THE UNIVERSITY OF MANITOBA

A GEOTECHNICAL STUDY OF REMOULDED WINNIPEG CLAY

by

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the University of Manitoba in partial fulfillment of the requirements
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ABSTRACT

Techniques for the preparation of remoulded samples have been developed. The main thrust of this thesis is to investigate the geotechnical properties of remoulded Winnipeg clay. The study involved triaxial tests, oedometer tests, and constant rate of strain (CRS) tests. High quality trimming and careful handling of samples have been emphasized.

Ten 76 mm diameter triaxial samples were tested using the stress-probe method. Critical State consolidation parameters λ and Γ were found to be 0.313 and 3.96, respectively, for the one-dimensional normal consolidation line (NCL).

Undrained strain-controlled triaxial tests were used to examine several aspects of the clay's behaviour. Based on the $(\sigma_1 - \sigma_3)_{max}/2$ criterion, the normally consolidated failure envelope was found to be slightly curved in p, q'-space. The Critical State Line (CSL) is parallel to the one-dimensional NCL and separated from it by a constant ratio of 1.4. This is similar to that of Winnipeg natural clay. The average value of s_u/σ'_{vc} was found to be 0.27. Values of A_f range between 0.23 to 1.06 and are generally lower than Winnipeg natural clay results, but close to Henkel's (1956) results. The relative stiffness, E_{50}/s_u varies between 293 and 689. The strain rate parameter, $\rho_{0.1}$ was found to lie between 5.4 and 8.2 percent.

Drained stress-controlled portions of the tests show clear yields in these samples. The preliminary shape of the yield envelope is similar to that of Winnipeg natural clay.

The CRS and oedometer testing on the remoulded samples show agree-

ment in σ'_{vc} and C_c-values. In natural samples, values of σ'_{vc} were found to be decreased by the softening procedures in oedometer tests. Yielding was not clearly observed in 'freeze - thaw' samples.

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LIST OF SYMBOLS

A,B	-	porewater pressure parameter (after Skempton, 1954)
A_f	-	value of A at failure
Bp	-	back pressure in CRS tests
c'	-	effective cohesion intercept
C_c	-	compression index
c_v	-	coefficient of consolidation
$C_{\alpha\varepsilon}$	-	coefficient of secondary compression measured from a log (time) versus vertical strain plot
CAD	-	stress-controlled, consolidated anisotropically drained test
CAU	-	strain-controlled, consolidated anisotropically undrained compression test
CRS	-	constant rate of strain oedometer test
CSL	-	critical state line
e	-	voids ratio
E_{50}	-	elastic modulus to 50 percent of failure stress
G_{eq}, K_{eq}	-	shear and bulk moduli dependent on stress path direction
G_s	-	specific gravity
I_p	-	plasticity index
K_o	-	coefficient of earth pressure at rest
LIR	-	load increment ratio
LSSV	-	length of stress vector
NCL	-	normal consolidation line
OCR	-	overconsolidation ratio
p'	-	effective mean principal stress = $(\sigma_1' + \sigma_2' + \sigma_3')/3$
p_y'	-	p' at yield

q - deviator stress = $(\sigma_1 - \sigma_3)$

q_{max} - maximum deviator stress

s_u - undrained strength: = $q_{max}/2$

u - porewater pressure

u_b - measured porewater pressure at the bottom of CRS cell

v - volumetric strain in triaxial compression test

v_c - v at the end of triaxial consolidation to $\sigma'_{1c}, \sigma_{3c}$

V - specific volume = $(1 + e)$

w - natural moisture content

w_i - initial moisture content

w_f - final moisture content

w_L - liquid limit

w_p - plastic limit

W - strain energy absorbed per unit volume

ε_1 ε_3 - major and minor principal strains (i.e. axial and radial strains in triaxial compression test)

ε - shear strain = $2(\varepsilon_1 - \varepsilon_3)/3$

$\varepsilon_{1c}, \varepsilon_{3c}$ - ε_1 and ε_3 at the end of triaxial consolidation to $\sigma'_{1c}, \sigma'_{3c}$

ε_V - vertical strain for oedometer test

ε_ρ - average axial strain during relaxation test in undrained compression test

$\dot{\varepsilon}_1$ - axial strain rate

$\rho_{0.1}$ - strain rate effect parameter for undrained strength

$\eta_{0.1}$ - strain rate effect parameter for preconsolidation pressure p'_c

σ'_1, σ'_3 - major and minor effective principal stresses

$\sigma'_{1c}, \sigma'_{3c}$ - σ'_1 and σ'_3 at the end of triaxial consolidation

σ'_{vc} - effective vertical preconsolidation pressure

$\sigma'_{cy\ell}$	-	effective vertical stress applied in reconsolidation cylinder
σ'_v	-	effective vertical stress
ϕ'	-	effective angle of shearing resistance
Γ	-	intercept of critical state line at $p' = 1$ kPa
θ	-	stress path direction arctan $(\Delta q/\Delta p')$
λ,κ	-	slopes of normal, reload lines in V, $\ell n\ p'$ space

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CHAPTER 1

INTRODUCTION

1.1 GENERAL HISTORICAL DEVELOPMENT

Soils are the oldest and perhaps most complex of the construction materials used by engineers. Yet, relatively little is known about the fundamental physical and mechanical properties of these materials. As a consequence, many early designs and construction procedures were to a large extent, based on individual judgement and empirical formulas. Because engineers have been unable to predict accurately how a given soil would perform, they are forced to build their structures with larger safety factors, load factors, or 'factors of ignorance'.

In the past few decades or so, research work on soils, particularly earthwork and foundation problems, have received considerable attention. Most of this work was built mainly upon the ideas of the Mohr-Coulomb strength and Terzaghi's consolidation theories, which constitute the framework for classical Soil Mechanics. However, the analyses of many practical problem, based on these different theories, are often inconsistent because they involve separate and frequently unrelated parameters, and are often restrictive in their assumptions (Kenney and Folkes, 1979).

In recent years, increased attention has been directed towards a more consistent and fundamental approach to soil mechanics called Critical State Soil Mechanics. The Critical State concepts originated from Cambridge University in England when Roscoe, Schofield and Wroth (1958) proposed the existence of limit and critical states in saturated remoulded clay. Over the past three decades, one of the primary aims of the research at Cambridge has been the development of stress-strain theories for soils using the Critical State framework. Throughout the years, the original theory was extended and revised (e.g., Burland, 1967; Schofield and Wroth, 1968). Historical development of the 'Critical State' model* and the concepts of limit and critical states have been reviewed by Atkinson and Bransby (1978) and Noonan (1980). The importance of the model is to provide a rational way to understand the fundamental behaviour of soil as a construction material, and to draw a comprehensive and unified picture of the concepts of compressibility, elasticity, yield, friction and cohesion, as they applied to soil (Bolton, 1979). However, the model has not been widely accepted in practice because the theories were based on isotropic test results obtained from remoulded Weald clay and kaolinite rather than natural soils.

Since Bjerrum (1967) emphasized the importance of handling and testing natural anisotropic soil samples, more research efforts have been directed towards 'undisturbed' soil deposits. Roscoe and Burland (1968) suggested that the limit state and critical state concepts could also be extended and modified to apply to natural anisotropic clays. Recently, Tavenas and Leroueil (1977), working with sensitive Champlain Sea clay found that a limit state surface existed in the natural clay. They proposed a limit state model (YLIGHT) which has been reviewed by Noonan (1980) and Lew (1981). The existence of a limit state surface (or yield

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* It should be understood that the use of the word 'model' in this context does not imply a physical representation in the sense of a scale model, but simply a conceptual idea, or a number of mathematical equations (Atkinson, 1981).

envelope) in natural clays was reported even earlier, for example, by Graham (1969); Crooks (1973); Crooks and Graham (1976).

Baracos et al, (1980) showed that a yield envelope also existed in the highly plastic glacio-lacustrine clays of Winnipeg. In the past few years, an extensive goetechnical study on Winnipeg natural clay was carried out in the University of Manitoba under the supervision of Dr. J. Graham. In two major laboratory studies (Noonan, 1980; Lew, 1981), good qualitative understanding of yielding and strength of the clay was obtained. The testing programs consisted of 76 mm diameter samples, which were trimmed by equipment specially designed to minimize disturbance. In these test series, clear yielding was observed and yield envelopes were obtained for four different depths, and therefore four different preconsolidation pressures. Yielding was determined by different criteria, which were examined by Lew (1981). Tavenas and Leroueil (1977) concluded that the known effects of aging (Bjerrum, 1967) and strain rate on preconsolidation pressure can be applied to the entire yield envelope. The influence of time effects on Winnipeg natural clay has recently been confirmed by Au (1982) in a separate study.

The major commonly understood feature of Critical State Soil Mechanics is the linearity and parallelism of the normal consolidation line (NCL) and the Critical State line (CSL) in log p', V-space.* Recently, laboratory data obtained by Noonan (1980) and Lew (1981) were further examined by Graham, Noonan and Lew (1983). Their paper concluded that Winnipeg natural clay showed quasi-elastic behaviour before yielding and

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* Symbols are defined in the LIST OF SYMBOLS.

that the elasticity is transversely isotropic. They also showed that the clay is cemented. More importantly, their paper reveals strong evidence of the existence of Critical State features, such as the parallelism of the NCL and CSL mentioned earlier. Furthermore, samples with different preconsolidation pressures were found to produce a well-defined normalized yield envelope in p'/σ'_{vc} and q/σ'_{vc}-space. Traces of the 'elastic wall' of these yield envelopes in p', V and q, V-space were geometrically similar (homothetic) for different preconsolidation pressures, and parallel to each other.

Although there is some understanding of the relationship of the behaviour of natural Winnipeg clay with the Critical State model (Graham, Noonan and Lew, 1983), the detailed applicability is still unclear. This is because Critical State Soil Mechanics was mostly built upon the testing of remoulded kaolinite. However, most of the clay minerals in Winnipeg clay are smectite (montmorillonite) and illite (Baracos, 1977). In order to facilitate the understanding of how Winnipeg clay is related to the Critical State model, the testing of remoulded Winnipeg clay was considered necessary. It is clear that test results of the remoulded clays cannot be used directly in practice. However, such testing facilitates a more fundamental understanding of their properties. The present study on the geotechnical properties of remoulded Winnipeg clay is designed to meet this particular purpose.

1.2 OBJECTIVES

As mentioned previously, the main purpose of the present study was to investigate the behaviour of remoulded Winnipeg clay, so as to bridge the gap between Critical State Soil Mechanics and its applicability to Winnipeg natural clay. In addition to this, there are two additional general targets:

1) To perform oedometer tests on 'fully-softened' and 'freeze - thaw' samples to complement the work done by Au (1982).

2) To continue the development work on Constant Rate of Strain (CRS) oedometer testing.

The specific aims of this thesis are as follows:

1) To develop techniques in the University of Manitoba for preparation and testing of one-dimensionally consolidated remoulded clay.

2) To measure Critical State parameters λ for one-dimensional normal consolidation line (NCL) and Critical State line (CSL), Γ, the ratio p'_{NCL}/p'_{CSL} and s_u/σ'_{vc} for remoulded Winnipeg clay.

3) To investigate yielding and to explore the preliminary shape of yield envelope for remoulded Winnipeg clay.

4) To determine the failure envelope for Winnipeg remoulded clay.

5) To investigate other traditional parameters, such as undrained shear strength, porewater pressure parameters, elastic moduli, relative stiffness and strain rate parameters for remoulded Winnipeg clay.

6) To examine the effects on softening and freeze - thawing on preconsolidation pressures in natural oedometer samples.

The laboratory testing program consisted of ten large diameter (76 mm) triaxial tests, four oedometer tests, six Constant Rate of Strain (CRS) oedometer tests, and standard classification tests on remoulded Winnipeg clay. The remoulded samples were obtained by artificial reconsolidation in the laboratory (Appendix 1). Four additional oedometer tests on 'fully-softened' and 'freeze -thaw' natural samples were also completed to complement the work by Au (1982). Results are presented in this thesis, although this is not the main thrust of the present work.

Before proceeding to the testing program in Cahpter 3, and its results (Chapters 3,4 and 5), a review of the properties of Winnipeg clay, sample preparation and test procedures will be given in Chapter 2. Discussion of test results and conclusions will be presented in Chapters 6 and 7, respectively.

CHAPTER 2

SOIL PROPERTIES, SAMPLE PREPARATION AND TEST PROCEDURES

2.1 INTRODUCTION

Although the laboratory work mainly involved tests on remoulded Winnipeg clay, additional oedometer tests were performed on samples of natural 'undisturbed' Winnipeg clay, which had been subject to 'fully-softened' and 'freeze-thaw' procedures, as described by Au (1982). This was done to investigate the relationship between σ'_{vc} and yielding in these samples. Sample preparation and procedures for both sets of tests will be described. Detailed accounts of the test results will be discussed in Chapters 3, 4 and 5.

2.2 WINNIPEG CLAY

Ten triaxial samples and ten oedometer samples tested in the present study were dried, pulverized and then remoulded from natural Winnipeg clay. The soil profile and properties of Winnipeg clay have been described by Baracos et al (1980). In its natural state, Winnipeg clay is highly plastic (CH), has laminated structure and medium-stiff to stiff consistency. Extensive nonhomogeneity, anisotropy and fissures are visually evident. Recently, Graham, Noonan and Lew (1983) further concluded that Winnipeg natural clay is cemented. This is supported by previous studies using electron microscopy (Baracos, 1977) and geohydrology (Render, 1970). The clay is lightly over-consolidated, having an over-consolidation ratio OCR of 2 to 3, due to a variety of processes such as groundwater level changes, cementation, porewater chemistry changes, delayed compression, desiccation and freeze-thaw effects. The most dominant clay minerals, in the order of decreasing occurrence, are smectite, illite, kaolinite. Since it contains a large proportion of smectite (montmorillonite), Winnipeg clay is known for its high swelling potential.

Although the results of tests on remoulded clays cannot be used directly for the solution of practical problems involving undisturbed clays, it is important that research on undisturbed natural clays be supplemented by research on remoulded clays, in order to have a more fundamental understanding of their properties. In particular, this project has examined the Critical State properties of remoulded Winnipeg clay. This has been done as a control for the natural clay properties reported recently by Graham, Noonan and Lew (1983). The use of remoulded soils in basic research has important advantages, especially in regard to the uniformity of test specimens, control of stress history, and the separation of the influence of many variables which govern the deformation and strength characteristics of soils.

2.3 PREPARATION OF REMOULDED CLAY

The testing of remoulded soils is common in many research laboratories. However, details concerning how these samples are prepared are not well documented in the literature. Dr. J. Graham suggested that ideal remoulded clay should not possess any 'memory' of its past experiences throughout geological time. Through the remoulding processes, influences such as stress history and the general macro-structure should be destroyed. Henkel (1956) suggested that remoulded samples should be prepared from a suspension, or at least consolidated from a water content close to the liquid limit, w_L, of the soil. The remoulded samples used in the present study were all formed from pulverized Winnipeg clay powder mixed thoroughly with distilled water in a mechanical mixing unit (Fig. 2.1). The prepared slurry had a moisture content close to twice the liquid limit of Winnipeg clay (w = 164%). This process of mixing at 2 x w_L conforms with experience reported informally to Dr. Graham during visits to several research laboratories in 1981-1982.

The slurry was then poured into a reconsolidation cylinder (Fig. 2.2) in which it was allowed to consolidate with top and bottom drainage under a vertical load. Attempts were initially made to monitor both the axial deformation and volumetric change throughout the reconsolidation process. Volume change measurement was found to be difficult to control consistently, and was later abandoned. Thus, only axial deformation was obtained. More importantly, because of the fluid-like nature of the slurry, it was very difficult to determine the starting position of the loading piston when it first made contact with the slurry.

Reconsolidation was performed in two load increments. Consolidation versus time readings were taken to ensure that an equilibrium condition was obtained in each of the load increments. The final vertical stresses in the cylinders for all the reconsolidation tests were about 80 kPa (except for T505, which had a final vertical stress of 100.2 kPa). In the present study, the total reconsolidation time for the two increments was about 30 days. As stated by Henkel (1956), this process is very time consuming and difficult to control completely. The choice of final vertical stress was decided on the basis that the reconsolidated remoulded clay should have a shear strength high enough to permit trimming of triaxial and oedometer samples. According to Graham, Noonan and Lew (1983), Winnipeg clay has

$s_u/\sigma'_{1c} = 0.22$. This produces a shear strength of 17.6 kPa for the remoulded clay under a vertical stress of 80 kPa. This strength is adequate to permit easy sample trimming with minimum disturbance. Appendix 1 contains the precise detail of how remoulded clay was prepared in the laboratory.

2.4 SAMPLE PREPARATION

The importance of high quality sampling and testing techniques, in regards to natural clay samples, has been emphasized by several investigators (Crooks, 1973; Graham, 1974; Crooks and Graham, 1976; Leroueil and Tavenas, 1977). The same importance should also be applied to remoulded clay samples prepared in the laboratory. Although the sampling problem is eliminated in these tests, any significant disturbance during sample preparation and testing should also be carefully minimized so that the results are meaningful. In this regard, the author will suggest an improved method of preparing test samples other than the one adopted in the current work. The method will be discussed in Chapter 8 and is thought to be helpful in minimizing the trimming disturbance.

The trimming equipment used in the present study was designed and constructed at the University of Manitoba (see Lew 1981, Fig. 3.3). The equipment is similar in principle to the equipment described by Landva (1964).

2.4.1 Triaxial Samples

Triaxial testing was done on the 76 mm dia. specimens that were carefully trimmed from remoulded Winnipeg clay extruded from the reconsolidation cylinder (Fig.2.3). The trimming and building-in procedures were described in detail by Lew (1981). The important feature is that the top of the triaxial sample is supported throughout the process and minimum disturbance is thus ensured. The remoulded clay extruded from the reconsolidation cylinder (102 mm dia.) is suitable for direct use on the trimming platform. Initial rough cutting to size is not needed (Noonan, 1980). The trimming and building-in procedures for triaxial samples can be outlined as follows:

The cell pedestal was de-aired by flushing water through it by means of two burettes attached to the pedestal drainage leads. The base plate was placed on the cell base and was adjusted until the inverted cutting cylinder was accurately centred over the pedestal base. The trimming table was then attached to the base plate. The trimming equipment was lubricated with silicone oil to facilitate smooth sliding. A lightly oiled cutting cylinder with a sharp leading edge was pushed carefully into the soil to a depth of slightly less than the full length of the cutting edge. The excess clay outside the cutting edge was then removed by trimming wire. This process was repeated until soil protruded from the top of the cylinder. The cutting cylinder was then removed from the uprights and placed over a glass plate. The excess clay was trimmed away.

A saturated de-aired filter stone in a holder was attached to one end of the sample. The sample was then lowered onto the cell pedestal, the top cap was located firmly by a central rod, and the cutting cylinder was removed. After the height and diameter of the sample was obtained, a thin coat of silicone stopcock grease was applied to the side of the pedestal and the top cap. Lateral drainage filter strips were applied longitudinally around the sample surface. Two membranes separated by a layer of silicone oil, were placed over the sample, together with two

O-rings on the top cap and three on the pedestal. The cell top was then fitted very carefully onto the cell base and screwed down. The loading piston was lowered until contact was made with the sample and the piston was locked in place. The cell was then filled with de-aired distilled water. A layer of engine oil about 2 cm thick was applied through the top of the cell to reduce leakage of cell water, and friction between the piston and the bushing.

2.4.2 Oedometer Samples

To minimize disturbance, oedometer samples were prepared using similar trimming equipment to the triaxial samples, but with some modifications. For the detailed set-up of the trimming equipment, the reader is referred to Figure 3.4 of Lew (1981). The building-in procedure was basically the same as conventional oedometer tests, and thus will not be described here. Besides testing remoulded clay, the author also performed oedometer tests on natural clay samples subjected to 'fully-softened' or 'freeze-thaw' procedures, as defined by Au (1982).

The following sections describe how they were prepared.

2.4.2.1 Fully-Softened Oedometer Samples

After the sample was placed in the oedometer frame as usual, a small axial stress of approximately 5 kPa was applied, in order to keep the loading frame just in contact with the top cap ball bearing. This procedure facilitated the measurement of axial deformation. The oedometer cell was then filled with de-aired distilled water, and the sample was allowed to absorb as much water as it wished. It was observed that the axial deformation caused by water absorption under a small constant load became stable after about 2 weeks. This is consistent with previous experience in 'fully-softened' triaxial samples (Au, 1982).

2.4.2.2 'Freeze-Thaw' Oedometer Samples

Prior to conventional testing, the soil sample, together with the ring and cell, were subjected to six cycles of freezing and thawing. The duration of each freeze - thaw cycle was about 12 hours. The average freezing temperature was -20°C and the average thawing temperature was 20°C.

2.4.3 Constant Rate of Strain (CRS) Oedometer Samples

Samples for CRS testings were no different from the conventional oedometer samples. The building-in procedures for these tests were described by Au (1982). The CRS oedometer cell has been modified to allow back-pressuring (Fig. 2.1) as suggested by Au (1982). This cell, and the accompanying back-pressuring procedures, will be described in section 2.5.3.

2.5 GEOTECHNICAL LABORATORY TEST PROCEDURES

This section summarizes the test procedures used in different types of laboratory testing exmployed in the precast study.

2.5.1 Triaxial Tests

Noonan (1981) described details of the two main phases of triaxial testing on undisturbed samples, namely, triaxial consolidation (drained stress-controlled testing), and undrained shear (strain-controlled testing). These procedures were directly applicable to the remoulded samples in the present study and will only be briefly summarized in the following sections.

2.5.1.1 Triaxial Consolidation Test Procedures

The remoulded samples were generally first reconsolidated anisotropically (following an approximate K_o-stress path) to the maximum vertical stress that the sample experienced in the reconsolidation cylinder. A constant stress ratio, $\sigma'_{3c}/\sigma'_{1c}$, of 0.62* was found closest to the K_o-consolidation in the first remoulded Winnipeg clay sample, T501. Discussion of difficulties in measuring the K_o-ratio has been given by Noonan (1980). This stress ratio was then used as the stress ratio in the rest of the remoulded Winnipeg clay samples subjected to K_o-triaxial consolidation. This ratio is slightly less than the value of 0.65 proposed by Baracos et al (1980) in natural Winnipeg clay. Crooks and Graham (1976) showed that laboratory reconsolidation strongly influences the stress-strain behaviour and porewater pressure generation during subsequent shearing of a natural undisturbed sample. In order to preserve the in-situ grain structure of natural Winnipeg clay, laboratory reconsolidation to its approximate in-situ stress state was deemed important by Noonan (1980), Lew (1981) and Au (1982).

Since the remoulded samples have their σ'_{vc}-values equal to their maximum vertical stresses experienced in the reconsolidation cylinders, the reconsolidation procedure permitted the evaluation of the Critical State parameter κ. In order to establish the reload curves, 3 to 4 loading increments were used to restress the samples to their maximum vertical stresses in the cylinders. Furthermore, the vertical stress of the first increment had to be high enough to avoid swelling. The present

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* The value of $K = \sigma'_{3c}/\sigma'_{1c} = 0.62$ produces small lateral strains, and is not exactly the "at-rest" K_o-condition. However, in subsequent sections K_o will be used to identify these tests for convenience.

study showed that a vertical stress of 40 KPa was high enough to be the first loading increment in the present study.

The consolidation stage of the triaxial tests was carried out on a steel frame, the general arrangement of which has been shown in Figure 3.5 of Lew (1981). The frame can accommodate a maximum of three rotating bush triaxial cells at one time. Dial gauges were used to monitor the vertical displacement of the samples, while the volume changes were observed by burettes. Before each load increment, water was flushed through the drainage to remove air which might have been trapped in the cell base passages. This procedure is especially important for soils of high organic contents because of their high gas releasing potential.

Cell pressure was applied through the de-aired distilled water in the cell, using compressed air in a separate pressurized water tank. The cell pressures and porewater pressures were both monitored by pressure transducers, which were re-zeroed to atmospheric pressure daily at mid-height of the sample. Axial loading was applied by dead loads on a hanger which rested freely on the piston. New load increments were added at 24-hour intervals. Strong efforts were taken to obtain constant load durations and consistent load increments on a 7-day per week basis. The calculations for each load increment have been given in Appendix A of the thesis by Noonan (1981). After the application of new lateral and axial stress increments, axial dial reading and volume change burette readings were taken using standard 'doubling' time intervals, (i.e. 1,2,4,8,15,30 min., 1,2,4 hr. etc.) similar to conventional consolidation time readings.

2.5.1.2 Undrained Shearing Test Procedures

Except for sample T509, all triaxial samples were subjected to strain controlled shearing after triaxial consolidation was completed. The triaxial cell was transferred carefully from the steel frame to a 10 kN compression frame. Careful efforts were made so that the changes in axial and lateral stresses were minimized. The piston was clamped before the axial dead loads were removed. However, the cell pressure line, burettes, dial gauge and pressure transducer connections were all maintained in place. The axial load was re-established in the compression frame by means of a proving ring (sensitivity = 1.237 N/div.).

Prior to back-pressuring, the drainage system was flushed again to ensure that any entrapped air was eliminated. A back pressure of approximately 210 kPa was applied in seven increments of 30 kPa each. At each increment, the external cell pressure and the internal back pressure in the porewater were each increased by the same amount. The proving ring force was also increased to a value just enough to counteract the force exerted on the piston by the increased cell pressure.

The sample was then allowed to sit under the back-pressure for a period of time, usually overnight. Tests for the "B" porewater pressure were performed to check the sample saturation. The porewater pressure parameter "B" was mostly greater than 97 percent (Table 7). The nominal strain rate used for undrained shearing was about 1 percent per hour. At the beginning of testing, readings of axial deflection, proving ring, porewater pressure and cell pressure were taken at 5-10 minute intervals, so that the 'elastic' part of the stress-strain curve was well defined. When the proving ring load was increasing very slowly, or reached a peak value, a longer time interval was used between readings. Usually a relaxation test (Graham, 1974) was carried out just after the peak shearing resistance had been reached to examine the effect of strain rate variation on the undrained shear strength. This procedure involves switching off the compression machine and noting changes with time in axial deflection, proving ring reading, porewater pressure and cell pressure. Stopping the compression machine allows the sample to continue straining at a decreasing rate, due to the stored energy in the proving ring. Relaxation tests were usually continued overnight. On the following morning, the compression machine was switched on again, and shearing continued. Careful readings were taken during the reloading section of the test, as the shearing resistance built up to about its former value.

2.5.2 Oedometer Tests

Oedometer tests were performed to study the general one-dimensional load - unload - reload behaviour of the different type of samples mentioned in section 2.4.2. Each oedometer cutting ring (25 mm deep x 76 mm dia.) was lubricated with silicone oil to aid trimming and reduce side friction during testing. After trimming, the ring with the contained sample was carefully placed in an oedometer cell, and the loading cap put on the sample. Except for the 'fully-softened' and 'freeze - thaw' natural clay samples, which required extra procedures (see sections 2.4.1.1 and 2.4.1.2) prior to the actual testing, the sample was then ready for loading. Pilot tests on the remoulded Winnipeg clay indicated that a load increment ratio, LIR, of 0.15 yielded well defined stress-displacement curves, while the 'fully-softened' and 'freeze - thaw' samples adopted a constant load increment of 20 N (Load Multiplication factor = 10.21). Each load increment was added at 24-hour intervals. The remainder of the test procedure followed that of Ackroyd (1957).

2.5.3 Constant Rate of Strain (CRS) Tests

The CRS oedometer tests in the present study were performed in a new piece of equipment modified from the one used previously by Au (1982). The main difference was its ability to allow back pressure application. Figure 2.1 shows the new CRS oedometer cell.

The drainage channel was carefully de-aired, leaving a reservoir of distilled water on the bottom of the cell, while the drainage was closed. The sample was then carefully placed onto the centre of the cell base. After tightening down the clamping ring that holds the consolidation rings, the top cap and the ball bearing were placed over the sample. In this new CRS cell, a cell top containing a loading piston was then placed on top of the cell and was screwed down to the cell base. The loading piston was carefully brought in contact with the lower ball bearing and then another ball bearing was placed over the loading piston. The cell was then slowly filled with de-aired distilled water through the bottom drainage lead. During this process the top valve was kept open until the cell was filled. The bottom drainage valve was closed and a back pressure of 210 kPa was then applied through the top valve of the cell. After the compression frame was adjusted and the strain rate was chosen, the machine was switched on to start the test.

A TYCO type pressure transducer with a range of 0 to 980 kPa was used for measuring porewater pressure at the bottom of the sample. The vertical force was measured with a TYCO (JP 1000) force transducer, ranging from 0 to 4500 N. The deformation was measured with LVDT, type HP 7DCDT-500. Readings were taken with the following accuracy:

Force - 1.0 N

Pressure - 0.1 kPa

Displacement - 0.001 mm

Data defined in engineering units were fed to conditioning units and recorded by a Consolidated Control Model 90 MCI Datalogger.

For the present study, a strain rate of 0.004 mm/minute was used for all the remoulded samples (approx. 1%/hr.). During the first hour of the test, vertical force, porewater pressure, cell pressure and axial displacement were taken at 5-minute intervals. Readings were taken at 30-minute intervals thereafter. A step changing test, Bell (1977) was performed on sample C518 to examine the applicability of time effects on remoulded clay. The effective axial pressure was calculated based on a parabolic porewater pressure distribution, throughout the sample (Sallfors, 1975). On this basis, the effective pressure can be approximated by:

$$\sigma_v' = \sigma_v - BP - \frac{2}{3}(U_b - BP)$$

The tests were run to an average axial strain of about 20 percent. Test results will be presented in Chapter 5.

CHAPTER 3

TRIAXIAL CONSOLIDATION TEST RESULTS

3.1 INTRODUCTION

The shear strength and stress-strain characteristics of remoulded Winnipeg clay have been investigated using drained stress-controlled and undrained shear triaxial tests. A total of ten triaxial samples (T501-T510) were tested in the present study. Triaxial samples were trimmed from clay prepared in reconsolidation cylinders, as described in sections 2.3 and 2.4.

Triaxial sample trimmings were used to determine the initial moisture contents and Atterberg limits of the samples. These results, along with the sample final moisture contents, and the limit test results, are listed in Table 1.

The triaxial testing program is described in section 3.2 Results from drained stress-controlled tests are presented in section 3.3. Undrained shear test results will be reported in Chapter 4.

The drained portion of the tests were designed to investigate several aspects of consolidation behaviour of the clay, particularly in the light of Critical State Soil Mechanics. These included one-dimensional consolidation parameter (κ and λ), yielding and 'elastic' moduli (K_{eq} and G_{eq}). The general Critical State concept was reviewed by Noonan (1981).

3.2 TESTING PROGRAM

In order to study the one-dimensional consolidation characteristics of remoulded Winnipeg clay, eight triaxial samples (T501-T504, T507-T510) were consolidated along the K_o-line in p', q-space. Samples T505 and T506 were consolidated along the isotropic effective stress path to study their isotropic consolidation behaviour. Figure 3.1 shows the stress paths of various triaxial samples, which were proposed by the Author at the beginning of the test program. Description of stress paths chosen for the present study can be divided into the following catagories:

1) <u>T501, T502, T504</u>

   approximate K_o-consolidation

   normally consolidated

2) <u>T503, T510</u>

   approximate K_o-consolidation

   loaded - unloaded to give an over-consolidation ratio (OCR) = 2

   sheared undrained

3) <u>T505</u>

   approximate isotropic consolidation

   normally consolidated

4) <u>T506</u>

   approximate isotropic consolidation

   loaded - unloaded to give an over-consolidation ratio (OCR) = 2

5) <u>T507, T508, T509</u>

   loaded - unloaded following approximate K_o-path to give an over-consolidation ratio (OCR) = 2

   T507 reloaded follows K_o-stress path

   T508 reloaded follows a stress path such that arctan $(\frac{\Delta q}{\Delta p'}) = -5°$

   T509 reloaded follows a stress path such that arctan $(\frac{\Delta q}{\Delta p'}) = 60°$

Except for T501, all K_o-reconsolidation tests had 4 to 6 stress points between the beginning of reconsolidation in the triaxial cell, and the previous maximum 'cylinder' stress levels, $\sigma'_{cy\ell}$.* The first triaxial sample (T501) had no intermediate stress levels, and it was loaded immediately in one increment to the maximum cylinder stress. The procedure was changed in later tests because major axial deformations ($\varepsilon_1 \simeq 3.5\%$) were observed during the increment. After reaching the cylinder pressure, a constant load increment ratio (LIR) of 0.15 was used for all samples following the K_o-consolidation path (T501-T504 and T507-T510) in their first time load increments. In order to create an OCR of 2 in samples T503, T506, T507, T508, T509 and T510, the samples were first loaded as before, and then stress levels were reduced in 1 or 2 load increments keeping $\sigma'_{3c}/\sigma'_{1c} = 0.62$. Table 2 shows results of the triaxial consolidations for restressing the samples to their approximate 'cylinder' stresses.

The reloading stress paths of samples T507, T508 and T509 were chosen to define yield stresses in various regions of the stress space. Figure 3.2 shows the stress paths which were actually followed during the investigation. The stress increments along the stress paths for samples T507, T508 and T509 were chosen to allow four stress points between the off-loaded stress level and the yield envelope, determined by Graham, Noonan and Lew (1983). Each stress was maintained for 24-hours. Detailed discussion of the loading procedures was given by Noonan (1980).

The complete stress-strain results for the stress-controlled drained tests are tabulated in Appendix 3 and shown in Figures 3.3 - 3.19. The triaxial consolidation results at the end of the drained tests are summarized in Table 3.

Because of the steeply inclined stress path taken by test T509

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* 'cylinder' stress level, $\sigma'_{cy\ell}$ refers to the maximum effective vertical stress the sample had experienced in the reconsolidation cylinder.

(Fig. 3.1b), failure occurred abruptly; and no undrained shear test was possible. Otherwise, all triaxial samples were subjected to strain-controlled undrained shear tests after triaxial consolidation was complete.

3.3 DRAINED STRESS-CONTROLLED TESTS

Drained consolidation usually takes up the largest portion of the total testing time in consolidated undrained triaxial tests. In the present study, the duration of the drained part of the tests ranged from 8 to 20 days. A ratio of horizontal to vertical effective stress of 0.62 was found experimentally in T501 to produce lateral compressive strains of less than 1.7 percent, and this stress ratio was used for the remainder of the samples. Drained compression results are presented in two different sections in this chapter. Section 3.3.1 presents all the 'first-time' loading results. Section 3.3.2 presents results from samples that were unloaded and then loaded along a variety of stress paths.

3.3.1 Triaxial Reconsolidation and First-Time Loading

Once the samples were extruded from the reconsolidation cylinders, the clay became slightly over-consolidated. In order to preserve the clay structure developed in the one-dimensional reconsolidation cylinder, careful laboratory reconsolidation is mandatory (Graham, 1974; Crooks and Graham, 1976). Reconsolidation procedures were performed in all K_o-consolidation tests (T501-T504; T507-T510). Previous investigations on natural Winnipeg clay (Noonan, 1980; Lew, 1981; Au, 1982) reported triaxial reconsolidation and drained compression results separately. In the present tests, the results were not separated because the two parts of the test are continuous. The stress-strain results of reconsolidating the remoulded samples to their approximate final cylinder stresses are tabulated in Table 2, so that direct comparison can be made with the behaviour of natural samples. The comparative study on the reconsolidation results of remoulded and natural Winnipeg clay are presented in Chapter 6.

All one-dimensional and isotropic consolidation results obtained from drained triaxial compression tests are plotted in V, log p' space, (Figs. 3.3-3.7). Specific volumes V = (1 + e) were calculated from initial moisture contents, plus volumetric changes during reconsolidation and stress probing. Consolidation parameters λ and κ for the slopes of normal consolidation line NCL and swelling (or reloading) line are listed in Table 5. In order to distinguish the first time reloading κ and λ-values from κ and λ-values created through an unload - reload cycle, first time reloading κ is denoted by κ_1 and subsequent reload following swelling by κ_2.

3.3.1.1 <u>κ_1-values</u>

All κ_1-values are tabulated in Table 5. An average κ_1-value of 0.149 was calculated from five K_o-consolidated samples (T502,T503,T507, T508 and T509). The highest and lowest κ_1-values obtained from samples T504 and T510 were not included in the averaging. No κ_1-value could be obtained from sample T501 because of loading schedule (section 3.2). The high κ_1-value of sample T504 (κ_1 = 2.50) was possibly due to sample disturbance introduced accidentally when filling the triaxial cell with a layer of engine oil with the bleeding valve closed. As a result, the sample had experienced a high isotropic stress (approx. 70 psi) prior to testing. This is supported by the high κ_1-value obtained in sample T505 which was consolidated isotropically from the beginning of the test.

Although sample T506 had also been isotropically consolidated, the low κ_1-value (0.179) probably resulted from a sudden loss of pressure on one occasion in the laboratory, because a tubing connector failed overnight. As a result, the sample experienced a period of axial loading without lateral support, and the κ_1-value reflects this period of anisotropic consolidation.

3.3.1.2 λ_1-values

Once the vertical stress of the sample exceeded its maximum cylinder stress, the sample changed from over-consolidated to normally consolidated behaviour. This is associated with a change in stiffness of soil, which can be identified usually with a change of slope in V, log p'-space. This process is called yielding. In the present study, post-yield behaviour of the clay is substantially linear in log(stress)-space over a large range of stresses after yield (e.g. Fig. 3.3b). Unlike the behaviour of natural Winnipeg clay, as shown for example by Figure 7 of Graham, Noonan and Lew (1983), no marked collapse of the particle structure was observed after yielding. The behaviour went directly into exponential compression, as shown for example by straight λ-lines in the Critical State Model. Further discussion on this topic is given in Chapter 6.

The values of λ_1 for samples T501 to T510 (ranged from 0.268 - 0.436) are tabulated in Table 5. An average λ_1-value of 0.363 was calculated from the samples which had been K_o-consolidated. This value is rather higher than λ = 0.305 obtained from first-time yielding of natural Winnipeg clay (Graham, Noonan and Lew, 1983), but lower than the post-compression value = 0.469 (C_c = 1.08).

3.3.1.3 Yield Determinations

Yield stresses have been interpreted from a variety of stress-strain relationships (Figs. 3.8 - 3.19). In the present study, a computer program TXCEP (Appendix 2) was developed to reduce and plot drained triaxial consolidation data. This program also included energy calculations (Lew, 1981). It produces six different stress-strain plots, which can be used in determining yield stresses, as follows: i) p', v; ii) q, ε; iii) σ_1', ε_1; iv) σ_3', ε_3; v) p', ε_1 and vi) W, LSSV. This section reports only yield stresses obtained from the 'first-time' loads. Second yields of samples T507-T509 are reported in section 3.3.2. The main purpose of establishing the first yields was to evaluate the validity of different yield criteria, by comparing the yield stresses obtained from different graphs with the cylinder stress levels. Yield stresses were identified by bilinear plotting techniques (Graham et al, 1982). Stresses and energies at yield from the graphs mentioned above were converted to a common stress variable p' (effective mean principal stress) for comparison purposes (Table 4). Values of p_y' were then converted to vertical stress σ_{vc}' using the known K-value and compared with $\sigma_{cy\ell}'$ (Table 5).

Tests T505 and T506 followed 'isotropic' stress paths (Fig. 3.1), with a small constant shear stress of about 5 kPa to ensure contact between the piston and the sample during the test, so that height changes of the sample could be monitored. Results from sample T506 have not been included because of the equipment problem mentioned in section 3.3.1.1.

To determine yielding for T505, all of the yield criteria mentioned earlier were examined in the usual way. In this case, however, the q vs ε plot (Fig. 3.11d) provides no information concerning yielding because q is essentially constant throughout the test. However, σ_1' vs ε_1 (Fig. 3.13d), σ_3' vs ε_3 (Fig. 3.15d), p' vs ε_1 (Fig. 3.17d) and W vs LSSV (Fig. 3.19d) are useful. The yield stresses or energies are indicated on the figures, and the equivalent mean effective stresses at yield p_y' are given in Table 4. It should be noted that p' vs v (Fig. 3.9d) was not used. This will be discussed later in Chapter 6.

Samples T501 to T504 and T507 - T510 had their first yields along the approximate K_o-stress path given by $\sigma_{1c}'/\sigma_{3c}' = 0.62$ (Fig. 3.1). Due to the different testing procedure of sample T501 (section 3.2), the sample was not included in evaluating the yield stresses from different criteria. Figures 312a - 3.13c show plots of σ_1' vs ε_1 of the remainder of the tests. For T502 and T504 (Figs. 3.12a and 3.12b), strain hardening behaviour was observed at axial strains of about 12 percent. This was also observed in natural Winnipeg clay (Baracos et al, 1980; Noonan, 1980; Lew, 1981). Similar stress-strain relationships were found in the p' vs ε_1 plots (Figs. 3.16a and 3.16b).

The bilinear plotting technique was also applied to graphs of p' vs v, q vs ε and W vs LSSV. These are shown in Figures 3.8a - 3.9c, Figures 3.10a - 3.11c, and Figures 3.18a - 3.19c, respectively. However, the initial sections of samples T503 and T504 did not reveal typical 'elastic' behaviour in p', v-space (Figs. 3.8c and 3.8b). Dr. J. Graham has suggested that this might be an indication of high creep rate as a result of undissipated excess porewater pressures in the early stage of the tests. Another explanation is that the samples had possibly been disturbed (section 3.3.1.1). No yield stress was therefore obtained from this plot for samples T503 and T504. Non-linearity was also observed in

T505 (Fig. 3.9d), which followed an 'isotropic' stress path. The initial part of the q, ε relationship for sample T504 (Fig. 3.10b) was not typical and the reason for such behaviour was unclear. It is interesting to note the remarkably straight pre-yield and post-yield sections obtained from the W vs LSSV plots for all the K_o-consolidated samples. Unlike the natural samples tested by Lew (1981), no exponential behaviour was observed in the W vs LSSV for the remoulded samples (Fig. 3.18a - 3.19c).

Figures 3.14a - 3.15c show plots of σ_3' vs ε_3 for all the K_o-consolidated samples. They do not indicate bilinear behaviour. They showed that the samples compressed laterally as they were loaded to a certain pressure, and then changed to lateral expansion (or dilation) behaviour at higher pressures. Attempts were made to relate yield stresses identified earlier with the stress state at which the lateral strains started to reverse.The reversal points were at stresses much higher than the 'cylinder' stress levels and it was considered inappropriate to treat them as yield points. Dr. J. Graham suggested that might be a reflection on the mechanical bending of clay platelets. However, the bilinear plotting technique was possible with sample T504 (Fig. 3.14b) and the yield stress seems to be reasonable.

Except for the σ_3' vs ε_3 plots, which have just been discussed, yield stresses obtained from all the other yield criteria are in close agreement with each other (Table 4). The average p_y' obtained from different plotting techniques were converted to σ_{vc}' using K = 0.62 and compared with the 'cylinder' stresses $\sigma_{cy\ell}'$ in Table 5. They agree closely, with an average difference of 4.3 percent. The averaging was based on the differences in magnitude only; no sign was included. Further discussion will be presented in Chapter 6.

3.3.2 Unloading and Reloading

In the present study, five samples (T503,T507,T508,T509 and T510) were K_o-unloaded from approximately σ'_v = 160 kPa to σ'_v = 80 kPa to create an overconsolidation ratio (OCR) of 2. They were then subjected to undrained shear tests, or to drained compression tests, at different stress paths (Fig. 3.1b) to determine the yield envelope of the remoulded clay. This section reports only the drained results of samples T507, T508 and T509. The undrained shear results (T503,T510) are presented in Chapter 4.

Unload and reload stress-strain results for samples T507 - T509 were plotted in V, log p' space (Figs. 3.6a,3.6b and 3.7a). The reload κ_2 values are tabulated in Table 5. All κ_2 values are lower than their corresponding κ_1 values. Samples T503, T507 and T508 were unloaded in two load increments to give an OCR of 2. Quite high creep displacements were observed (Figs. 3.4a,3.6a and 3.6b). Samples T509 and T510 were off-loaded in one increment to reduce this problem.

Both T507 and T508 were stressed beyond their yield states. The λ_2-values were close to corresponding λ_1-values in both cases (Table 5).

Yield stresses for samples T507 - T509 were determined by the yield criteria mentioned in section 3.3.1.3, and the equivalent p'_y values are tablulated in Table 4. A significant level of agreement was obtained from different plots (Table 4). The average values of p, q established using the various criteria were used for defining the yield envelope in p', q space in Figure 3.20.

3.3.3 Bulk and Shear Moduli

In order to describe cross-isotropy of clays by means of anisotropic elasticity theory, five elastic parameters are needed (Graham and

Houlsby, 1983). Pseudo-elastic equivalent bulk and shear moduli, K_{eq} and G_{eq} can be obtained from the pre-yield linear sections of p', v and q, ε curves (e.g. Figs. 3.8a and 3.10a). These values are tabulated in Table 6. The stiffness of lightly overconsolidated clays is related to preconsolidation pressure σ'_{vc}. For example, in these clays, the ratio of E_{50}/s_u can be used to express stiffness under direct compressive stresses, and s_u/σ'_{vc} is approximately constant when OCR is less than 2.5 - 3.6 (Graham, 1979; Larsson, 1980). Thus an isotropic, but non-homogeneous lightly overconsolidated deposit can be expected to have constant values of K_{eq}/σ'_{vc} and G_{eq}/σ'_{vc}. However, Graham and Houlsby (1983) showed that these parameters for natural Winnipeg clay are not constant, but depend on stress path. The clay is therefore anisotropic. The values of K_{eq} and G_{eq} obtained in the present study plotted against $\theta = \arctan(\Delta q/\Delta p')$ are compared with the results of Graham and Houlsby (1983) in Figures 3.21a,b. The results agree rather closely. They will be discussed further in Chapter 6.

CHAPTER 4

UNDRAINED SHEAR TEST RESULTS

4.1 INTRODUCTION

Samples which had not failed during the drained stress-controlled portion of the test were transferred to a 10 kN strain-controlled compression frame for undrained shearing to rupture. To ensure that the samples were fully saturated prior to shearing, a back-pressure of around 210 kPa was applied. Results of the undrained shear testing are summarized in Table 7. Values of the porewater pressure parameter B can generally be considered satisfactory, although in one or two cases (e.g. T506) is rather low. All samples were sheared at a strain rate of about 1 percent/hour. The undrained shear tests allowed examination of stress-strain and porewater pressure parameters of the clay. These include the undrained shear strength, the normally consolidated Coulomb-Mohr rupture envelope, the porewater pressure parameter A_f, the strain-rate parameter $\rho_{0.1}$, and the elastic modulus E_{50}.

Failure stresses from undrained tests on the overconsolidated samples (T503 and T510) were used, in conjunction with the results from the drained stress-controlled tests (T507,T508 and T509) to identify the yield envelope in the overconsolidated region (Fig. 4.1b).

The following sections will present the undrained results in more detail.

