	188.81	0.02	146.44	0.00	13.90	29.95	0.00	0.00	3.6757	-1.2714	0.0000	0.0000

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ϵ_s^p	ϵ_v^p	ϵ_s^r	ϵ_v^r
					TEST NO		4.4	U.C.R.	1			
					A.G.L. 42.79		R.G.L. 39.73					
1	166.33	0.00	46.53	0.00	-10.75	-3.57	0.03	-0.00	-0.1510	0.0012	0.0006	-0.0020
1	187.55	47.11	46.14	0.05	9.98	14.25	34.58	47.12	-0.1824	0.0070	0.0029	-0.0007
1	209.81	43.62	50.41	0.02	66.44	41.73		44.20	-0.1809	0.0076	0.0036	0.0013
1	232.56	46.92	48.12	2.04	66.71	67.22		43.79	-0.1798	0.0046	0.0038	0.0020
1	255.84	46.06	46.27	0.11	82.00	84.88	40.31	42.72	-0.1825	0.0088	0.0033	0.0010
1	163.84	41.32	49.24	-0.02		0.20		45.83	-0.1812	0.0057	0.0027	0.0015
1	133.46	43.52	45.68	-2.20		-25.76		48.00	-0.1818	0.0082	0.0017	0.0023
1	110.13	43.70	49.63	-0.21	-42.95	-44.75		45.14	-0.1814	0.0032	0.0018	0.0026
1	140.83	39.67	47.19	0.27	-25.23	-23.29	75.45	87.81	-0.1811	0.0039	0.0018	0.0014
1	184.36	33.97	46.95	-0.16	13.99	20.34	81.51	73.80	-0.1813	0.0045	0.0009	0.0014
1	227.34	104.04	47.61	0.18	49.55	68.30	68.10	100.88	-0.1814	0.0091	0.0036	0.0032
1	183.69	1.51	46.83	47.90		10.36		-4.42	-0.2368	0.0374	0.0492	0.0036
1	204.69	-0.15	47.03	43.77		23.16		-6.11	-0.2362	0.0444	0.0505	0.0053
1	231.50	1.29	46.04	48.89		32.69		-5.20	-0.2517	0.0362	0.0513	0.0043
1	253.54	-6.59	47.38	47.67		34.83		5.76	-0.2618	0.0145	0.0503	0.0053
1	160.86	1.66	46.86	48.52	131.68	9.11	7.02	- 2.70	-0.2451	0.0491	0.0507	0.0049
1	140.64	1.01	47.45	48.50	90.79	-9.23	- 1.84	- 1.57	-0.2440	0.0450	0.0507	0.0052
1	110.58	-0.08	47.17	46.62	53.14	-25.58		- 1.09	-0.2479	0.0507	0.0510	0.0068
1	135.30	-42.52	47.03	45.39	20.79	-10.74		-44.99	-0.2533	0.0572	0.0436	0.0027
1	187.72	-47.08	47.81	44.83	-14.73	36.25		-55.27	-0.2440	0.0879	0.0444	0.0024
1	231.70	-45.90	46.51	44.66	69.84	81.39	-38.65	-55.02	-0.2596	0.0412	0.0443	0.0041
1	220.51	45.77	47.26	44.24		79.46		32.90	-0.2587	0.0689	0.0448	-0.0012
1	187.11	46.87	47.37	42.16	28.10	39.05	52.44	37.31	-0.2536	0.0723	0.0440	0.0005
1	135.79	46.82	46.81	44.66	-22.43	-4.08	53.13	32.87	-0.2527	0.0776	0.0439	-0.0012
1	185.45	30.20	45.23	34.00	29.10	36.53	46.72	8.14	-0.2865	0.0842	0.1210	0.0085
1	176.75	32.23	46.50	84.44	22.08	39.63	44.48	8.93	-0.3154	0.0715	0.1264	-0.0062
1	184.95	7.44	45.83	54.16	33.85	48.72		- 1.69	-0.3364	0.0432	0.1511	0.0068
1	203.42	3.17	45.45	86.54	44.40	76.98		- 3.20	-0.3291	0.0043	0.1647	0.0070
1	229.06	-5.18	45.35	79.54	77.10	87.69	2.35	- 3.78	-0.3332	-0.0096	0.1605	-0.0019
1	256.93	-7.13	45.82	84.92	102.37	119.83	2.11	- 3.30	-0.3266	-0.0109	0.1591	0.0016
1	153.61	2.68	45.40	87.09	12.98	37.40		- 7.69	-0.3453	-0.0221	0.1734	0.0041
1	142.97	1.63	45.86	84.94	-6.31	15.66		- 5.26	-0.3473	-0.0192	0.1740	-0.0032
1	185.29	-92.92	46.07	86.98	38.63	60.21	78.44	-118.03	-0.3334	-0.0407	0.1661	-0.0078
1	225.65	-95.36	44.51	87.05	79.00	91.51	-75.50	-102.49	-0.3429	-0.0390	0.1665	-0.0170
1	230.94	91.08	44.45	89.31	86.36	97.19	91.18	45.91	-0.3401	-0.0421	0.1860	0.0026
1	184.64	90.75	46.28	85.24	39.35	67.09	93.90	70.33	-0.3367	-0.0525	0.1904	-0.0020
1	135.81	91.64	46.46	85.88	-7.86	14.74	104.76	66.68	-0.3383	-0.0521	0.1909	0.0047
1	159.09	0.19	46.63	-0.07	22.26	33.60	0.00	-0.18	-0.3519	-0.0485	-0.0009	-0.0065
1	167.13	0.00	70.02	0.00	28.34	45.43	0.00	0.00	-0.2864	-0.0542	0.0015	-0.0053
1	139.76	41.70	68.80	0.02		16.49		44.76	-0.2869	-0.0562	-0.0006	-0.0067
1	162.93	43.04	68.30	2.22	26.15	43.08	41.83	45.17	-0.2820	-0.0555	0.0014	-0.0067
1	187.26	43.23	67.42	1.97	50.82	68.92	41.75	42.64	-0.2889	-0.0460	0.0022	-0.0099
1	207.97	47.95	67.71	2.47	69.35	89.72	42.38	42.69	-0.2799	-0.0455	-0.0001	-0.0061
1	232.29	48.05	65.05	0.11	93.82	97.00	42.13	42.21	-0.2821	-0.0397	-0.0001	-0.0043
1	254.02	49.02	67.52	0.02	114.33	133.52	43.30	46.70	-0.2885	-0.0524	0.0002	-0.0085
1	163.60	-49.21	68.83	43.88	28.17	41.46	-47.80	-64.59	-0.2522	-0.0397	0.0668	0.0074
1	204.87	-48.68	68.26	42.28	68.22	74.45	-42.48	-49.23	-0.2507	-0.0189	0.0648	0.0103
1	248.16	-49.29	69.20	41.36	108.80	128.60	-46.58	-65.54	-0.2541	-0.0257	0.0689	0.0094
1	255.07	-2.31	69.22	46.21	117.62	118.20	-14.04	-11.46	-0.2269	0.0024	0.0633	0.0154
1	226.54	-3.58	67.77	44.91	38.97	89.87	-11.06	-13.45	-0.2503	-0.0347	0.0629	0.0117
1	206.64	-1.73	68.96	42.71	73.18	86.03	-12.33	-11.99	-0.2464	-0.0363	0.0639	0.0084
1	163.37	-4.25	69.20	42.87	49.16	63.47	-15.58	-19.60	-0.2438	-0.0410	0.0621	0.0122

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	160.06	-3.77	69.20	42.96	26.25	37.81	- 5.12	- 7.48	-0.2401	-0.0379	0.0636	0.0068
1	135.91	-3.33	69.01	43.49	4.85	11.08	- 3.29	- 5.41	-0.2525	-0.0363	0.0680	0.0087
1	116.60	44.17	68.89	42.30	-16.60	-6.12	43.97	24.50	-0.2468	-0.0237	0.0723	0.0174
1	160.89	42.24	68.05	42.00	28.27	40.45	46.27	33.07	-0.2542	-0.0438	0.0695	0.0097
1	205.66	49.82	63.57	51.75	72.90	87.76	46.37	31.08	-0.2462	-0.0374	0.0679	0.0076
1	249.41	45.03	68.94	42.66	110.37	109.57	47.57	28.61	-0.2417	-0.0355	0.0706	0.0203
1	174.81	0.14	71.51	0.05	42.36	46.22	0.06	0.46	-0.2387	-0.0480	-0.0049	-0.0197
1	186.35	-0.24	116.43	-0.62	0.90	0.01	0.06	0.03	-0.0594	0.1272	0.0004	-0.0121
1	159.95	0.52	46.05	-0.27	-30.02	-15.16	0.01	0.15	-0.2463	-0.0253	-0.0022	-0.0043
1	183.33	43.84	47.62	3.13	-2.19	5.96	42.94	39.63	-0.2561	-0.0145	-0.0009	-0.0050
1	183.02	100.70	47.35	5.81	5.89	15.20	95.77	99.96	-0.2445	-0.0093	-0.0002	-0.0043
1	187.05	-6.23	48.83	48.29	6.64	16.80	-19.10	-23.86	-0.2564	0.0048	0.0483	0.0167
1	137.03	16.36	49.15	48.52	7.35	18.96	23.52	4.39	-0.2581	0.0056	0.0523	0.0171
1	183.30	-15.21	48.97	47.79	8.07	20.26	-23.37	-33.48	-0.2876	0.0339	0.0463	0.0151