4.2 STRESS-STRAIN RELATIONSHIPS

The stress-strain conditions for each sample prior to undrained shearing were summarized in Table 3. Graphs of $(\sigma_1-\sigma_3)/2\sigma'_{1c}$, σ'_1/σ'_3 and $\Delta u/\sigma'_{1c}$ versus ε_1 are shown in Figures 4.1 to 4.9. The effective stress paths in (p',q) stress space are shown in Figure 4.10 for each test and the complete shear test results are summarized in Table 7. For tests T501, T503, T504, T507, T508 and T510, the stress-strain curves (Figs. 4.1,4.3,4.4,4.7,4.8 and 4.9) appear broken because of the relaxation tests used to investigate the strain-rate effect. This will be reported in Section 4.6.

Some of the samples were consolidated isotropically and others anisotropically to stresses above and below σ'_{vc} before they were put into undrained shearing. For normally consolidated CAU samples with $\sigma'_{1c} = \sigma'_{vc}$ (T501,T502,T504 and T507), maximum deviator stresses were found to occur at 0.6 to 0.7 percent axial stress (Fig. 4.1,4.2,4.4 and 4.7). Strain softening behaviour was observed after they had reached their peaks. However, the strain softening effect observed in these remoulded samples was not as marked as that in the natural clay samples tested by Lew (1981) and Au (1982). For overconsolidated CAU samples $\sigma'_{1c} < \sigma'_{vc}$ (T503 and T510), maximum deviator stresses occurred at higher strains, of between 1 - 1.5 percent (Figs. 4.3 and 4.9). In both normally and overconsolidated CAU samples, the deviator stresses rise quickly to peak values and then decrease with increasing axial strain exhibiting strain-softening behaviour. This is more marked in the overconsolidated samples (Figs. 4.3 and 4.9).

One possible factor of strain softening observed in both natural and remoulded samples was their common mineralogy. However, this is not the only factor involved because the strain softening effect was not as significant in the remoulded samples as the natural samples tested by Lew (1981). Bjerrum and Kenney (1967) suggested that 'peaking' resulted from failure of the structure of the soil skeleton, and subsequent straining led to mobilization of inter-particle sliding (frictional) resistance. Comparison of the stress-strain characteristics of the remoulded and natural clays suggest that Winnipeg clay in its natural state possesses a significant structural strength. This supports the suggestion by Graham, Noonan and Lew (1983) that the clay is cemented. The lower degree of strain softening observed in the remoulded samples can be explained by their higher densities (lower specific volumes). This can be inferred from the moisture contents presented in Table 1. They therefore possess higher frictional resistance. This will be discussed in Chapter 6.

Figures 4.5 and 4.6 show the stress-strain behaviour of samples which had been isotropically consolidated to stresses higher and lower than their σ'_{VC}-values. Sample T505 was normally consolidated and sample T506 was overconsolidated CIU samples. Undrained shearing of these samples showed that the deviator stresses rise gradually to maximum values, at which point they remain relatively constant for subsequent straining. The maximum deviator stresses of the CIU samples occurred at much higher axial strains (4 - 6%) than that of samples which had been anisotropically consolidated. Similar behaviour was also observed in the natural clay samples (Lew, 1981), confirming that consolidation history has considerable effect on stress-strain behaviour of clay samples (Crooks and Graham, 1976). The stress-strain behaviour of sample T508 (Fig. 4.8) was very similar to that of T505, because the consolidation stress path it had taken ($\theta = -5°$) was very close to the 'isotropic' stress path (Fig. 4.1b).

4.3 EFFECTIVE STRESS PATHS

The effect of consolidation history on undrained shearing behaviour is shown clearly by the effective stress paths during shearing (Fig. 4.10). Effective stress paths of samples which had been consolidated (isotropically or anisotropically) above their σ'_{vc} (T501,T502,T504,T505,T507 and T508) generally shifted leftwards in the early stages of the tests to give lower p' values than the final p' in the drained part of the tests. This loss of effective stress was due to undissipated excess porewater pressures remaining in the samples at the end of the drained testing. Those samples were back-pressured immediately after a standard 24-hour load increment. T501, T505, T507 and T508 experienced an average leftwards shift corresponding to a porewater pressure Δu = 14 kPa. The stress paths of samples T502 and T504 had lower excess porewater pressures because they were allowed to consolidate for 48 hours prior to back-pressuring.

Porewater pressures generated during the initial stage of shearing the normally consolidated CAU samples. T501, T502, T504 and T507 were substantially linear with respect to changes in total mean principal stress (Fig. 4.14). As a result, the effective stress paths (Fig. 4.10) were almost linear, almost vertical, but slightly inclined to the left until just before the maximum shear stresses were reached. After this point shear strains began to have a significant influence on the porewater pressures. The stress paths moved sharply to the left, indicating the breakdown of soil structures developed through consolidation.

Although sample T508 had been loaded - unloaded anisotropically, the sample behaved more like sample T505, which had been consolidated isotropically. This was because sample T508 followed a stress path of increasing p' with gradually decreasing q, (Fig. 4.1b). The stress paths of these two samples were remarkably similar. They were more rounded as they approached their maximum shear stresses and then continued to decrease gradually toward the left. The initial sections were linear, but not as steep as the anisotropic stress paths. Using the undrained shear strengths of this test program (Table 7), a normally consolidated Coulomb-Mohr envelope for the remoulded Winnipeg clay is proposed (Fig. 4.11). The proposed Coulomb-Mohr envelope is slightly curved with smaller ϕ' in the increasing p' direction. Details are presented in Chapter 6.

The influence of overconsolidation was clearly demonstrated by the effective stress paths of the two overconsolidated CAU samples (T503 and T510). The initial sections of these stress paths were almost straight and cross the Coulomb-Mohr rupture envelope. Because the porewater pressure decreases slightly after about 75 percent of the shear strength has been applied, the stress paths curve to the right before reaching the maximum shear stress. After reaching this peak stress, the samples tend to dilate on further straining. This is accompanied by a decrease in porewater pressure, and the shear stress drops abruptly, drawing the effective stress paths toward the left, forming 'hooks'.

Sample T506 was also an overconsolidated sample, but was consolidated isotropically. The effective stress path (Fig. 4.10) of this sample is also remarkably straight, similar to those of T503 and T510. However, the 'hook' formed in the opposite direction, indicating that the sample tended to compress, rather than dilate, after the maximum shear stress was reached, (see also Fig. 4.17). Discussions concerning the anisotropy of the remoulded samples are presented in Chapter 6.

4.4 POREWATER PRESSURE GENERATION

The relationships between $\Delta u/\sigma'_{1c}$ and ε_1 for all the undrained shear samples are given in Figures 4.1 to 4.9. Porewater pressures generated at the beginning of the undrained shearing rose quickly until the maximum deviator stress was reached. For samples which had been anisotropically unloaded (T503 and T510) to give an OCR $\simeq$ 2, the porewater pressure started to decrease before the maximum deviator stresses were reached, (Figs. 4.3 and 4.9), showing peaks in the curves. Similar peaks were also observed in natural samples (Lew, 1981; Au, 1982), but they occurred after the maximum deviator stresses were reached. For normally consolidated CAU samples, and all the CIU samples, the porewater pressures after q_{max} continued to rise at a slower rate. It was observed that most anisotropically consolidated samples had fairly constant porewater pressure at large strains ($\varepsilon_1 \simeq 10\%$).

The porewater pressure parameter $A = \Delta u/\Delta(\sigma_1 - \sigma_3)$ (Skempton, 1954) was obtained from each test and tabulated in Table 7. Figures 4.12 and 4.13 show the relationship of A_f plotted against $1/\sigma'_{1c}$ and overconsolidation ratio OCR respectively. The values of A_f for overconsolidated samples which had been K_o-consolidated (T503 and T510) are 0.31 and 0.23. For normally consolidated CAU samples, the values of A_f range from 0.54 to 0.94. These values are generally lower than those obtained from natural samples (Lew, 1981; Au, 1982). The difference may be due to the cemented structure (Graham, Noonan, Lew, 1983) of the natural Winnipeg clay.

Porewater pressure behaviour is also examined in normalized values of $\Delta u/\sigma'_{1c}$ versus $\Delta p/\sigma'_{1c}$ (Fig. 4.14 - 4.17) for both normally and overconsolidated samples. In studying natural Winnipeg clay, Baracos et al, (1980) revealed that a linear relationship exists between the change in porewater pressure and the change in total mean principal stress in the initial stage of testing. Similar results were obtained by Lew (1981). In the present study, most CAU samples, which had been normally consolidated, gave initial linear (Fig. 4.14) relationships in the $\Delta u/\sigma'_{1c}$ versus $\Delta p/\sigma'_{1c}$ plots. The gradients of the linear section, m, are summarized in Table 7. These values range from 1.3 to 2.7 with an average of 2.0, which were found to be generally higher than equivalent values observed in natural samples. At larger strains, normally consolidated samples produce strongly increasing porewater pressures. For samples which has been unloaded anisotropically (T503 and T510), the initial relationship in the $\Delta u/\sigma'_{1c}$ versus $\Delta p/\sigma'_{1c}$ plots was slightly curved and became distinctively non-linear thereafter (Fig. 4.15). The initial curved behaviour was also observed in 'undisturbed' samples at low stresses ($p'_o/3$) and 'fully-softened" samples (Au, 1982).

For CIU samples, which has been normally consolidated (T505), the relationship of $\Delta u/\sigma'_{1c}$ versus $\Delta p/\sigma'_{1c}$ is curvilinear and the porewater pressures are considerably higher than the CAU tests. A similar trend is also observed in T508 (Fig. 4.15), which had been reloaded following a $\theta = -5°$ stress path. Sample T506 had been isotropically unloaded to give an OCR $\simeq$ 2. The m value obtained for this sample is 1.3, which is closest to the line m = 1, where $\Delta u = \Delta p$, ($\Delta p' = 0$). Figure 4.17 shows the plot of this test.

4.5 'E_{50}' PARAMETER

In the present study, the non-linearity of the $(\sigma_1-\sigma_3)$ versus ε_1 curves from undrained shearing tests has been approximated by a secant modulus E_{50} from the end of consolidation to 50 percent of the reserve resistance (Graham, 1974). Values of E_{50} have been normalized by dividing by undrained strength $s_u = (\sigma_1-\sigma_3)_{max}/2$ to give what is known as the relative stiffness, E_{50}/s_u. Table 7 summarizes all values of E_{50} and E_{50}/s_u. As in most studies of this type, the results vary considerably with test type, and show significant scatter (Fig. 4.18).

In both isotropically and anisotropically consolidated samples, E_{50}/s_u values from normally consolidated samples are generally higher than the corresponding overconsolidated samples. A similar phenomenon was observed in natural Winnipeg clay samples (Lew, 1981). However, the remoulded samples generally had higher relative stiffness values than those of natural samples. It is interesting to note that the testing of Norwegian quick clay has the opposite experience (Bjerrum and Kenney, 1967), in which overconsolidated samples were found to have higher relative stiffness values.

4.6 '$\rho_{0.1}$' PARAMETER

Bjerrum, Clausen and Duncan (1972) have drawn attention to the large variations in undrained shear strength $(\sigma_1-\sigma_3)_{max}/2$, which accompany changes in straining rate during the testing of carefully sampled natural clays. Crooks and Graham (1976) demonstrated that an axial strain-rate effect is important for Belfast soft clays, and have recently generalized their studies to an examination of a wide range of natural soils (Graham, Crooks and Bell, 1983). In the present study, the strain rate effect on remoulded samples was examined using the 'relaxation' test described by Kenney (1966).

The strain rate effect can be represented by a parameter $\rho_{0.1}$, which describes the percentage change in shearing resistance produced by a tenfold change in strain rate, referred to the shearing resistance at a strain rate of 0.1 percent/hour.

In this testing program, relaxation procedures were performed on samples T501, T503, T505, T507, T508 and T510, as shown in Figures 4.1, 4.3, 4.5, 4.7, 4.8 and 4.9. The procedures were performed at different axial strains to examine the dependency of strain rate effects on the magnitude of strain. The $\rho_{0.1}$ values obtained from these tests are tabulated in Table 7, and range from 5 to 8 percent (Fig. 4.19). These values are rather more consistent than values obtained from natural samples (Lew, 1981; Au, 1982), but are of the same general magnitude. These values are rather lower than are commonly found for many clays (Graham, Crooks and Bell, 1983). In general, the $\rho_{0.1}$ values decreased with increasing axial strain (Fig. 4.20). This confirms earlier work by Lew (1981), and Graham, Crooks and Bell (1983). The values of $\rho_{0.1}$ versus plasticity index for these tests are plotted along with data from Figure 7a of Graham, Crooks and Bell (1983), and are shown in Figure 4.21. This confirms that $\rho_{0.1}$ is essentially independent of plasticity index I_p.

CHAPTER 5

OEDOMETER AND CRS TEST RESULTS

5.1 INTRODUCTION

This chapter reports the one-dimensional consolidation results obtained from conventional and constant rate of strain (CRS) oedometer tests. The different test procedures were described in sections 2.4.2, 2.5.2 and 2.5.3. Each remoulded oedometer sample was obtained from clay immediately adjacent to a triaxial sample in the same reconsolidation cylinder. Table 8 lists the oedometer test numbers, together with the corresponding triaxial test numbers for comparison purposes.

5.2 CONVENTIONAL OEDOMETER CONSOLIDATION

In the present study, three different types of sample were tested in conventional oedometer cells. These samples were: i) remoulded samples, ii) 'fully-softened' natural samples, and iii) 'freeze - thaw' natural sample. Their results are reported in sections 5.2.1, 5.2.2 and 5.2.3, respectively.

5.2.1 Remoulded Samples

In addition to the triaxial tests, four conventional oedometer tests (C512-C515) were carried out to investigate their consolidation behaviour. The samples were 76 mm in diameter and 25 mm thick. A computer program OEDOMP (Appendix 2) was developed to reduce and plot the test data. It produces three different plots, namely, i) V vs σ_v' , ii) V vs log σ_v' and iii) ε_v vs log σ_v' . Log σ_v' , V curves for the four oedometer tests are shown in Figures 5.1 - 5.4. All the curves reveal a change from low to high compressibility at a vertical stress close to the 'cylinder' pressure $\sigma'_{cy\ell}$. Casagrande's empirical method was used to determine preconsolidation pressures σ'_{vc}. These values of $\sigma'_{cy\ell}$ and σ'_{vc} along with the κ and λ-values were tabulated in Table 9. The λ-values ranged from 0.340 to 0.392 with an average of 0.367. The value is very close to the average λ-value obtained from triaxial tests ($\lambda = 0.363$). However, λ-values from oedometer results show much less scattering than that of the triaxial results. The average κ-values obtained were generally lower than those from the triaxial tests. Results from C512 and C514 (Figs. 5.1 and 5.3) appeared to have non-regular spacing of data points. This was due to the use of different load increment ratios (LIR). In the present study, different load increment ratios were examined and they are marked on the figures.

Post-yield behaviour for samples C512, C514 and C515 (Figs. 5.1, 5.3 and 5.4) is linear but gradually goes to exponential behaviour at large strains. To assist in trying to determine if the linear-to-exponential shape of these curves is due to cementation, or to some other phenomenon, natural strains (Graham et al, 1982) were calculated for test C515. Results are shown in Figure 5.5, together with the stress strain results in terms of engineering strains. The 'natural strain curve' deviated from the 'engineering strain curve', especially at large strains and exhibited essentially linear post-yield behaviour. This suggests that the clay is not cemented.

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5.2.2 Fully-Softened and Freeze - Thaw Samples

Au (1982) suggested that σ'_{vc}-values should be confirmed by performing standard one-dimensional oedometer tests on 'fully-softened' and 'freeze - thaw' samples. In response to these suggestions, two 'fully-softened' (C501 and C502) and two 'freeze - thaw' (C503 and C504) oedometer tests were performed on Winnipeg natural clay in the present study. The samples were trimmed from block samples obtained from a depth of 8.7 m, which was the same depth as the 'fully-softened' and 'freeze - thaw' triaxial samples tested by Au (1982).

Figure 5.6 shows the V, log σ'_v curves of the 'fully-softened' samples C501 and C502, respectively. Results obtained from both tests were remarkably similar. The calculated average κ and λ-values were 0.092 and 0.293. The preconsolidation pressures were estimated by means of Casagrande's empirical method to be 315 and 324 kPa, respectively. Table 9 summarizes all the consolidation parameters mentioned above. It is interesting to note that sharp σ'_{vc} breaks were still observed, despite the significant swelling allowed ($\varepsilon_1 \simeq 3\%$) prior to testing. This phenomenon is contrary to the argument (Leroueil et al, 1979) that swelling causes sample disturbance and give rounded V, log σ'_v curves.

Figure 5.7 shows the V, log σ'_v curves for the 'freeze - thaw' samples (C503 and C504). Unlike the behaviour of the 'fully-softened' samples, no marked σ'_{vc}-break were observed in the 'freeze - thaw' samples. Both samples show a very slight change of slope at around 500 kPa vertical pressure. D.H. Shields (personal communication) has suggested that the nugget structure resulting from 'freeze - thaw' cycles causes the clay to show no yield behaviour. The slight changes of slope in both samples at around 500 kPa might represent yielding of the intact clay structure between fissure planes. The average slope for the two test lines in Figure 5.7 gives λ = 0.14. This number lies between the κ-and λ-values obtained from 'undisturbed' clay samples (Lew, 1981). 'Freeze - thaw' cycling therefore causes significant changes in the behaviour of originally intact clay.

5.3 CONSTANT RATE OF STRAIN (CRS) TESTS

Six CRS tests were performed on remoulded Winnipeg clay. A new CRS cell, described by Romanetz (1983) in his undergraduate thesis, was used for the tests (Fig. 2.4). The main advantage of the new CRS cell, over the previous one (Au, 1982), is its ability to allow back-pressuring procedures to assist saturation. Sample preparation and test procedures were outlined in sections 3.4.3 and 3.5.3. In the present study, three samples were tested under a back-pressure of 200 kPa (C516A,C516B and C519), and three were without back-pressure (C517,C518 and C520). Results of these tests were plotted in ε_v,log σ'_v spaces and are presented in Figures 5.8 - 5.13.

Two methods of graphical construction, namely bilinear intersection and Casagrande's method were used in establishing σ'_{vc}-values from the ε_v, log σ'_v curves. With these tests, the bilinear technique was found to give σ'_{vc}-values closest to the $\sigma'_{cy\ell}$-values. Casagrande's method gives σ'_{vc}-values higher than the $\sigma'_{cy\ell}$-values, and has therefore not been used in the present study.

A strain rate of 0.004 mm/minute (or approx. 1%/hr.) was used for all CRS tests. The effect of strain rate on σ'_{vc} was investigated in sample C518 (Fig. 5.11) by step changing technique (Sallfors, 1975; Bell, 1977).

The two strain rates used were 0.004 mm/minute to 0.005 mm/minute in this test. Assuming that the slopes of the reload and normal consolidation portions of the curves are unaffected by the change in strain rate, two compression curves were obtained by extrapolation. The relationship between σ'_{vc} and strain rate is shown in Figure 5.14 and the value of $\eta_{0.1}$ was calculated to be 17.2 percent. This value is plotted along with other $\eta_{0.1}$-values obtained from various soil types and tests in Figure 5.15. It is interesting to note that the $\eta_{0.1}$-values of Winnipeg natural clay (Graham, Crooks and Bell, 1983) are generally lower than the $\eta_{0.1}$-value obtained in the remoulded sample. However, both of them, like most of the various soils, lie within a narrow range of 10 to 20 percent (Graham, Crooks and Bell, 1983).

The σ'_{vc}-values obtained vary from 60-96 kPa (Table 10). Although these values did not agree closely with each other, they are certainly in the right order of magnitude. The compression index, $C_c(\lambda = C_c/2.303)$ from the six CRS tests ranged from 0.811 to 0.955 with an average of 0.889. This C_c-value is close to the average value obtained from conventional oedometer tests ($C_c = 0.845$) on remoulded samples (Table 9).

CHAPTER 6

DISCUSSION OF RESULTS

6.1 INTRODUCTION

The present study of remoulded Winnipeg clay involves three different types of test, namely, triaxial, oedometer and Constant Rate of Strain (CRS) tests. In general, the test results have been reported in detail in Chapters 3 to 5. They are further examined by topic in the remainder of this chapter, in order to have a more detailed understanding of the clay behaviour. Where possible, the results are compared with similar results for natural Winnipeg clay reported by Graham, Noonan and Lew (1983).

6.2 DRAINED COMPRESSION BEHAVIOUR

6.2.1 One-Dimensional NCL and Critical State Line (CSL)

Graham, Noonan and Lew (1983) were the first to use the concepts of Critical State Soil Mechanics to analyze consolidation data obtained from the testing of natural Winnipeg clay. One interesting aspect discussed in their paper was that the Critical State Line (CSL), the one-dimensional NCL and the isotropic NCL were parallel to each other in V, log p'-space. Critical State consolidation parameters, such as κ, λ and Γ were evaluated from both drained and undrained triaxial compression tests. The parallelism of the one-dimensional NCL and the CSL of natural Winnipeg clay has an important implication because the Critical State Line (CSL) and the NCL can be described by lines with the same slope: $V = \Gamma - \lambda \, \ell n p'$ in V, $\ell n p'$-space (or in V, log p'-space since $\ell n p' = 2.303 \log p'$).

Another important aspect of the paper is that Critical State Soil Mechanics concepts are applicable not only in remoulded clays, but also in natural clays. This relationship has been reported for only a very limited number of natural clays.

One objective of the present work on remoulded Winnipeg clay was to provide results for a comparative study in the light of Critical State Soil Mechanics. As mentioned in section 3.1, the drained portion of the triaxial tests were designed to investigate different aspects of consolidation behaviour. This section of the thesis presents the estimated one-dimensional NCL and the Critical State Line (CSL) in V, log p'-space. Section 6.2.2 will discuss the yield states and present the preliminary shape of the yield envelope for the clay.

The one-dimensional NCL and CSL for the remoulded Winnipeg clay are constructed in Figure 6.1, based on results from four triaxial tests (T501, T502,T504 and T507). Samples T501, T502 and T504 were consolidated along the approximate one-dimensional ($K_o = 0.62$) stress-path beyond their preconsolidation pressures, σ'_{vc}. These samples had different final consolidation pressures in their normally consolidated states prior to triaxial undrained shearing. The specific volume corresponding to the final consolidation state of each sample was calculated from its final moisture content, which was obtained immediately after the undrained shearing test.* The three points obtained from these samples resulted in a quite well-defined straight line with $\lambda = 0.313$ in V, log p'-space. This straight line was defined as the one-dimensional NCL for the remoulded Winnipeg clay. The λ-value

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* $\Delta V = 0$ in undrained shearing tests.

obtained here (λ = 0.313) is slightly different from the average λ = 0.363 reported in section 3.3.1.2. The latter value was averaged from the λ-value measured from 'forward calculations'.* Based on this second method, the calculated final points of the tests resulted in a large scatter in the V, log p'-space and thus the second method was not adopted in defining the one-dimensional NCL.

It was originally thought that the final consolidation state of sample T507 should also line up with the other three points, because it was loaded - unloaded - reloaded beyond its preconsolidation pressure along the K_o-stress path. However, the final specific volume calculated, based on its final moisture content, was rather higher than that of the one-dimensional NCL formed earlier, as shown in Figure 6.1.The only difference in test procedure applied in sample T507 was the unload - reload step. Detailed reasons why the specific volumes for this should not agree with those from the other tests are unclear. One possible explanation might be that the exponential behaviour at large engineering strains pushes the final part of the log p', V curve outward to the right, and thus results in high specific volumes for a given mean principal stress, p' (e.g., see Fig. 5.5). However, this is probably not an adequate explanation because sample T502 was loaded one-dimensionally to approximately the same stress level and did not show the same behaviour.

The p'-values corresponding to the q_{max}-values for samples T501, T502, T504 and T507 obtained during undrained shearing tests are plotted as open triangles in Figure 6.1. Since the shearing tests were carried

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* Specific volumes at different stages were calculated on the basis of initial moisture content obtained from trimmings, plus the volume changes measurements throughout the test.

out under undrained conditions, each p'-value corresponding to its q_{max}-value can be plotted at the same specific volume. A straight line was drawn parallel to the NCL ($\lambda = 0.313$) was also found to fit well with test data shown as open triangles in Figure 6.1. This line was defined as the Critical State Line (CSL). It should be noted that due to the difficulty discussed earlier, the Critical State value for sample T507 was taken from the assumed NCL position, which was plotted as an open circle in Figure 6.1.

The concept of undrained strength at large strains (USALS) has been known for some time (LaRochelle et al, 1974). Au (1982) observed a marked post-peak drop of shear strength in his testing of natural Winnipeg clay in the low effective stresses region of p', q-space (e.g. see Fig. 4.20 of Au, 1982). He observed that the p'-values corresponding to USALS approach the CSL proposed by Graham, Noonan and Lew (1983). Figure 5.3 of Au's thesis showed that differences in effective mean principal stresses ($\Delta p'$) were only a few kilopascals between the USALS and q_{max} criteria for these samples coming from the 'wet'* side of the CSL. Since the drops in shear strength are relatively small after q_{max} in the present remoulded samples (Figs. 4.1 - 4.9), the USALS criterion has not been examined further.

As other researchers have found (e.g. Au, 1982; Graham, Noonan and Lew, 1983), it is more difficult to determine the CSL based on the data from the 'dry'* side because of large scatter in the test results. Therefore, the CSL proposed in the present study is based only on data from the 'wet' side. In order to confirm the position of the CSL, more tests are required.

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* The terms 'wet' and 'dry' of the CSL refer respectively to states to the right of, or above the CSL; and to the left of, or below the CSL.

Figure 6.1 shows also the CSL, isotropic and one-dimensional NCL of natural Winnipeg clay proposed by Graham, Noonan and Lew (1983). It was observed that Winnipeg clay has very similar λ-values in both its natural and remoulded states, but the remoulded NCL and CSL are on the left side of the natural ones. That is, at a given stress level, a natural sample has higher specific volume than a remoulded sample. It is of interest to note that the distance separating the one-dimensional NCL and CSL for both types of clay are about the same. The ratio between p'-values for remoulded and natural one-dimensional consolidation samples at constant V is around 1.4 (or about 0.044 less in V for a given effective mean principal stress p'). One possible explanation for this difference is a cemented particle structure in natural Winnipeg clay, as suggested by Graham, Noonan and Lew (1983). Figure 7 of that paper presented four different K_o-consolidated results in log (axial stress σ_1) versus specific volume, V space. It was pointed out that the slope right after yield, C_c was not constant, but was steeper than C_y immediately after σ'_{vc}. It became less steep at large stresses and approached the slope C_y at lower specific volumes. The reason for such a behaviour was interpreted as an indication of the breakdown of a cemented particle structure. Comparing the general shape of remoulded K_o-consolidated log (stress), specific volume-curves with those obtained from natural samples described earlier, it was observed that the remoulded curves (e.g. Fig. 3.3b) revealed rather straight post-yield sections throughout the normally consolidated range. Since the one-dimensional NCL was based on yield stresses, it is therefore logical that the remoulded one-dimensional NCL lies below the corresponding line for natural samples.

Campanella and Mitchell (1968) showed that compression indices C_c

of illite do not change with temperature. However, at higher temperatures, the clay reached equilibrium at lower void ratios (specific volumes) for a given vertical pressure (see Fig. 6.2). It is clear that the remoulded clay tested in the present study was consolidated under a higher temperature in the laboratory* than that of the natural clay consolidated in post-glacial Lake Agassiz. The effect of temperature differences upon consolidation might be, therefore, another possible explanation for the difference in the one-dimensional NCL positions. However, it must also be pointed out that the remoulded Winnipeg clay contains smectite as the predominant clay mineral, along with illite and other non-clay minerals (Baracos, 1977). Also it should be noted that the effect of temperature upon consolidation depends on stress level (Plum and Esrig, 1969). Generally, the effect becomes more pronounced at higher pressures(Fig. 6.3).

6.2.2 Yield States

A major problem in determining the yield envelope of a clay lies in establishing criteria by which the yield stresses can be identified. Lew (1981) examined and evaluated the usefulness of different yield criteria. In general, yield stresses were taken as the intersection of straight line approximations of the initial stiff section of stress-strain behaviour, and to the subsequent more flexible response to applied stresses. In the present study, most of the criteria described by Lew were used for evaluating yield stresses (section 3.3.1.3). Bilinear curve-fitting procedures were done with careful judgement (Graham et al, 1981).

Results shown in Figures 3.8 - 3.19 show how these various criteria

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* The laboratory was temperature controlled at around 20°C.

can be used, but more importantly, they demonstrated that clearly defined yield points did exist even in this remoulded reconstituted clay. Samples T503, T507, T508, T509 and T510 were designed to investigate the shape of the yield envelope in p', q-space (section 3.2). The range of yield stresses defined by various yield criteria can be seen in Table 4 and the average yield stresses from the various criteria were used to identify the yield envelope. The average values were plotted dimensionally in kPa in Figure 3.20. Despite the limited data, it is possible to fit the yield envelope of Winnipeg natural clay (Graham, Noonan and Lew, 1983) quite well on the remoulded results from the present study. It is interesting to note that the remoulded yield envelope does not conform to the 'elliptical shape' proposed by the Cam-clay model.

Graham, Noonan and Lew (1983) showed that natural yield envelopes at four different depths were homothetic and can be normalized to a single locus (or perhaps to a limited range of loci, depending on strain rates) (Graham, et al, 1936b) by dividing the yield stress by one-dimensional preconsolidated pressures (Graham, 1974; Bell, 1977; Lew, 1981). However, other representative stress parameters, such as the isotropic yield stress or the mean effective pressure p' at Critical State, are possible alternatives for the normalizing stress. Figure 5 of Graham, Noonan and Lew (1983) shows results for natural Winnipeg clay normalized using σ'_{vc}.

The five yield stresses used to define the yield envelope from remoulded samples were normalized by their respective preconsolidation pressures ($\sigma'_{vc} \simeq 160$ kPa) and the results were plotted in p'/σ'_{vc}, q/σ'_{vc}-space and p'/σ'_{vc}, V-space together with the natural clay results (Fig. 6.4).

The data points in p'/σ'_{vc}, q/σ'_{vc}-space are closely related to the normalized yield envelope in the natural clay proposed by Graham, Noonan and Lew (1983). Because of the difficulty in harmonizing the moisture contents obtained from the 'forward' and 'backward' calculations (as discussed in section 6.1), there is still some uncertainty in determining the specific volumes at yields for samples T507 and T508. With the limited information around the 'small θ region' (Fig. 6.4), (or close to the isotropic region), an elastic wall, which appeared hooked in p'/σ'_{vc}, V-space as the one shown by Graham, Noonan and Lew (1983) could not be identified. It is interesting to note that sample T509, which followed a steeply inclined stress path and failed abruptly, has its rupture very close to the Critical State Line.

6.3 UNDRAINED SHEARING BEHAVIOUR

6.3.1 Undrained Shear Strength

Samples which had not failed during the drained, stress-controlled portions of the testing program were sheared to rupture in undrained conditions. The undrained shear results were presented in Chapter 4. The results show that there is a difference in shearing behaviour between isotropically and anisotropically consolidated samples because of different consolidation histories. For example, the strains (ε_f) required to attain $(\sigma_1-\sigma_3)_{max}/2$ in the CIU samples were rather higher than those of the CAU samples (Table 7). A similar phenomenon was also observed by Lew (1981) in natural clay.

The relationship between $(\sigma_1-\sigma_3)_{max}/2$ and σ'_{vc}* for consolidated undrained tests in remoulded Winnipeg clay is given in Figure 6.5. It can be

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* $\sigma'_{vc} = \sigma'_{1c}$ in normally consolidated samples.

approximated very well by a straight line passing through the origin with slope $s_u/\sigma'_{vc} = 0.27$. There is some tendency for the CIU values to lie below the average for CAU tests.

Figure 6.6 shows a plot of normalized undrained shear strength versus plasticity index, which has been prepared by combining data of this study with that obtained by Trak et al (1980), Larsson (1980) and Lew (1981). Based on data obtained from reported failures of embankments, foundations and large-scale loading tests, Larsson (1980) showed that there is a trend of slight increase in normalized undrained shear strength with increasing plasticity. It was also pointed out that the trend was less certain in organic clays. He suggested that $s_u/\sigma'_{vc} = 0.22$ corresponds to an average for all the clays, but overestimates the s_u in very low-plasticity clays and underestimates s_u in high-plasticity clays.

Winnipeg natural clay was found to have a $s_u/\sigma'_{vc} = 0.22$ (Lew, 1981). This value agrees with the average value suggested by Larsson, but is slightly lower than that of the remoulded clay in the present study.

6.3.2 Normally Consolidated Failure Envelope

A normally consolidated failure envelope for the remoulded Winnipeg clay was constructed on the basis of the test results. Failure points were determined using the $(\sigma_1-\sigma_3)_{max}/2$ criterion in the undrained shear tests. These points were marked by arrows in Figure 4.10. It is noted that sample T509 failed abruptly during the drained test and the failure point was also indicated in the same diagram. The envelope was found to be slightly curved with smaller ϕ' in the increasing p' direction.

Trainor (1982) compared the c' and ϕ' parameters of Winnipeg natural clay, which were postulated by different researchers (Mishtak, 1964;

Crawford, 1964; Freeman and Sutherland, 1974, and Pietrzak, 1979), and indicated some discrepancies in their results, although generally their proposed failure envelopes were in quite good agreement (see Fig. 5.5 Trainor, 1981). From earlier tests, and the results of his own testing, he concluded that the failure envelope of Winnipeg natural clay is curved.

The author's test results agree with Trainor in the fact that the failure envelope of Winnipeg clay is curved. However, it should be pointed out that Trainor's envelope does not distinguish overcondolidated undrained strengths from those of normally consolidated samples. In other words, his envelope is a combined one, rather than a normally consolidated failure envelope. This explains why Trainor's envelope is rather higher than the authors at low stresses (Fig. 4.11).

Winnipeg clay contains 75 to 85 percent clay size minerals. The clay minerals are mainly smectites* and illites in approximately equal amounts, with lesser amounts of kaolinites present (Wicks, 1965; Baracos, 1977). The dominant exchange cation has been found to be calcium (Wicks, 1965).

Mesri and Olson (1970) tested artificially sedimented calcium montmorillonite prepared from a Wyoming Bentonite deposit and concluded that both the normally consolidated and overconsolidated envelopes of this material are curved. The normally consolidated ϕ'-values (tangent) vary from about 27° at low stresses to 14° at much higher stresses. Much of the curvature occurs at low stress regions ($p' < 70$ kPa) and the envelope

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* Generic name, including montmorillonites and bentonites.

becomes substantially linear at high stresses ($p' > 160$ kPa). Similar descriptions can also be used for the failure envelope obtained from remoulded Winnipeg clay. However, the former is slightly higher at $p' < 75$ kPa and rather lower at higher p'-values (Fig. 4.11).

It is rather interesting to note that the ϕ' parameters proposed by different researchers (Lew, 1981; Trainor, 1982; Graham, Noonan and Lew, 1983) are rather similar at $p' > 200$ kPa for Winnipeg clay ($\phi' \simeq 18°$). Olson (1962) suggested that calcium illite has a constant $\phi' = 24°$. Since Winnipeg clay has about equal amount of calcium illite and montmorillonite, the ϕ'-value seems to be reasonable, lying between 24 and 14 degrees.

It is impossible to test the hypothesis that the normally consolidated envelope in natural clay at low stresses is curved (Trainor, 1982), because the clay is lightly overconsolidated in the field. The remoulded samples tested in the present study enable the detailed construction of a normally consolidated failure envelope in this stress region. Results suggest that the normally consolidated failure envelope at low stresses is also slightly curved, but less than the envelope suggested by Trainor.

6.3.3 Porewater Pressure Generation

Skempton's (1954) parameter 'A' is one of the most widely known and used porewater pressure parameters. Henkel (1956) showed that the A-value at failure conditions (A_f), is highly dependent on the overconsolidation ratio (OCR) in general. Crooks (1973) and Lew (1981) confirmed this for Belfast estuarine clays and Winnipeg natural clay, respectively.

Figure 4.13 showed the variation of A_f with overconsolidation ratio for remoulded Winnipeg clay. Also included in the figure are results obtained by Henkel (1956), Crooks and Graham (1976) and Au (1982) for remoulded Weald clay, Belfast natural clay and Winnipeg natural clay, respectively. The variation of A_f with OCR from the present study follows the expected pattern, that is, the value of A_f decreases with increasing degree of overconsolidation and is consistently lower than results of natural Winnipeg clay. However, the A_f-values for the remoulded Winnipeg clay are very close to the results of remoulded Weald clay obtained by Henkel (1956). This suggests that the porewater pressure generation during undrained shearing is closely related to the micro- and macrostructure of soils and is perhaps less related to their mineralogy.

In previous studies by Baracos et al. (1980), A_f-values were plotted against $(1/\sigma'_{1c})$ because of some uncertainty associated with the measured oedometer σ'_{vc}-values. A plot of A_f values $(1/\sigma'_{1c})$ was presented in Figure 4.12 for the remoulded Winnipeg clay. The results support the trend proposed by Baracos et al. (1980), despite the differences between the two clays.

6.4 ANISOTROPY

Most post-glacial clays are deposited in conditions which produce varved, laminated, or banded structures (Quigley, 1980). Even if they appear massively bedded, electron microscopy reveals flocculent, pedal micro-structures with preferred particle orientations (Baracos, 1977). It is not surprising, therefore, that the undrained strengths of such deposits vary with the orientation of the failure surface (Mitchell, 1972; Freeman and Sutherland, 1974; Graham, 1979). That is, the undrained strengths of these clays are anisotropic. Because of periodic deposition of finer and coarser particle sizes, their permeabilities are also anisotropic.

Graham and Housby (1983) have proposed mathematical techniques for describing pre-yield mechanical properties of clays using anisotropic elasticity theory, and for determining appropriate material parameters from triaxial tests. Equivalent moduli K_{eq} and G_{eq} for a particular stress path in anisotropic clay can be described mathematically by the following equations:

$$K_{eq} = \frac{dp'}{dv} = \frac{dp\ Det}{3G^*dp - Jdq} = \frac{Det}{3G^* - J(dq/dp)}$$

$$G_{eq} = \frac{1}{3}\frac{dq}{d\varepsilon} = \frac{1}{3}\frac{dp\ Det}{K^*dq - Jdp} = \frac{1}{3}\frac{Det}{K^* - J(dp/dq)}$$

where, K^* and G^* = Modified bulk and shear moduli.

J = Cross modulus.

Det = Determinant of material matrix = $(3K^*G^* - J^2)$.

NOTE: $$\begin{pmatrix} p \\ v \end{pmatrix} = \begin{pmatrix} K^* & J \\ J & 3G^* \end{pmatrix} \begin{pmatrix} v \\ \varepsilon \end{pmatrix}$$

These equations demonstrate that the equivalent moduli depend on the stress path in p,q space and only the special case of isotropy ($J = 0$) is exceptional. Figures 3.21a and 3.21b, respectively, showed the K_{eq}/σ'_{vc} and G_{eq}/σ'_{vc}-values versus the direction θ of the stress path in p,q-space for Winnipeg natural clay (Graham and Houlsby, 1983). It was clear that the moduli K_{eq} and G_{eq} were not constant with dq/dp, and this was taken as an indication that the clay was anisotropic. Equivalent K_{eq}/σ'_{vc} and G_{eq}/σ'_{vc} values obtained from the present study were plotted against stress path direction θ, together with results obtained from the natural clay (Figs. 3.21a and 3.21b). The remoulded results also show variations of the moduli for different θ. Despite the limited data, it is evident that the clay is anisotropic. More data along different stress paths are needed in order to draw definite conclusions. Graham and Houlsby (1983) pointed out that the moduli obtained from Winnipeg natural samples were rather lower than that might be expected from other soils (Worth et al, 1979). It is rather interesting to note that the K_{eq}/σ'_{vc}-values for both remoulded and natural samples are rather close, but the G_{eq}/σ'_{vc}-values for the remoulded samples are consistently higher than those of the natural samples.

Graham and Houlsby (1983) suggested two more ways to examine anisotropic elastic properties of clay. One of them was to look at the relationship between the volumetric strain (v) and the axial strain (ε_1) of overconsolidated samples in isotropic consolidation tests. T506 was the only sample of this type in the present study. However, due to the difficulties described in section 3.3.1.1, this method was not used.

Another way suggested by Graham and Houlsby (1983) was to study the undrained stress paths of overconsolidated samples. T503 and T510 were sheared under undrained conditions at stresses lower than σ'_{vc}. The early parts of the effective stress paths for these samples (Fig. 4.10) are slightly inclined leftward. This again renders evidence that the clay might have an anisotropic elastic structure. However, the later parts of the stress paths are rather straight vertically. Reasons for such behaviour are still unclear.

6.5 CEMENTATION

Graham, Noonan and Lew (1983) observed that Winnipeg natural samples became highly compressible after σ'_{vc} was reached. After further straining, the V, log σ'_1-curve became less steep, and approached the slope C_y at specific volumes lower than those associated with the one-dimensional NCL in Figure 7 of their paper. Thus, once yielding had occurred the particle structure compressed and post-yield states lay inside the yield surface in p' q, V-space. They suggested therefore, that Winnipeg natural clay is cemented.

Figure 3.3b shows a typical V, log p'-curve for remoulded Winnipeg clay obtained from a K_o triaxial consolidation test. The remoulded curve shows a sharp σ'_{vc}-break and the post-yield section is straight with a constant compression index. This contrasts clearly with the earlier tests on undisturbed samples. It offers confirmatory evidence that Winnipeg clay in its natural state is cemented and that the cemented structure is destroyed through remoulding.

There are two more pieces of evidence from the present study, which support the view that Winnipeg clay in its natural state is cemented. Firstly, as mentioned in section 4.3, the values of A_f obtained from the remoulded samples were generally quite significantly lower than those of the natural samples (Fig. 4.13). Secondly, when comparing the undrained stress-strain characteristics of the overconsolidated natural with the remoulded samples (see for example, Fig. 4.20 of Au (1982) and Fig. 4.3 of this thesis), the natural sample exhibits relatively larger decrease of post peak shearing resistance (USALS). This again can be argued as being due to the effect of cementation upon the structural strength of natural Winnipeg clay.

6.6 STRAIN RATE EFFECT

Until recently, it has generally been considered that time effects influence the stress-strain behaviour of clays in only a relatively minor way. Graham, Crooks and Bell (1983), however, showed that important engineering properties, such as s_u and σ'_{vc} of a wide variety of lightly overconsolidated naturals, are significantly time-dependent. Strain rate parameters $\rho_{0.1}$ and $\eta_{0.1}$ evaluated from relaxation and step-changing procedures, respectively, suggested that s_u and σ'_{vc} decrease by 10 to 20 percent with a tenfold decrease in strain rate.

Results for strain rate parameters $\rho_{0.1}$ and $\eta_{0.1}$ for remoulded Winnipeg clay have been presented in sections 4.6 and 5.3, respectively. The $\rho_{0.1}$ parameter ranges from 5.4 to 8.2 percent, which is slightly lower than the average results obtained from natural samples (Fig. 4.19). However, the $\rho_{0.1}$ parameters obtained in the present study are rather more consistent, and demonstrate that strain rate effects are important even in this highly plastic remoulded clay. The step-changing procedure carried out in the CRS test (C518,Fig.5.11) showed that the preconsolidation pressure, σ'_{vc} is also significantly time-dependent in remoulded Winnipeg clay. The $\eta_{0.1}$ parameter calculated from this test is rather higher than that of the natural Winnipeg samples. However, the value lies within the range showed in Graham, Crooks and Bell (1983). More importantly, the significance of strain rate effect on remoulded clay is again demonstrated.

6.7 ONE-DIMENSIONAL CONSOLIDATION OF SLURRY

During the course of making reconsolidated remoulded clay in the laboratory (Appendix 1) efforts were made to observe the one-dimensional consolidation behaviour of slurry. The slurry was very soft and fluid-like, and possessed almost no shear strength. Terzaghi's consolidation theory has been known for its applicability to soils, if the following assumptions are met:

1) the soil is saturated and homogeneous;
2) the principle of effective stress is valid;
3) Darcy's law is valid;
4) the porewater and soil grains are incompressible;
5) all displacements of the soil and flow of the porewater are one-dimensional;
6) the coefficient of permeability, k, and compressibility, m_v, remain constant.

Conventional consolidation tests are carried out in soils which possess a certain amount of shear strength, often in the range 10 kPa to 150 kPa. However, consolidation behaviour of very wet slurries, such as the one used in the present study (w = 164%) have seldom been reported, (see, for example Been and Sills (1981)).

Figures 6.7a and 6.7b are plots of log-time versus displacement for two load increments during reconsolidating the second sample of remoulded clay in a one-dimensional reconsolidation cylinder. It is interesting to note that they do show typical inverse s-shape curves similar to soils, despite the high moisture content of the slurry. The coefficients of consolidation, c_v, for the two load increments were calculated by Casagrande's Log Time Method to be $5.0 \times 10^{-8} m^2/s$ and $4.0 \times 10^{-8} m^2/s$, respectively. These numbers are rather close to the range of c_v-values ($0.5 - 5.0 \times 10^{-8}$ m^2/s) obtained in oedometer tests of Winnipeg natural clay (Au, 1982).

The decrease of c_v-values with respect to the increase of vertical pressure also conform to the general normally consolidated behaviour of clay (e.g. see Fig. 3.19 of Au, 1982).

Theoretical Log-time consolidation curves consist of three parts: an initial curve, which approximates closely to a prabolic relationship, followed by a linear relationship, and finally by a change of slope at which secondary consolidation (or creeping) starts. Figure 6.7b shows a clear change of slope signifying the end of primary consolidation. However, the clay was still very 'young' and had a high creep rate of about $C_{\alpha\varepsilon}$ = 3.5 percent. Problems associated with the high creep rates will be discussed separately in section 6.8.

6.8 EQUILIBRIUM PROBLEMS AND EFFECTS OF HIGH CREEP RATE

Consolidation of slurry in the cylinders is a very slow process. For example, Figure 6.7b shows that the total consolidation time for the second increment of sample T502 is around 350 hours, or almost 15 days. Three reasons can account for this:

a) The clay is fine-grained and with a high clay fraction (CF = 75 - 85%).

b) The clay is homogeneous and lacks macrostructure.

c) The drainage path is long, with only top and bottom drainage.