1	134.57	-54.06	48.58	47.56	4.81	16.31	-47.95	-66.40	-0.2791	0.0360	0.0412	0.0106
1	194.25	-22.42	47.16	45.91	21.98	28.94	-54.74	-42.67	-0.2939	-0.0145	0.0479	0.0175
1	204.53	30.19	69.29	3.34	33.97	39.47	46.80	52.60	-0.2811	-0.0204	-0.0009	-0.0040
1	207.11	-49.90	66.70	44.91	33.96	36.88	-46.54	-66.10	-0.2740	-0.0157	0.0353	-0.0051
1	201.69	0.62	66.72	45.50	31.21	34.63	-18.66	-16.28	-0.2686	-0.0051	0.0415	0.0114
1	207.32	51.21	66.34	44.29	33.71	37.68	52.96	41.78	-0.2690	-0.0038	0.0444	0.0090
1	179.80	0.26	22.97	-0.14	8.02	15.04	0.31	-0.03	-0.3314	-0.0134	0.0007	-0.0003
1	182.82	40.47	23.03	0.71	13.06	19.50	40.85	44.30	-0.3366	-0.0142	-0.0002	-0.0023
1	210.92	46.28	25.34	2.04	38.07	48.55	45.51	48.72	-0.3345	-0.0108	-0.0032	-0.0076
1	237.08	50.03	24.74	0.30	62.24	71.77	46.10	45.25	-0.3362	-0.0212	-0.0001	-0.0024
1	248.79	42.59	23.71	0.21	77.15	86.65	34.40	38.87	-0.3388	-0.0150	-0.0010	-0.0029
1	162.55	41.98	22.91	0.02	-6.68	-1.80	44.35	41.83	-0.3325	-0.0063	-0.0010	-0.0028
1	140.43	39.59	22.85	-0.27	-27.63	-21.07	40.75	35.40	-0.3311	-0.0032	-0.0013	-0.0038
1	114.80	46.18	23.63	-0.09	-52.50	-48.67	39.73	43.95	-0.3350	-0.0151	-0.0005	-0.0009
1	160.38	-36.02	24.48	41.82	-6.40	-0.24	-36.99	-51.73	-0.3590	-0.0063	0.0393	0.0050
1	204.37	-46.67	24.22	43.17	35.97	41.70	-42.34	-55.89	-0.3681	-0.0026	0.0383	0.0002
1	253.24	-51.52	24.06	45.46	81.34	87.01	-38.25	-53.21	-0.3712	-0.0053	0.0381	-0.0021
1	117.14	-47.75	23.75	43.60	-46.72	-40.02	-39.98	-56.96	-0.3759	-0.0031	0.0408	0.0041
1	117.86	-4.60	24.31	45.41	-48.89	-44.20	- 8.24	- 7.66	-0.3844	0.0001	0.0523	0.0146
1	141.25	-6.11	23.99	45.00	-26.38	-17.43	- 5.71	- 8.99	-0.3762	0.0097	0.0470	0.0112
1	159.65	-2.92	26.30	45.96	-5.99	0.46	- 3.92	- 6.03	-0.3797	-0.0035	0.0487	0.0085
1	185.99	-4.44	26.75	45.69	19.09	26.59	- 2.45	- 3.43	-0.3805	0.0041	0.0456	0.0065
1	205.48	-5.43	24.84	43.28	39.73	50.35	- 4.49	- 2.46	-0.3709	0.0065	0.0430	0.0083
1	231.42	-2.78	26.07	45.18	65.34	74.38	- 4.56	- 7.07	-0.3806	-0.0060	0.0445	0.0024
1	251.29	-1.17	25.50	46.37	81.19	94.93	- 2.17	- 6.49	-0.3793	-0.0098	0.0444	0.0057
1	251.15	46.50	24.57	44.15	84.32	96.10	45.25	29.99	-0.3939	-0.0166	0.0483	0.0114
1	207.58	47.85	26.62	44.91	45.20	55.23	51.11	34.55	-0.3923	-0.0110	0.0507	0.0142
1	160.74	40.86	27.13	46.17	-4.47	1.66	48.96	31.85	-0.3802	0.0075	0.0529	0.0162
1	115.71	45.29	25.45	44.27	-45.08	-44.21	45.67	35.91	-0.3927	-0.0045	0.0575	0.0192
1	165.94	-0.00	22.88	-0.09	3.49	9.17	0.00	0.03	-0.3956	-0.0094	-0.0024	-0.0065
1	180.83	0.34	89.15	0.00	18.55	15.47	-0.11	-0.10	-0.2829	-0.0090	-0.0003	-0.0024
1	181.85	38.23	88.46	0.05	17.97	17.75	36.39	38.10	-0.2723	-0.0001	-0.0014	-0.0034
1	205.38	41.72	88.60	-0.82	41.88	44.21	39.63	44.58	-0.2756	-0.0079	0.0006	-0.0021
1	231.31	51.85	89.08	1.01	65.33	71.53	43.89	47.42	-0.2746	-0.0086	0.0005	-0.0023
1	257.27	50.75	88.19	-0.55	85.80	91.76	41.40	43.51	-0.2778	-0.0124	-0.0009	-0.0046
1	161.34	43.67	83.29	0.53	-3.46	-2.67	45.70	49.13	-0.2798	-0.0071	-0.0007	-0.0031
1	133.67	42.10	88.98	0.57	-26.74	-26.09	42.25	43.72	-0.2736	-0.0043	-0.0013	-0.0046
1	182.35	90.36	87.82	0.05	16.52	20.11	88.90	93.40	-0.2817	-0.0133	-0.0001	-0.0036
1	229.10	90.49	87.83	0.53	61.02	67.28	81.49	89.09	-0.2706	-0.0023	-0.0008	-0.0034
1	184.16	-1.71	91.00	41.64		21.54	0.10		-0.2464	0.0085	0.0441	0.0115
1	204.04	-7.11	89.52	38.80		45.04	0.32		-0.2512	0.0080	0.0428	0.0131

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	229.59	-5.21	89.26	39.62		70.89	0.38		-0.2425	0.0166	0.0450	0.0086
1	253.14	-2.24	89.13	38.39		93.51	0.17		-0.2570	0.0039	0.0435	0.0123
1	163.54	0.09	89.74	39.09		-0.55	0.07		-0.2461	0.0141	0.0431	0.0168
1	137.82	-1.52	89.46	39.74		-28.54	0.21		-0.2541	0.0054	0.0458	0.0138
1	182.39	-42.78	89.04	37.29		21.08	0.18		-0.2490	0.0037	0.0400	0.0064
1	229.56	-49.05	89.53	39.32		68.89		-57.90	-0.2487	-0.0004	0.0391	0.0093
1	229.09	47.86	89.58	39.26		69.90		36.65	-0.2519	0.0026	0.0492	0.0175
1	185.53	45.71	90.06	38.39		23.22		38.28	-0.2408	0.0145	0.0516	0.0188
1	142.48	43.06	89.76	40.15		-24.23		34.32	-0.2473	0.0065	0.0505	0.0174
1	163.00	27.59	90.29	82.68		-27.11		30.65	-0.2381	-0.0047	0.1041	0.0175
1	158.71	-6.91	90.65	82.47		-3.79		- 7.49	-0.2060	0.0051	0.1031	0.0017
1	184.21	-4.33	90.34	82.81		24.14		- 3.89	-0.2087	-0.0083	0.1039	-0.0047
1	207.13	-6.75	90.23	82.42		49.62		- 5.24	-0.2020	-0.0085	0.0993	-0.0123
1	229.04	-9.63	88.79	79.08		73.19		- 2.97	-0.1954	0.0061	0.1161	-0.0645
1	231.92	-93.11	89.80	84.02		69.86		-117.06	-0.1910	0.0018	0.0866	-0.0323
1	239.09	93.44	88.87	83.86		73.55		67.12	-0.1843	-0.0042	0.1101	-0.0053
1	186.12	92.64	90.12	82.38		28.60		74.90	-0.1726	-0.0001	0.1137	0.0030
1	133.28	90.21	89.96	83.34	-21.20	-19.99	90.83	66.02	-0.1709	-0.0015	0.1144	0.0034
1	189.05	0.05	88.69	-0.05	20.30	23.86	-0.03	0.10	-0.1817	-0.0085	-0.0036	-0.0069
1	187.65	0.01	111.71	-0.07	27.72	26.20	-0.06	-0.03	-0.1445	-0.0086	-0.0009	-0.0061
1	181.26	40.61	107.93	-0.14	21.76	23.02	38.44	43.44	-0.1504	-0.0221	-0.0011	-0.0047
1	203.89	48.82	107.24	-1.05	44.21	48.30	47.40	53.97	-0.1440	-0.0093	0.0005	-0.0027
1	227.17	51.33	108.29	-0.92	65.13	70.98	43.78	45.55	-0.1498	-0.0129	-0.0096	-0.0036
1	253.62	50.36	107.60	-1.81	90.31	97.31	41.51	46.19	-0.1379	-0.0024	-0.0014	-0.0049
1	250.72	73.60	110.84	42.21	88.14	93.52	66.16	54.74	-0.1257	-0.0087	0.0382	0.0093
1	206.81	74.88	110.70	42.37	45.08	48.81	69.61	63.88	-0.1282	-0.0213	0.0390	0.0072
1	181.57	27.22	110.67	41.86	20.80	22.36	28.25	16.54	-0.1248	-0.0122	0.0336	0.0077
1	189.30	-2.71	111.12	43.30	19.75	21.11		- 9.34	-0.1205	-0.0059	0.0333	0.0085
1	207.72	-8.67	110.94	41.70	46.44	50.64		- 1.41	-0.1234	-0.0073	0.0358	0.0074