For productivity reasons, samples were not fully consolidated at many stages of loading. Therefore, during most of the loading period, the clay was at states above the 1-D NCL obtained from the long periods of consolidation to equilibrium. Even when consolidation was complete, it was essential to initiate testing as quickly as possible, so that the testing series could be completed in a reasonable time. The net effect is that large creep strain rates were often observed. There are three aspects of the test results where this is seen.

a) Triaxial Reconsolidation

Triaxial consolidation results for the restressing of samples to their 'cylinder' stress were presented in Table 2. The vertical strains, lateral strains, and volume strains obtained were much higher than the values obtained from restressing natural samples to their approximate 'in-situ' stress (e.g. see Table 3 of Lew, 1981. It is clear that the 'cylinder' stress levels for the natural samples do not agree with the overburden pressures. That is, the natural samples are overconsolidated. Strains for the remoulded samples are higher than in the natural samples before yielding. It could be argued that the high strainings indicate significant sample disturbance. However, high quality trimming techniques (Lew, 1981) and the clear yields which have been observed, show that this is not a problem. Therefore, the high straining of the samples during reconsolidation reflect the high creep rates in these "young" samples

b) Undrained Shear Tests

After triaxial consolidation was completed, samples were subjected to back pressuring procedures and then sheared under undrained conditions. Undissipated excess porewater pressures were observed in most of the samples ($\sim 0.05 \times \sigma'_{1c}$). Because of this problem, some of the samples were allowed to sit under back pressure for two days. This problem is also reflected as a leftwards shift in the effective stress paths in Figure 4.10.

c) Offloading in V, log p'-space

Stress release usually associates with increase in specific volume. However, Figures 3.4a and 3.7b show continued compression in the early stages of offloading. The equilibrium problem and the high creep rate are once again revealed.

CHAPTER 7

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

7.1 CONCLUSIONS

1) Based on the K_o-consolidation test results, the critical state consolidated parameters Γ and λ were found to be 3.96 and 0.313, respectively, for remoulded Winnipeg clay. These values are similar to that of natural Winnipeg clay ($\Gamma = 3.99$, $\lambda = 0.305$, Graham, Noonan and Lew, 1983).

2) The one-dimensional Normal Consolidation Line (NCL) and the Critical State Line (CSL) of remoulded Winnipeg clay are parallel when plotted in V, log p'-space (Fig. 6.1).

3) The parallelism of the one-dimensional NCL and the CSL in V, log p'-space can be described by $p'_{NCL}/p'_{CSL} = 1.4$ which represents the distance separating the two lines. The p'_{NCL}/p'_{CSL} ratio of natural Winnipeg clay was found to be similar to that of the remoulded clay.

4) Clear yields were shown in overconsolidated samples of remoulded Winnipeg clay (e.g., Figs. 3.8 - 3.19). The preliminary shape of the yield envelope (Figs. 3.20 and 6.4a) was found to be similar to that of Winnipeg natural clay.

5) In the present study, most of the criteria used to examine yield stresses in natural Winnipeg clay were found to be applicable in remoulded Winnipeg clay also.

6) Based on the $(\sigma_1-\sigma_3)_{max}/2$ failure criterion, the normally consolidated failure envelope at low stresses ($p' < 200$ kPa) was found to be slightly curved with smaller ϕ' in the increasing p' direction. The ϕ'-values of both remoulded and natural Winnipeg clay were found to be similar at $p' > 200$ kPa (Fig. 4.11).

7) The values of s_u/σ'_{vc} were found to be rather consistent in remoulded Winnipeg clay (Fig. 6.5). The average value was found to be 0.27, which is slightly higher than that of the natural clay ($s_u/\sigma'_{vc} = 0.22$; Lew, 1981).

8) The porewater pressure parameter, A_f, of Winnipeg remoulded clay was found to be generally lower than the natural clay results (Fig. 4.13), but closer to remoulded Weald clay results (Henkel, 1956).

9) The following evidence from the present study (section 6.5) tend to confirm that Winnipeg clay in its natural state is cemented:

    a) the relatively low A_f values observed in the remoulded clay;
    b) the relatively small drops of q-values from $q_{max}/2$ to USALS found in the remoulded clay;
    c) the relatively sharp-σ'_{vc}-breaks of remoulded samples.

10) The shear strengths, s_u and the preconsolidation pressures, σ'_{vc} of remoulded Winnipeg clay were found to be strain rate dependent. The $\rho_{0.1}$ and $\eta_{0.1}$ parameters were estimated to be 5.4 - 8.2 percent and 16.9 percent, respectively.

11) Both Constant Rate of Strain (CRS) and Oedometer tests showed agreement between the 'cylinder' stresses and the measured σ'_{vc}-values. The average C_c-values measured from the two tests were found to be similar.

7.2 SUGGESTIONS FOR FURTHER RESEARCH

1) More attention should be directed towards the consolidation time in the one-dimensional reconsolidation cylinders. A standard period of aging should be allowed at the end of primary consolidation.

2) Due to the slow consolidation process, more reconsolidation cylinders are required for productivity reasons.

3) Smectite (montmorillonite) and illite are the major clay minerals in Winnipeg clay (Baracos, 1977). In order to have a more fundamental understanding of the clay, studies on artificially consolidated smectite and illite are required.

4) Conclusive definition of the shape and orientation of yield envelopes in remoulded Winnipeg clay requires more tests, especially at the small and large θ regions.

5) Further attention should be paid to anisotropy and elasticity of remoulded Winnipeg clay before yield.

6) Further attention should be paid to the testing procedures of the Constant Rate of Strain (CRS) tests.

7) In order to minimize any disturbance that might be introduced to the sample, triaxial and oedometer samples should be trimmed directly from the cylinder when the clay is extruded.

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TEST NUMBER	T501	T502	T503	T504	T505	T506	T507	T508	T509	T510
TEST TYPE	CK_oU	CK_oU	CK_oU	CK_oU	CIU	CIU	CK_oU	CAU	CAD	CAU
INITIAL MOISTURE CONTENT (%)	66.8	64.8	62.0	63.2	59.0	64.5	68.7	60.5	64.5	59.3
FINAL MOISTURE CONTENT (%)	50.8	45.9	53.8	53.0	49.9	51.2	48.6	49.5	55.8	52.9
LIQUID LIMIT (%)	83.6	-	-	-	-	-	85.3	82.1	85.0	79.3
PLASTIC LIMIT (%)	27.5	-	-	-	-	-	29.8	28.0	29.2	27.6
PLASTICITY INDEX (%)	56.1	-	-	-	-	-	55.5	54.0	55.8	51.7

- not obtained for this test

TABLE 1 - BASIC SOIL PROPERTIES

TEST NUMBER	T501	T502	T503	T504	T505	T506	T507	T508	T509	T510
$\sigma'_{cy\ell}$(kPa)	83.5	86.7	86.6	86.4	100.2	86.7	86.4	86.6	86.7	86.4
$\sigma'_{3cy\ell}/\sigma'_{1cy\ell}$	0.65	0.62	0.62	0.62	0.98	0.98	0.62	0.62	0.61	0.62
$\varepsilon_{1cy\ell}$(%)	3.52	4.72	5.02	6.96	1.90	3.22	5.93	3.72	4.76	3.74
$\varepsilon_{3cy\ell}$(%)	1.47	1.03	1.75	4.45	7.36	12.07	2.10	1.82	0.95	1.49
$v_{cy\ell}$	6.45	6.76	8.52	15.86	16.61	4.43	10.12	7.36	6.66	6.71

TABLE 2 - TRIAXIAL CONSOLIDATION RESULTS FOR RESTRESSING TO APPROXIMATE 'CYLINDER' STRESS

TEST NUMBER	T501	T502	T503	T504	T505	T506	T507	T508	T509	T510
$\sigma'_{cy\ell}$(kPa)	83.5	86.7	86.6	86.4	100.2	86.7	86.4	86.6	86.7	86.4
σ'_{vc_1}(kPa)*	-	88.1	90.4	81.7	98.8	-	81.7	96.2	88.4	83.3
σ'_{vc_2}(kPa)*	-	-	-	-	-	-	177.0	147.0	126.6	-
σ'_{1c}(kPa)	212.3	319.4	83.2	173.0	249.3	89.6	319.6	233.1	153.3	82.8
$\sigma'_{3c}/\sigma'_{1c}$	0.62	0.62	0.62	0.61	0.98	0.98	0.62	0.92	0.45	0.63
ε_{1c}(%)	12.6	22.1	12.8	13.3	4.7	5.6	20.5	10.1	16.3	8.9
ε_{3c}(%)	1.4	0.4	1.2	6.9	14.2	6.7	4.6	9.1	-0.8	1.8
ε_{vc}(%)	15.3	22.7	15.1	27.1	33.1	19.0	29.6	28.3	14.7	12.4

* based on equivalent σ'_{vc}-values on Table 4

\- not applicable

TABLE 3 - TRIAXIAL CONSOLIDATION RESULTS AT THE END OF STRESS-CONTROLLED TESTING

	TEST NUMBER	T502	T503	T504	T505	T507	T507*	T508	T508*	T509	T509*	T510
Plotted Parameter	p' vs v	66	-	-	-	66	125	69	117	67	83	57
	q vs ε	64	62	-	-	59	137	71	-	67	81†	61
	σ_1 vs ε_1	66	67	57	96	58	130	73	110†	61	85	64
	σ_3 vs ε_3	-	-	61	102	-	-	-	125	-	-	-
	p' vs ε_1	67	71	59	95	58	134	74	137	64	86	64
	W vs LSSV	66	70	67	97	64	133	72	132	71	85	65
	AVERAGE p'_y (kPa)	65.8	67.5	61.0	97.5	61.0	131.8	71.8	127.8	66.0	84.8	62.2
	EQUIVALENT σ'_{vc} (kPa)	88.1	90.4	81.7	98.8	81.7	177.0	96.2	147.0	88.4	126.6	83.3

NOTE: All yield stresses presented in this table have been put in terms of p' along the stress path for the test.

* second yield

† not included in the average

TABLE 4 - YIELD STRESSES FROM DIFFERENT YIELD CRITERIA

TEST NUMBER	T501	T502	T503	T504	T505	T506	T507	T508	T509	T510
TEST TYPE	CK_oU	CK_oU	CK_oU	CK_oU	CIU	CIU	CK_oU	CAU	CAU	CK_oU
$\sigma'_{cy\ell}$ (kPa)	83.5	86.7	86.6	86.4	100.2	86.7	86.4	86.6	86.7	86.4
σ'_{vc1} (kPa)	-	88.1	90.4	81.7	98.8	-	81.7	96.2	88.4	83.3
κ_1	-	0.134	0.169	0.250	0.307	0.179	0.177	0.131	0.134	0.084
λ_1	0.268	0.355	0.312	0.436	0.515	0.286	0.436	0.420	0.346	0.328
σ'_{vc2} (kPa)	-	-	-	-	-	-	177.0	147.0	126.6	-
κ_2	-	-	-	-	-	-	0.124	0.113	0.077	-
λ_2	-	-	-	-	-	-	0.415	0.480	-	-

TABLE 5 - SUMMARY OF TRIAXIAL CONSOLIDATION RESULTS

TEST NUMBER	T502	T503	T507	T507*	T508	T508*	T509	T509*	T510
K_{eq} (kPa)	644	-	629	1900	829	1875	778	2438	988
σ'_{vc} † (kPa)	88.1	90.4	81.7	177.0	96.2	147.0	88.4	126.6	83.3
K_{eq}/σ'_{vc}	7.3	-	7.7	10.7	8.6	12.8	8.8	19.3	11.9
G_{eq} (kPa)	608	1053	521	6833	1087	-	379	2667	687
G_{eq}/σ'_{vc}	6.9	11.6	6.4	38.6	11.3	-	4.3	21.2	8.2

† based on equivalent σ'_{vc}-values on Table 4

* K_{eq} and G_{eq} values obtained from reload curve

TABLE 6 - SUMMARY OF EQUIVALENT BULK AND SHEAR MODULI, K_{eq} AND G_{eq}

TEST NUMBER		T501	T502	T503	T504	T505	T506	T507	T508	T510
TEST TYPE		CK_oU	CK_oU	CK_oU	CK_oU	CIU	CIU	CK_oU	CAU	CAU
σ'_{vc}	(kPa)	212.3	319.4	166.2	173.0	249.3	178.3	319.6	233.1	164.1
σ'_{1c}	(kPa)	212.3	319.4	83.2	173.0	249.3	89.7	319.6	233.1	82.8
$\sigma'_{3c}/\sigma'_{1c}$		0.62	0.62	0.62	0.61	0.98	0.98	0.62	0.92	0.63
$OCR = \sigma'_{vc}/\sigma'_{1c}$		1.0	1.0	2.0	1.0	1.0	1.0**	1.0*	1.0*	2.0
$q_{max}/2 = (\sigma_1-\sigma_3)/2_{max}$	(kPa)	58.5	87.0	38.0	50.8	64.7	44.9	83.3	65.4	38.5
$q_{max}/2\sigma'_{vc}$		0.275	0.273	0.229	0.293	0.259	0.252	0.261	0.280	0.235
ϵ_1 at $q_{max}/2$	(%)	0.67	0.64	1.16	0.73	3.71	4.97	0.64	4.14	1.55
p' at $q_{max}/2$	(kPa)	134.0	217.2	62.1	108.3	152.9	84.3	211.2	138.6	68.3
$(\sigma'_1/\sigma'_3)_{max}$@		2.45#	2.25	3.125	2.74#	2.53#	2.83#	2.01#	2.68#	2.86
ϵ_1 at $(\sigma'_1/\sigma'_3)_{max}$	(%)	10.14†	6.42	0.77	11.11†	10.30	9.03†	9.01†	11.04†	0.80
E_{50}	(MPa)	31.0	44.9	15.8	30.3	44.6	13.2	30.9	33.6	15.8
E_{50}/s_u		529	516	416	596	689	293	371	514	411
A_f		0.54	0.63	0.31	0.90	1.06	0.42	0.67	0.94	0.23
B	(%)	94.9	100	99	100	-	94	100	96	100
$m - \Delta u/p$		1.38	2.00	2.70	2.00	x	1.30	1.85	2.08	2.50
$\rho_{0.1}$ at ϵ_ρ	(%)	6.7	x	6.1	x	5.4	x	7.1	7.2	8.2
ϵ_ρ	(%)	3.29	x	5.63	x	10.40	x	4.66	6.58	2.79
ϵ_1	(%/hr)	0.80	1.27	0.79	0.73	0.97	0.98	0.88	0.77	0.75
E_{50}/σ'_{vc} or E_{50}/σ'_{1c}		146	141	190	175	179	147	97	144	191

** initially isotropically loaded to σ'_1 = kPa, off loaded to kPa (OCR = 2.0, K = 0.), reloaded isotropically beyond σ'_{vc} into normally consolidated behaviour (OCR = 1.0)

* initially K_o-loaded to σ'_1 = 164 kPa, offloaded to 82 kPa (OCR = 2.0, K = 0.62), reloaded beyond σ'_{vc} into normally consolidated behaviour (OCR = 1.0).

@ or at end of test

\# σ'_1/σ'_3 value obtained from end of test

† ϵ_1 at $(\sigma'_1/\sigma_3)_{max}$ value from end of test.

\- assumed to be satisfactory.

x not obtained

TABLE 7 - SUMMARY OF UNDRAINED SHEAR TEST RESULTS

CYLINDER NUMBER	1	2	3	4	5	6	7	8	9	10
TRIAXIAL TEST NUMBER	T501	T502	T503	T504	T505	T506	T507	T508	T509	T510
OEDOMETER TEST NUMBER	-	C512	C513	C514	C515	-	-	-	-	-
CRS TEST NUMBER	-	-	-	-	-	C516A C516B	C517	C518	C519	C520

TABLE 8 - CORRESPONDING TRIAXIAL, OEDOMETER AND CRS SAMPLES
TO THEIR RECOMMENDATION CYLINDER NUMBER

TEST NUMBER	C501	C502	C512	C513	C514	C515
SAMPLE TYPE	FS	FS	R	R	R	R
$\sigma'_{cy\ell}$ (kPa)	#	#	86.7	86.6	86.4	100.2
σ'_{vc} (kPa)	315	324	83.5	87.5	88.0	94.5
κ	0.088	0.095	0.089	0.097	0.084	0.064
λ	0.295	0.292	0.372	0.340	0.394	0.362

\# not applicable

\- not obtained

FS 'fully-softened' sample

R remoulded sample

TABLE 9 - SUMMARY OF OEDOMETER TESTS

TEST NUMBER	C516A	C516B	C517	C518	C519	C520
$\sigma'_{cy\ell}$ (kPa)	86.7	86.7	86.4	86.6	86.7	86.4
BP (kPa)	200	200	0	0	200	0
ε_1 (%/hr)	0.94	0.94	0.94	0.94*	0.94	0.94
σ'_{vc} (kPa)	96	84	60	90	84	89
C_c	0.924	0.864	0.896	0.885	0.955	0.811
λ	0.401	0.375	0.389	0.384	0.415	0.352
$\eta_{0.1}$	-	-	-	16.9	-	-

\- not obtained

* step changing procedure applied (other strain rate used = 0.012%/hr.)

TABLE 10 - SUMMARY OF CONSTANT RATE OF STRAIN (CRS) TESTS

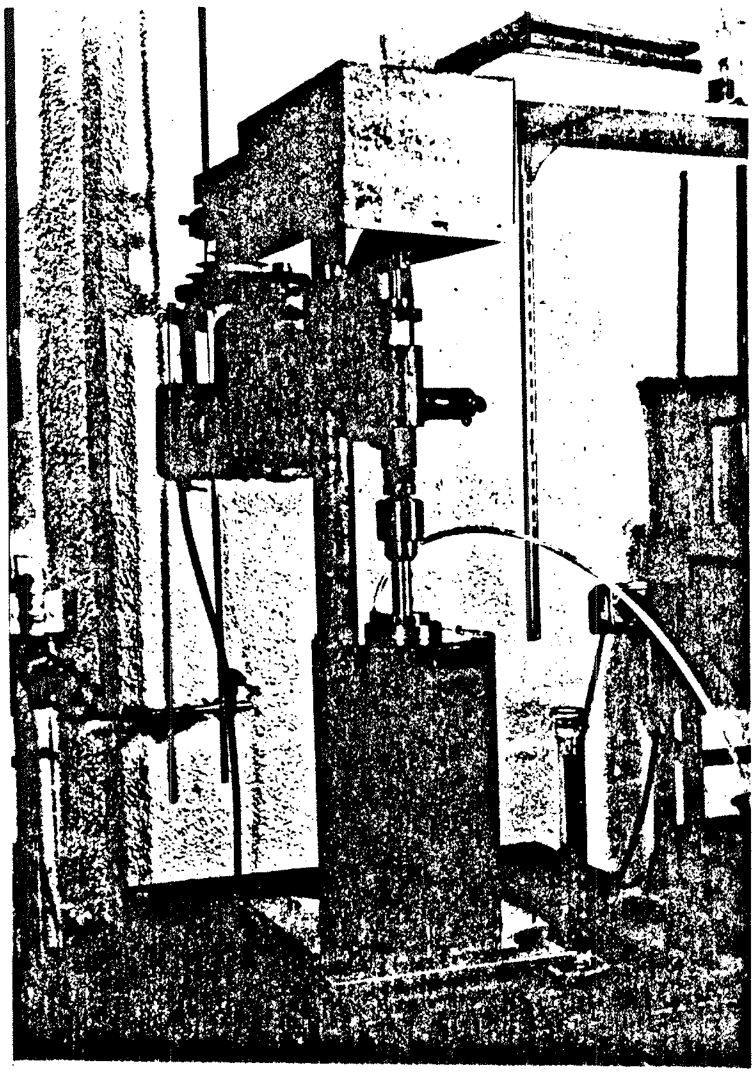


FIGURE 2.1 - MECHANIICAL MIXING UNIT

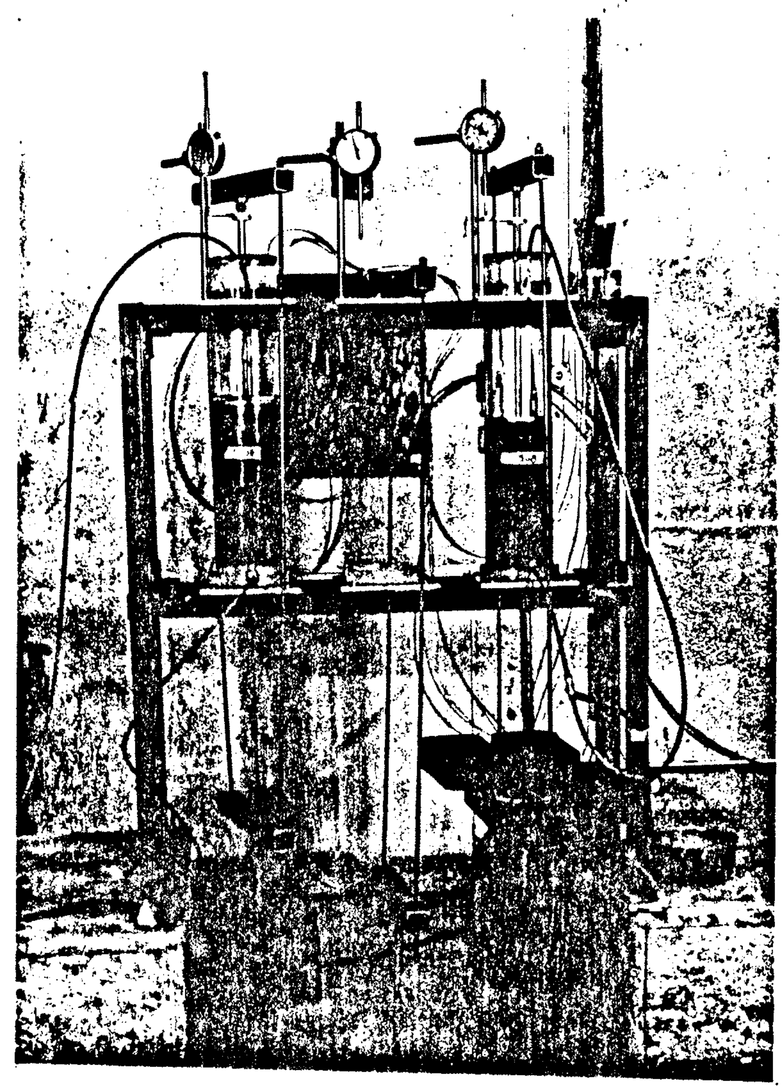


FIGURE 2.2 - RECONSOLIDATION UNIT

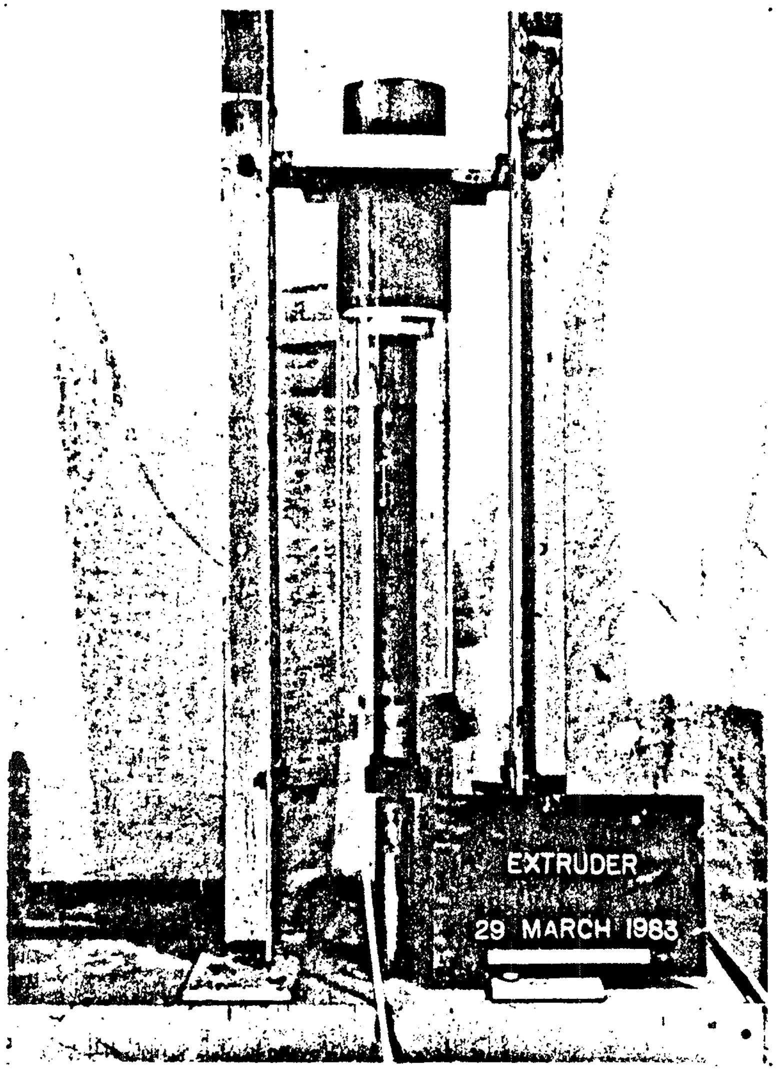


FIGURE 2.3 - EXTRUDING UNIT

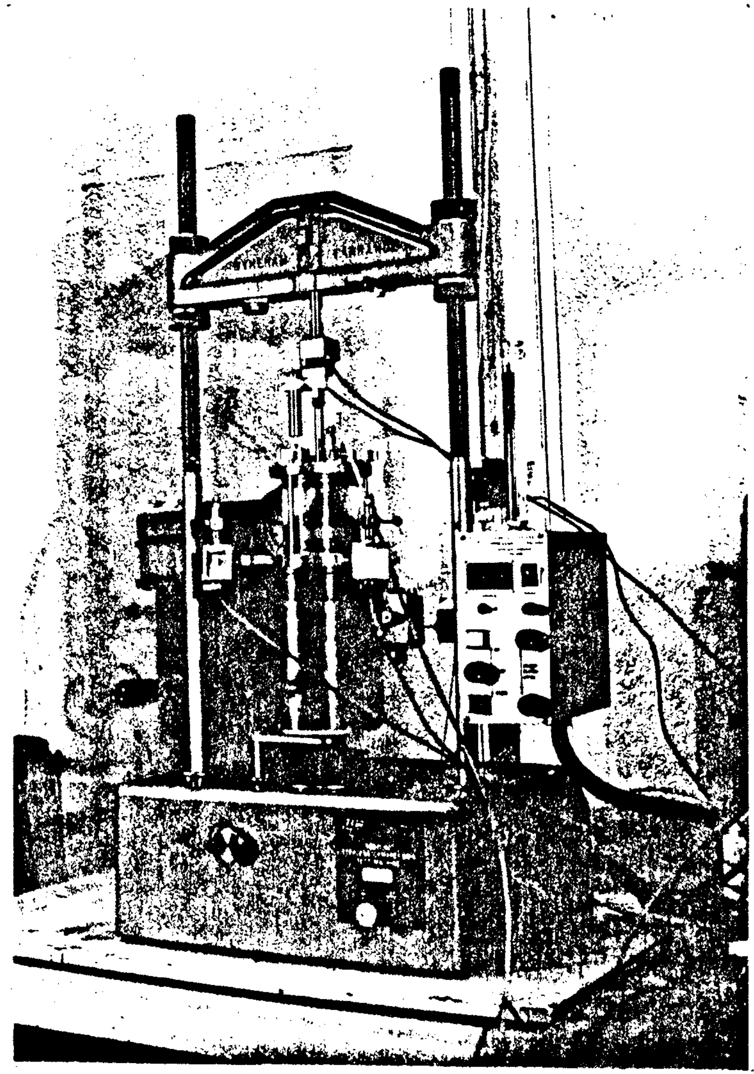


FIGURE 2.4 - CONSTANT RATE OF STRAIN (CRS) TEST

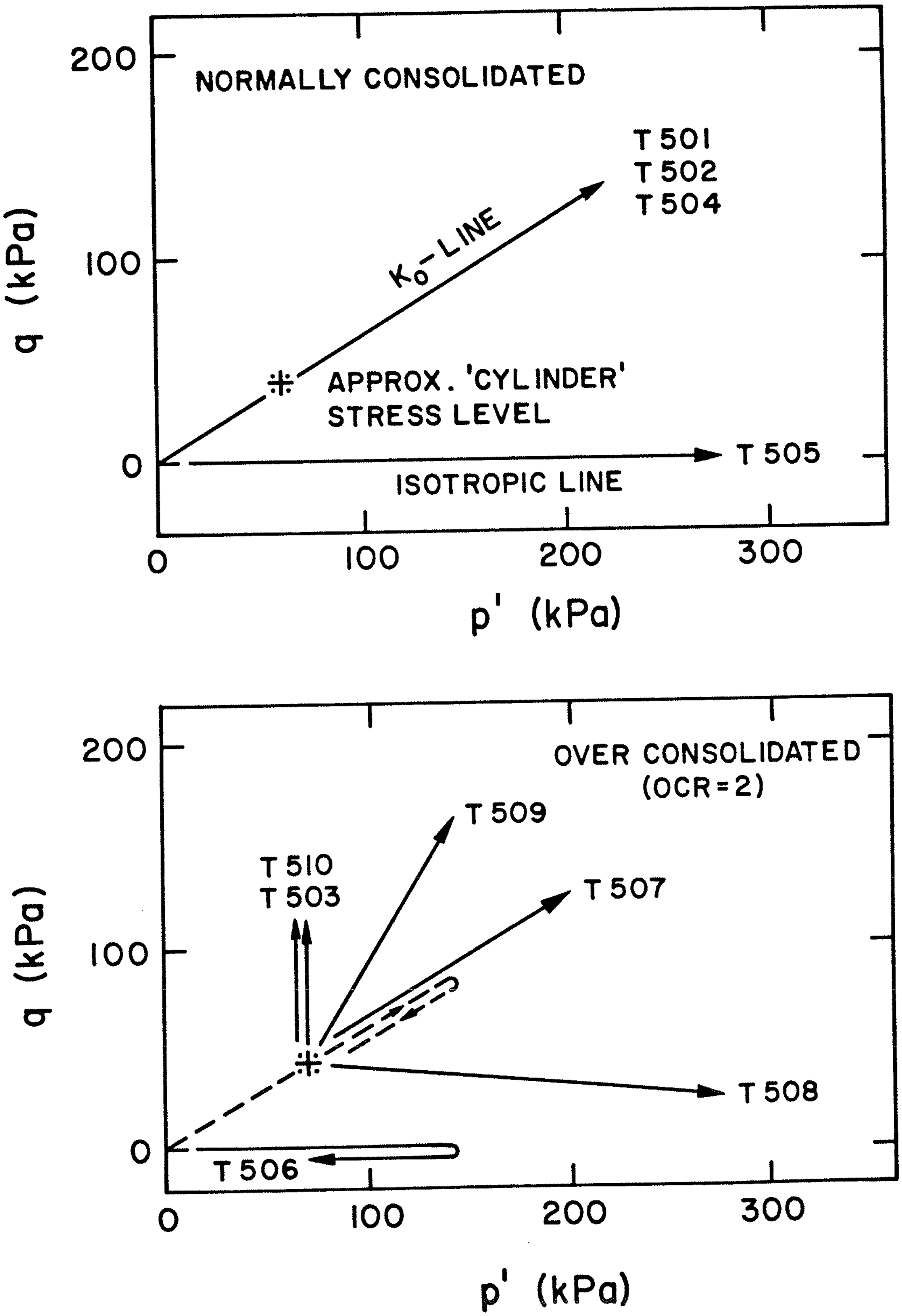


FIGURE 3.1 - DIAGRAMMATIC DESCRIPTION OF TRIAXIAL TESTING PROGRAMME

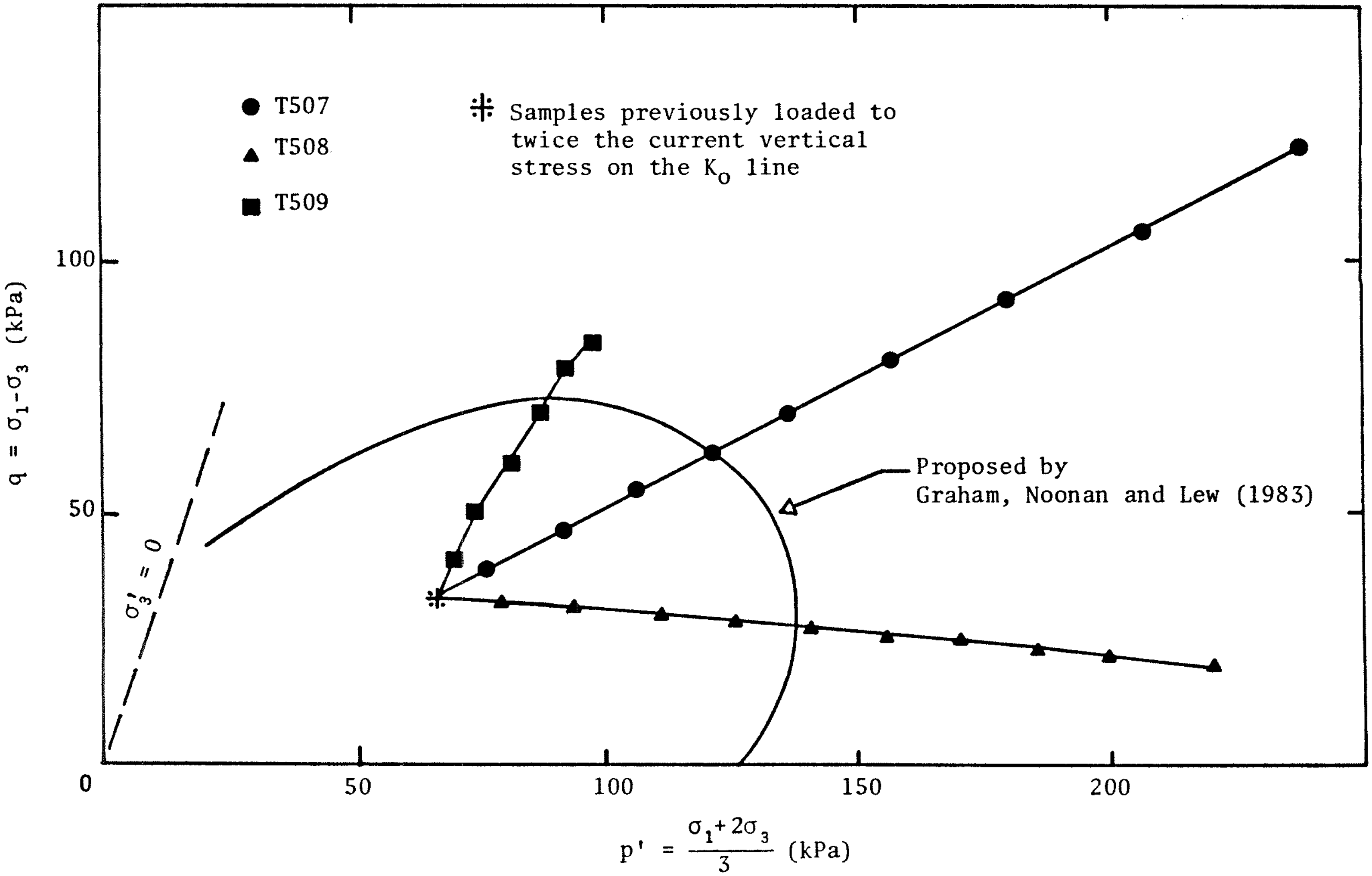


FIGURE 3.2 - PROPOSED STRESS PATHS FOR DRAINED STRESS-CONTROLLED TESTS IN EXPLORING YIELD ENVELOPE

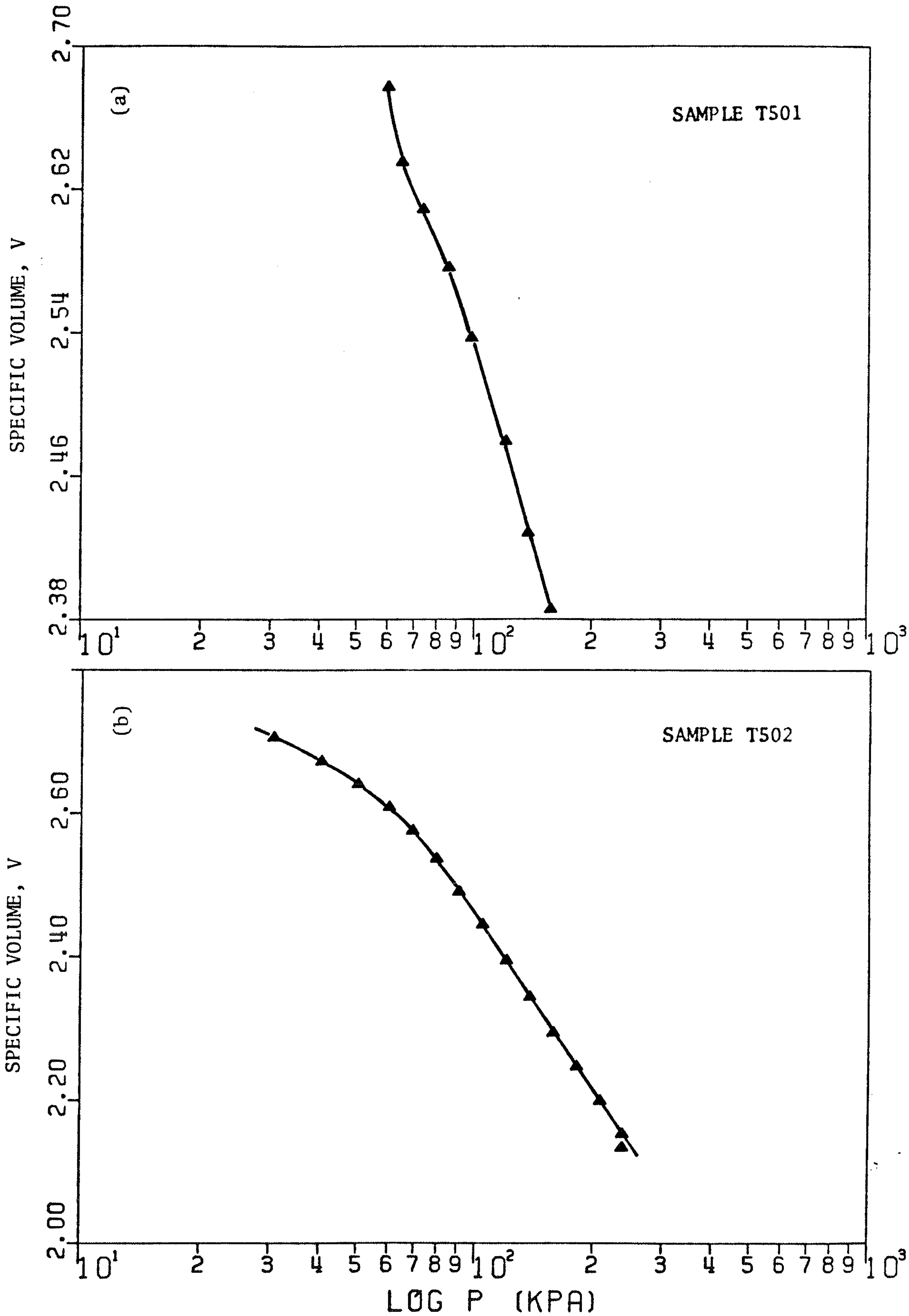


FIGURE 3.3a,b - TRIAXIAL CONSOLIDATION,
V vs Log p', T501,T502

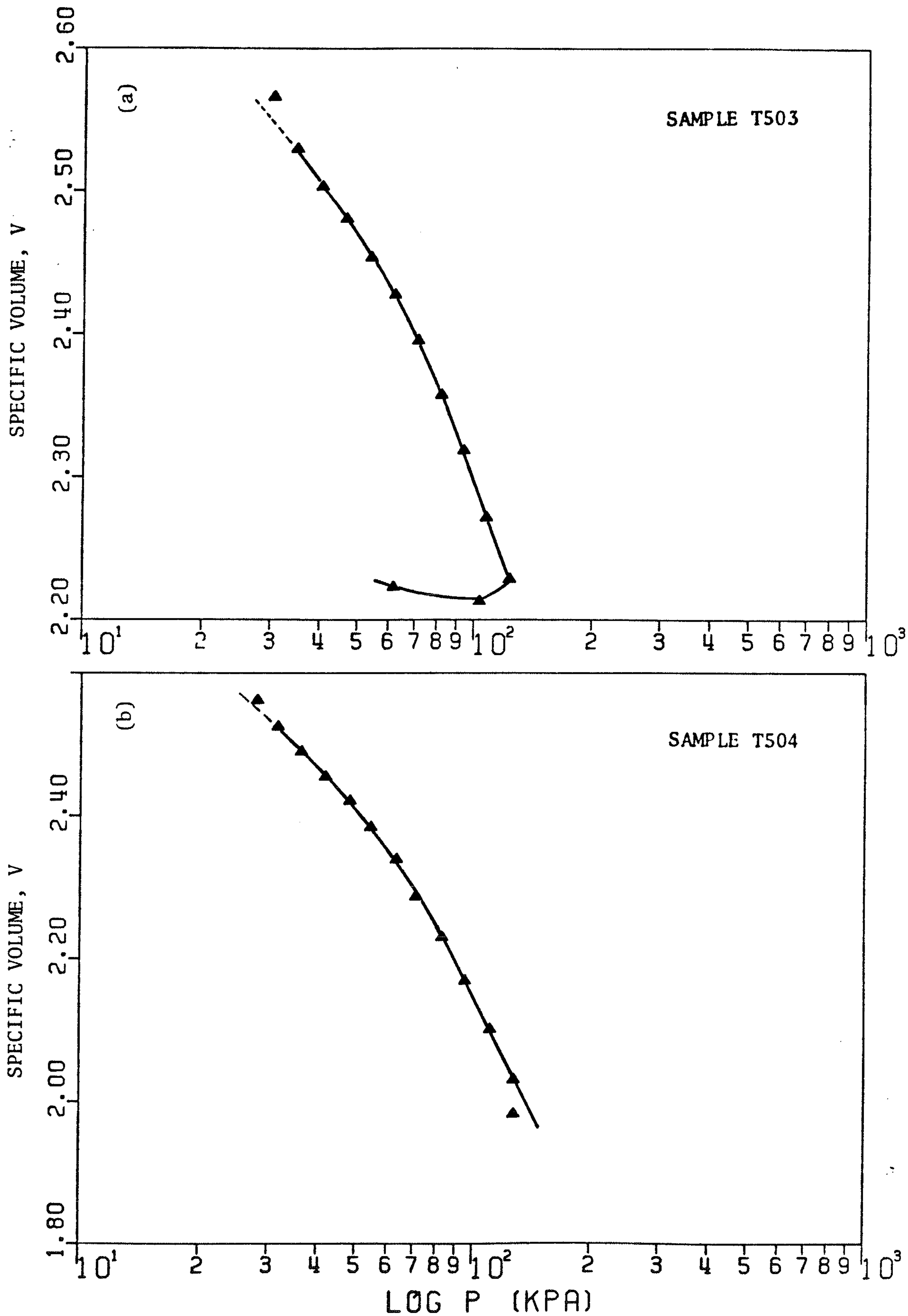


FIGURE 3.4a,b - TRIAXIAL CONSOLIDATION
V vs Log p', T503,T504

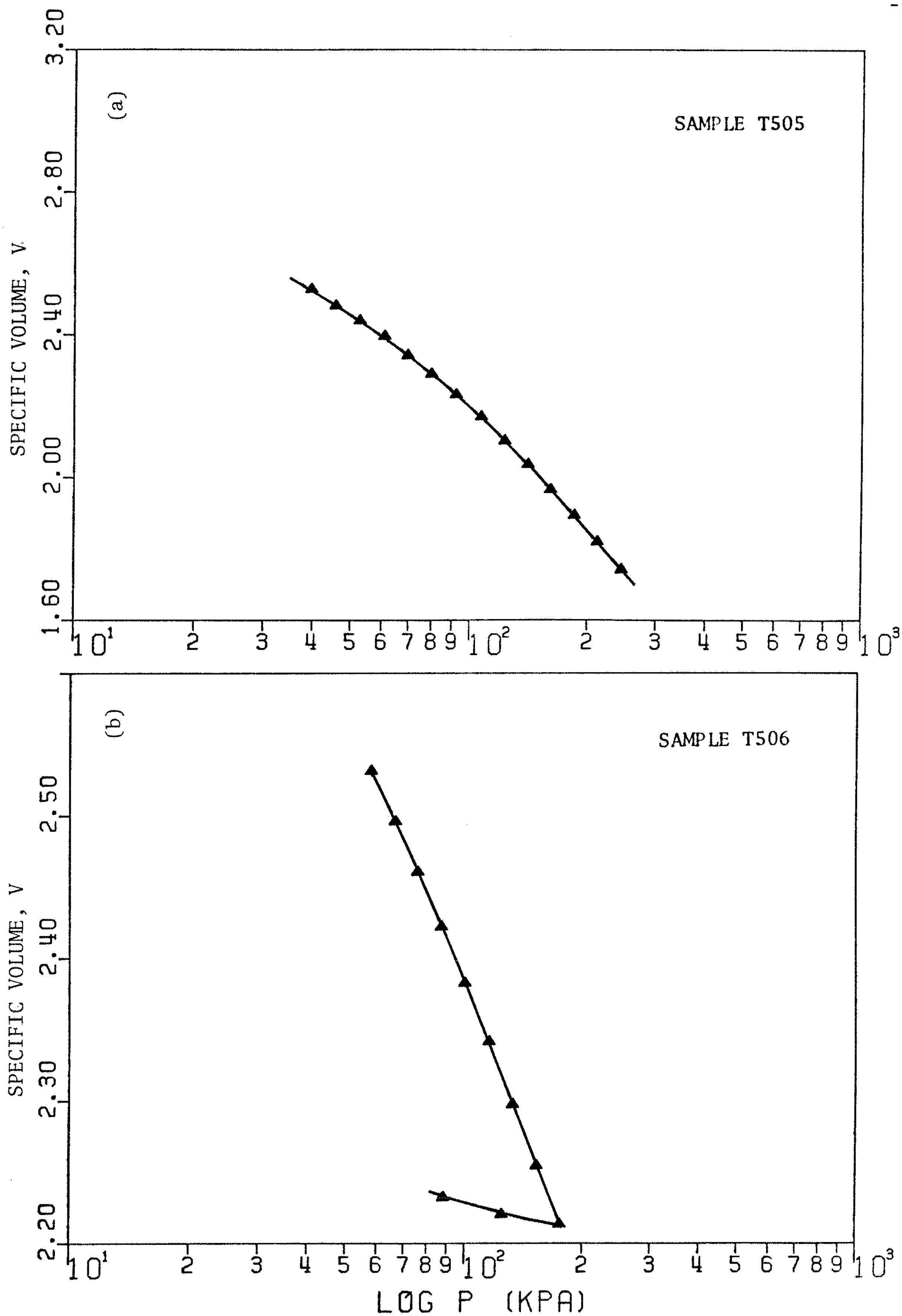


FIGURE 3.5a,b - TRIAXIAL CONSOLIDATION,
V vs Log p', T505,T506

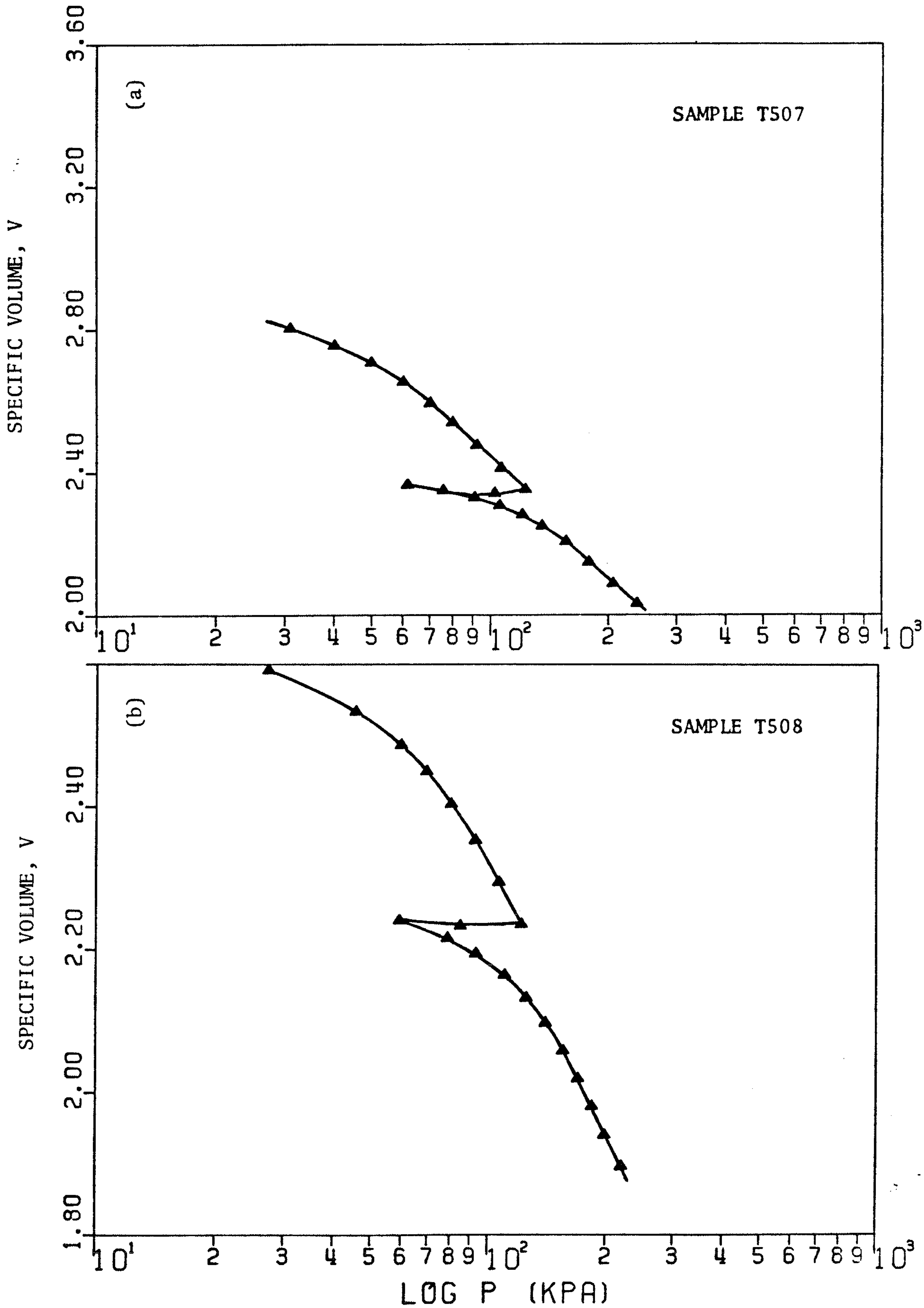


FIGURE 3.6a,b - TRIAXIAL CONSOLIDATION,
V vs Log p', T507,T508

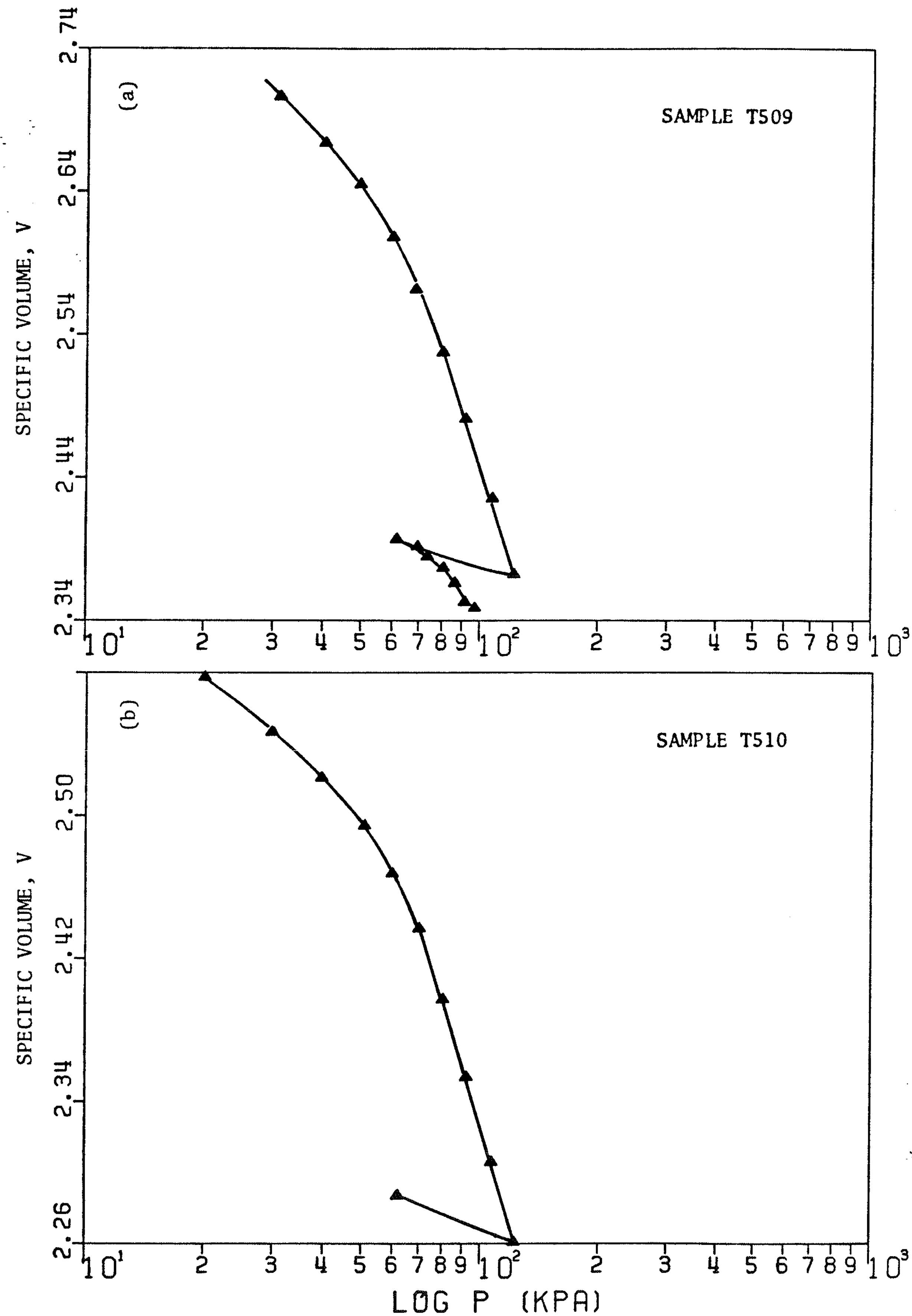


FIGURE 3.7a,b - TRIAXIAL CONSOLIDATION,
V vs Log p', T509,T510

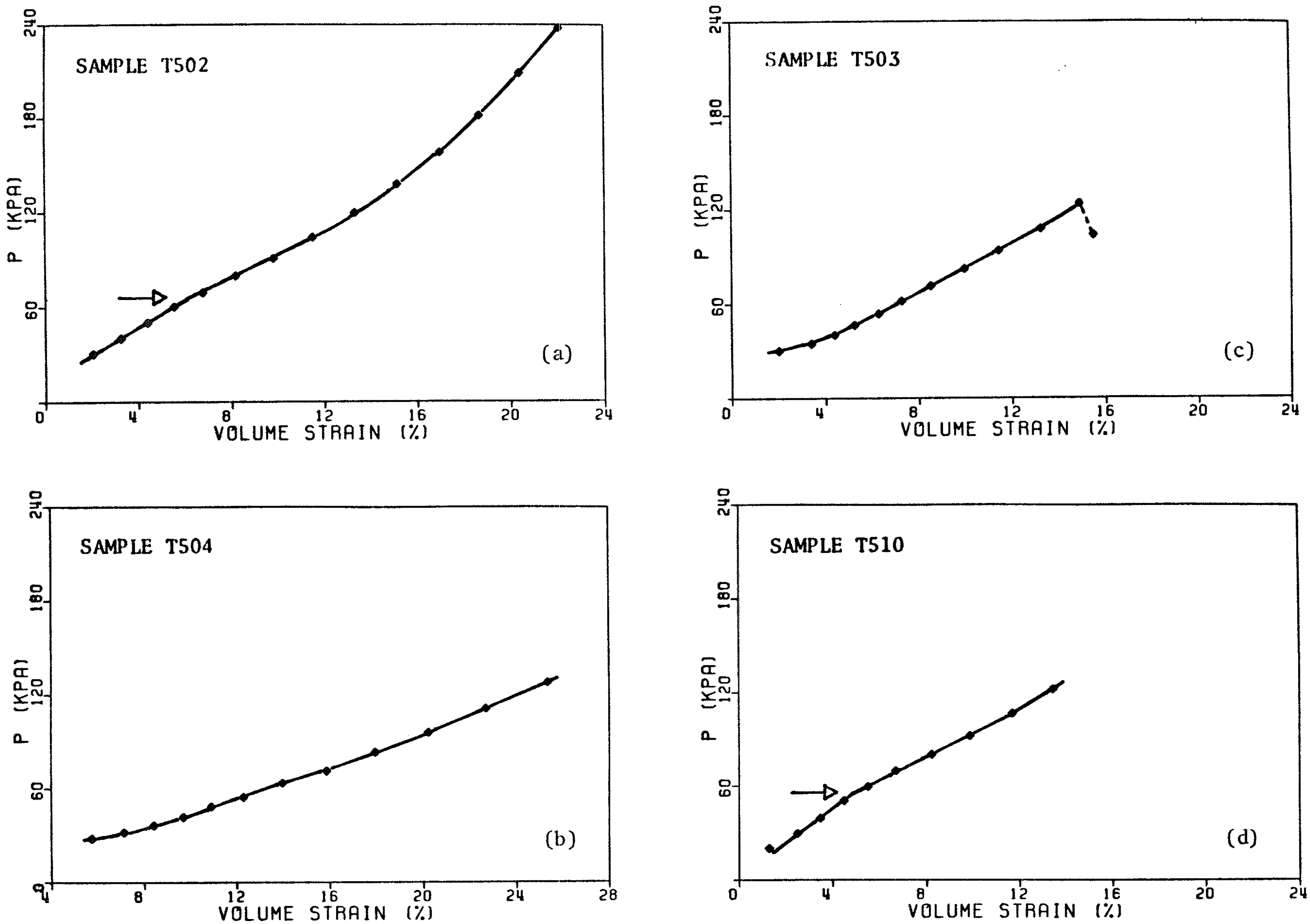


FIGURE 3.8a,b,c,d - YIELD DETERMINATION,
p' vs v, T502,T504,T503,T510

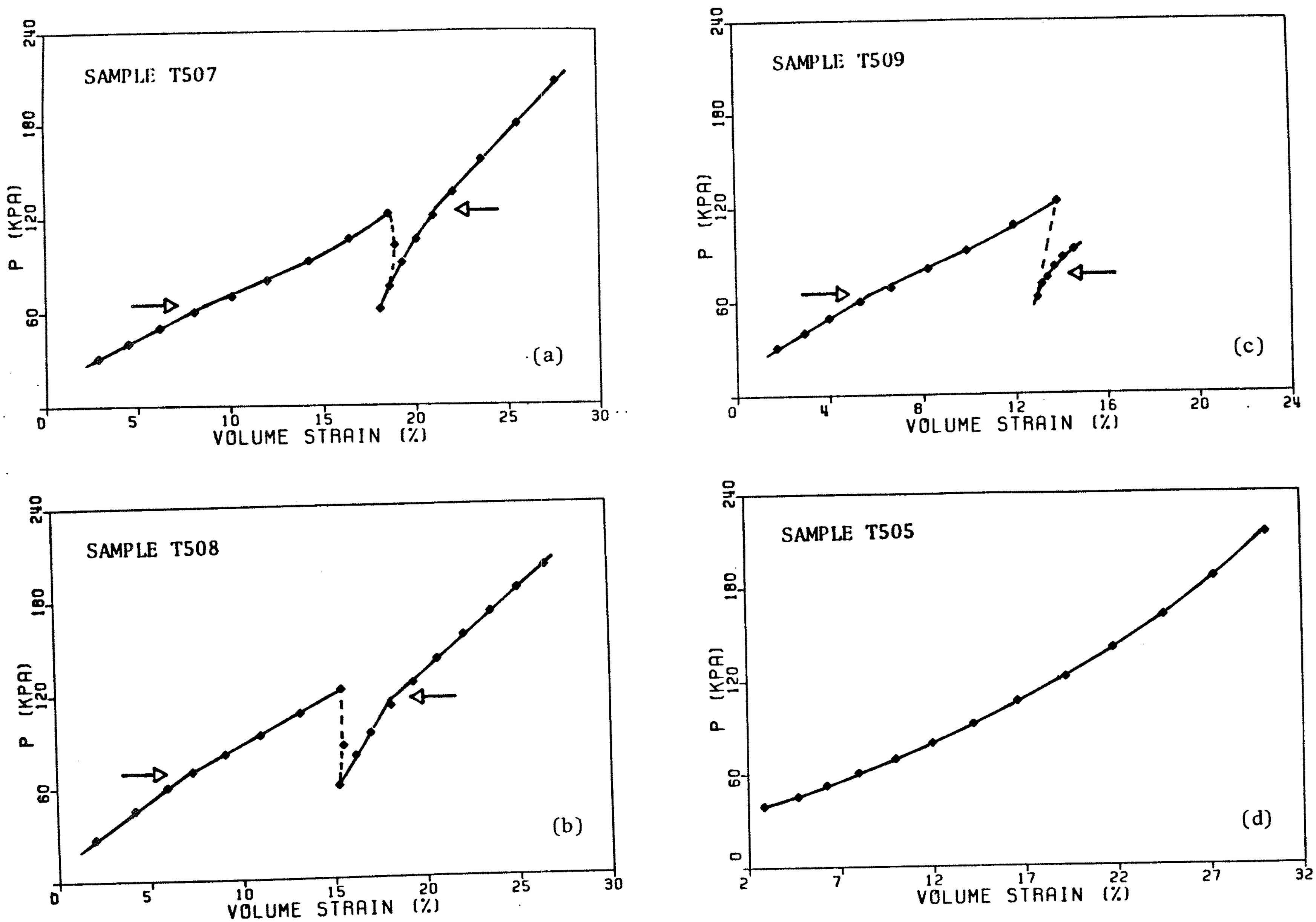


FIGURE 3.9a,b,c,d - YIELD DETERMINATION
p' vs v, T507,T508,T509,T505

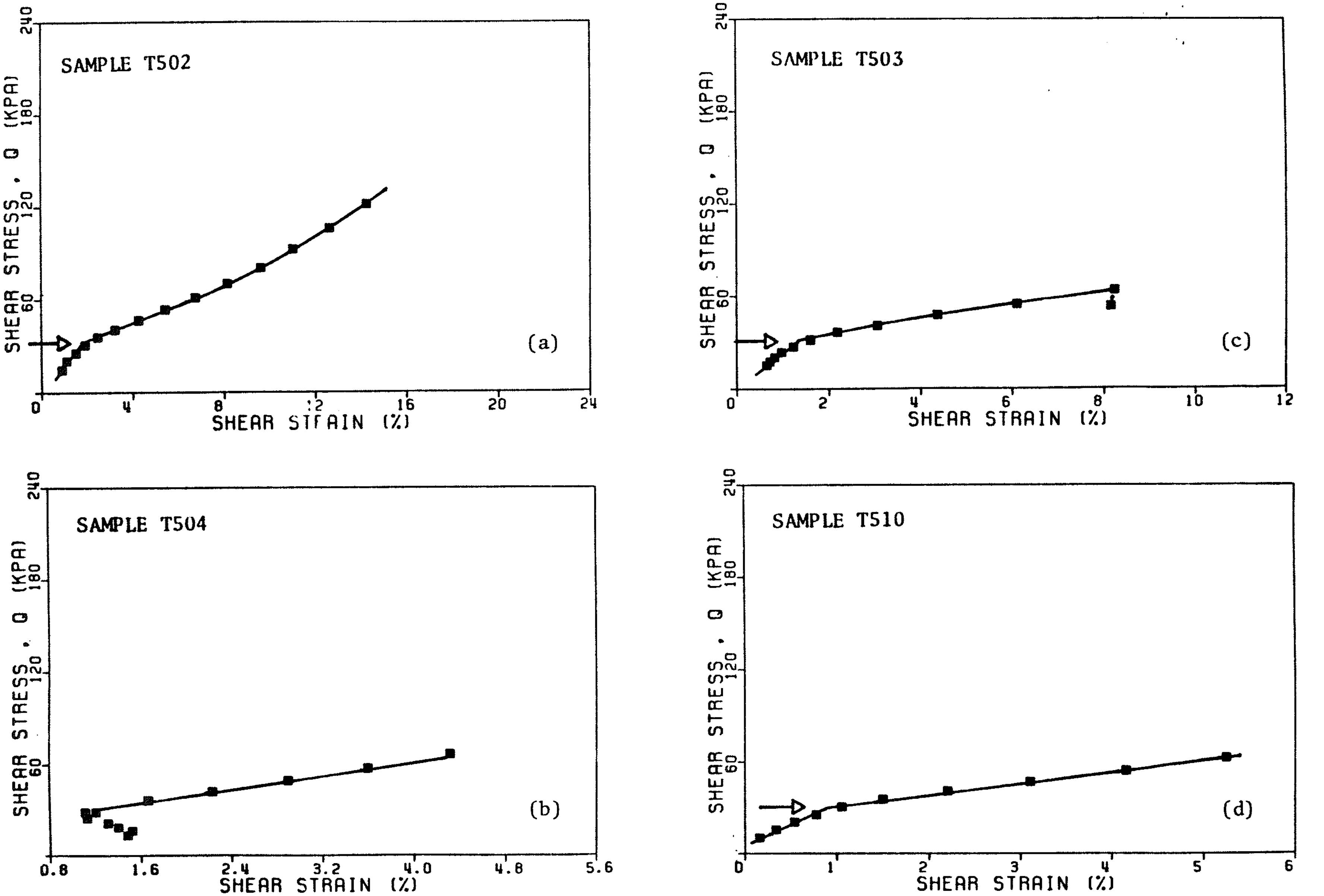


FIGURE 3.10a,b,c,d - YIELD DETERMINATION
q vs ε, T502,T504,T503,T510

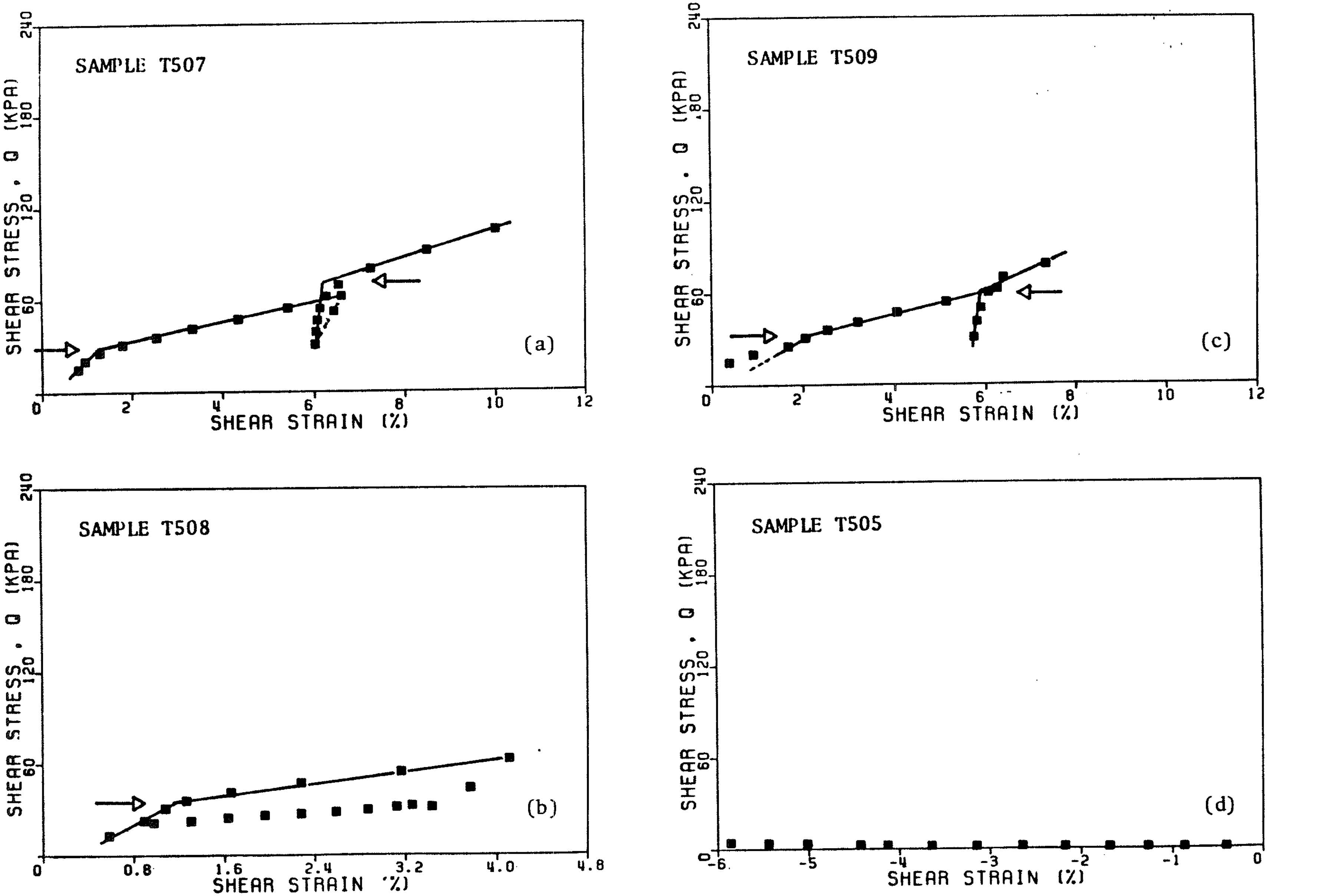


FIGURE 3.11a,b,c,d - YIELD DETERMINATION
q vs ε, T507,T508,T509,T505

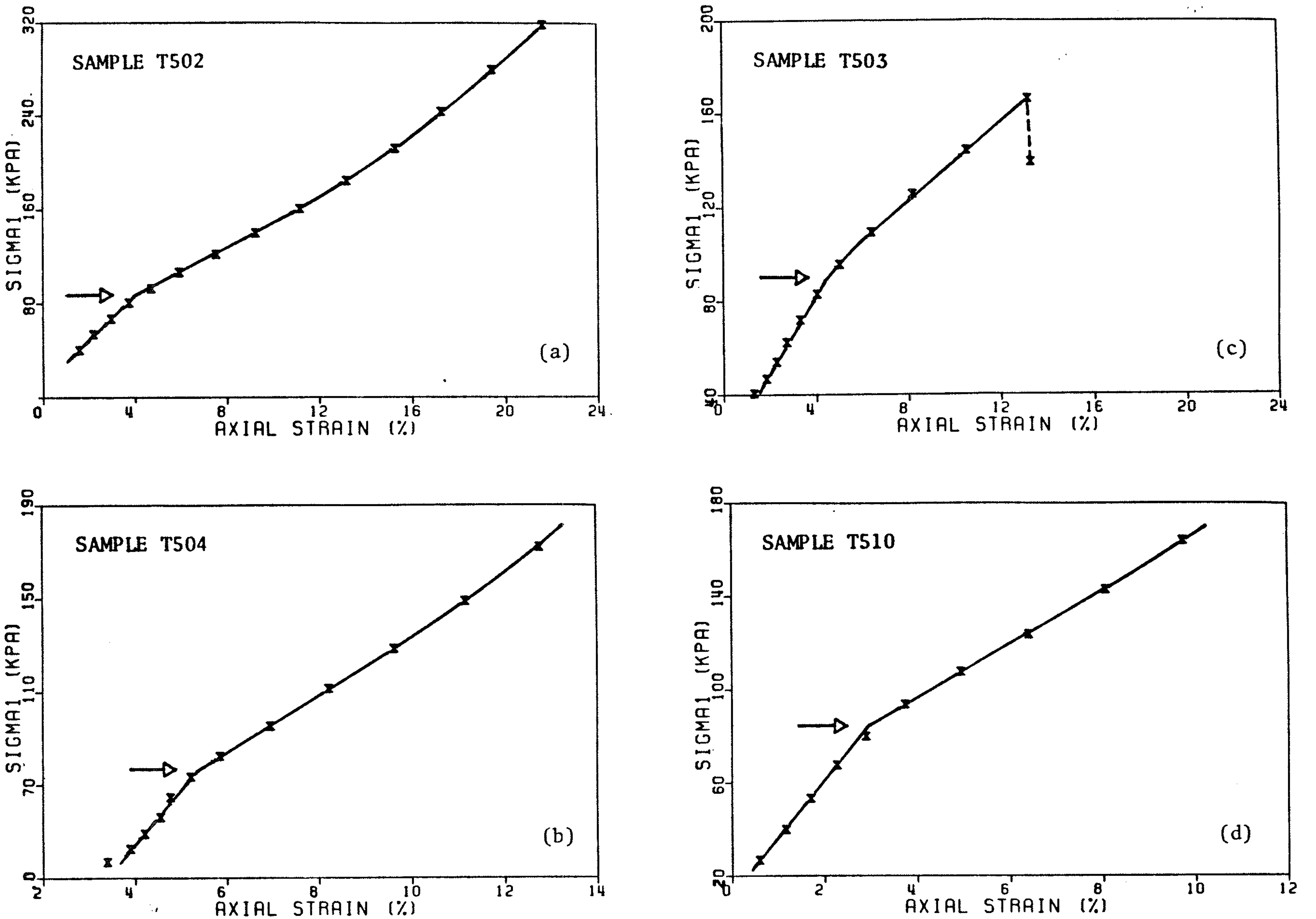


FIGURE 3.12a,b,c,d - YIELD DETERMINATION
σ_1' vs ε_1, T502,T504,T503,T510

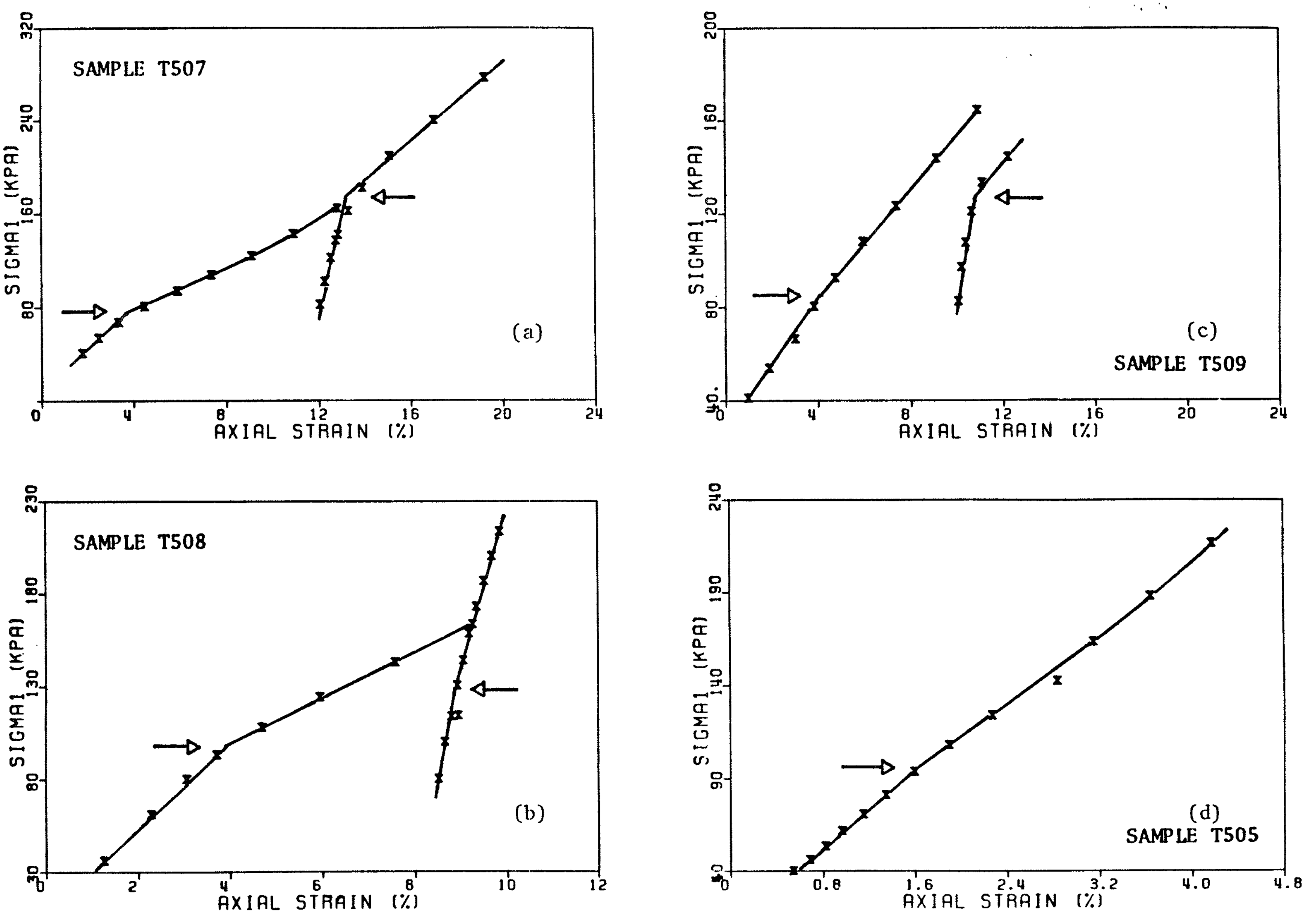