1	226.10	-2.69	110.00	42.98	64.80	70.54		- 5.31	-0.1273	-0.0115	0.0377	0.0083
1	249.57	-2.17	110.99	42.82	86.16	91.39		- 5.79	-0.1348	-0.0102	0.0357	0.0088
1	250.49	-41.52	111.05	43.44	87.21	92.18	-55.95	-50.99	-0.1195	0.0060	0.0362	0.0091
1	207.86	-43.96	110.87	42.07	47.16	49.53	-44.31	-60.58	-0.1191	0.0079	0.0346	0.0044
1	162.46	41.56	111.16	44.26	0.60	0.89	42.70	30.83	-0.1216	-0.0077	0.0359	0.0078
1	206.55	47.66	111.10	42.71	44.25	48.74	46.86	37.16	-0.1082	-0.0033	0.0350	0.0060
1	243.98	44.37	110.55	43.07	83.30	90.16	37.63	29.09	-0.1244	-0.0192	0.0349	0.0045
						DRAINED REST PERIOD						
					A.G.L. 42.82		R.G.L. 40.01					
1	206.00	49.97	108.85	0.11	17.91	17.44	43.86	48.41	0.0022	0.0017	0.0036	0.0034
1	205.93	-44.66	110.61	42.80	18.46	21.36	-45.60	-63.09	0.0058	-0.0010	0.0283	0.0086
1	206.28	-2.84	112.67	44.54	18.76	19.93	-14.31	-18.48	0.0098	0.0070	0.0329	0.0084
1	205.67	49.23	111.76	42.11		18.80		39.84	0.0062	0.0142	0.0351	0.0077
1	184.16	40.01	91.10	0.80		-0.51		45.12	-0.0156	-0.0030	0.0000	-0.0034
1	185.78	81.48	89.40	-2.42		1.01		86.33	-0.0298	-0.0040	0.0004	-0.0036
1	181.25	-0.07	88.13	42.34		-0.33		-16.00	-0.0304	-0.0088	0.0463	0.0154
1	182.34	-43.98	87.18	39.80		0.03		-58.75	-0.0349	-0.0118	0.0421	0.0122
1	181.78	45.09	88.48	39.21		-1.28		34.30	-0.0316	-0.0008	0.0486	0.0223
1	181.72	-5.38	88.42	82.79		0.13		-34.61	-0.0317	-0.0051	0.0990	0.0124
1	187.05	92.96	87.39	84.07	-1.12	5.84	102.34	68.85	-0.0463	0.0009	0.0989	0.0036
1	205.38	41.91	70.80	0.00	25.35	32.42	40.92	44.48	-0.0583	0.0154	-0.0010	-0.0056
1	205.08	-44.23	67.93	42.53		32.82		-60.38	-0.0670	0.0210	0.0401	0.0067
1	207.16	-0.25	63.23	42.89	27.09	33.87		- 6.64	-0.0664	0.0265	0.0497	0.0155
1	203.34	48.51	69.15	42.69	28.91	35.64	51.97	41.88	-0.0745	0.0137	0.0579	0.0264
1	194.24	67.25	45.39	0.00	11.62	16.12	45.00	58.93	-0.1234	0.0092	-0.0008	-0.0023
1	179.80	54.96	46.71	0.09	13.47	16.51	81.91	92.03	-0.1157	0.0092	-0.0000	-0.0056

N	P_m	P_r	q_m	q_r	u_B^p	u_C^p	u_B^r	u_C^r	ε_s^p	ε_v^p	ε_s^r	ε_v^r
1	136.27	-3.39	47.50	48.02	13.92	17.17	-9.87	-17.97	-0.1257	0.0184	0.0469	0.0126
1	184.51	-42.77	47.91	48.84	11.97	14.94	-36.26	-58.11	-0.1260	0.0274	0.0419	0.0119
1	184.53	37.99	48.34	44.79	13.75	16.21	41.29	26.74	-0.1379	0.0112	0.0522	0.0191
1	186.03	-5.50	45.73	86.98	12.52	22.75	-11.41	-6.42	-0.1744	0.0405	0.1219	0.0127
1	189.44	-75.64	46.12	87.30	13.66	24.77	-70.07	-75.58	-0.1937	0.0222	0.1261	0.0064
1	186.57	35.23	47.66	84.57	16.28	22.39	96.46	81.84	-0.1890	0.0369	0.1208	0.0024
1	205.36	-43.32	24.41	47.45	42.88	54.73	-41.30	-58.36	-0.2534	0.0307	0.0494	0.0063
1	204.41	1.27	24.25	48.09	43.02	55.74	-17.53	-13.02	-0.2471	0.0458	0.0546	0.0091
1	203.86	49.69	22.09	0.02	44.51	56.28	44.81	47.08	-0.2459	0.0459	-0.0013	-0.0049