FIGURE 3.13a,b,c,d - YIELD DETERMINATION
σ_1' vs ε_1, T507,T508,T509,T505

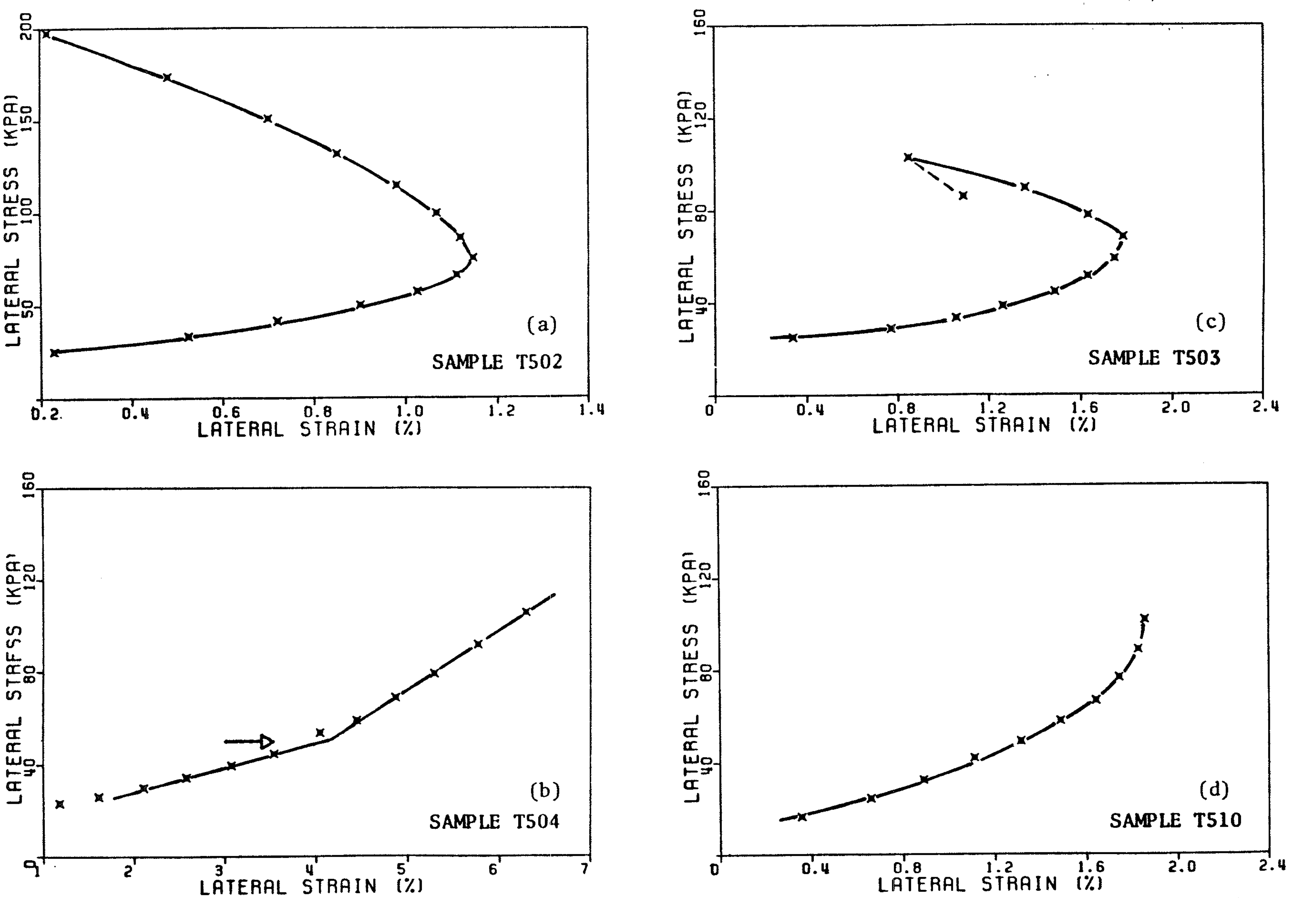


FIGURE 3.14a,b,c,d - YIELD DETERMINATION
σ_3' vs ε_3, T502,T504,T503,T510

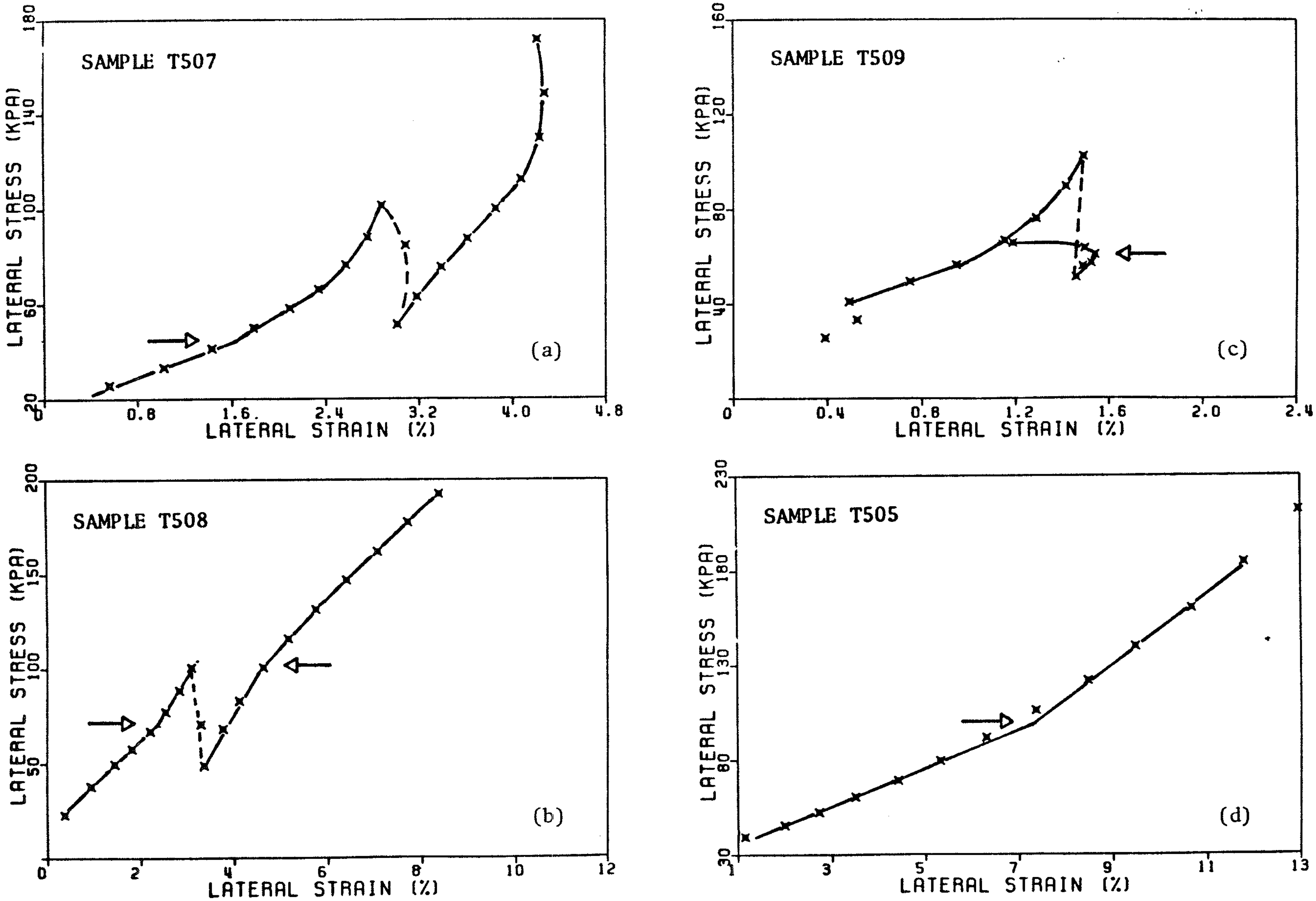


FIGURE 3.15a,b,c,d - YIELD DETERMINATION
σ'_3 vs ε_3, T507,T508,T509,T505

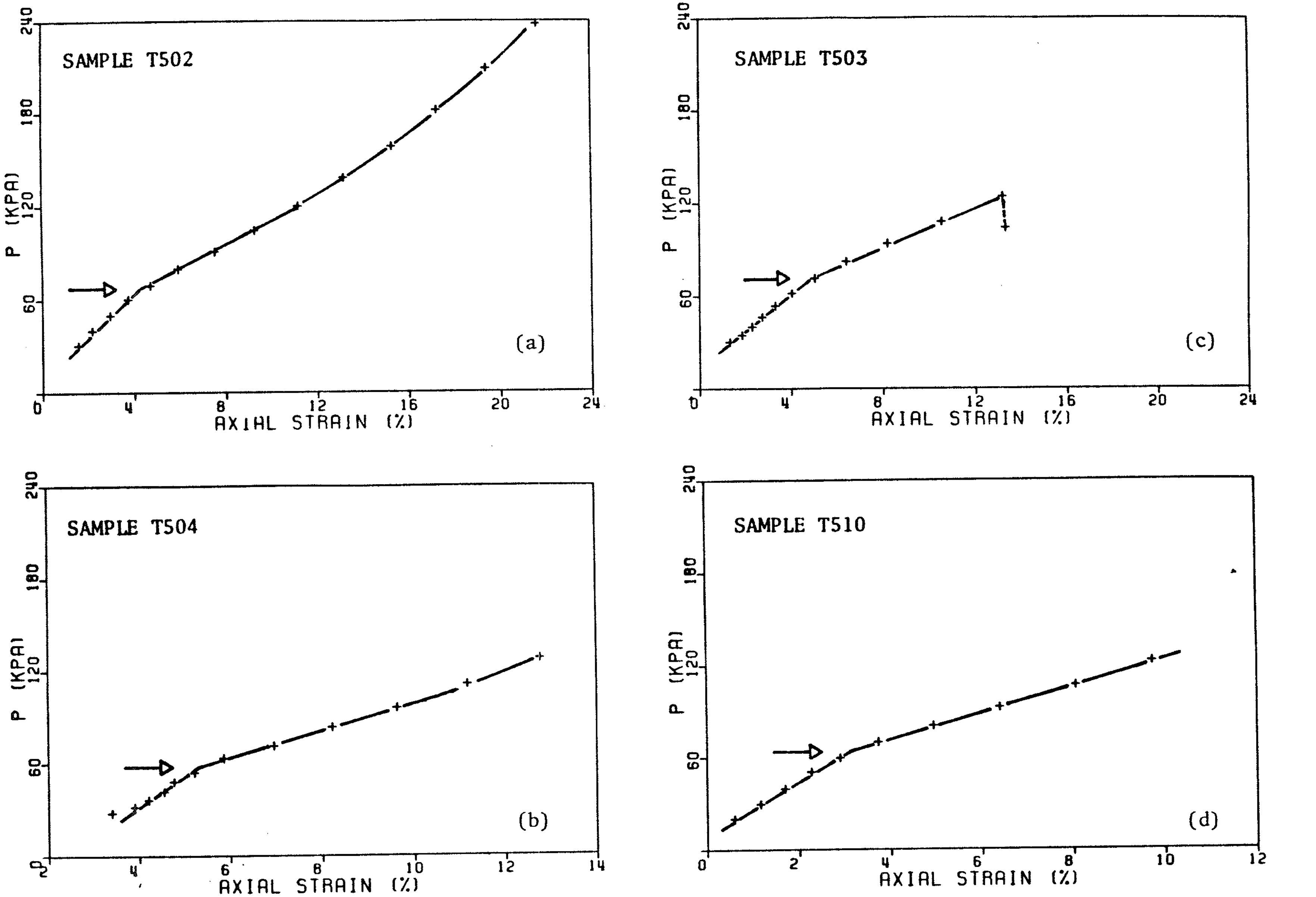


FIGURE 3.16a,b,c,d - YIELD DETERMINATION
p' vs ε_1, T502,T504,T503,T510

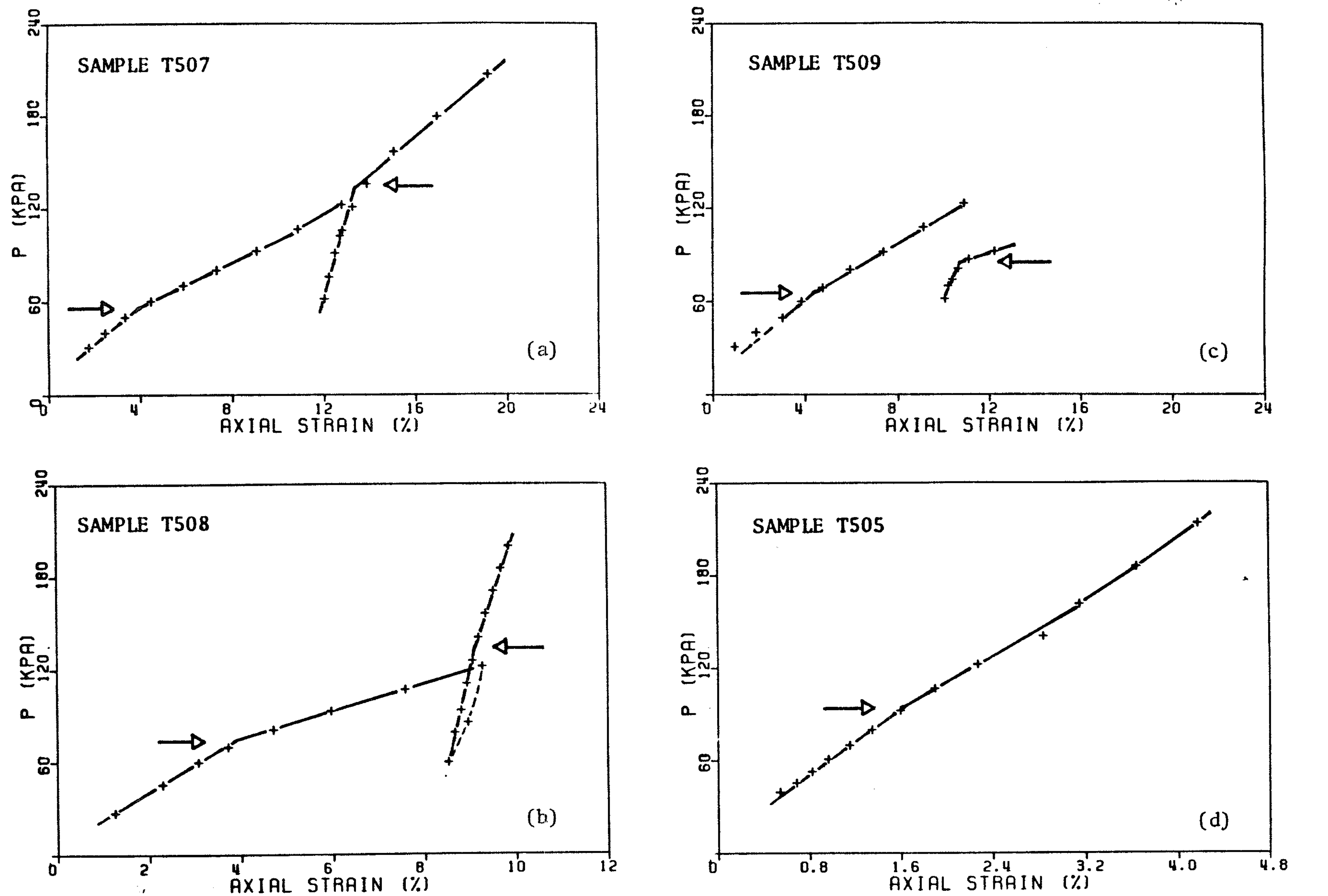


FIGURE 3.17a,b,c,d - YIELD DETERMINATION
p' vs ε_1, T507,T508,T509,T505

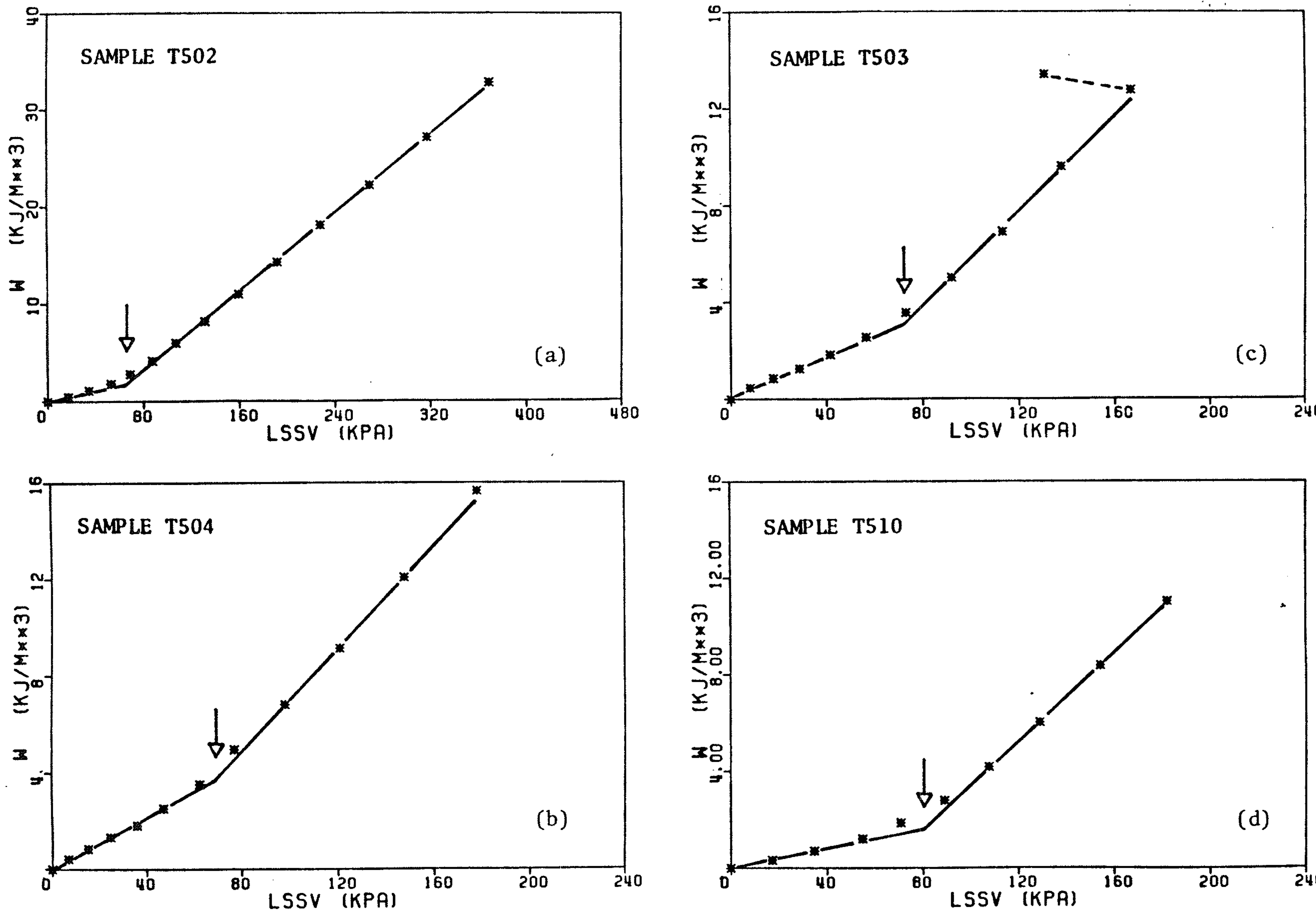


FIGURE 3.18a,b,c,d - YIELD DETERMINATION
W vs LSSV, T502,T504,T503,T510

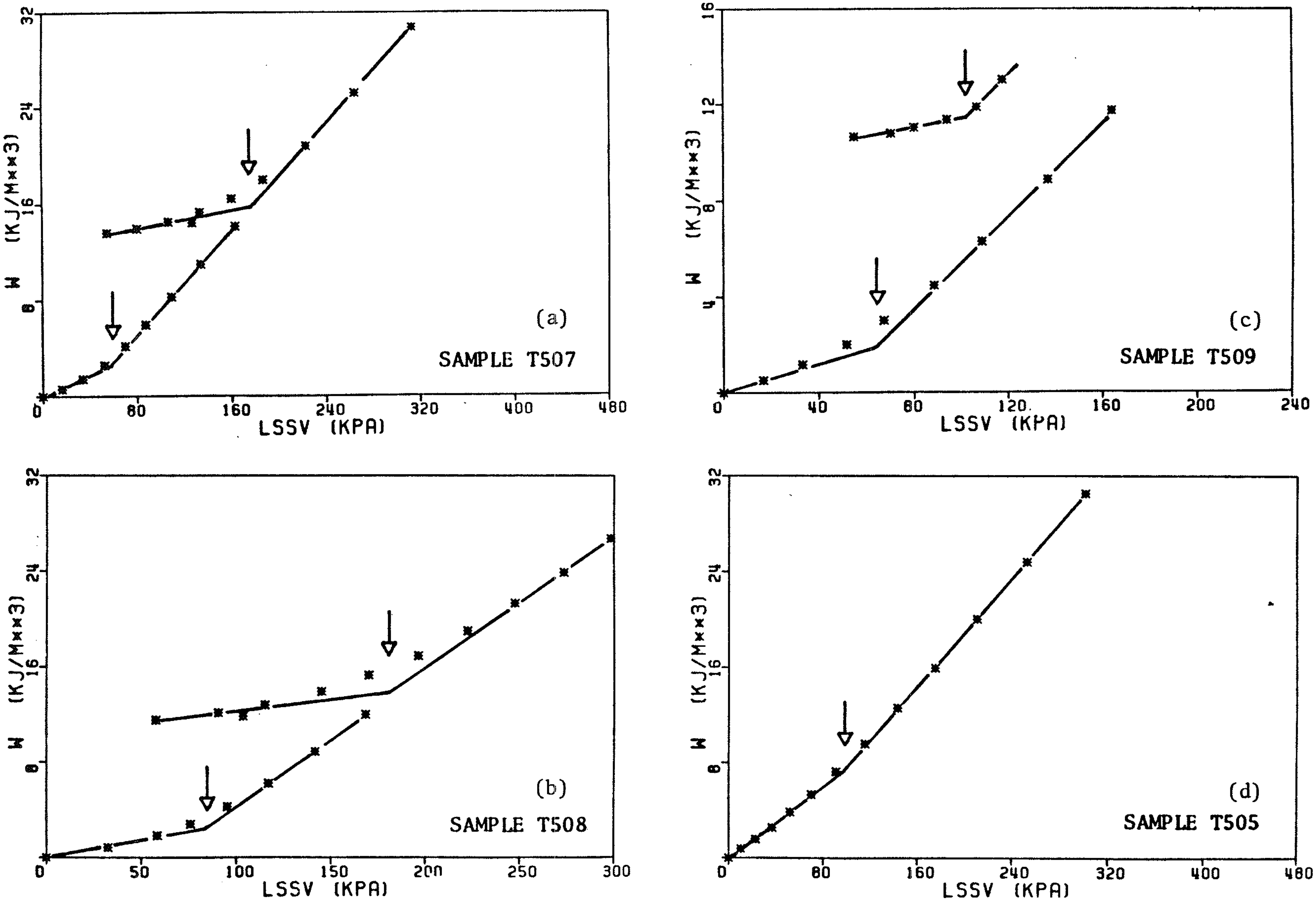


FIGURE 3.19a,b,c,d - YIELD DETERMINATION
W vs LSSV, T507,T508,T509,T505

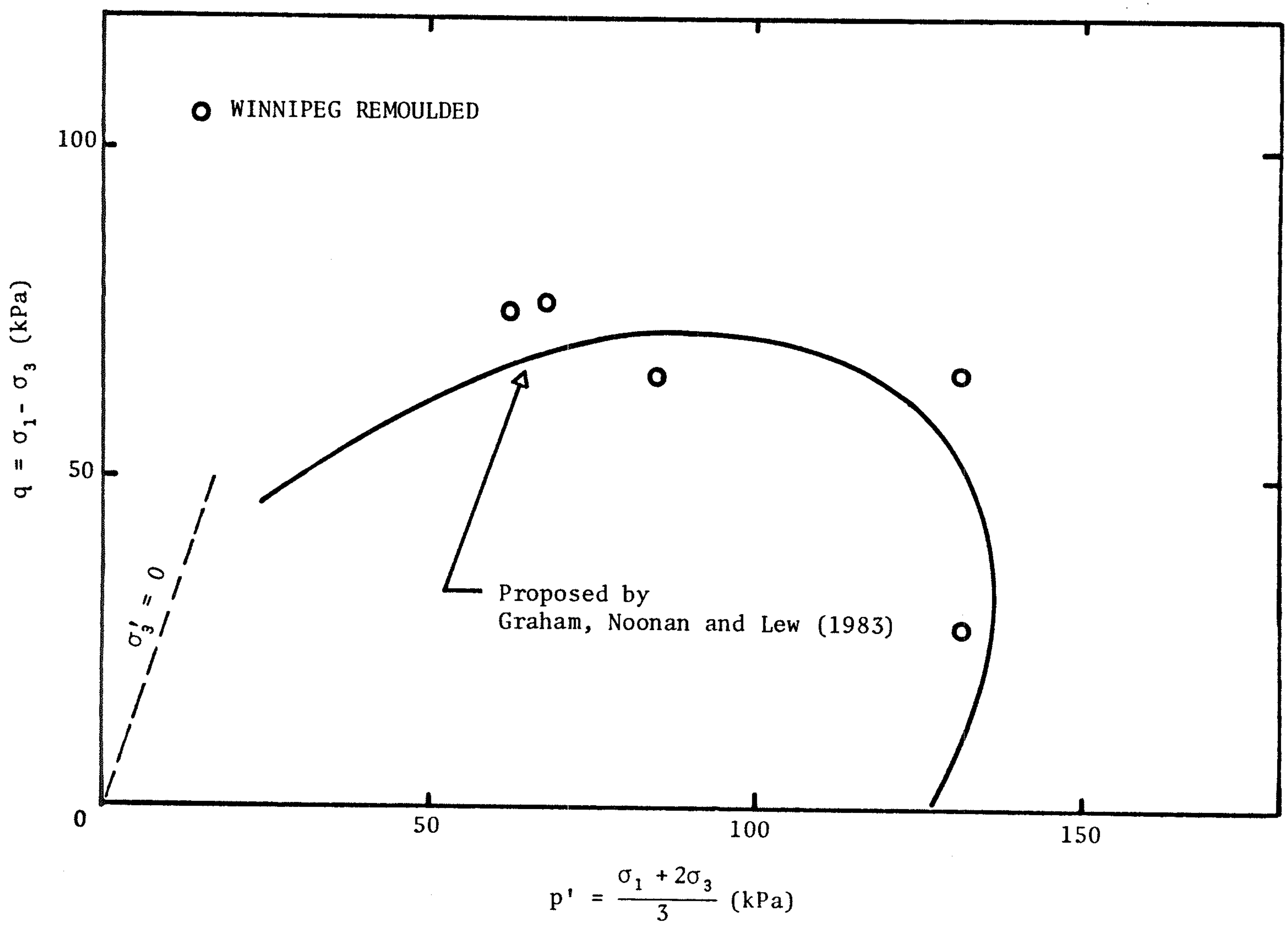


FIGURE 3.20 - YIELD ENVELOPE FROM TESTS ON REMOULDED WINNIPEG CLAY

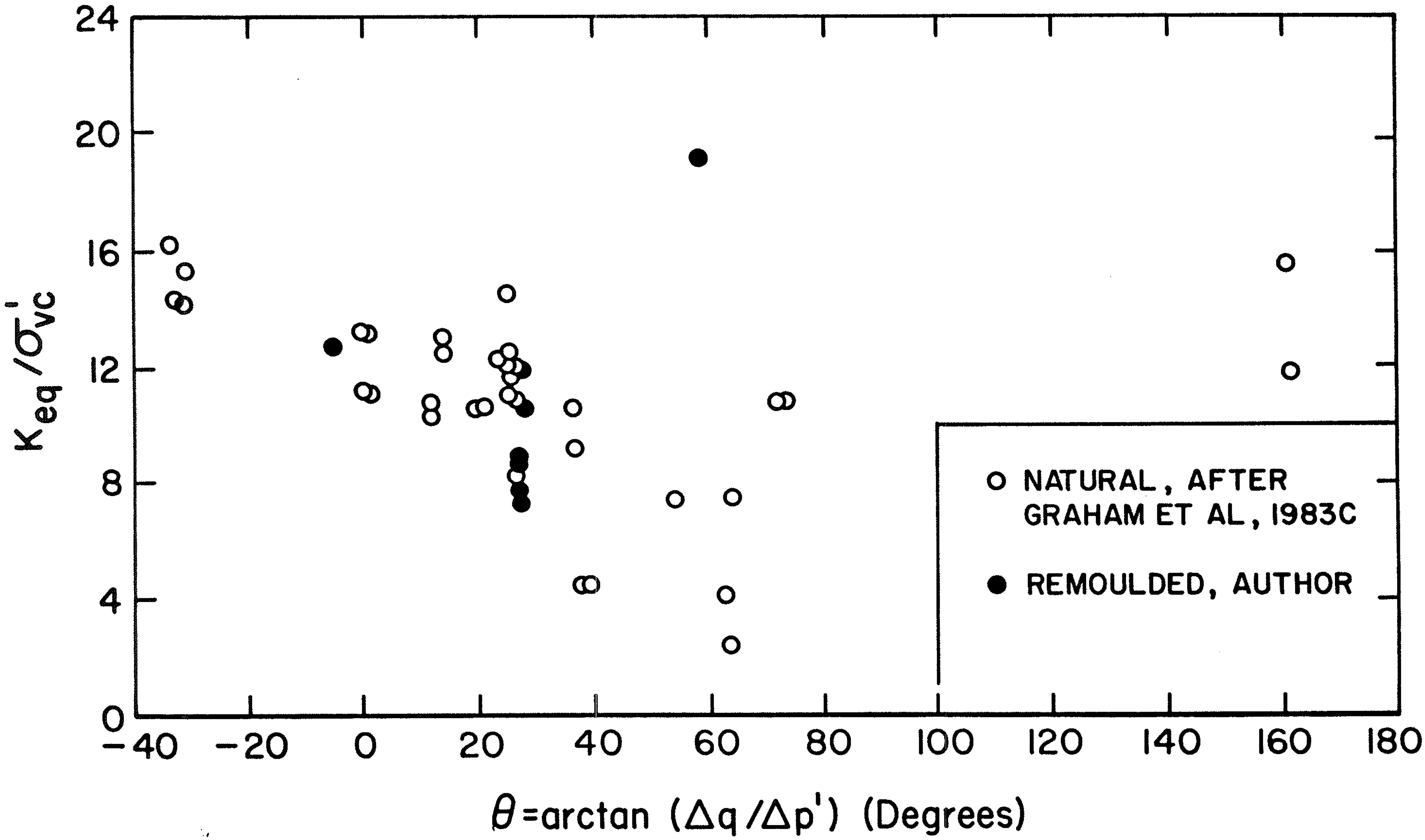


FIGURE 3.21a - VARIATION OF NORMALIZED EQUIVALENT BULK MODULUS WITH STRESS PATH DIRECTION IN TRIAXIAL TESTS

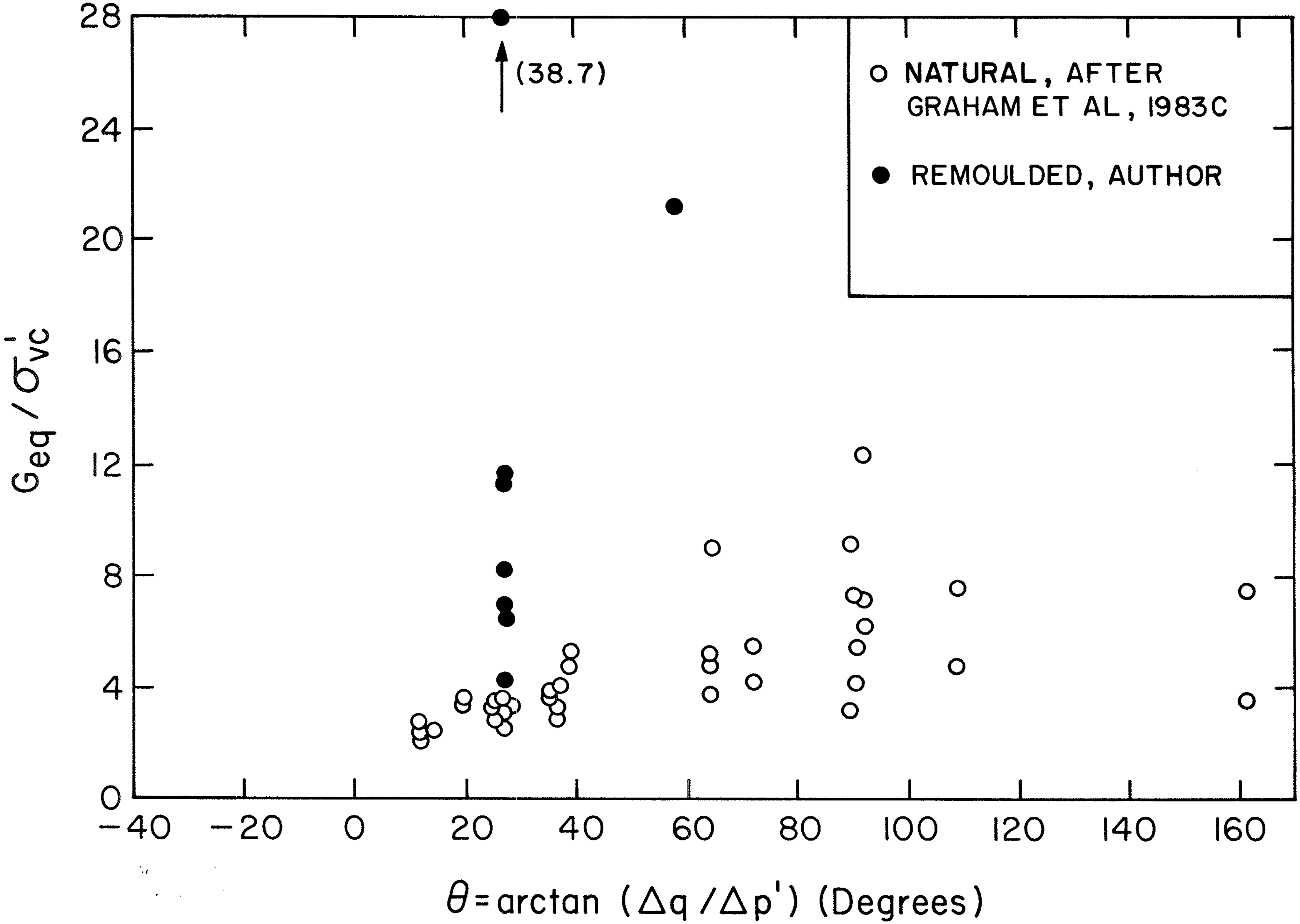


FIGURE 3.21b - VARIATION OF NORMALIZED EQUIVALENT SHEAR MODULUS WITH STRESS PATH DIRECTION IN TRIAXIAL TESTS

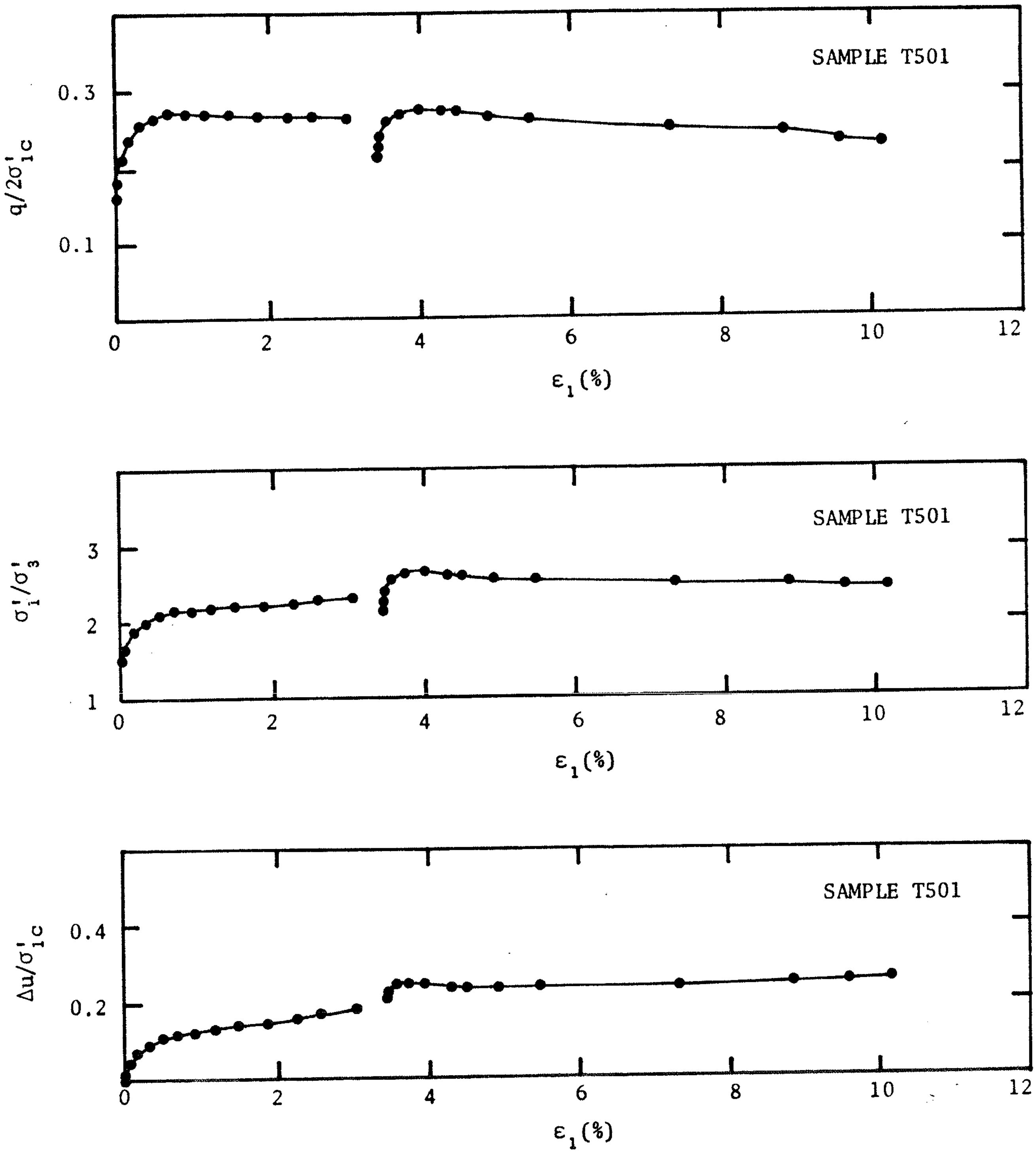


FIGURE 4.1 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T501

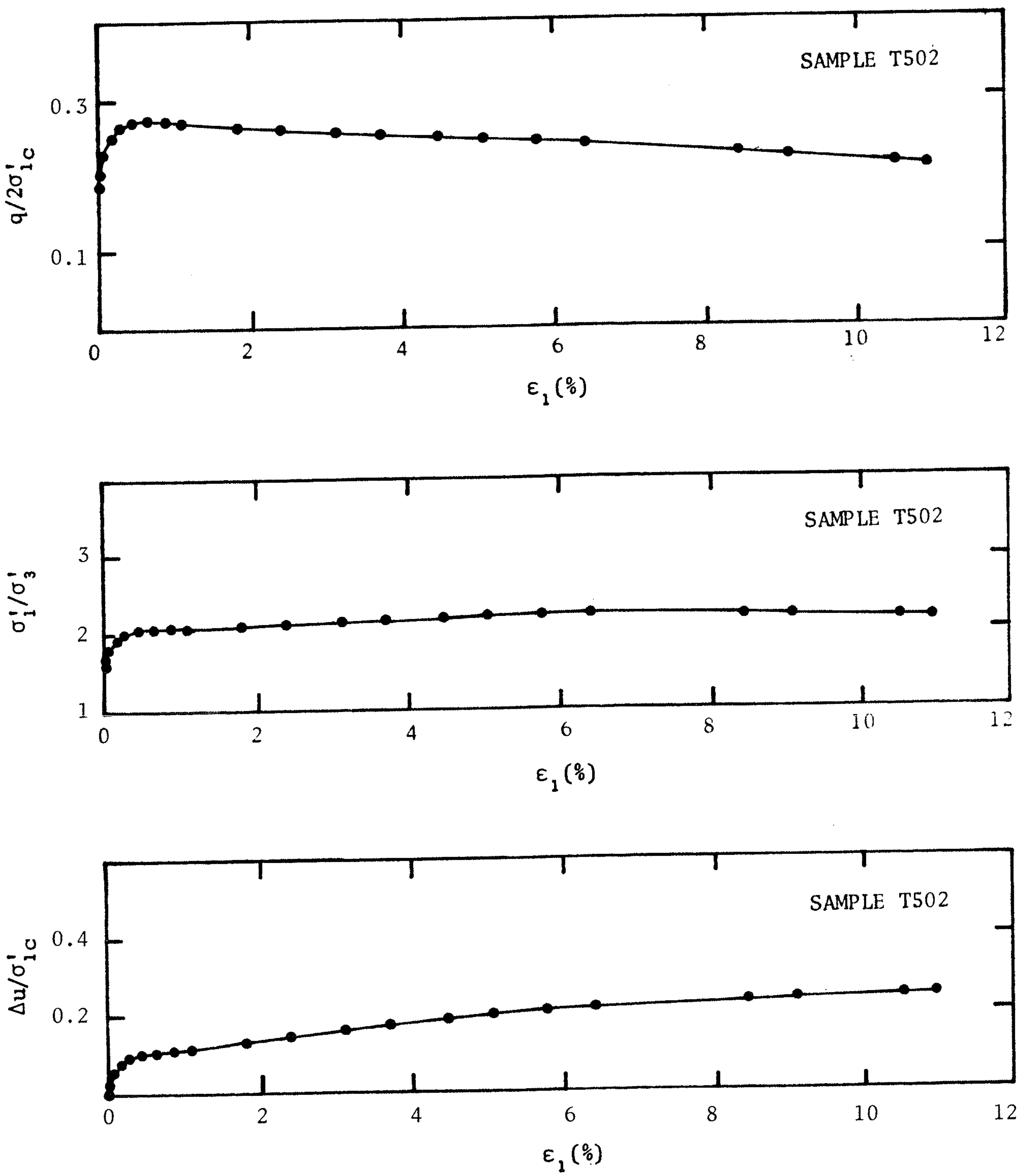


FIGURE 4.2 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T502

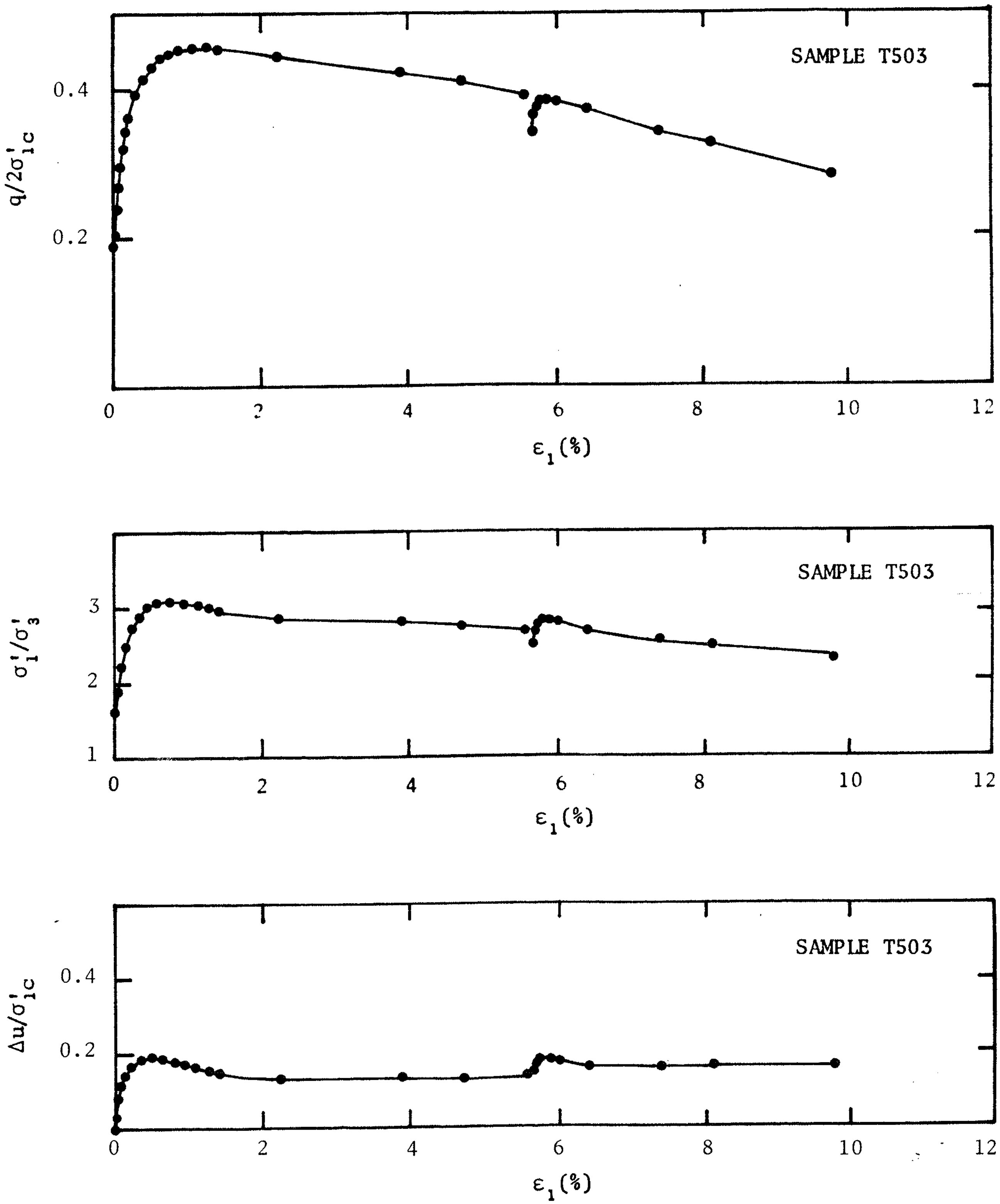


FIGURE 4.3 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T503

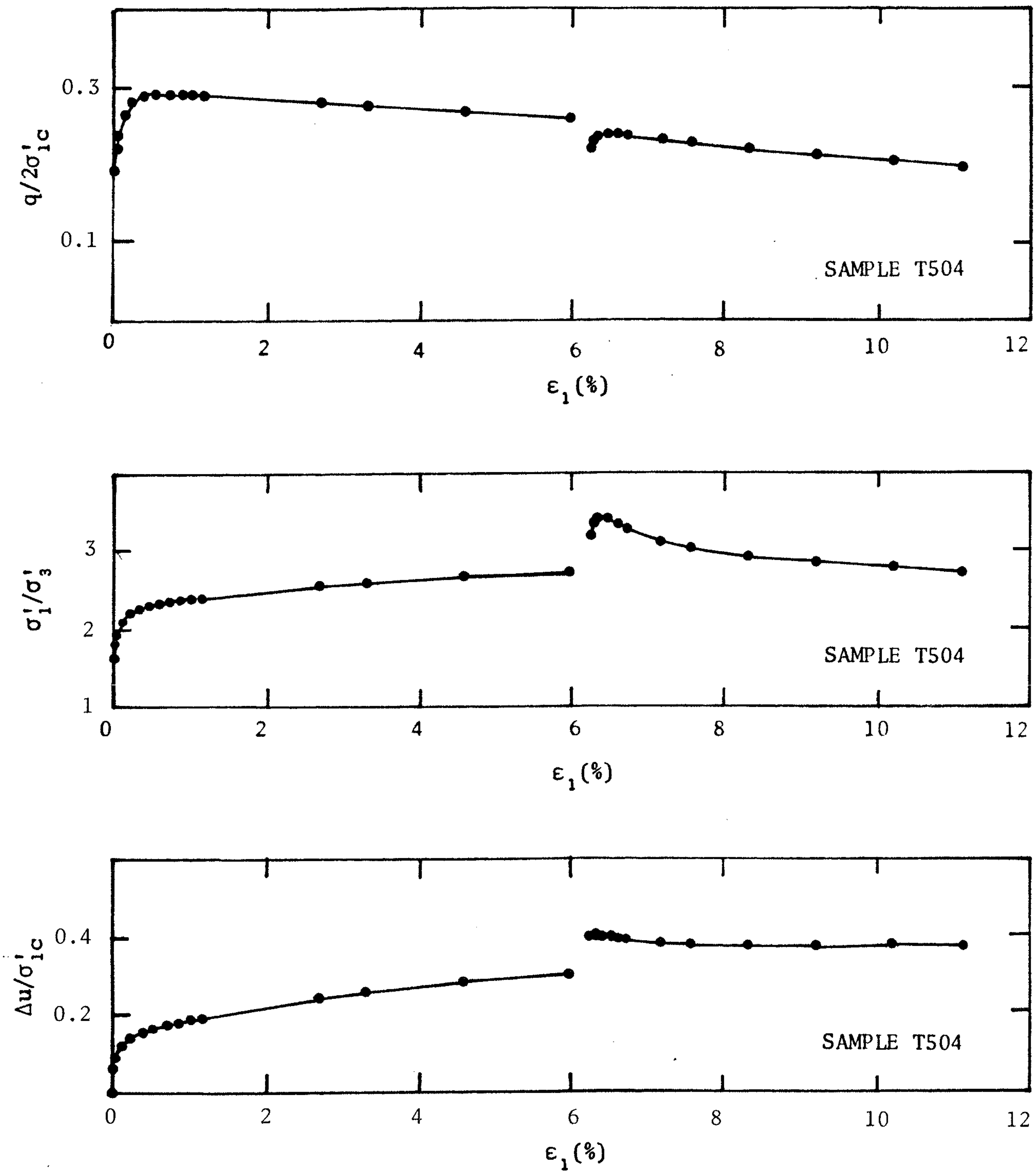


FIGURE 4.4 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T504

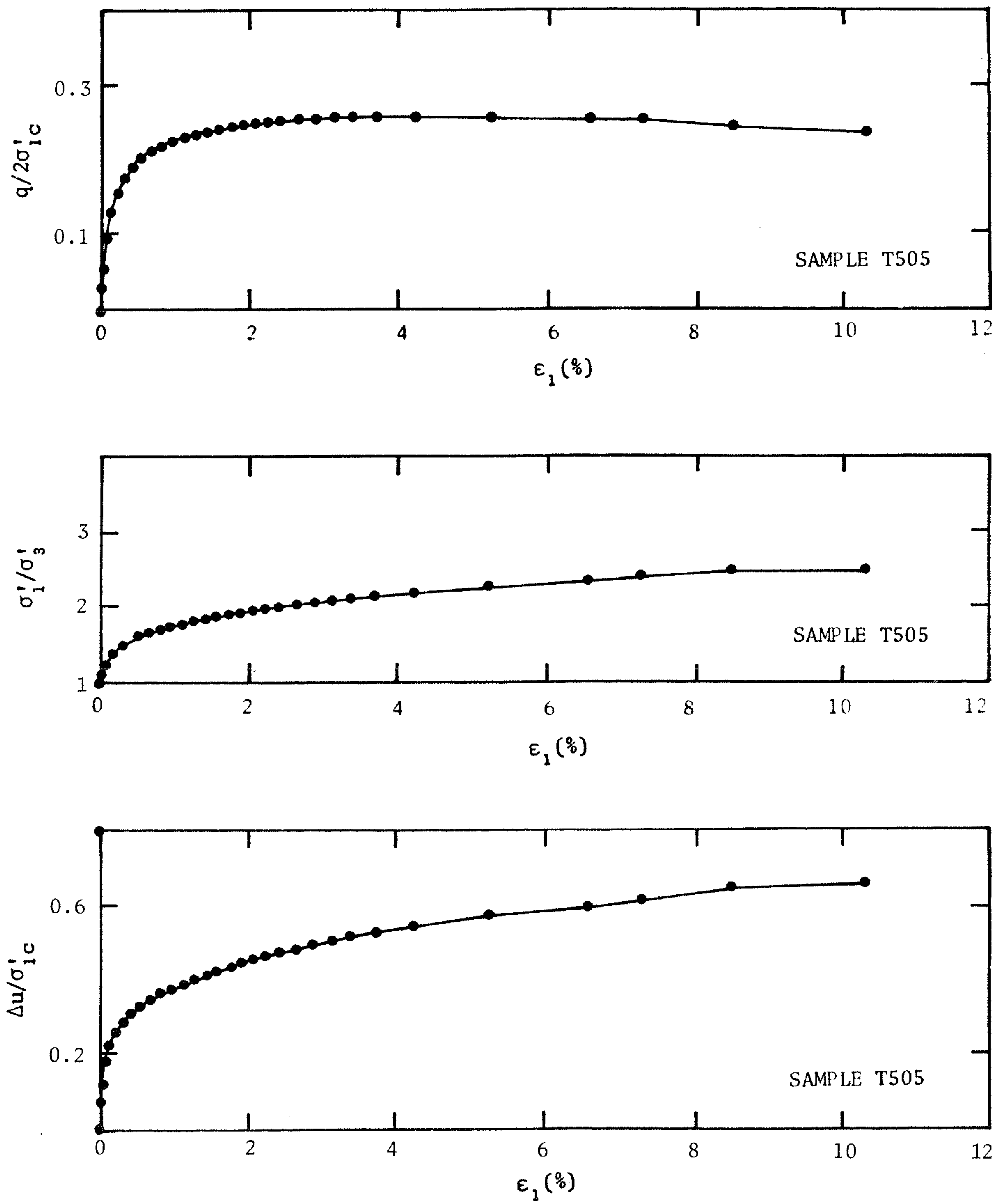


FIGURE 4.5 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T505

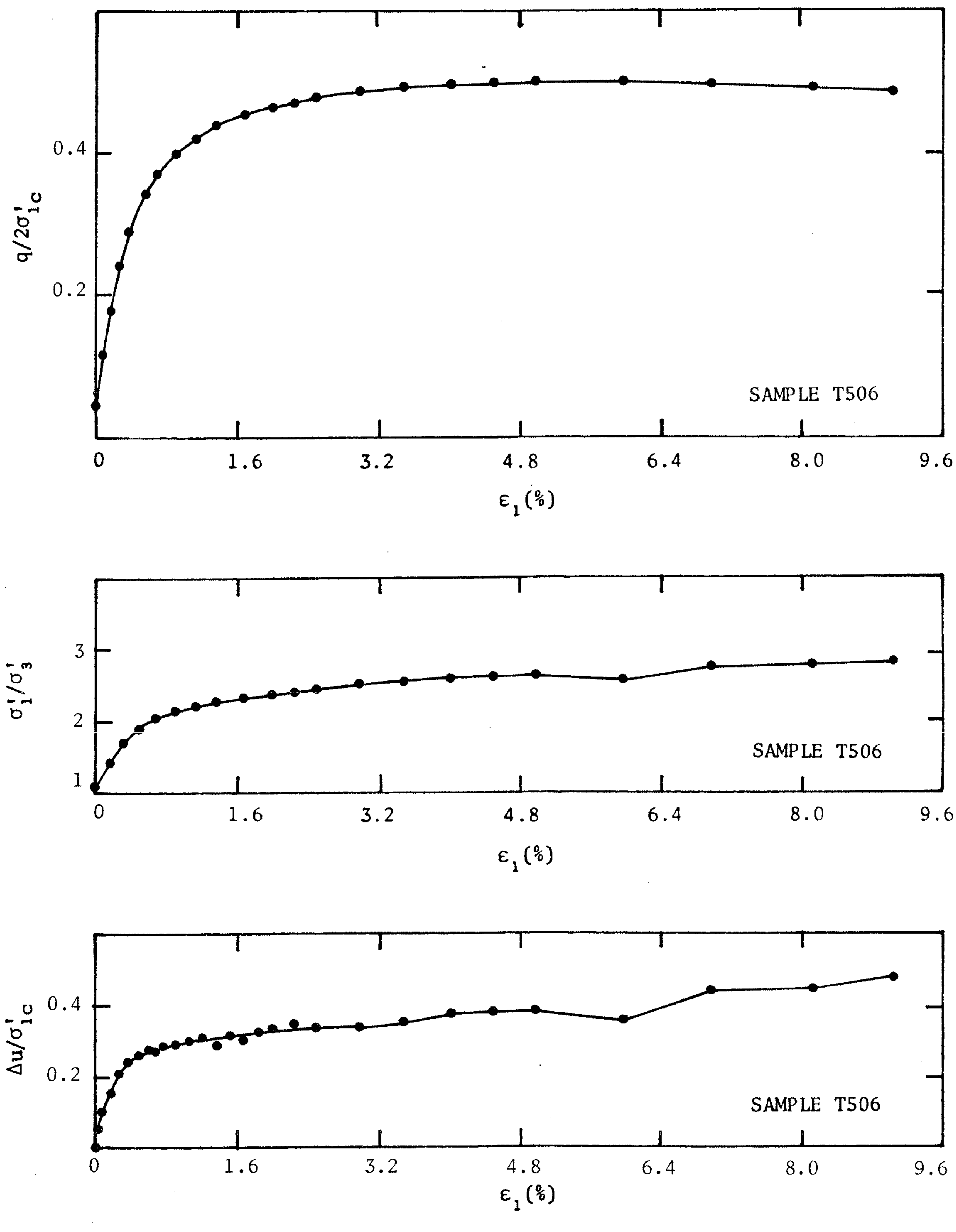