1	205.51	51.75	25.24	49.67	37.66	58.34	37.04	37.36	-0.2510	0.0434	0.0595	0.0309
1	179.07	0.00	-0.34	0.00	1.01	17.14	-0.06	-0.08	-0.2553	0.1015	-0.0005	-0.0025
1	182.85	40.08	6.23	0.02	-2.47	18.59	54.56	45.55	-0.2690	0.1280	-0.0008	-0.0014
1	209.86	47.13	6.42	0.39	34.19	51.21	42.62	49.84	-0.2626	0.1303	-0.0016	-0.0072
1	231.22	52.47	6.69	0.57	54.01	70.63	50.79	49.02	-0.2709	0.1225	0.0002	-0.0020
1	257.96	51.90	6.51	0.16	76.20	92.93	45.16	45.96	-0.2599	0.1391	0.0002	-0.0040
1	166.35	43.02	5.33	-0.05	-8.42	2.73	44.03	49.20	-0.2667	0.1395	-0.0014	-0.0068
1	133.03	50.23	4.94	-3.11	-41.31	-28.54	68.05	56.73	-0.2808	0.1115	-0.0004	-0.0033
1	124.50	124.14	6.10	-0.07	-27.88	-24.33	82.25	99.04	-0.2699	0.1328	-0.0002	-0.0010
1	186.26	89.11	4.37	-0.23	13.24	24.49	86.35	92.51	-0.2659	0.1372	-0.0011	-0.0029
1	237.68	35.72	4.42	-3.89	55.65	69.61	84.06	88.32	-0.2762	0.1168	0.0003	-0.0025
1	235.00	15.79	36.32	47.56	27.24	73.85	29.54	6.12	-0.3871	0.1523	0.0532	-0.0045
1	184.03	-0.71	0.95	47.75	12.93	36.49	- 2.75	- 6.54	-0.4490	0.1474	0.0581	0.0058
1	185.73	-46.87	-0.01	48.16	16.78	40.67	-36.33	-64.44	-0.4754	0.1519	0.0581	0.0051
1	183.43	44.85	-0.07	46.17		40.08		39.07	-0.4934	0.1503	0.0634	0.0154
1	187.64	32.17	8.93	90.03		43.64		13.12	-0.5481	0.1778	0.1424	-0.0025
1	186.40	31.44	2.67	86.19		34.32		17.00	-0.6610	0.1348	0.1783	0.0240
1	189.51	43.34	0.79	88.67		74.43		23.61	-1.3755	0.1528	0.3253	-0.0074
1	192.92	17.89	21.12	48.65		84.37		5.05	-1.2100	0.1909	0.1369	0.0193
1	193.37	16.79	21.41	50.73		85.38		4.21	-1.1941	0.1735	0.1313	0.0180
1	210.09	16.02	50.17	42.76		87.07		5.41	-0.9168	0.1919	0.1228	0.0173
1	202.85	10.91	46.92	60.11		86.95		5.61	-0.8859	0.1950	0.1614	0.0218
					DRAINED REST PERIOD							
					A.G.L. 42.92		R.G.L. 40.21					
1	212.11	0.02	108.61	0.05	43.27	12.33	-0.07	0.87	0.0115	0.0055	-0.0016	-0.0058
1	206.58	54.52	108.38	0.05	32.34	0.38	50.20	57.27	0.0029	-0.0124	-0.0020	-0.0103
1	189.38	-36.13	111.88	43.97	19.35	-14.85	-45.82	-58.03	0.0061	0.0023	0.0234	0.0105
1	202.99	-3.74	111.22	41.13	30.37	-4.78	- 2.51	- 1.41	0.0112	-0.0098	0.0302	0.0130
1	205.68	47.72	110.60	46.53	31.74	-1.22	49.49	32.67	0.0455	0.0485	0.0337	0.0180
1	185.84	39.12	90.65	-0.41	10.43	-21.76	39.14	42.85	0.0353	0.0405	-0.0022	-0.0032
1	181.81	-5.10	88.58	38.32	10.22	-23.52	-18.56	-19.93	0.0275	0.0433	0.0385	0.0165
1	180.76	-47.29	88.25	39.85	8.95	-23.94	-49.45	-65.84	0.0283	0.0430	0.0313	0.0088
1	179.26	44.32	86.65	39.16	10.46	-21.73	49.29	34.53	0.0103	0.0312	0.0344	0.0149
1	183.77	-4.54	87.05	83.20	12.60	-15.27	-10.95	- 3.15	0.0007	0.0217	0.0922	0.0172
1	182.53	91.75	86.20	84.29	14.14	-8.64	99.71	72.55	0.0011	0.0145	0.0955	0.0268
1	208.61	37.56	68.05	-0.18	-27.99	16.22		40.04	-0.0231	0.0233	0.0008	-0.0018
1	205.31	-46.80	67.21	40.58	-28.73	16.08		-58.39	-0.0316	0.0010	0.0343	0.0048