FIGURE 4.6 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T506

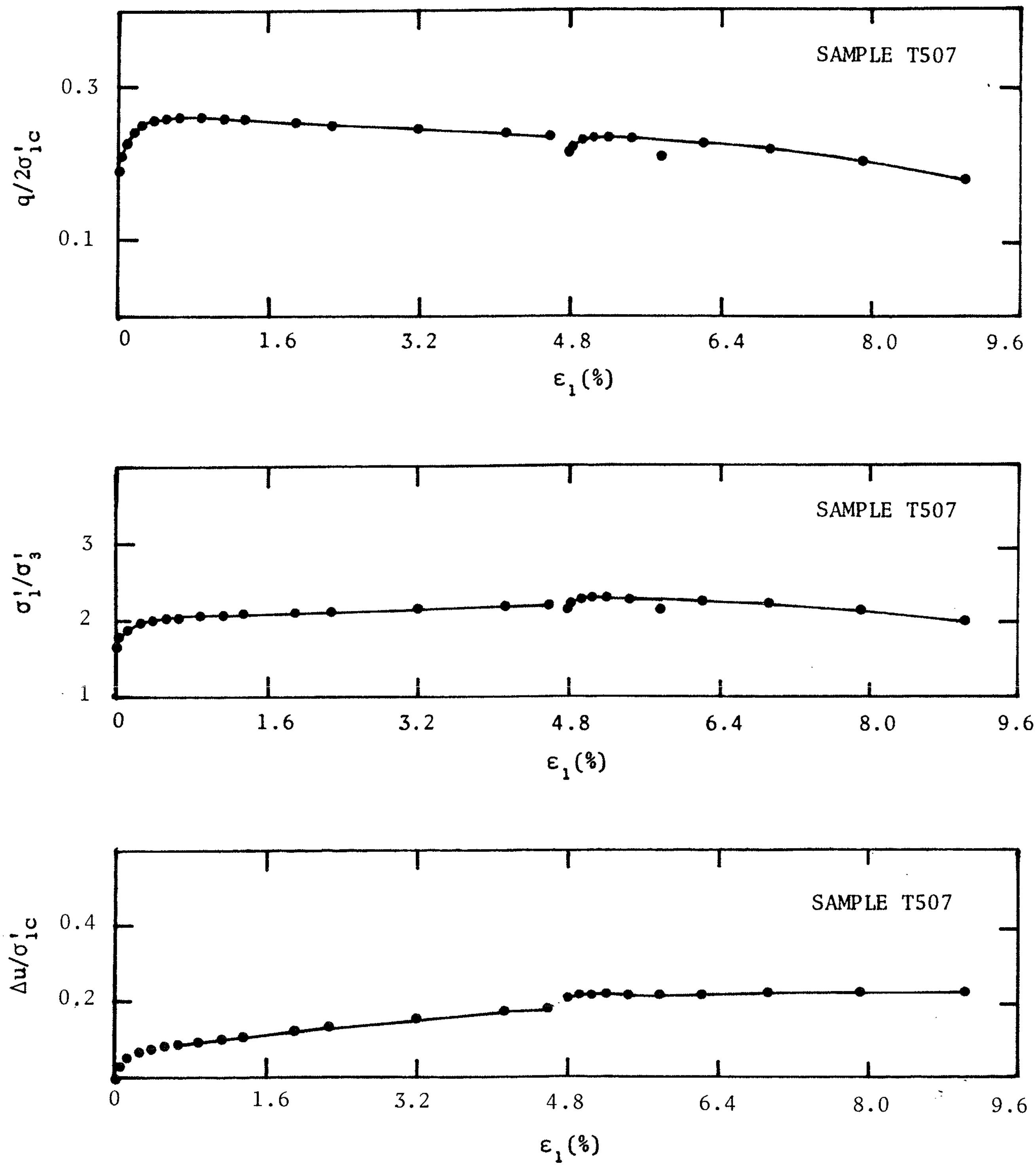


FIGURE 4.7 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T507

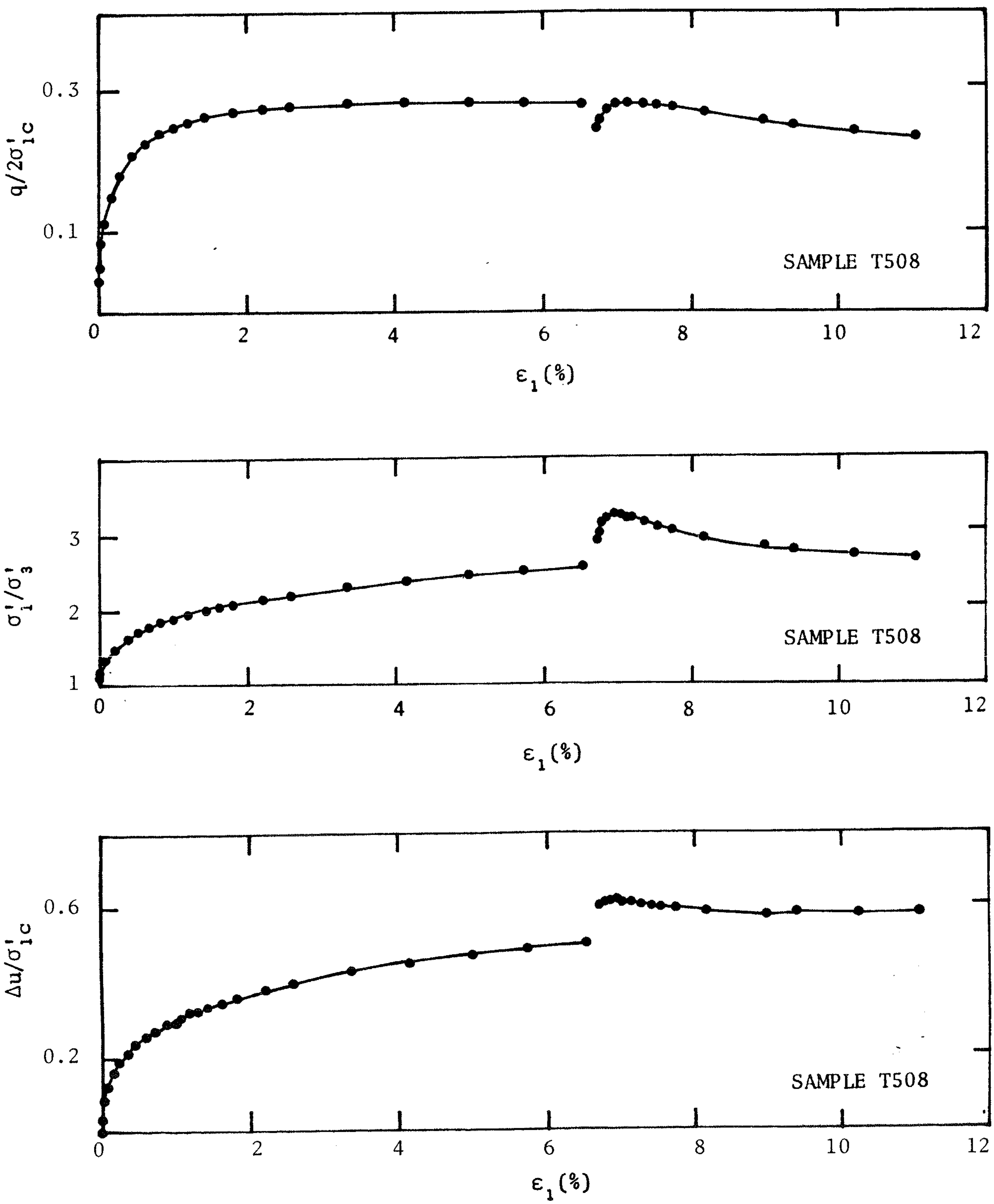


FIGURE 4.8 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T508

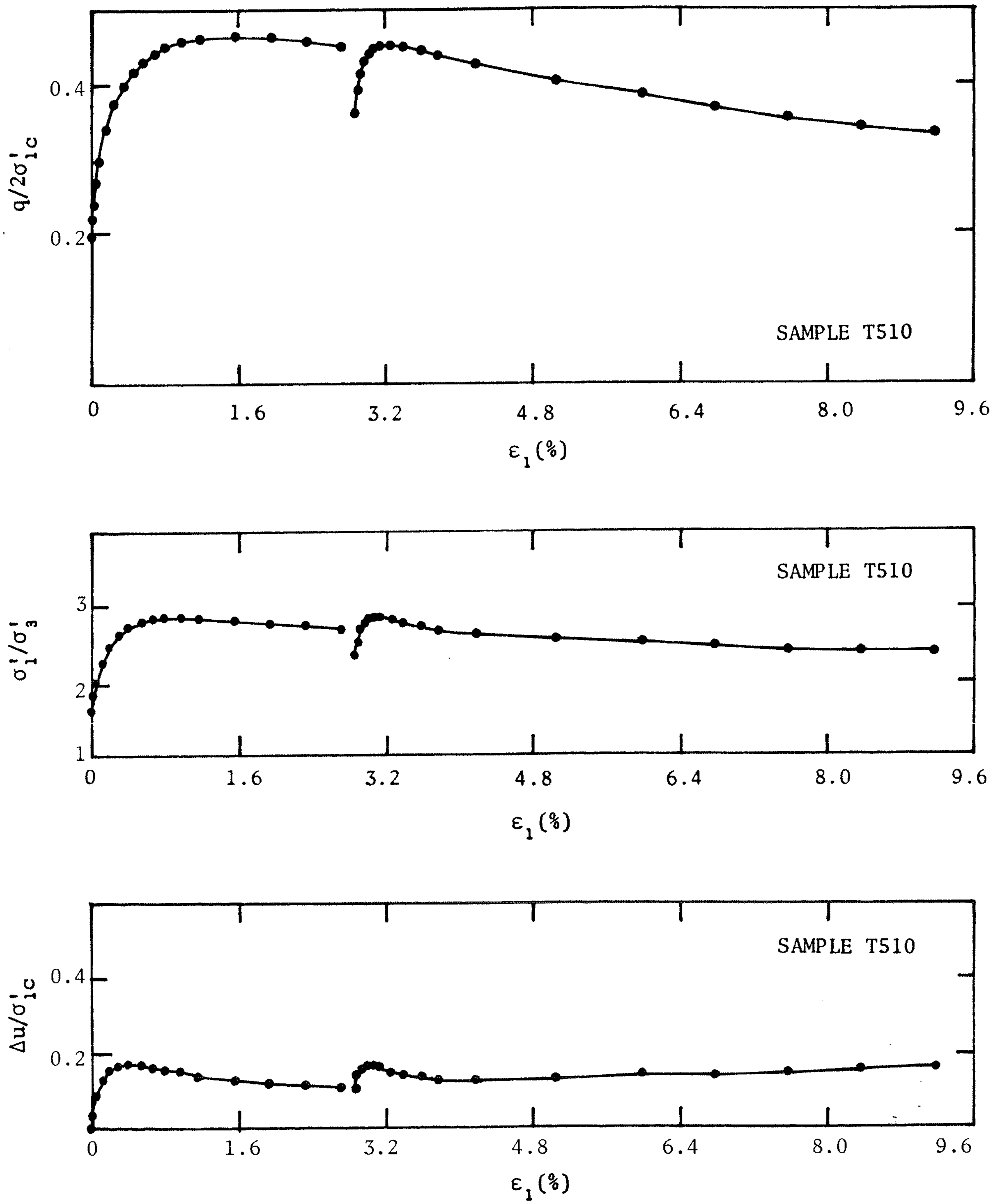


FIGURE 4.9 - UNDRAINED STRESS-STRAIN POREWATER PRESSURE RESULTS, T510

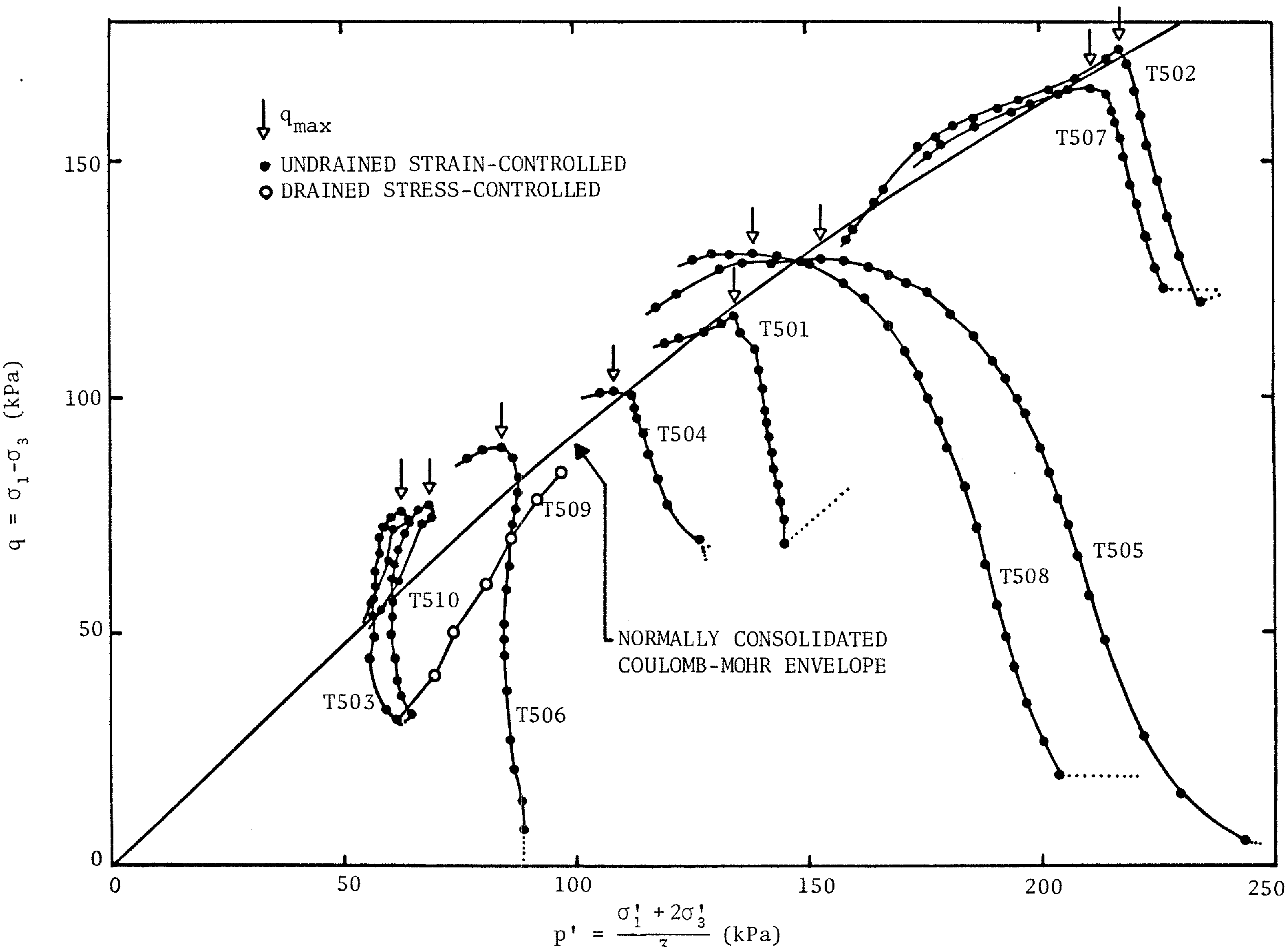


FIGURE 4.10 - EFFECTIVE STRESS PATHS AND FAILURE ENVELOPE

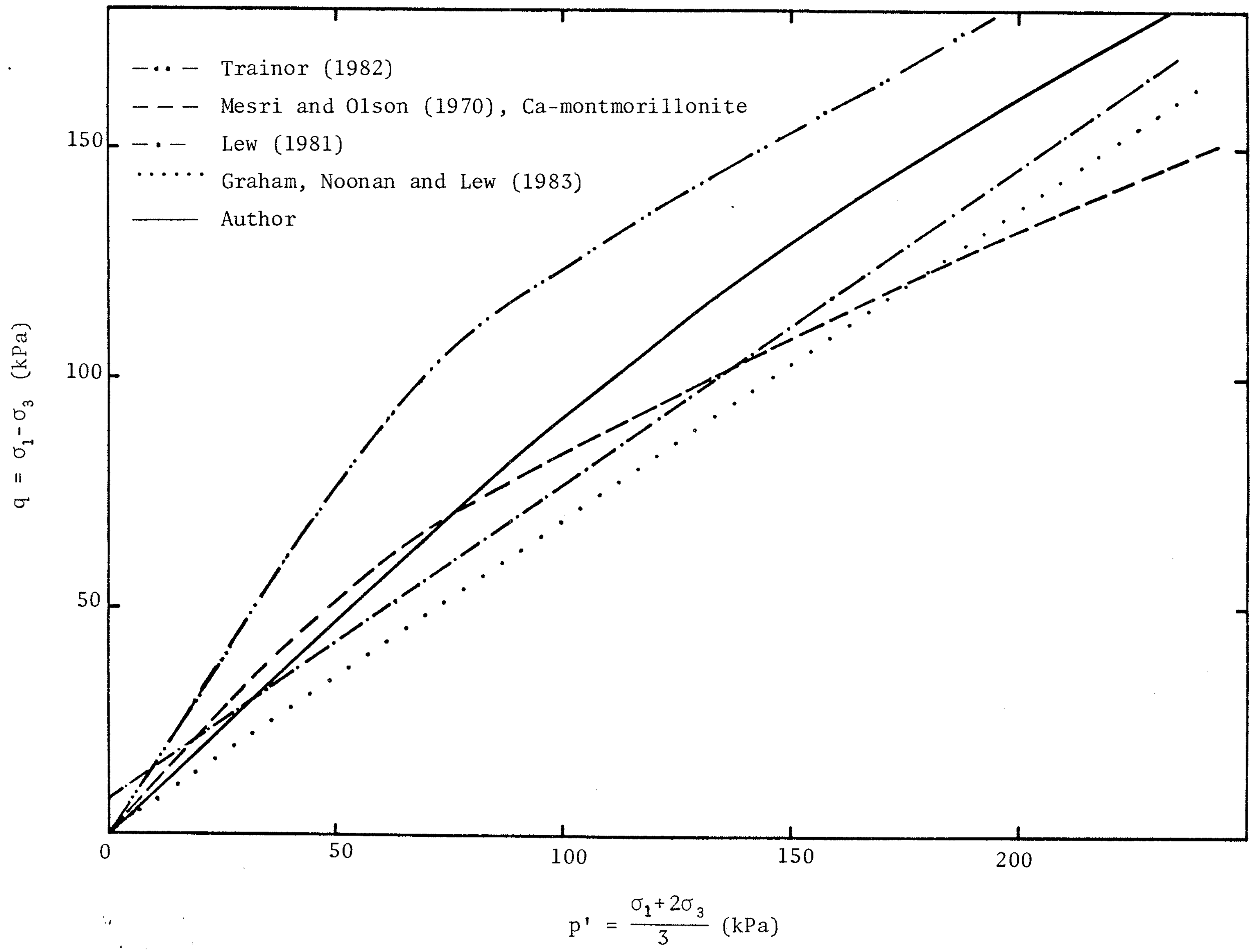


FIGURE 4.11 - COMPARISON OF FAILURE ENVELOPE

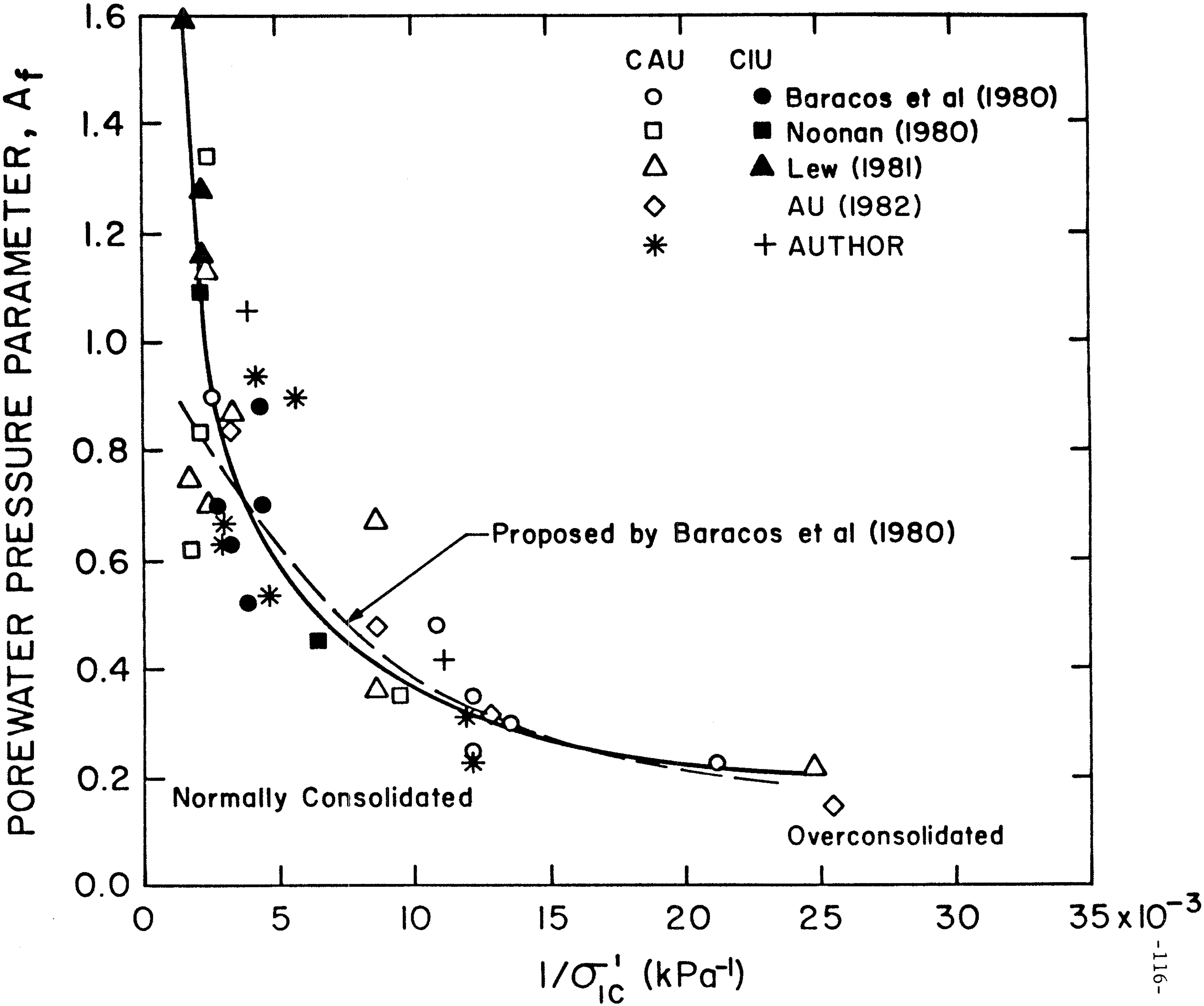


FIGURE 4.12 - GRAPH OF POREWATER PRESSURE PARAMETER, A_f, VERSUS $1/\sigma'_{1c}$

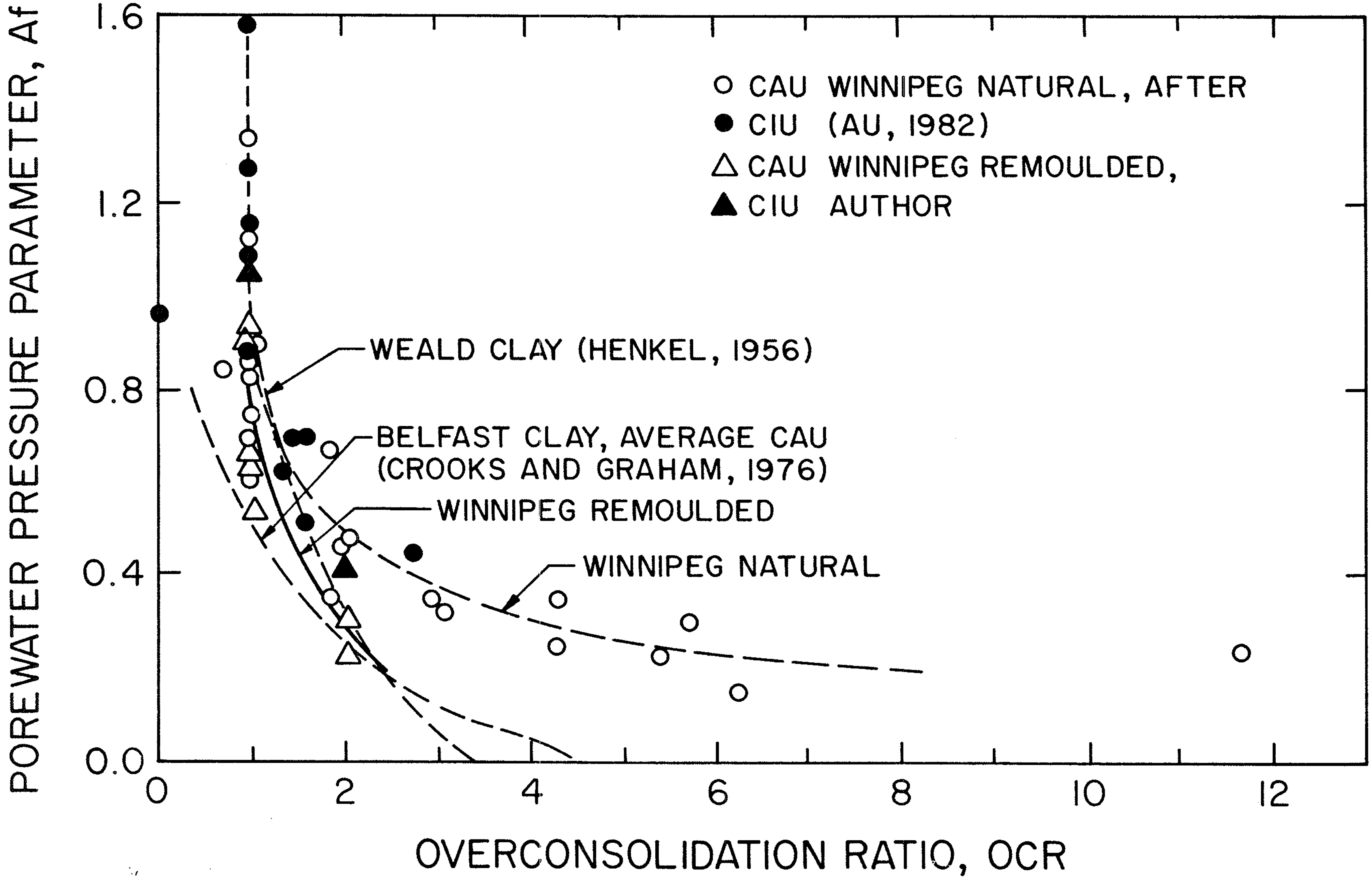
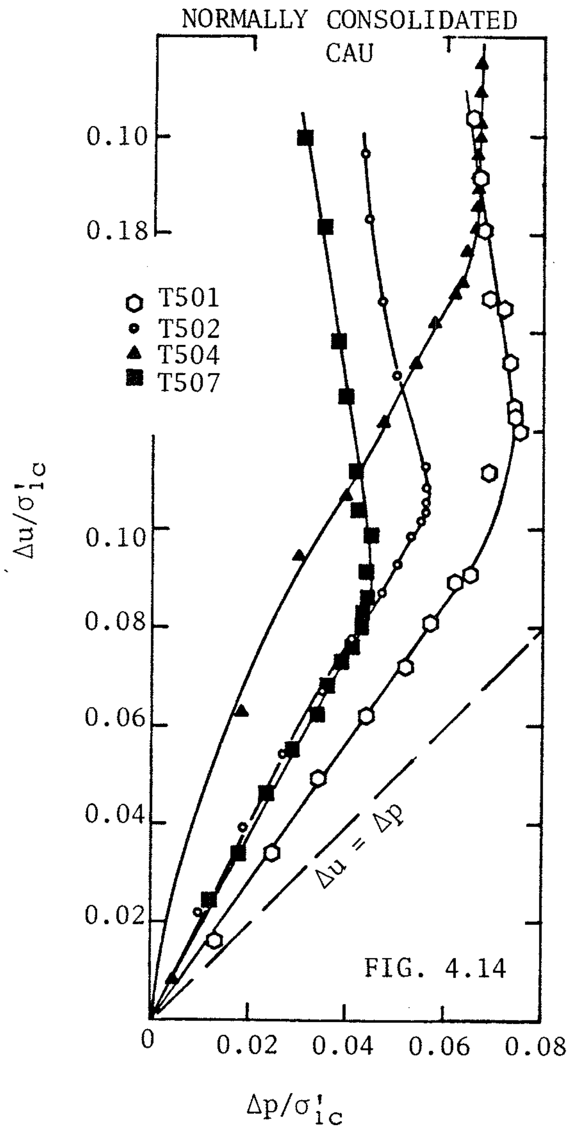


FIGURE 4.13 - SUMMARY GRAPH OF POREWATER PRESSURE PARAMETER, A_f, VERSUS OVERCONSOLIDATION RATIO, OCR



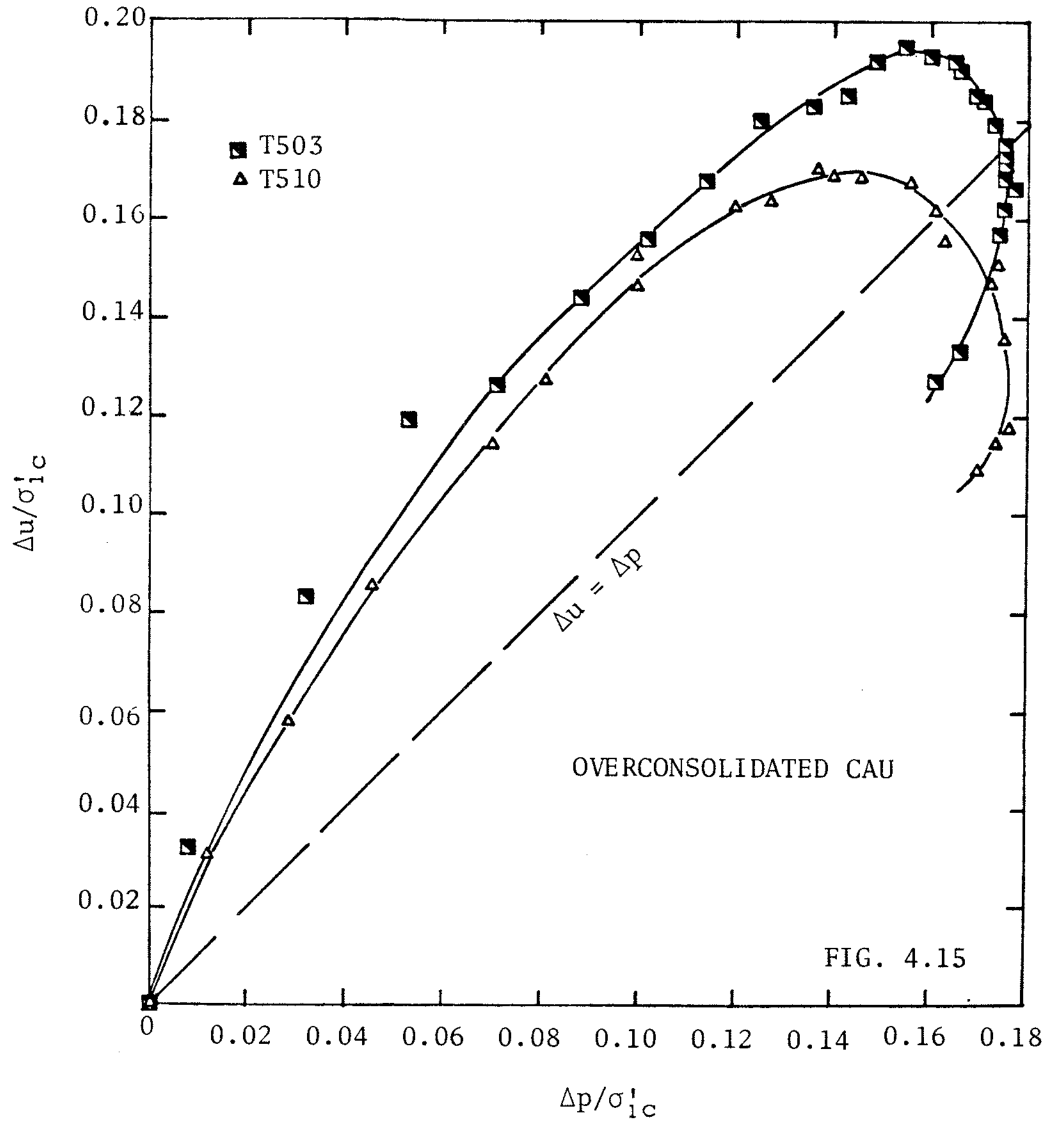


FIGURE 4.14,4.15 - POREWATER PRESSURE BEHAVIOUR, $\Delta u/\sigma'_{1c}$ VS $\Delta p/\sigma'_{1c}$;
T501,T502,T504,T507,T503,T510

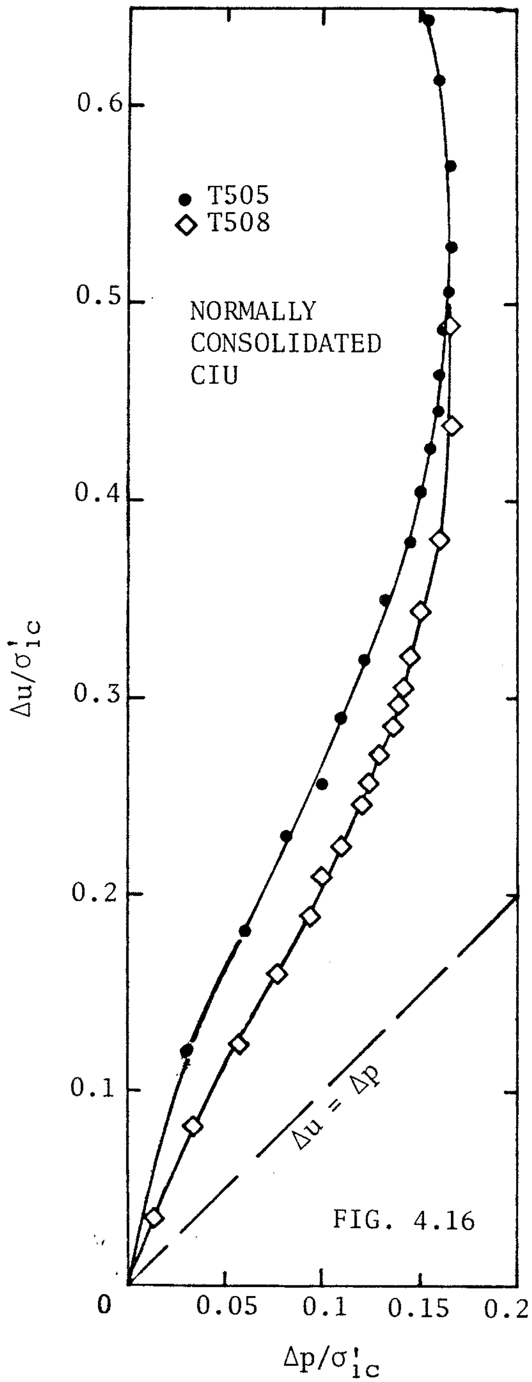


FIG. 4.16

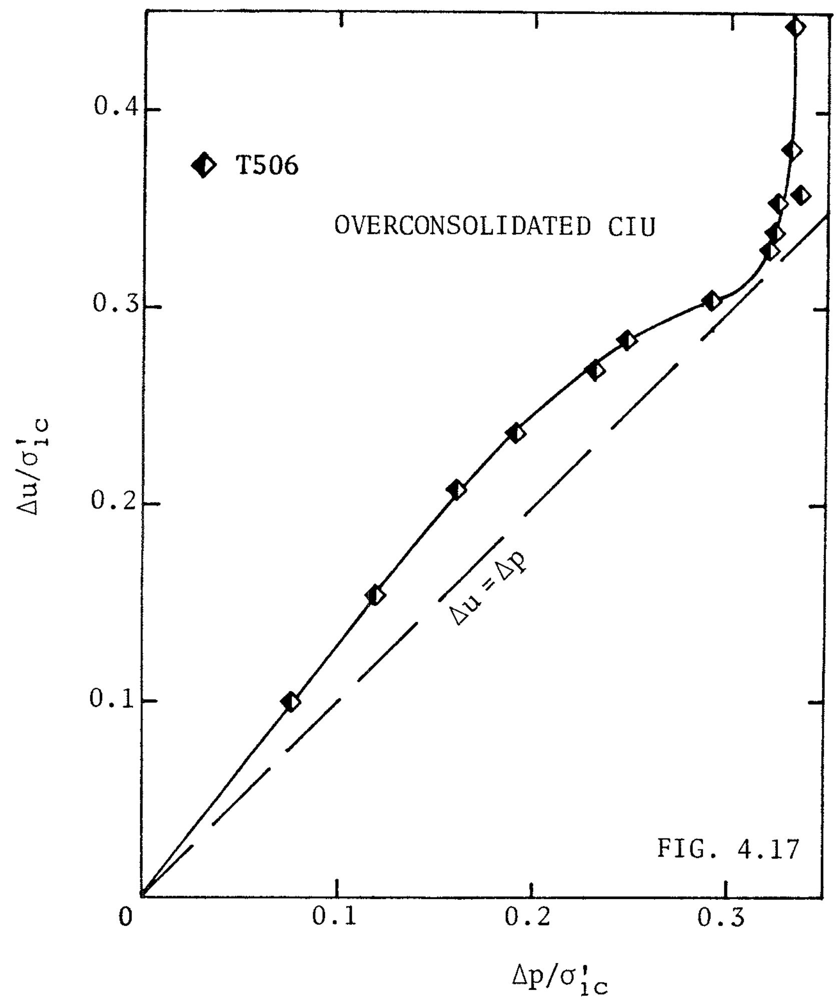


FIG. 4.17

FIGURE 4.16,4.17 - POREWATER PRESSURE BEHAVIOUR, $\Delta u/\sigma'_{1c}$ vs $\Delta p/\sigma'_{1c}$, T505,T508,T506

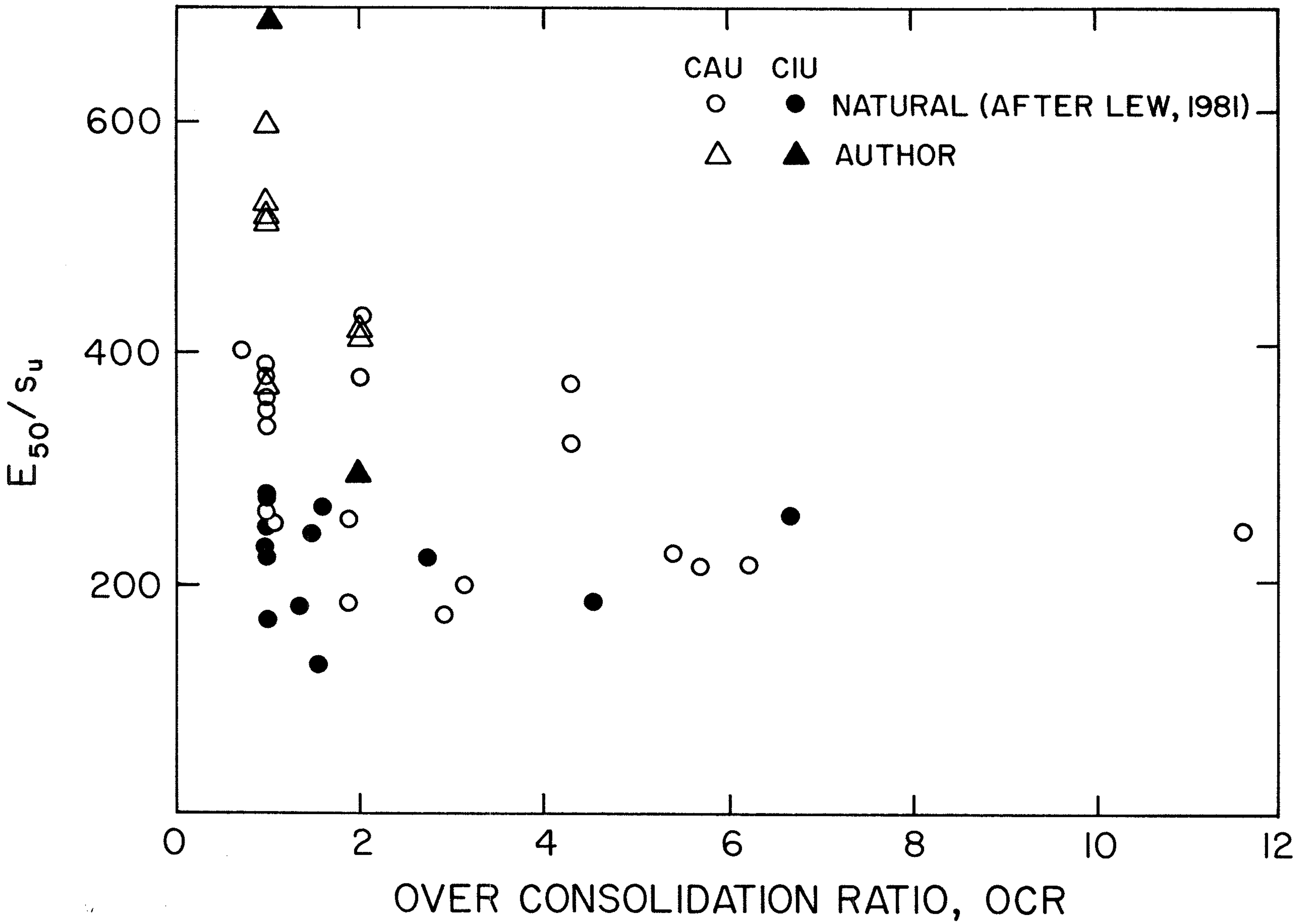


FIGURE 4.18 - RELATIVE STIFFNESS, E_{50}/s_u VERSUS OVERCONSOLIDATION RATIO, OCR

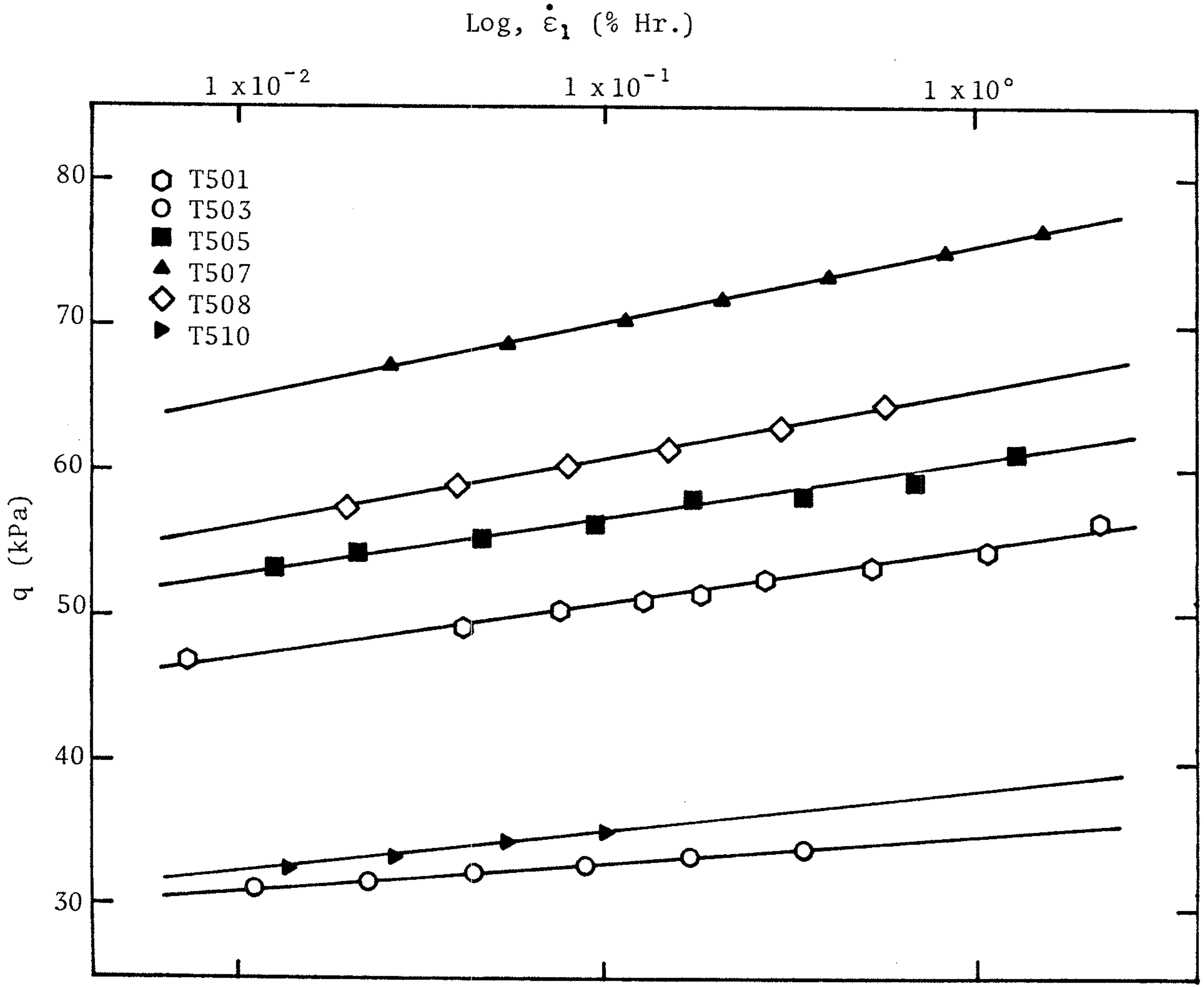


FIGURE 4.19 - STRAIN RATE EFFECTS FROM RELAXATION TESTS;
T501,T503,T505,T507,T508,T510

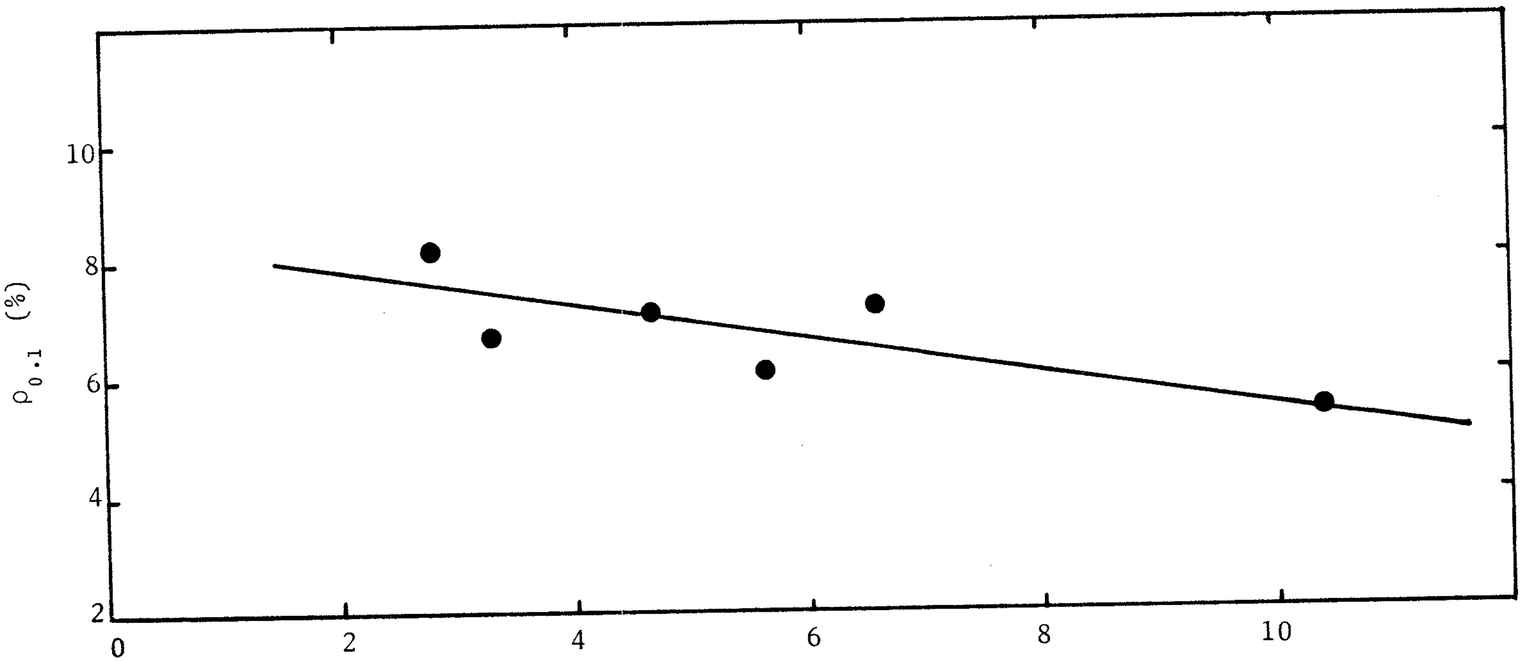


FIGURE 4.20 - RELATIONSHIP BETWEEN $\rho_{0.1}$ PARAMETER AND ε_ρ

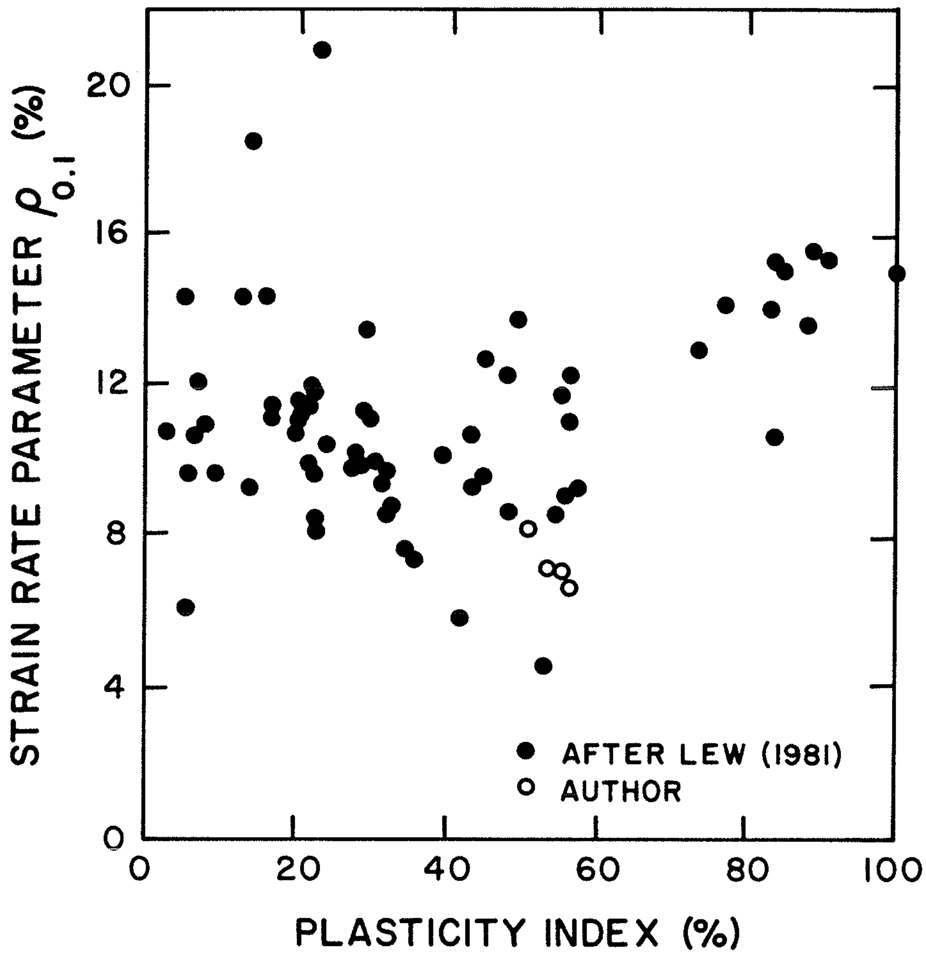
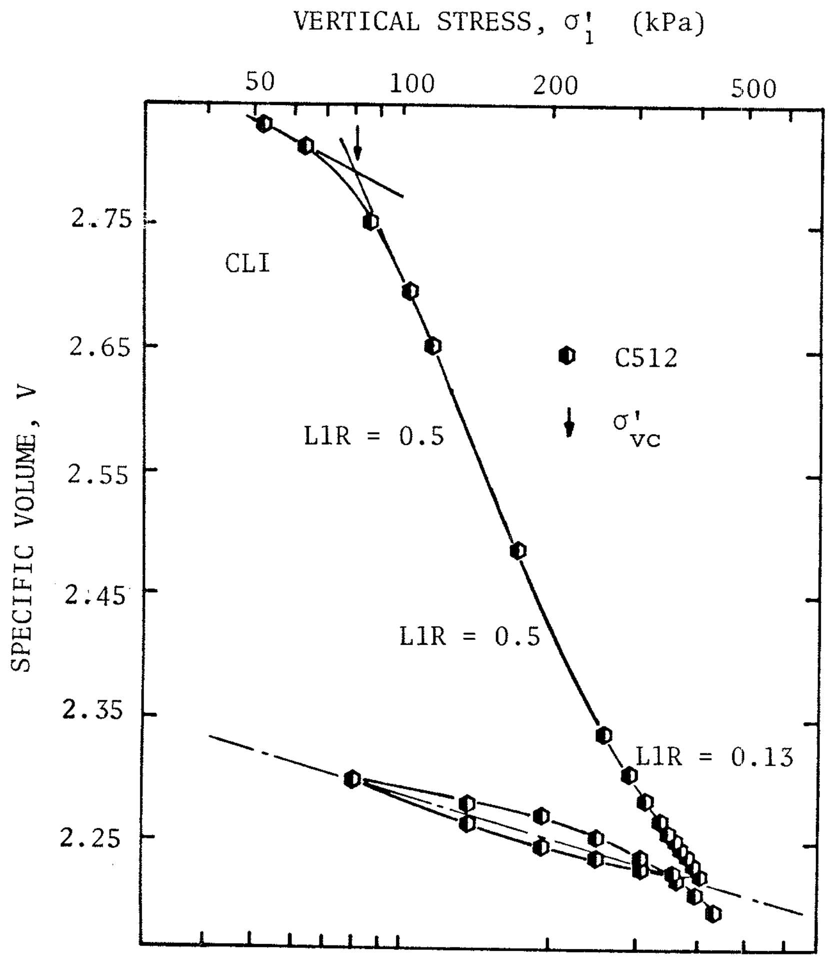


FIGURE 4.21 - SUMMARY GRAPH OF $\rho_{0.1}$ PARAMETER VERSUS PLASTICITY INDEX, I_p



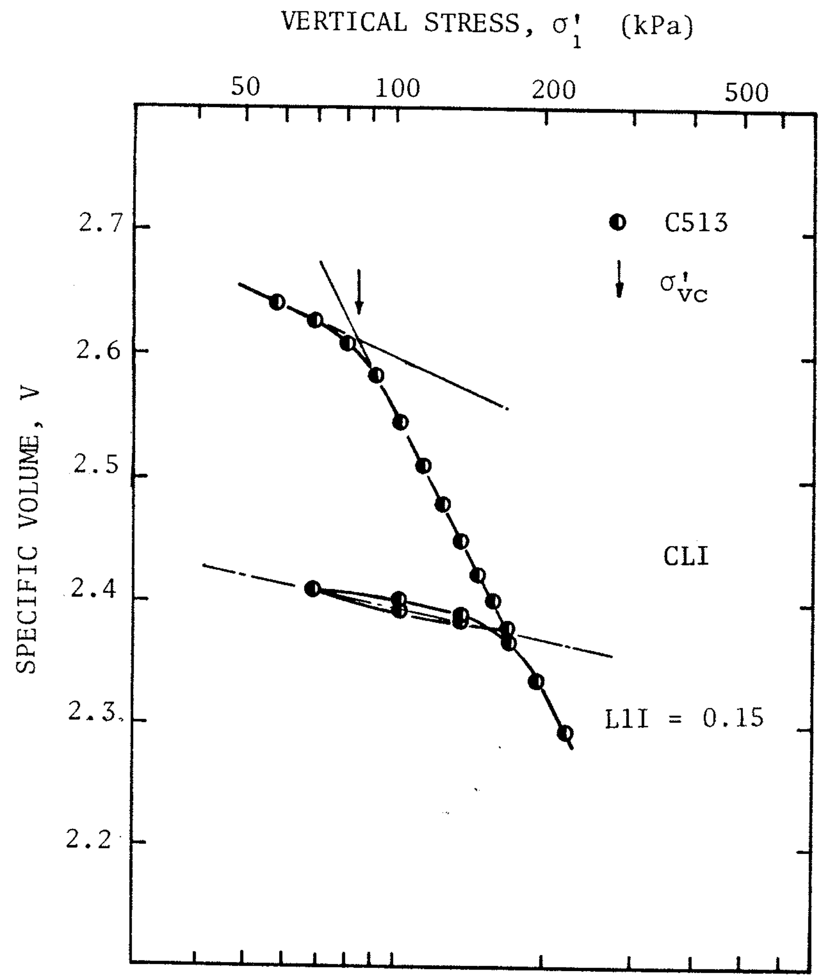
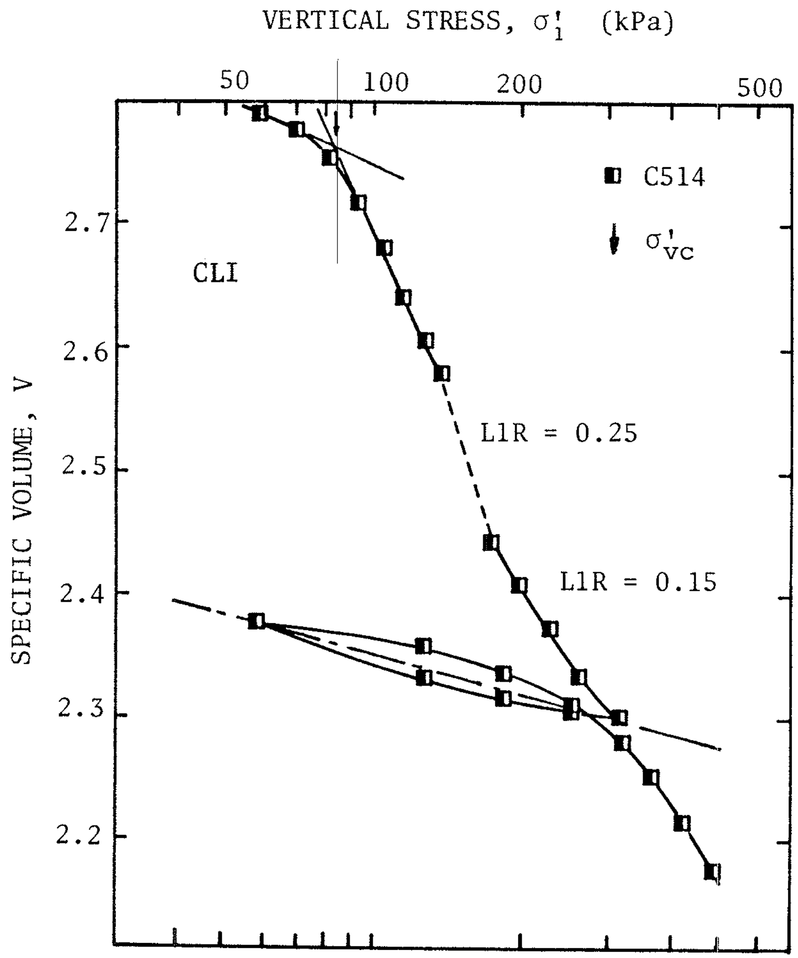


FIGURE 5.1,5.2 - OEDOMETER RESULTS ON REMOULDED SAMPLES; C512,C513



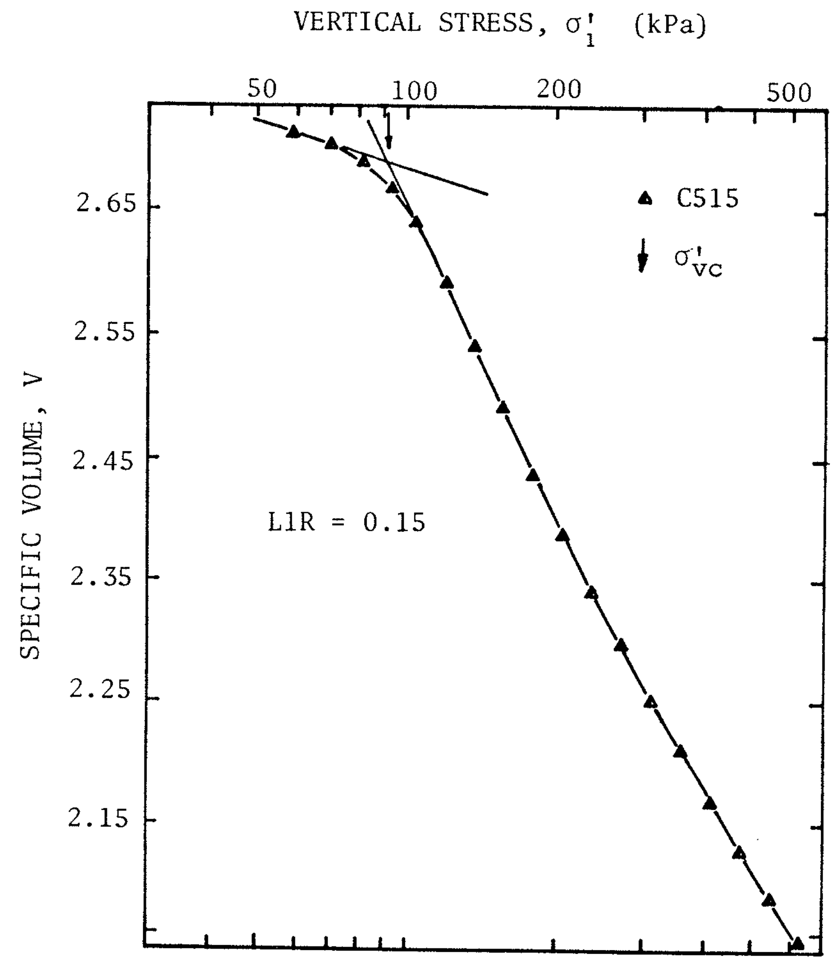


FIGURE 5.3,5.4 - OEDOMETER RESULTS ON REMOULDED SAMPLES:
C514,C515

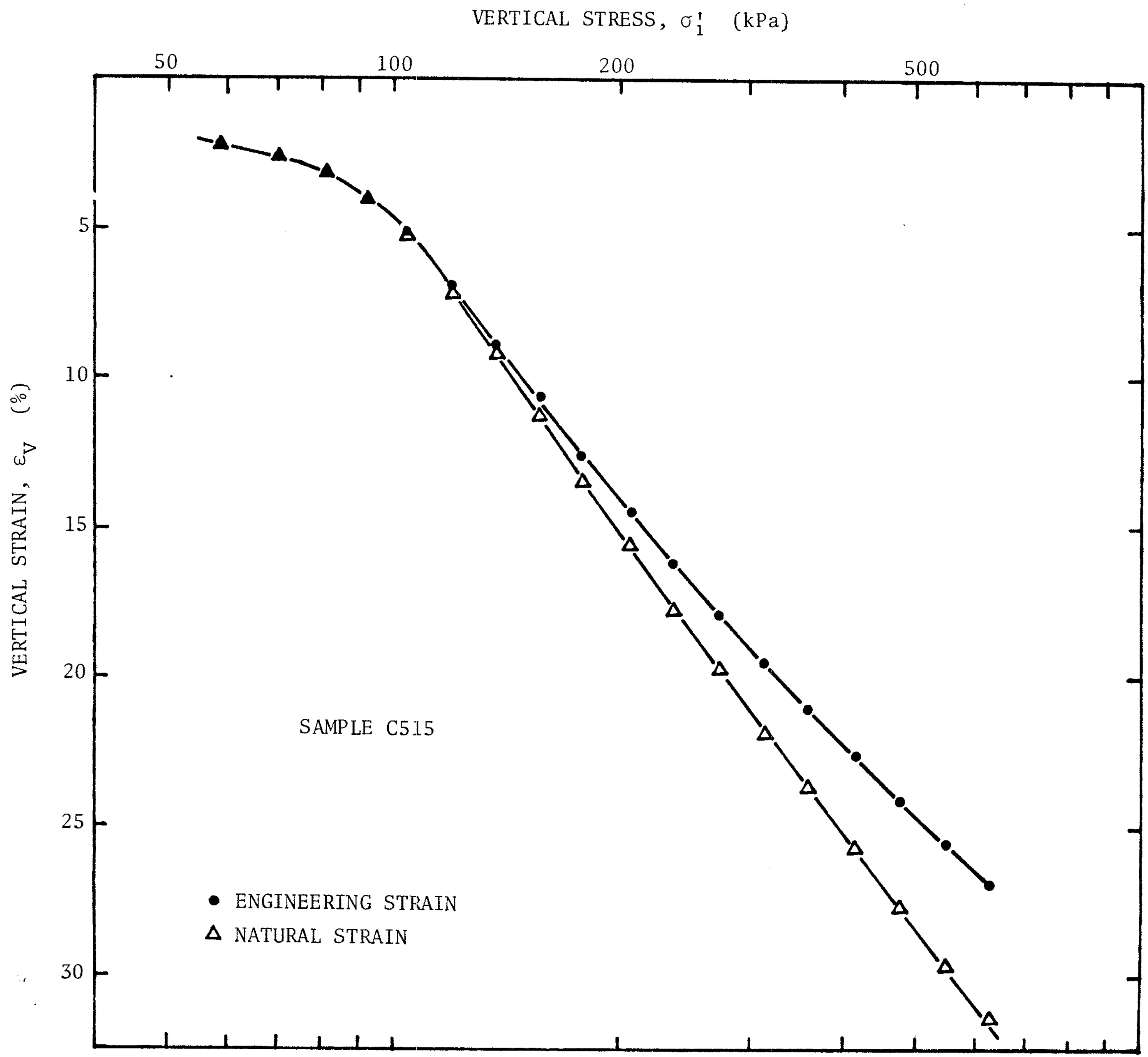


FIGURE 5.5 - COMPARISON OF ε_v, Log σ_v' CURVES OBTAINED BY ENGINEERING STRAIN AND NATURAL STRAIN CALCULATIONS

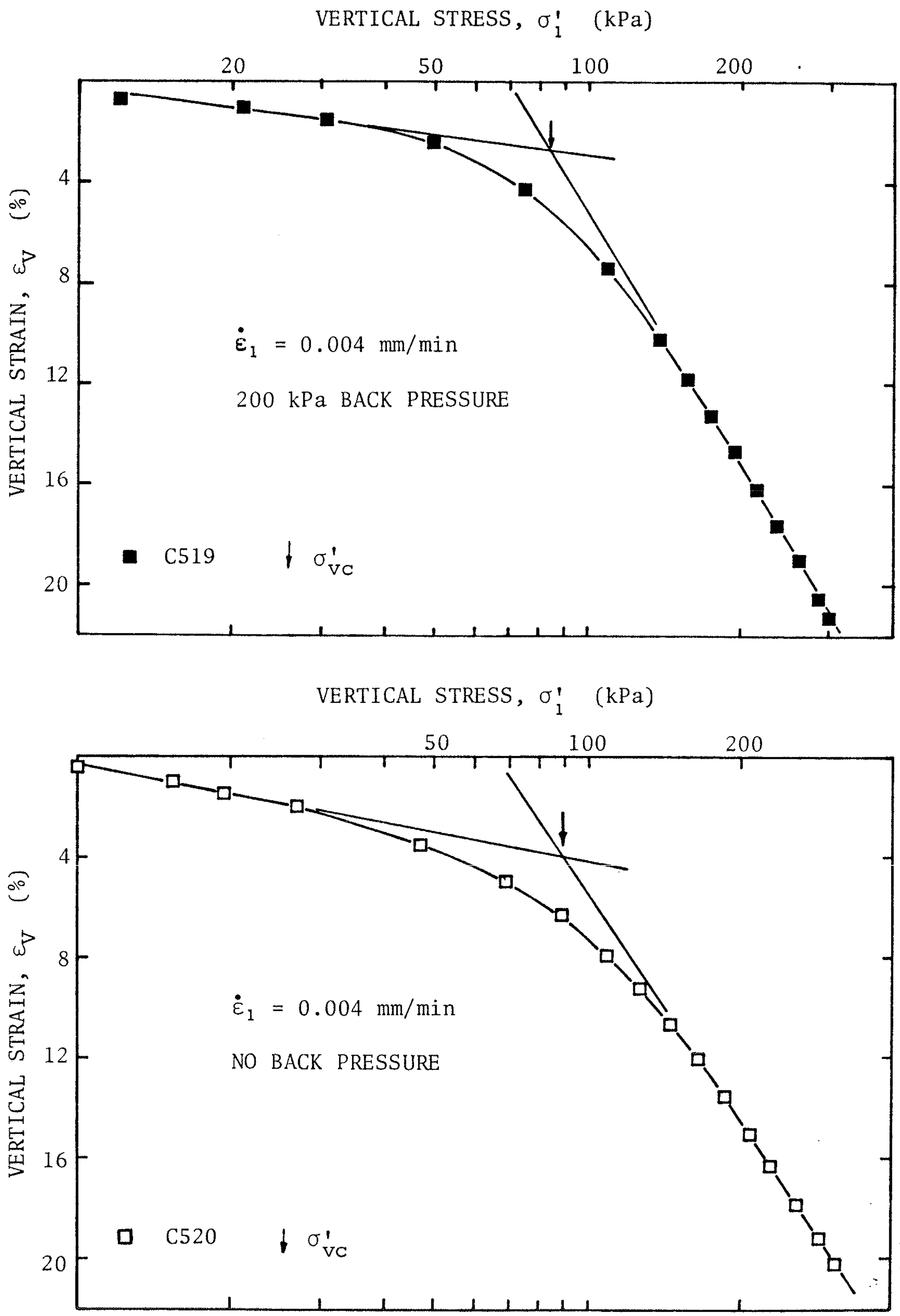
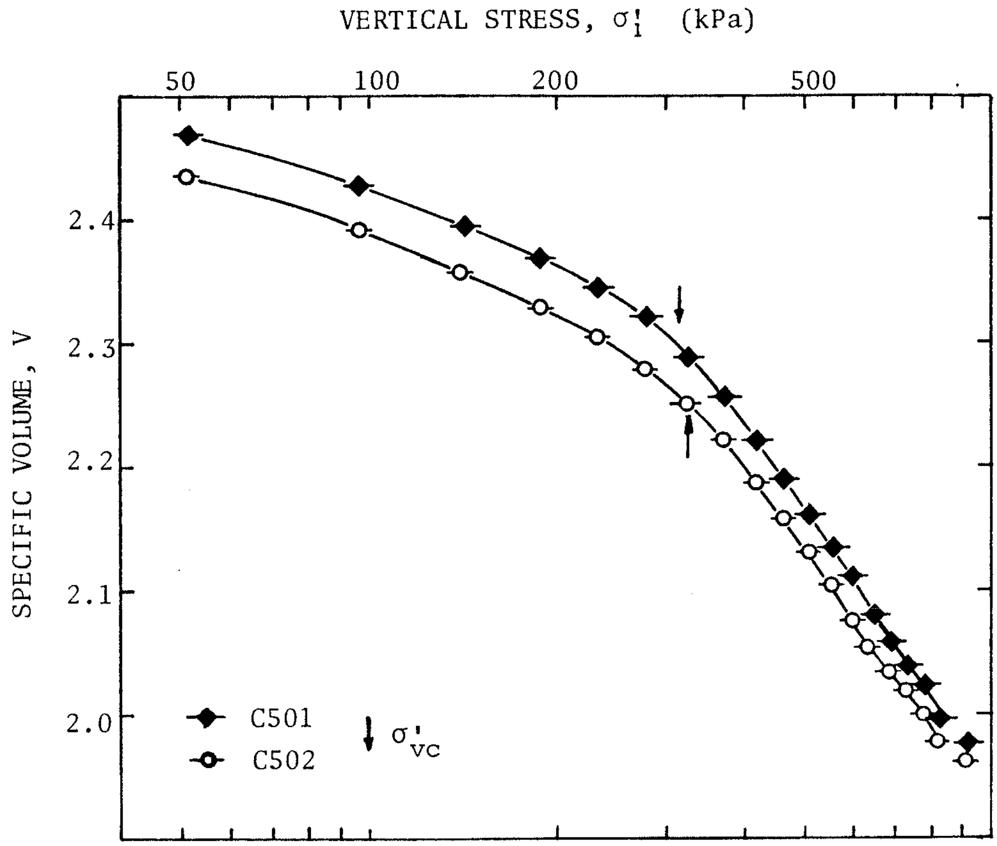


FIGURE 5.12,5.13 - CONSTANT RATE OF STRAIN, CRS RESULTS; C519,C520



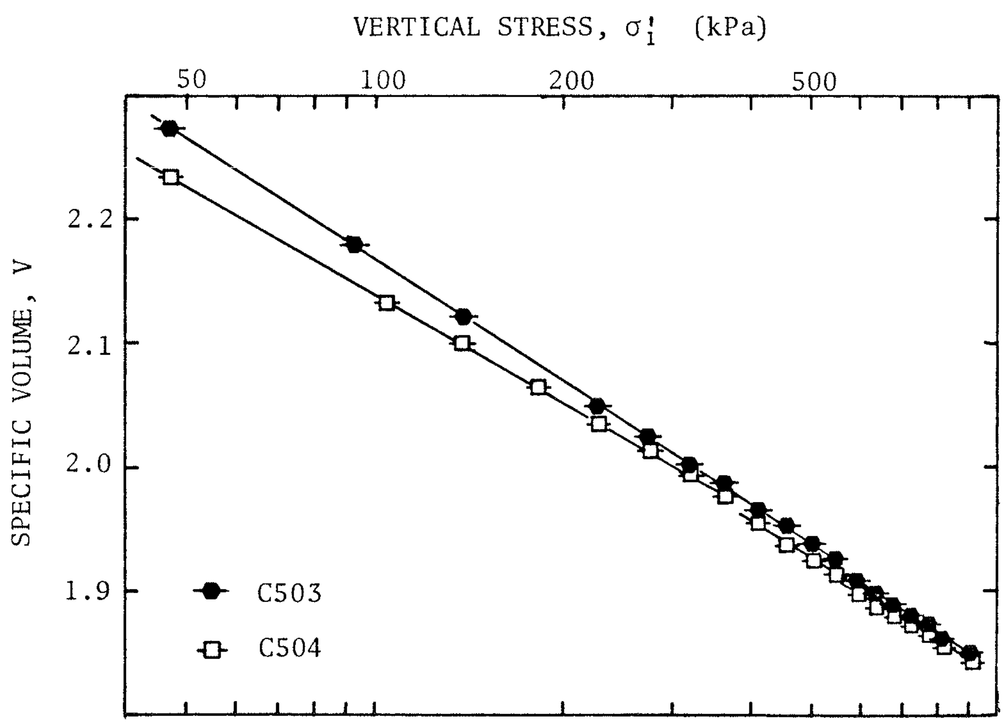
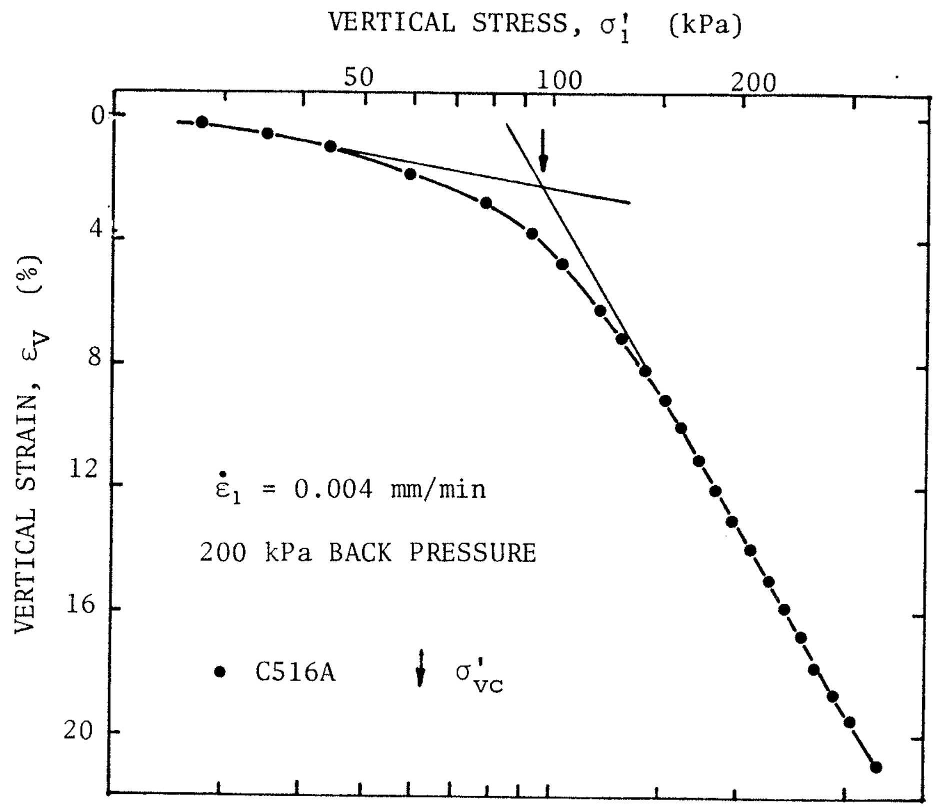


FIGURE 5.6,5.7 - OEDOMETER RESULTS FOR 'FULLY-SOFTENED' SAMPLES: C501,C502 AND 'FREEZE - THAW' SAMPLES: C503,C504



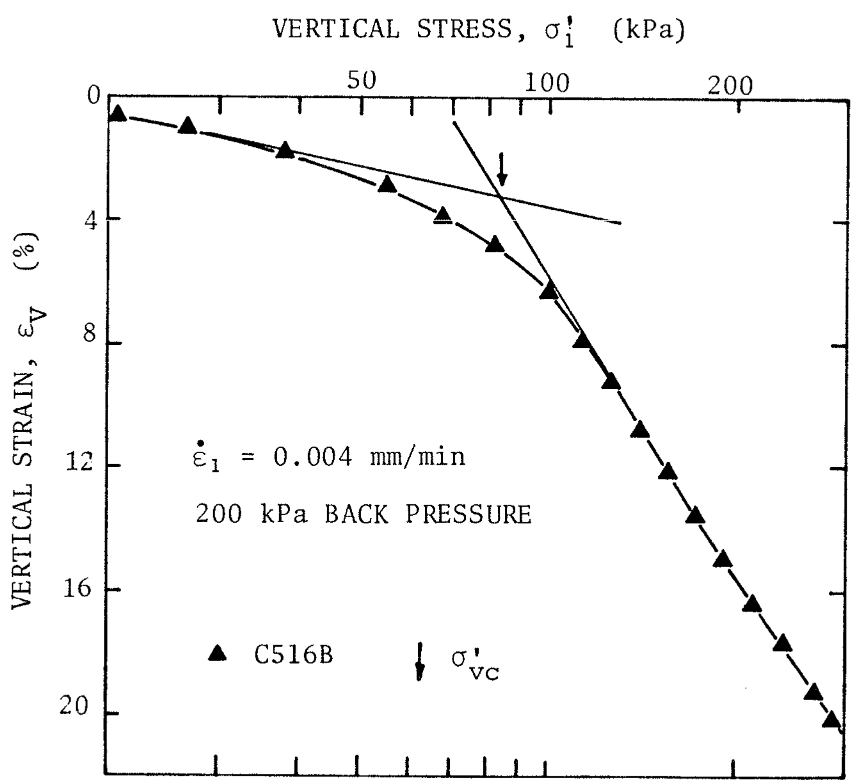


FIGURE 5.8,5.9 - CONSTANT RATE OF STRAIN, CRS RESULTS;
C516A,C516B

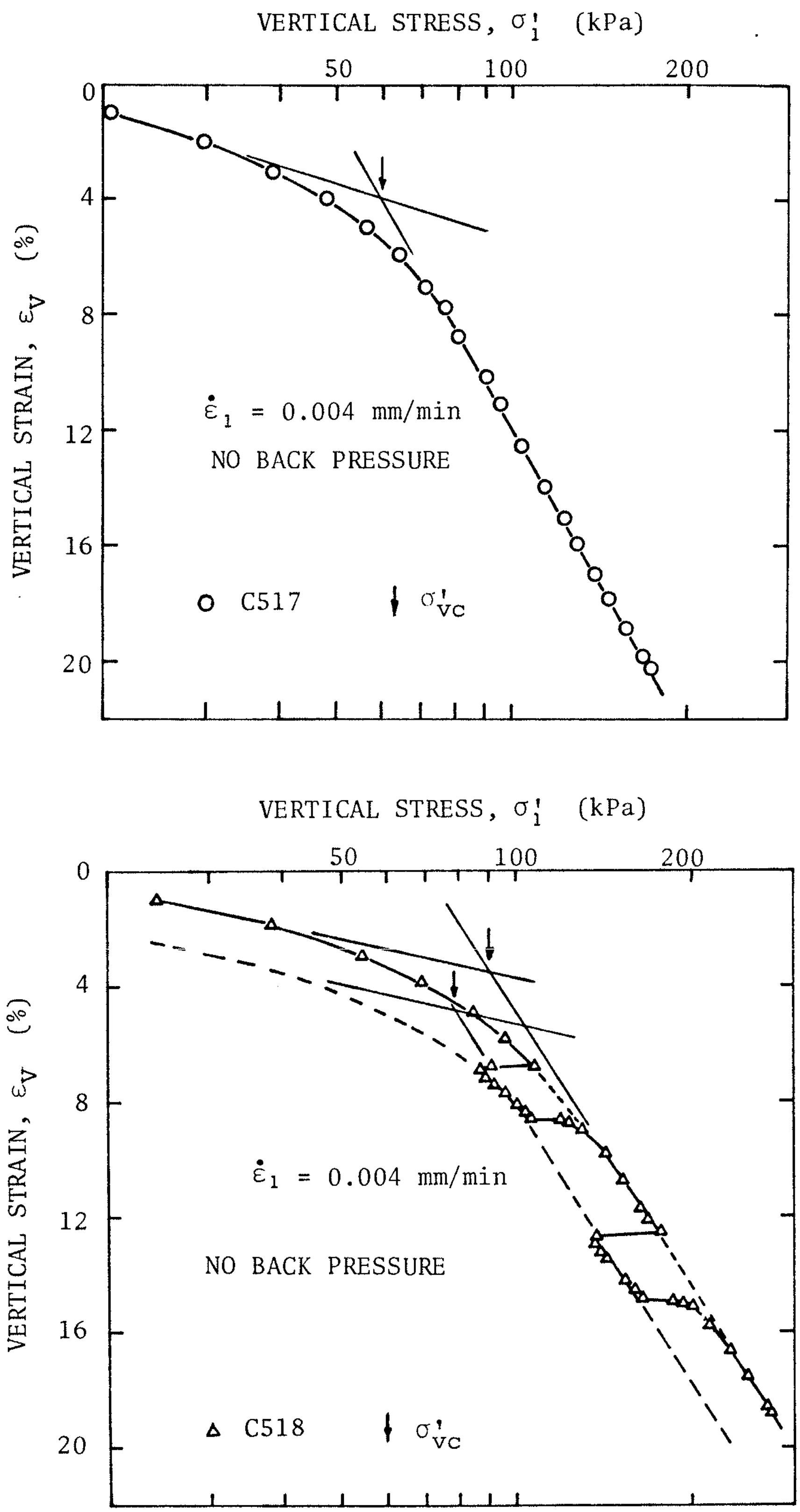


FIGURE 5.10,5.11 - CONSTANT RATE OF STRAIN, CRS RESULTS; C517,C518

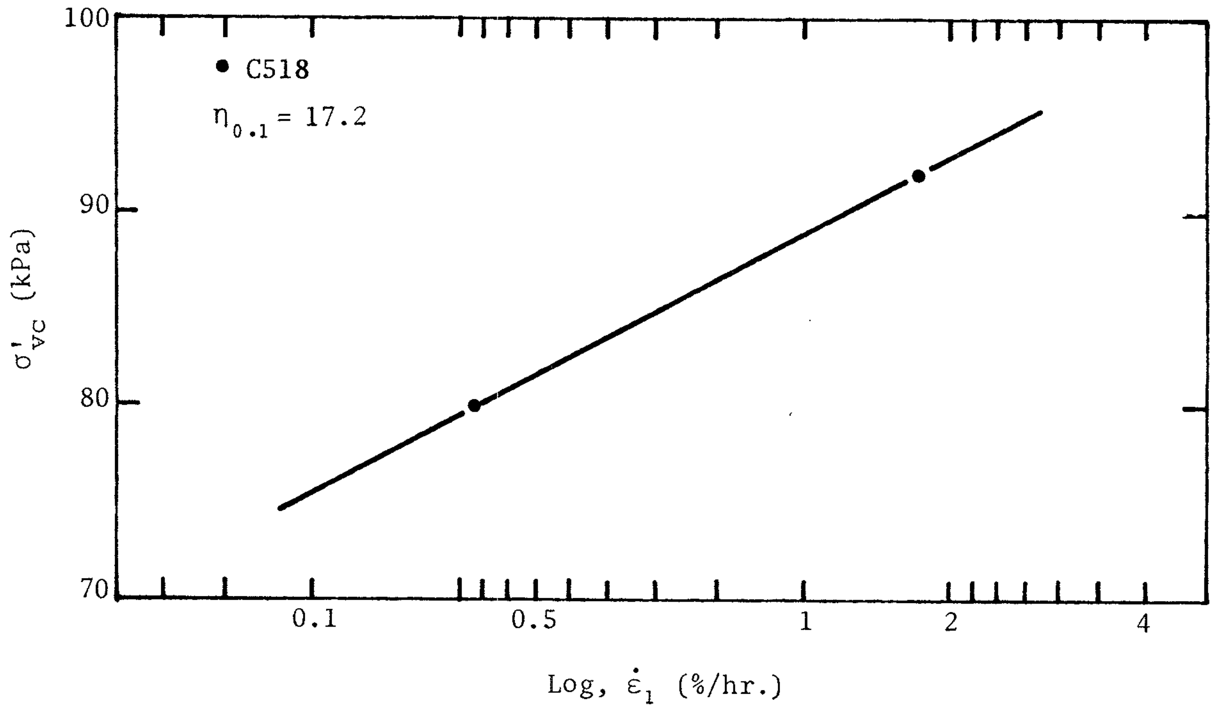


FIGURE 5.14 - STRAIN RATE EFFECTS FROM CRS STEP-CHANGING TEST, C518

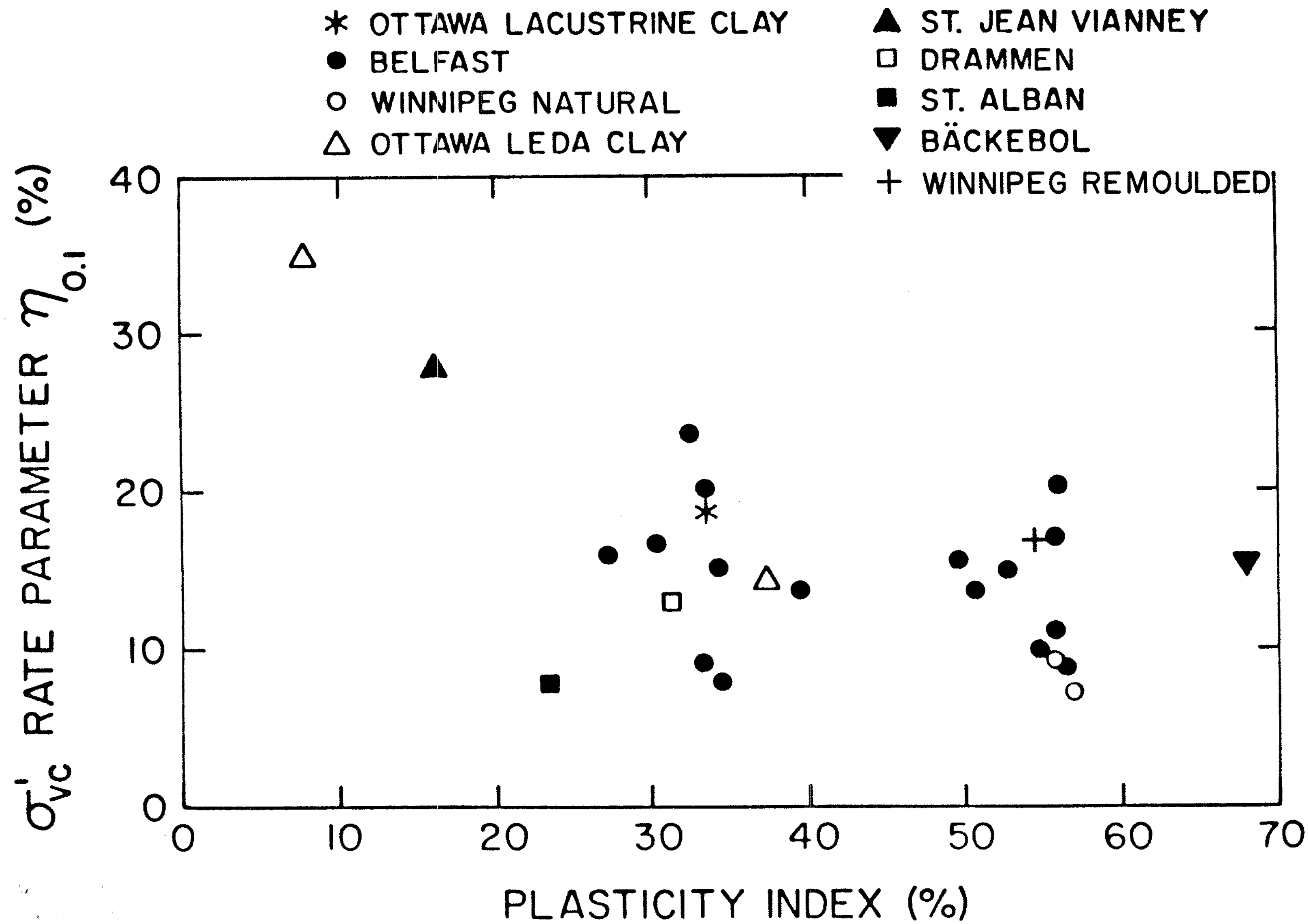


FIGURE 5.15 - VARIATION OF STRAIN RATE PARAMETER, $\eta_{0.1}$ WITH PLASTICITY INDEX, I_p

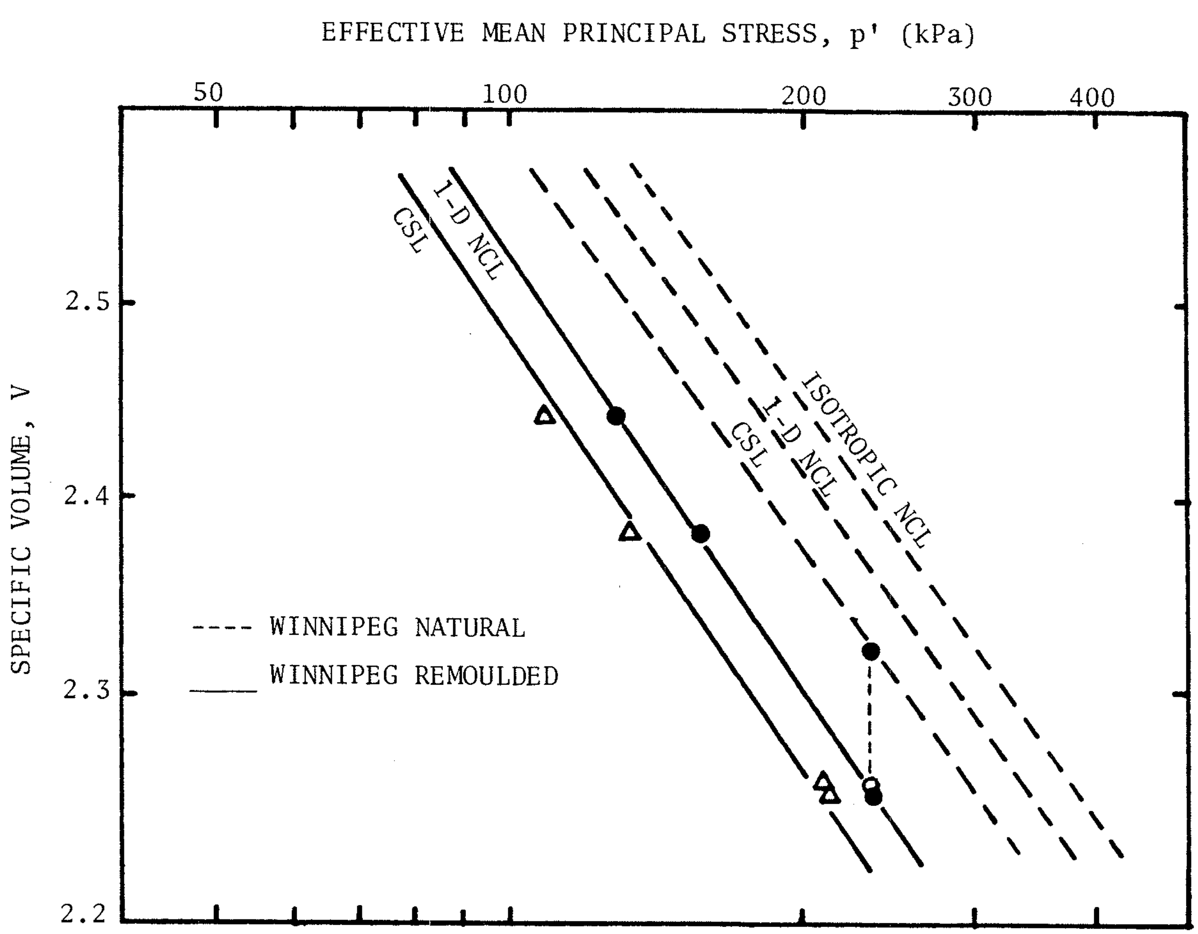


FIGURE 6.1 - GRAPH OF SPECIFIC VOLUME, V VERSUS LOG p'

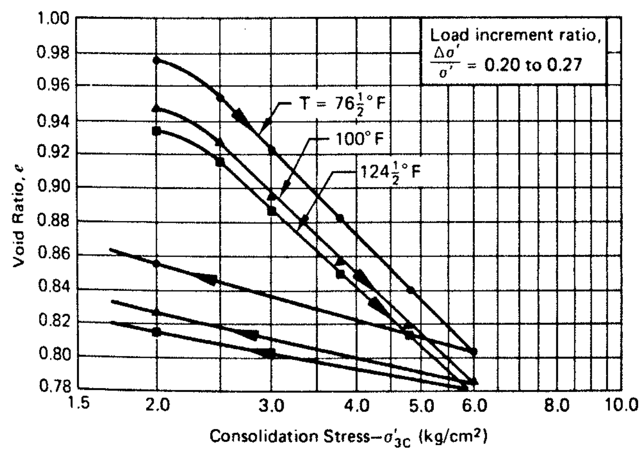


FIGURE 6.2 - EFFECT OF TEMPERATURE ON ISOTROPIC CONSOLIDATION OF ILLITE (from Mitchell, 1976, p. 281)

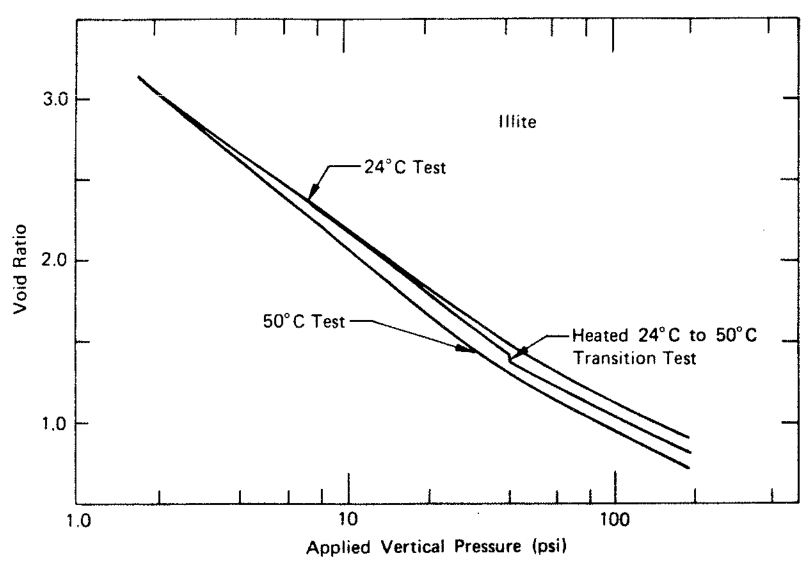


FIGURE 6.3 - INFLUENCE OF TEMPERATURE ON CONSOLIDATION OF ILLITE (from Mitchell, 1976, p. 281).