1	205.76	-1.68	65.31	43.74	-28.56	13.87	0.31	- 6.21	-0.0284	0.0209	0.0360	0.0085
1	207.60	47.04	66.26	44.22	-29.49	3.36		63.77	-0.0369	0.0131	0.0376	0.0049
1	183.59	47.91	47.16	0.25	-27.75	-3.78		51.65	-0.0464	0.0194	0.0008	-0.0031
1	184.17	3.90	48.26	49.39	-28.64	-3.67	0.38	-14.04	-0.0455	0.0543	0.0423	0.0048
1	184.95	-44.06	47.26	45.61	-28.06	-0.74		-59.92	-0.0501	0.0838	0.0370	0.0087
1	184.22	53.11	47.27	49.43	-28.33	-0.55		44.33	-0.0537	0.0724	0.0417	0.0080
1	184.14	-6.00	46.38	85.85	-26.71	7.21	2.38	- 2.44	-0.0784	0.0636	0.1172	0.0189
1	187.61	-76.29	45.27	86.52	-28.02	10.99		-109.10	-0.0698	0.0874	0.1154	0.0182
1	186.51	34.92	47.36	85.21	32.49	-5.31	94.96	57.88	-0.0895	0.0622	0.0323	-0.0150

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ϵ_s^p	ϵ_v^p	ϵ_s^r	ϵ_v^r
1	207.90	45.33	26.62	-0.11	-27.91	37.55	0.01	47.03	-0.1301	0.0583	-0.0011	-0.0024
1	207.22	-49.44	25.71	48.59	-27.64	37.21	0.15	-66.05	-0.1306	0.0656	0.0493	0.0014
1	204.71	-1.05	24.27	47.08	56.35	37.32	-11.62	-18.96	-0.1323	0.0619	0.0503	0.0026
1	204.13	49.95	24.40	48.66	58.42	37.62	53.91	37.72	-0.1417	0.0672	0.0493	0.0123
1	252.24	44.84	2.65	0.00	107.34	80.87	37.11	38.59	-0.1773	0.0696	-0.0006	-0.0043
1	215.09	70.27	2.75	0.00	87.50	60.23	35.64	37.92	-0.1729	0.0801	-0.0013	-0.0037
1	220.43	50.68	3.35	0.43	69.47	50.34	59.36	48.62	-0.1658	0.0773	-0.0009	-0.0069
1	183.84	43.34	3.57	0.18	45.53	18.72	43.99	48.77	-0.1822	0.0770	0.0007	-0.0023
1	162.90	42.01	2.83	-0.14	19.33	-9.76	35.39	44.02	-0.1584	0.0964	0.0003	-0.0014
1	136.63	50.79	2.80	0.11	-8.04	-38.24	52.99	52.04	-0.1888	0.0731	0.0009	-0.0030
1	140.29	86.96	4.37	0.64	-3.34	-33.04	83.65	91.49	-0.1837	0.0815	-0.0015	-0.0017
1	187.37	87.43	2.20	0.05	41.81	13.68	81.24	90.09	-0.1827	0.0650	-0.0017	-0.0057
1	229.46	90.05	0.34	-0.41	85.79	59.84	81.62	86.72	-0.1754	0.0882	-0.0004	-0.0007
1	173.30	-2.87	-0.50	46.21	40.89	22.18	-8.79	- 3.78	-0.2787	0.0787	0.0487	0.0010
1	182.48	-34.77	0.59	49.32	42.39	20.80	-30.42	-55.58	-0.2852	0.0958	0.0490	0.0093
1	180.77	45.00	0.43	47.90	40.52	19.19	53.42	33.53	-0.3051	0.0818	0.0507	0.0088
1	224.42	51.36	0.65	46.10	82.24	65.05	55.08	34.04	-0.2800	0.1128	0.0533	0.0131
1	223.30	-41.56	1.59	46.73	85.03	66.06	-23.98	-46.57	-0.2964	0.1000	0.0516	0.0082
1	229.94	-0.47	0.41	45.34	87.06	67.79	-16.00	-10.49	-0.2920	0.1046	0.0533	0.0085
1	250.57	-2.06	0.31	45.05	105.41	87.67	-11.52	-12.68	-0.3028	0.0910	0.0524	0.0090
1	207.81	0.73	-0.51	46.10	68.31	49.28	17.43	-11.59	-0.2964	0.1052	0.0536	0.0075
1	157.11	2.75	0.48	45.21	17.84	-5.93	20.52	-9.98	-0.3049	0.0906	0.0544	0.0142
1	127.13	-17.67	-22.83	0.14	-5.60	-36.83	-10.44	-17.61	-0.3190	0.0790	0.0471	0.0057
1	103.87	-2.52	0.03	44.86	-31.84	-59.21	-16.70	- 7.61	-0.3165	0.0863	0.0556	0.0155
1	135.68	-42.21	-0.27	46.03	-5.98	-31.94	-31.53	-58.16	-0.3150	0.0809	0.0485	0.0104
1	186.61	34.32	0.55	93.16	18.94	23.76	56.04	14.65	-0.5168	-0.1456	0.1178	-0.0590

DRAINED REST PERIOD

A.G.L. 42.91 R.G.L. 40.11

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ϵ_s^p	ϵ_v^p	ϵ_s^r	ϵ_v^r
0	173.13	-0.00	102.39	0.09	16.51	-11.43	0.07	-0.66	0.0036	0.0039	-0.0017	-0.0054
0	147.80	-0.11	12.06	0.23	-18.17	-26.77	0.03	0.05	-0.1515	0.0112	-0.0005	-0.0007
0	182.52	47.99	1.78	0.59	22.95	13.09	39.98	52.06	-0.1772	0.0196	-0.0010	-0.0040
0	187.64	-2.04	2.93	45.66	23.77	14.15	9.83	-18.76	-0.2365	0.0406	0.0512	0.0139
0	184.55	-48.50	2.73	45.13	23.01	12.15	-38.99	-66.40	-0.2486	0.0348	0.0491	-0.0027
0	187.10	52.68	4.11	44.86	22.59	11.39	57.16	39.02	-0.2678	0.0147	0.0518	0.0106
0	182.90	28.35	3.00	87.80	32.01	23.63	55.62	13.27	-0.3286	0.0270	0.1542	0.0134
0	172.60	-0.35	-21.00	-0.05	-3.05	33.02	0.14	0.10	-0.5165	0.0253	-0.0011	-0.0048
0	171.76	14.38	-21.45	43.49		30.36		6.25	-0.5363	0.0063	0.0792	0.0046
0	170.54	13.16	-21.64	43.51		28.16		6.20	-0.5420	0.0449	0.0670	0.0147
0	182.86	16.43	1.41	49.49	44.09	36.00	30.10	3.65	-0.5004	0.0517	0.0425	0.0041
0	183.39	27.45	3.17	86.55	41.66	37.00	57.78	7.15	-0.4959	0.0590	0.1599	0.0068
0	182.97	15.93	1.11	48.52	42.51	38.91	31.15	7.43	-0.5147	0.0377	0.0625	0.0119
0	183.96	16.44	20.34	50.06	52.60	41.06	29.64	4.70	-0.4601	0.0575	0.0665	0.0139
0	202.88	15.46	47.28	43.44	62.55	50.39	24.84	6.30	-0.3405	0.0848	0.0502	0.0071
0	167.63	14.28	66.79	43.40	32.47	10.55	23.55	3.60	-0.2349	0.1010	0.0557	0.0042

STRAIN CONTROL FAILURE TEST

N	P_m	P_r	q_m	q_r	U_B^p	U_C^p	U_B^r	U_C^r	ϵ_s^p	ϵ_v^p	ϵ_s^r	ϵ_v^r
0	182.29	0.01	119.85	0.00	-3.07	-5.00	0.00	0.00	0.0070	0.0087	0.0000	0.0000
0	185.04	0.03	128.10	0.00	-2.37	-3.99	0.00	0.00	0.0126	0.0133	0.0000	0.0000
0	185.04	-0.02	128.08	0.00	-2.13	-2.94	0.00	0.00	0.0122	0.0122	0.0000	0.0000
0	194.59	0.01	156.73	0.00	8.37	7.68	0.00	0.00	0.0729	0.0135	0.0000	0.0000
0	196.05	-0.07	161.11	0.00	10.73	11.16	0.00	0.00	0.1314	-0.0096	0.0000	0.0000
0	197.12	0.04	164.38	0.00	14.46	15.80	0.00	0.00	0.3393	-0.0227	0.0000	0.0000
0	197.48	0.00	165.42	0.00	14.51	15.81	0.00	0.00	0.3766	-0.0140	0.0000	0.0000
0	195.86	0.01	160.55	0.00	14.41	16.02	0.00	0.00	0.4739	0.0002	0.0000	0.0000
0	196.02	-0.01	161.03	0.00	23.57	25.45	0.00	0.00	1.1958	0.0108	0.0000	0.0000
0	195.86	0.02	160.54	0.00	28.64	31.56	0.00	0.00	1.7954	0.1321	0.0000	0.0000
0	195.03	-0.05	158.07	0.00	36.92	40.12	0.00	0.00	2.7252	0.9815	0.0000	0.0000
0	194.34	-0.03	155.98	0.00	39.53	45.61	0.00	0.00	4.0809	1.5691	0.0000	0.0000
0	194.57	0.02	156.68	0.00	43.16	44.82	0.00	0.00	5.5051	0.1509	0.0000	0.0000
0	192.94	0.00	151.80	0.00	44.42	48.95	0.00	0.00	4.4505	2.3479	0.0000	0.0000
0	187.57	0.02	135.69	0.00	38.60	51.08	0.00	0.00	4.4498	2.3603	0.0000	0.0000