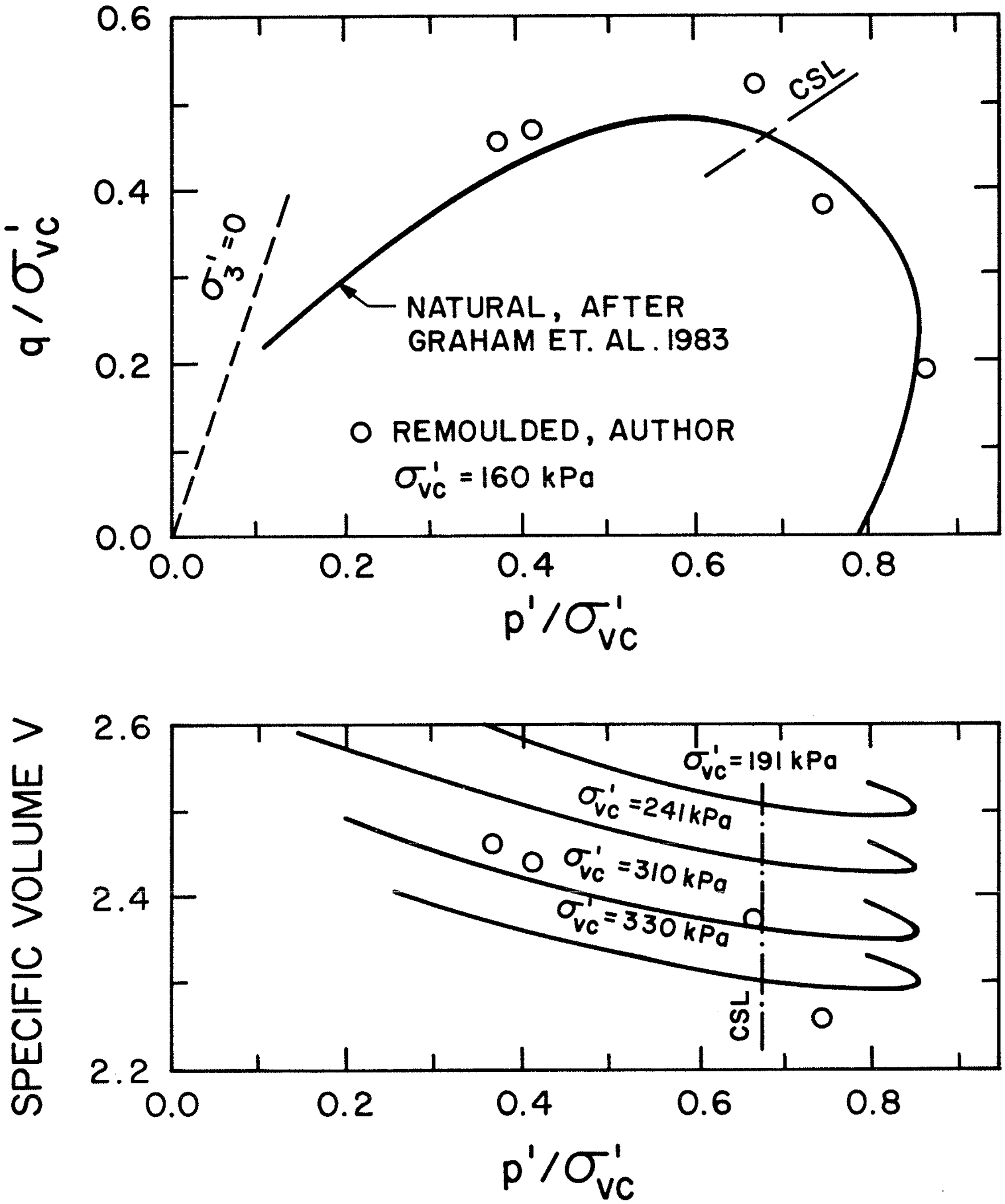


FIGURE 6.4 - YIELD STATES IN NON-DIMENSIONAL STRESS-SPACE: q/σ'_{vc} VS p'/σ'_{vc} AND V VS p'/σ'_{vc}

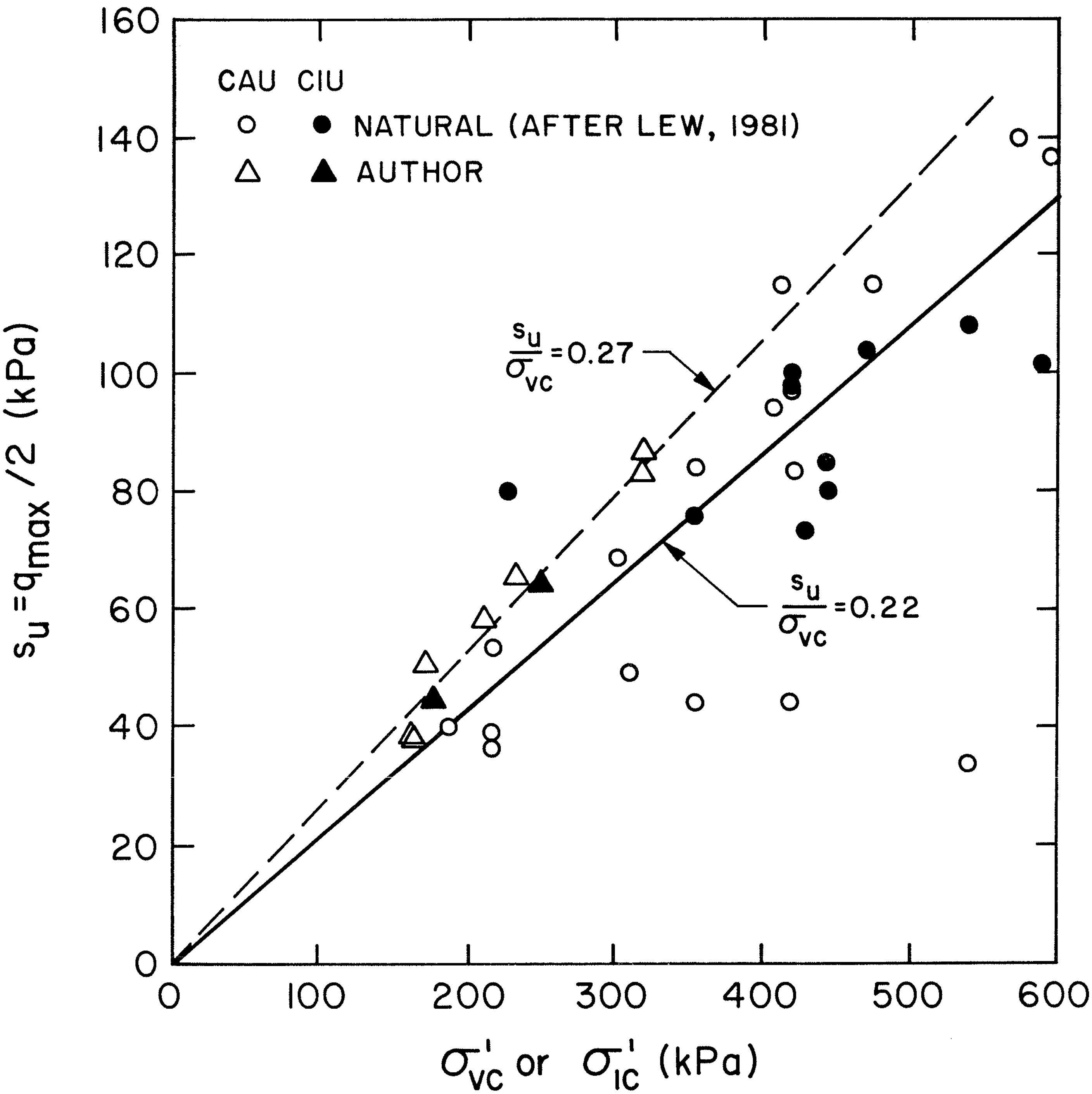


FIGURE 6.5 - RELATIONSHIP BETWEEN UNDRAINED SHEAR STRENGTH AND PRECONSOLIDATION PRESSURE

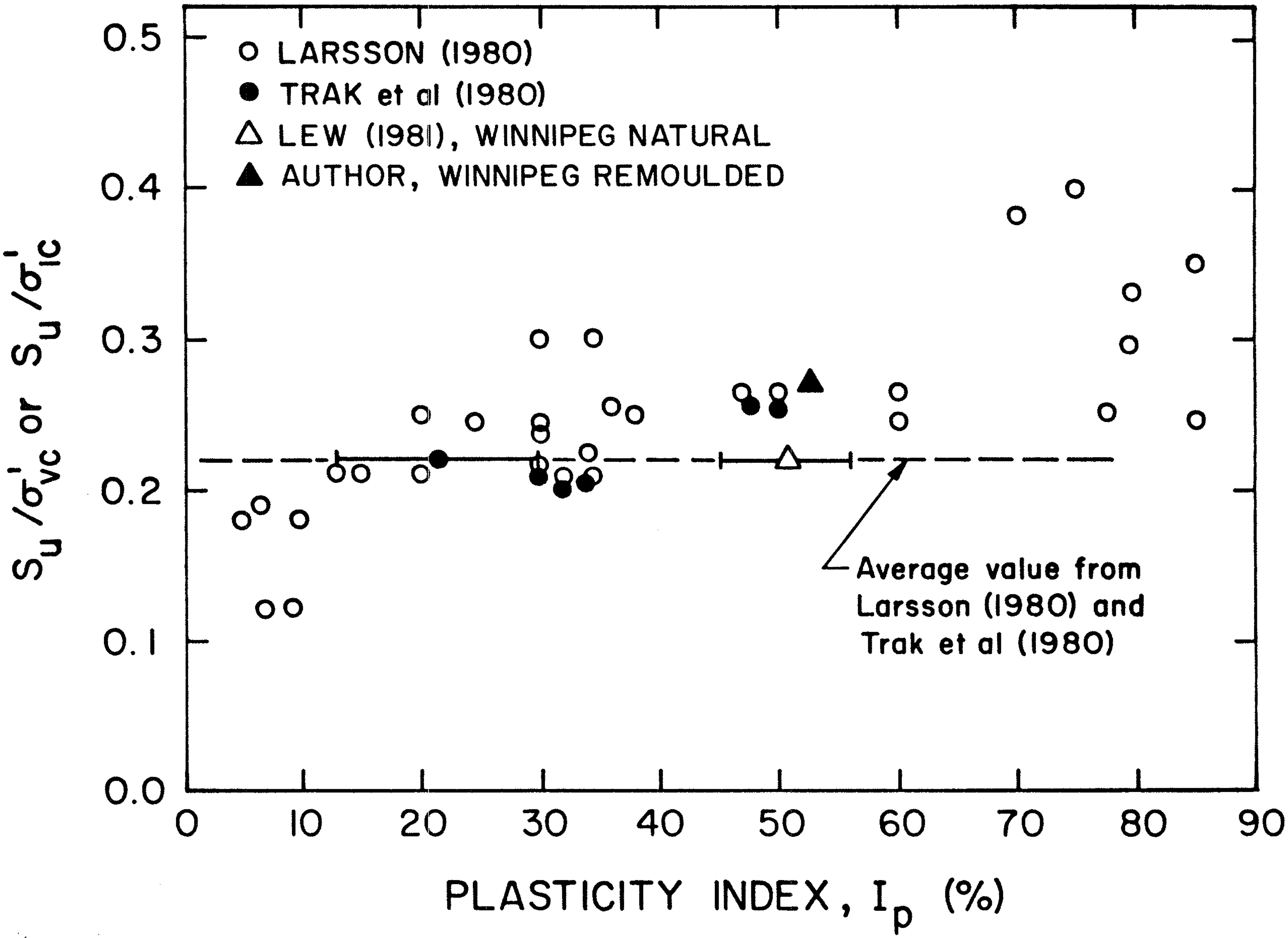
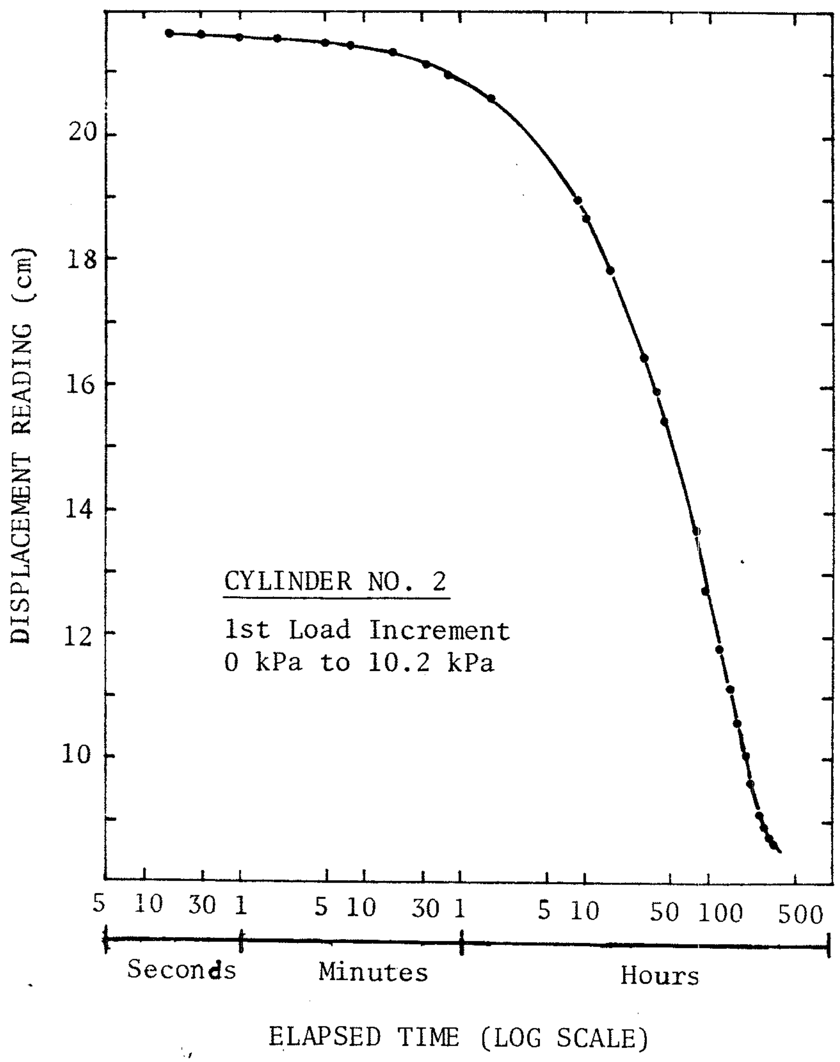


FIGURE 6.6 - SUMMARY GRAPH OF UNDRAINED SHEAR STRENGTH RATIO s_u/σ'_{vc} VERSUS PLASTICITY INDEX, I_p



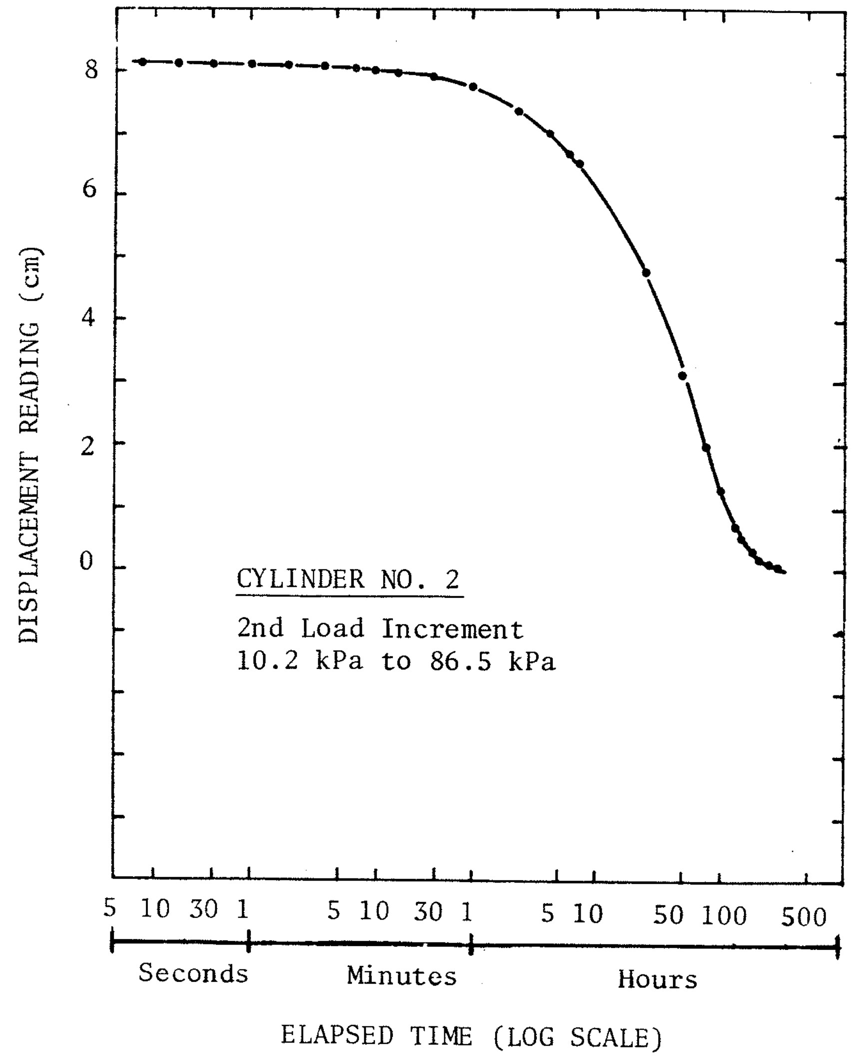


FIGURE 6.7 - CONSOLIDATION TIME CURVES FROM RECONSOLIDATION CYLINDER TEST NUMBER 2

A P P E N D I X 1

PREPARATION OF REMOULDED CLAY FOR GEOTECHNICAL TESTING

1.0 INTRODUCTION

This note describes the process of preparing remoulded clay pertinent to tests, such as triaxial compression and oedometer tests in the Geotechnical Laboratories, University of Manitoba.

Basically, there are two steps in the process, namely,

- Remoulding
- Reconsolidating

'Remoulding' here refers to the breakdown of intact clay structure through grinding air-dried natural clay into ground soil. A slurry is formed by mixing the ground soil with distilled water to a consistency of twice the liquid limit of that clay. The slurry is then allowed to 're-consolidate' under an applied load to form remoulded clay, which can be trimmed in the laboratory.

The equipment used throughout the process was mostly designed by Dr. J. Graham, to complement the ongoing research program directed by himself. Technical staff, Mr. J. Clark, Mr. S. Meyerhoff, and Mr. N. Piamsalee are acknowledged for their contribution in making and modifying the equipment needed. The basic equipment includes: i) a mechanical mixing unit (Fig. A), ii) a reconsolidation unit (Fig. B), and iii) an extruding unit (Fig. C).

The note takes the form of a set of abbreviated instructions for the preparation of the sample and the operation of the equipment.

2.0 REMOULDING

2.1 Prepare soil which has been de-aired previously. Pulverize soil by grinding them in a grinder, such as the one in the Geotechnical Laboratories, University of Manitoba. Finely ground soil should pass a No. 4 sieve.

2.2 Calculate the amount of pulverized soil solid and distilled water required to form a slurry of twice its liquid limit consistency.

NOTE: 1) The maximum amount of slurry the mixer can hold without spilling during the mixing process is 4,160 c.c.

2) Based on the typical Winnipeg clay profile shown by Au (1982). The mixer can hold 2,075 g. of pulverized soil solid and 3,400 c.c. of distilled water.

2.3 In order to avoid the formation of lumps, it is desirable to mix the soil solid with distilled water by hand stirring prior to the mechanical mixing process. Care should be taken to ensure full transference of soil solids into the mixing container.

2.4 Set up the mechanical mixing unit (Fig. A).

1) Place the top cover (which has a beater bar system attached) onto the mixing container.
2) Tighten the 6 screws holding the top in place.
3) Secure the whole mixing container onto the steel base plate.
4) Fasten the steel shaft of the beater bar system to the vertical rotating shaft of the drill press which is used to drive the mixer.
5) Apply a vacuum to the mixer through the top connection. Switch on the mixer motor.

2.5 In order to obtain consistent samples, a mixing and idling time schedule is recommended:

1) Switch the mixer on for one hour with the vacuum pump on.
Switch the mixer and the pump off to idle for twenty-four hours.

2) Switch the mixer on for half an hour without the vacuum pump, and then let it idle for three hours.

3) Repeat step 2) four times.

2.6 Once the slurry is prepared, it is poured into a perspex cylinder allowing the slurry to consolidate. Before removing the mixing container from the mechanical mixing unit, it is recommended to mix the slurry for ten minutes, so that uniformly mixed slurry can be obtained.

3.0 <u>THE POURING OF MIXED SLURRY INTO CONSOLIDATION CYLINDER</u>

Prior to pouring the mixed slurry into the reconsolidation cylinders it is important to have made the following advance preparations:

3.1 Lightly grease the interior of the perspex consolidation cylinder by silicone grease. This reduces piston friction during the consolidation and also provides less resistance during the extrusion of the remoulded sample.

3.2 Prepare two 4" diameter (101.6 mm) filter paper discs, which are used to prevent the porous stones from getting clogged by fine clay particles during drainage, and to facilitate the removal of the clay after the reconsolidation process.

3.3 Close the bottom drainage lead and lay a filter paper disc on top of the bottom porous stone.

3.4 Weigh the empty cylinder (without top cover) together with the bottom porous stone and filter paper. Measure the diameter of the cylinder. Record them in sheet i).

3.5 Pour slurry into the cylinder through a funnel until it is about 5 - 8 cm from the top of the cylinder.

NOTE: It is important to support the cylinder throughout the pouring process.

3.6 Re-weigh the cylinder with slurry and enter the weight in sheet i). This procedure is done to calculate the total amount of slurry in the cylinder.

3.7 Measure five moisture contents from the slurry remaining inside the mixer.

4.0 RECONSOLIDATION

Figure B shows a photograph of the reconsolidation unit.

4.1 Transfer the cylinder to the consolidation frame. Care should be taken not to disturb other consolidating samples in the frame.

4.2 Place a filter paper on top of the slurry. Prior to loading, weight the hanger, ball bearing, piston with top filter stone and dial gauge platform, and record them in sheet i).

4.3 Apply a thin layer of silicon oil to the piston shaft and a thin coat of silicone grease to the sides of the piston.

4.4 Connect top drainage lead to the piston. Make sure the top cap of the cylinder has the drainage tubing coming out through the hole of the cap. Also, connect the bottom drainage lead to the base of the cylinder.

4.5 Lower the piston slowly until the bottom of the piston is brought into contact with the slurry.

NOTE: Because of the fluid-like nature of the slurry, it is very difficult to determine the 'exact' initial position when contact has been made.

4.6 Attach a dial gauge platform on the piston shaft and set the vertical dial gauge in place. Its placement should facilitate the reading during loading. Zero the dial gauge and record the initial reading.

4.7 Since the mixed slurry inside the consolidation cylinder is very soft, it is recommended to put 50 N on the hanger and allow the slurry to stabilize for twenty-four hours, and then start the first load increment.

4.8 Determine the desired vertical stress level and calculate the load requirement.

<u>NOTE</u>: 1) In order to obtain satisfactory triaxial or oedometer samples which can be trimmed into the triaxial cells or oedometer rings, estimation of the initial water contents corresponding to the lowest shear strength must be done (Henkel, 1956).

2) For the remoulded Winnipeg clay, a vertical stress of no more than 40 kPa is recommended for the first increment, and a minimum final vertical stress of 80 kPa is recommended in order to obtain a satisfactory clay to work with.

4.9 Place the desired weight on the hanger and record times and dial gauge readings according to the following elapsed time schedule: 30 sec., 1 min., 2 min., 4 min., 8 min., 15 min., 30 min., 1 hr., 2 hr., 4 hr., 8 hr., 16 hr., 24 hr., and then observe and record readings every twenty-four hours until equilibrium is observed.

<u>NOTE</u>: 1) It is not uncommon to re-zero a 50 mm dial gauge four to five times in the first load increment before equilibrium is obtained. Care must be taken to avoid the dial gauge from going out of travel.

2) In order to determine the end of primary consolidation, it is recommended to plot the consolidation time relationship daily.

4.10 Once equilibrium for a load increment is obtained, determine the stress level required for the next increment. Repeat step 4.8 to 4.9 until the desired vertical stress level is obtained.

NOTE: The process of reconsolidation is very time consuming (Henkel, 1956). For example, the time for the formation of remoulded Winnipeg clay with top and bottom drainage requires approximately 30 days to obtain equilibrium under a vertical stress of 80 kPa.

5.0 EXTRUSION OF THE REMOULDED RECONSOLIDATED CLAY

Figure C shows a photograph of the extrusion unit.

5.1 Once equilibrium is obtained for the desired stress level, weights, hanger, ball bearing and dial gauge platform are removed after the final readings are recorded.

5.2 Disconnect drainages and remove top cylinder cover.

5.3 Weigh the cylinder and piston with the remoulded reconsolidated clay and record the weight in sheet ii).

5.4 Drain away any water which has escaped past the sealing ring on the piston.

5.5 Unscrew the three bottom screws on the reconsolidation cylinder. Remove the bottom part of the cylinder and the bottom filter stone.

5.6 Invert the cylinder and place the extruder in place under the piston.

5.7 Tighten the screw of the base adapter on top of the jack shaft. Care must be taken to line up the adapter vertically.

5.8 Connect the extruder to the base adapter. Place the top adapter on top of the inverted cylinder.

5.9 Raise the jack shaft, together with the whole cylinder, up until the top adapter is about 1 cm away from the top guiding plate.

5.10 Raise the cylinder by hand so that the top adapter is brought in contact with the top guiding plate.

5.11 Raise the jack so that the extruder is brought in contact with the piston. The whole system should be tightly fitted by now.

5.12 Use the jack to slowly push soil up from the cylinder. <u>Both</u> the clay and the cylinder should be supported during this process.

5.13 The clay is then ready to be trimmed into the triaxial cell using techniques described by (Lew, 1981).

5.14 Five moisture content of the clay is obtained from trimmings and can be recorded in sheet ii).

5.15 Finally, all the equipment should be cleaned and set aside for the next sample.

Sheet i)

ONE-DIMENSIONAL CYLINDER CONSOLIDATION

Sample Number: ____________________

Date: ____________________

Dimensions:

Cylinder diameter	=	cm
Cylinder area	=	cm^2

Weight Terms:

Hanger	=	gm
Steel ball	=	gm
Piston + top filter stone	=	gm
Dial gauge platform	=	gm
W_o	= ________	kg
or	= ________	N

Slurry Weight:

wt. of cyl. + bottom filter stone	=	gm
wt. of cyl. + bottom filter stone + slurry	=	gm
wt. of slurry	= ______	gm

Slurry Moisture Content:

TARE NO.					
WT. WET SOIL + TARE					
WT. DRY SOIL + TARE					
WT. WATER					
WT. TARE					
WT. DRY SOIL					
WATER CONTENT %					

Sheet ii)

Sample Number: ____________________

Date: ____________________

Total Weight of Remoulded Soil:

wt. of cyl. + bottom filter stone + piston
+ top filter stone = gm

wt. of cyl. + bottom filter stone + piston
+ top filter stone + remoulded soil = gm

wt. of remoulded soil = ______ gm

Remoulded Soil Moisture Content:

TARE NO.					
WT. WET SOIL + TARE					
WT. DRY SOIL + TARE					
WT. WATER					
WT. TARE					
WT. DRY SOIL					
WATER CONTENT %					

APPENDIX 2

COMPUTER PROGRAM MANUAL

2.1 INTRODUCTION

The primary motivation for the development of TXCEP (Triaxial Consolidation with Energy Calculation and Plots), USHEARP (Undrained Shear with Plots) and OEDOMP (Oedometer test with Plots) was dissatisfaction with then current tedious data reduction and plotting procedures used for interpreting triaxial and oedometer tests in the geotechnical laboratory. These programs facilitate the handling of the large amount of data generated from the research program initiated and supervised by Dr. J. Graham. The Author thanks Dr. Graham for his encouragement and suggestions in developing these computer programs.

TXCEP and USHEARP are used for drained triaxial consolidation tests and undrained triaxial shear tests respectively while OEDOMP is applicable to conventional oedometer testings. All programs were written in FORTRAN H with free format input. Input data should be separated by either commas or blanks. To distinguish real numbers from integers, real numbers should contain a decimal point. All the plotting is done by the CALCOMP (California Computer) Plotter located in the 6th floor of Engineering Building, University of Manitoba. The computer graphics software is executed by calling a series of FORTRAN subroutines which are shown in the program listings.

The general operational procedures are given in the next section, and then instructions for each computer program will be presented subsequently.

2.2 OPERATIONAL PROCEDURE

The programs are all written in FORTRAN H and can be operated on the system currently in operation at the 5th floor Computer Terminal, Engineering Building, University of Manitoba. The Job Control Cards are as follows:

```
//jobname(1) JOB 'XXX,YYY,,L=2,T=1Ø,C=Ø,CO=1','USERNAME'

/*D800 VPLOT(2)

//   EXEC FORTXCG,USERLIB='SYS2.VPLOTLIB',SIZE=256K

//*

//*  USE SYS3.VPLOTLIB FOR MULTIPLE PLOTS

//*FORT.SYSIN DD *

 | PROGRAM |

/*

//*

//GO.SYSIN DD *

 | INPUT DATA |

//GO.FTØ1FØØ1 DD DSN=&& FTØ1FØØ1,UNIT=SYSDA,DISP=(NEW,PASS),

//   SPACE=(CYL,(2,2))

//GO.VWORK DD DSN=&&VWORK,UNIT=SYSDA,DISP=(NEW,PASS),

//   SPACE=(CYL,(2,2))

//*

// EXEC VPLOT(2)

//
```

NOTE:

(1) Jobname should not be more than 8 characters.

(2) It is not uncommon to have input errors especially for tests having a large number of data points. In the early stages of checking the input data ('debugging') process, this card can be deleted temporarily and the plotting procedures will not be executed. This will give a listing of the program, the input data and the calculated output. This procedure is recommended in order to save computer time.

APPENDIX 2A -TXCEP

TXCEP (Triaxial Consolidation with Energy Calculations and Plots)

2.A.1 Introduction

TXCEP is a computer program written in FORTRAN H for the reduction of data obtained from drained triaxial consolidation test. TXCEP includes ENERGY, a computer program written previously (Lew, 1981), to enable energy calculations. Eight different plots are generated from the results:

1) Deviator Stress, q vs Effective Mean Principal Stress, p'
2) Specific Volume, V vs Log Effective Mean Principal Stress, Log p'
3) Effective Mean Principal Stress vs Volumetric Strain, v
4) Shear Strain, ε vs Shear Stress, q
5) Axial Strain, ε_1 vs Effective Axial Stress, σ_1'
6) Laterial Strain, ε_3 vs Effective Lateral Stress, σ_3'
7) Axial Strain, ε_1 vs Effective Mean Principal Stress, p'
8) Energy, W vs Length of Stress Vector, LSSV

These plots facilitate studies of Critical State and yield determinations of the tested soil.

2.A.2 Input Order

Card		Input Element Type	Format
1	TSAMP	Sample No.	Integer
	NHOLE	Hole No.	Integer
	TOPTHM	Depth of Sample (Top)	Real
	BOPTHM	Depth of Sample (Bottom)	Real

Card		Input Element Type	Format
2	IMC	Initial Moisture Content (%)	Real
	GS	Specific Gravity	Real
3	INTHT	Initial Sample Height	Real
	INTVOL	Initial Sample Volume	Real
4	JDATES	Starting Date of Test	Integer
	JDATEE	Ending Date of Test	Integer
5	M	Total No. of Data Points	Integer
6*	SIGMA1	Effective Axial Stress (kPa)	Real
	SIGMA3	Effective Laterial Stress (kPa)	Real
	DELTAH	Change in Sample Height (cm)	Real
	DELTAV	Change in Sample Volume (cm^3)	Real

(*One input element for each of M data points)

2.A.3 Output

There are two kinds of output generated, namely, the LINE Printer output and the plots from the CALCOMP Plotter.

2.A.3.1 From the LINE Printer

Following the program listing, the printer prints the background information in the following order:

1) Sample No.
2) Hole No.

3) Depth of Sample (Top)

4) Depth of Sample (Bottom)

5) Initial Moisture Contact

6) Specific Gravity of Soil

7) Initial Void Ratio

8) Initial Height of Sample

9) Initial Volume of Sample

10) Effective Principal Stress Ratio

11) Final Moisture Content

12) Starting and Ending Data of test

The calculated results are printed in a form of the well organized table which consists of the following:

1) Effective Axial Stress

2) Effective Lateral Stress

3) Axial Strain

4) Lateral Strain

5) Effective Mean Principal Stress

6) Effective Deviator Stress

7) Void Ratio

8) Specific Volume

Then another table by the title of 'Summary of Essential Results Stored in File' will be listed. This table, containing the basic information of the triaxial consolidation test, is formatted to allow easy storage into a MANTES (Manitoba Text Editing System) file. The table does not contain any new information and is solely for archiving purposes. For further information concerning the copying technique, the readers are referred to MANTES USER MANUAL (Ferch, Neufeld, Zarnke, 1978). The data should be transferred on to Dr. Graham's archive file, using the program prepared by Kwok (1983).

The computer will then print out two tables of energy calculations as described by Lew (1981).

2.A.3.2 <u>From the CALCOMP Plotter</u>

The eight plots mentioned earlier are received at the Input/Output (I/O) Window located on the 6th floor of Engineering Building, University of Manitoba.

'TXCEP' PROGRAM LISTING

```
C
C
C
C     ***************************
C     *                         *
C     *          TXCEP          *
C     *                         *
C     ***************************
C
C
C     THIS PROGRAM REDUCES DATA FROM TRIAXIAL CONSOLISATION
C     TEST.  REDUCED DATA INCLUDES :
C
C          1)  EFFECTIVE AXIAL STRESS
C          2)  EFFECTIVE LATERAL STRESS
C          3)  AXIAL STRAIN
C          4)  LATERAL STRAIN
C          5)  VOLUMETRIC STRAIN
C          6)  EFFECTIVE P
C          7)  EFFECTIVE Q
C          8)  VOID RATIO
C          9)  SPECIFIC VOLUME
C         10)  SHEAR STRAIN
C     THE PROGRAM ALSO INCLUDES ENERGY CALCULATION WHICH WAS
C     WAS BASICALLY THE SAME PROGRAM AS 'ENERGY'.
C     BESIDES THE FUNCTIONS MENTIONED ABOVE, THIS PROGRAM
C     ALSO PRODUCES THE FOLLOWING PLOTS :
C
C          1)  LOG P VS. V
C          2)  P VS. Q
C          3)  SHEAR STRAIN VS. Q
C          4)  VOL. STRAIN VS. P
C          5)  LATERAL STRAIN VS. LATERAL STRESS
C          6)  AXIAL STAIN VS. LATERAL STRESS
C          7)  LSSV VS. W
C          8)  AXIAL STRAIN VS. P
C
C
C
C
      DIMENSION SIGMA1(90),SIGMA3(90),STRAN1(90),STRAN3(90),VOLSTR(90)
     &,P(90),Q(90),VR(90),SPVOL(90),DELTAH(90),DELTAV(90),IBUF(4000)
      DIMENSION JPT(90),ESIMA1(90),ESIMA3(90),ASTRN1(90),RSTRN3(90),
     1DEVSTM(90),OCTSTM(90),VOLSTN(90),ASIMA1(90),ASIMA3(90),
     1DESTN1(90),DESTN3(90),LSSV(90),DELENE(90),TOTENE(90),
     1NSTRN1(90),NSTRN3(90),DELENN(90),TOTENN(90),INCSN1(90),
     1INCSN3(90),INVOL(90),NVOLSN(90),LSNVE(90),LSNVN(90),SHESTR(90)
      REAL LSSV,NSTRN1,NSTRN3,NVOLSN,INCSN1,INCSN3,INVOL,LSNVE,LSNVN
      REAL ISTRN1,ISTRN3
      REAL IMC,GS,IVR,RATIO,FMC,INTHT,INTVOL
C
C
C     READING IN ESSENTIAL INFORMATION
C     ================================
C
C
C
      WRITE(6,60)
      WRITE(6,61)
      READ* ,JSAMP,NHOLE,TDPTHM,BDPTHM
      IF (NHOLE.LT.0) GO TO 42
      WRITE(6,630)JSAMP,NHOLE,TDPTHM,BDPTHM
      GO TO 43
   42 WRITE(6,631) JSAMP
```

```
   43 READ* ,IMC,GS
      IVR=GS*IMC/100
      WRITE(6,100)IMC
      WRITE(6,101)GS
      WRITE(6,102)IVR
      READ* ,INTHT,INTVOL
      WRITE(6,120)INTHT
      WRITE(6,121)INTVOL
      READ* ,JDATES,JDATEE
      READ* ,M
      I=1
    2 IF(I.GT.M) GO TO 3
      READ* ,SIGMA1(I),SIGMA3(I),DELTAH(I),DELTAV(I)
      STRAN1(I)=DELTAH(I)/INTHT*100
      VOLSTR(I)=DELTAV(I)/INTVOL*100
      STRAN3(I)=(VOLSTR(I)-STRAN1(I))/2
      SHESTR(I)=(STRAN1(I)-STRAN3(I))*2/3
      P(I)=(SIGMA1(I)+SIGMA3(I)*2)/3
      Q(I)=SIGMA1(I)-SIGMA3(I)
      VR(I)=IVR-VOLSTR(I)/100*(1+IVR)
      SPVOL(I)=1+VR(I)
      I=I+1
      GO TO 2
    3 RATIO=SIGMA3(M)/SIGMA1(M)
      WRITE(6,103)RATIO
      FMC=100*VR(M)/GS
      WRITE(6,104)FMC
      WRITE(6,165)JDATES,JDATEE
      WRITE(6,64)
      WRITE(6,65)
      WRITE(6,69)
      WRITE(6,70)
      I=1
    4 IF(I.GT.M) GO TO 5
      WRITE(6,980)I,SIGMA1(I),SIGMA3(I),STRAN1(I),VOLSTR(I),STRAN3(I),
     &P(I),Q(I),VR(I),SPVOL(I),SHESTR(I)
      I=I+1
      GO TO 4
    5 L=JSAMP/100
      NS=JSAMP-L*100
C
C
C     PLOT LOG P VS V
C     ===============
C
C
C
      CALL PLOTS(IBUF,4000)
      CALL PLOT(0.0,-5.0,-3)
      CALL PLOT(0.0,1.5,-3)
      CALL SCALG(P,5.5,M,1)
      CALL SCALE(SPVOL,4.0,M,1)
      CALL LGAXS(0.0,0.0,' LOG P  (KPA)',-12,5.5,0.0,
     &P(M+1),P(M+2))
      CALL AXIS(0.0,0.0,'SPECIFIC VOLUME',15,4.0,90.0,
     &SPVOL(M+1),SPVOL(M+2))
      CALL LGLIN(P,SPVOL,M,1,-1,2,-1)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(5.5,4.0,2)
      CALL PLOT(5.5,0.0,2)
C
C
C     PLOT P VS Q
C     ===========
C
```

```
C
      CALL PLOT (0.0,4.5,-3)
      P(M+1)=0.0
      P(M+2)=60.0
      Q(M+1)=0.0
      Q(M+2)=60.0
      CALL AXIS(0.0,0.0,'P  (KPA)',-7,5.5,0.0,P(M+1),P(M+2))
      CALL AXIS(0.0,0.0,'Q  (KPA)',7,3.5,90.0,Q(M+1),Q(M+2))
      CALL LINE(P,Q,M,1,-1,1)
      CALL PLOT(0.0,3.5,3)
      CALL PLOT(5.5,3.5,2)
      CALL PLOT(5.5,0.0,2)
      CALL PLOT(12.0,0.0,-3)
C
C
C
C
      WRITE(6,981)
      WRITE(6,71)
      WRITE(6,72)
      I=1
    6 IF(I.GT.M) GO TO 7
      WRITE(6,982) I,SIGMA1(I),SIGMA3(I),STRAN1(I),STRAN3(I),SPVOL(I)
      I=I+1
      GO TO 6
    7 PRINT 981
C
C
C
      N=M
      PRINT  60
      PRINT  61
      PRINT  63
      PRINT  66
      PRINT  80,  JSAMP,NHOLE,TDPTHM,BDPTHM
      PRINT  85, JDATES,JDATEE
      PRINT  81
      PRINT  82
      PRINT  83
      PRINT  84
      DO      10   I=1,N
C
C
C     READING IN STRESS-STRAIN VALUES
C     ===============================
C
C
      ESIMA1(I)=SIGMA1(I)
      ESIMA3(I)=SIGMA3(I)
      ASTRN1(I)=STRAN1(I)
      VOLSTN(I)=VOLSTR(I)
      JPT(I)=I
      DEVSTM(I)=ESIMA1(I)-ESIMA3(I)
      OCTSTM(I)=(ESIMA1(I)+2*ESIMA3(I))/3
      RSTRN3(I)=(VOLSTN(I)-ASTRN1(I))/2
   10 CONTINUE
      L=N-1
      NSTRN1(1)=ASTRN1(1)/(1-ASTRN1(1)/200)
      NVOLSN(1)=VOLSTN(1)/(1-VOLSTN(1)/200)
      NSTRN3(1)=(NVOLSN(1)-NSTRN1(1))/2
      DO      12   II=1,L
      INCSN1(II)=(ASTRN1(II+1)-ASTRN1(II))/
     1            (1-(ASTRN1(II+1)+ASTRN1(II))/200)
      INVOL(II)=(VOLSTN(II+1)-VOLSTN(II))/
     1            (1-(VOLSTN(II+1)+VOLSTN(II))/200)
      INCSN3(II)=(INVOL(II)-INCSN1(II))/2
   12 CONTINUE
      DO      13   K=1,L
      NSTRN1(K+1)=INCSN1(K)+NSTRN1(K)
      NSTRN3(K+1)=INCSN3(K)+NSTRN3(K)
      NVOLSN(K+1)=INVOL(K)+NVOLSN(K)
   13 CONTINUE
      OSIMA1=ESIMA1(1)
      OSIMA3=ESIMA3(1)
      OSTRN1=ASTRN1(1)
      OSTRN3=RSTRN3(1)
      ISTRN1=NSTRN1(1)
      ISTRN3=NSTRN3(1)
      DO      11   I=1,N
      LSSV(I)=SQRT((ESIMA1(I)-OSIMA1)**2+2*(ESIMA3(I)-OSIMA3)**2)
      LSNVE(I)=SQRT((ASTRN1(I)-OSTRN1)**2+2*(RSTRN3(I)-OSTRN3)**2)
      LSNVN(I)=SQRT((NSTRN1(I)-ISTRN1)**2+2*(NSTRN3(I)-ISTRN3)**2)
   11 CONTINUE
C
C
C     ENERGY CALCULATIONS
C     ===================
C
C
      M=N-1
      DO      20   J=1,M
      ASIMA1(J)=(ESIMA1(J+1)+ESIMA1(J))/2
      ASIMA3(J)=(ESIMA3(J+1)+ESIMA3(J))/2
      DESTN1(J)=ASTRN1(J+1)-ASTRN1(J)
      DESTN3(J)=RSTRN3(J+1)-RSTRN3(J)
      DELENE(J)=(ASIMA1(J)*DESTN1(J)+2*ASIMA3(J)*DESTN3(J))/100
      DELENN(J)=(ASIMA1(J)*(NSTRN1(J+1)-NSTRN1(J))   +
     1          2*ASIMA3(J)*(NSTRN3(J+1)-NSTRN3(J)))/100
   20 CONTINUE
      TOTENE(1)=0.0
      TOTENN(1)=0.0
      DO      30  K=1,M
      TOTENE(K+1)=DELENE(K)+TOTENE(K)
      TOTENN(K+1)=DELENN(K)+TOTENN(K)
   30 CONTINUE
C
C
C     PRINT CALCULATED RESULTS
C     ========================
C
C
      DO      40  KK=1,N
      PRINT  90, JPT(KK),ESIMA1(KK),ESIMA3(KK),DEVSTM(KK),OCTSTM(KK),
     1ASTRN1(KK),RSTRN3(KK),VOLSTN(KK),LSSV(KK),LSNVE(KK),TOTENE(KK)
      IF  (KK.EQ.N)   GO TO 40
      PRINT  91,  DELENE(KK)
   40 CONTINUE
      PRINT  60
      PRINT  61
      PRINT  63
      PRINT  73
      PRINT  80,   JSAMP,NHOLE,TDPTHM,BDPTHM
      PRINT  85,  JDATES,JDATEE
      PRINT  81
      PRINT  82
      PRINT  83
      PRINT  84
      DO      41  JJ=1,N
```

```
      PRINT  90, JPT(JJ),ESIMA1(JJ),ESIMA3(JJ),DEVSTM(JJ),OCTSTM(JJ),
     1NSTRN1(JJ),NSTRN3(JJ),NVOLSN(JJ),LSSV(JJ),LSNVN(JJ),TOTENN(JJ)
      IF (JJ.EQ.N)  GO TO 41
      PRINT  91, DELENN(JJ)
   41 CONTINUE
      PRINT  981
C
C
C     SHEAR STRAIN VS SHEAR STRESS PLOT
C     ================================
C
C
      CALL PLOT(0.0,-5.0,-3)
      CALL SCALE(SHESTR,6.0,M,1)
      Q(M+1)=0.0
      Q(M+2)=60.0
      CALL AXIS(0.0,0.0,'SHEAR STRAIN (%)',-16,6.0,0.0,
     &SHESTR(M+1),SHESTR(M+2))
      CALL AXIS(0.0,0.0,'SHEAR STRESS , Q (KPA)',22,4.0,90.0,
     &Q(M+1),Q(M+2))
      CALL LINE(SHESTR,Q,M,1,-1,0)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(6.0,4.0,2)
      CALL PLOT(6.0,0.0,2)
C
C
C     PLOT VOLUME STRAIN VS P
C     =======================
C
C
      CALL SCALE(VOLSTR,6.0,M,1)
      P(M+1)=0.0
      P(M+2)=60.0
      CALL PLOT(0.0,4.5,-3)
      CALL AXIS(0.0,0.0,'VOLUME STRAIN (%)',-17,6.0,0.0,
     &VOLSTR(M+1),VOLSTR(M+2))
      CALL AXIS(0.0,0.0,'P (KPA)',7,4.0,90.0,P(M+1),P(M+2))
      CALL LINE(VOLSTR,P,M,1,-1,5)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(6.0,4.0,2)
      CALL PLOT(6.0,0.0,2)
      CALL PLOT(12.0,0.0,-3)
C
C
C     PLOT LATERAL STRAIN VS LATERAL STRESS
C     =====================================
C
C
      CALL PLOT(0.0,-4.5,-3)
      CALL SCALE(STRAN3,6.0,M,1)
      CALL SCALE(SIGMA3,4.0,M,1)
      CALL AXIS(0.0,0.0,'LATERAL STRAIN (%)',-18,6.0,0.0,
     &STRAN3(M+1),STRAN3(M+2))
      CALL AXIS(0.0,0.0,'LATERAL STRESS (KPA)',20,4.0,90.0,
     &SIGMA3(M+1),SIGMA3(M+2))
      CALL LINE(STRAN3,SIGMA3,M,1,-1,10)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(6.0,4.0,2)
      CALL PLOT(6.0,0.0,2)
C
C
C     PLOT AXIAL STRAIN VS AXIAL STRESS
C     =================================
C
C
      CALL SCALE(STRAN1,6.0,M,1)
      CALL SCALE(SIGMA1,4.0,M,1)
      CALL PLOT(0.0,4.5,-3)
      CALL AXIS(0.0,0.0,'AXIAL STRAIN (%)',-16,6.0,0.0,
     &STRAN1(M+1),STRAN1(M+2))
      CALL AXIS(0.0,0.0,'SIGMA1 (KPA)',12,4.0,90.0,SIGMA1(M+1),
     &SIGMA1(M+2))
      CALL LINE(STRAN1,SIGMA1,M,1,-1,12)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(6.0,4.0,2)
      CALL PLOT(6.0,0.0,2)
      CALL PLOT(12.0,0.0,-3)
C
C
C     PLOT LSSV VS W
C     ==============
C
C
      CALL SCALE(LSSV,6.0,M,1)
      CALL SCALE(TOTENE,4.0,M,1)
      CALL PLOT(0.0,-4.5,-3)
      CALL AXIS(0.0,0.0,'LSSV (KPA)',-10,6.0,0.0,
     &LSSV(M+1),LSSV(M+2))
      CALL AXIS(0.0,0.0,'W  (KJ/M**3)',12,4.0,90.0,
     &TOTENE(M+1),TOTENE(M+2))
      CALL LINE(LSSV,TOTENE,M,1,-1,11)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(6.0,4.0,2)
      CALL PLOT(6.0,0.0,2)
C
C
C     PLOT AXIAL STRAIN VS P
C     ======================
C
C
      CALL PLOT(0.0,4.5,-3)
      CALL AXIS(0.0,0.0,'AXIAL STRAIN (%)',-16,6.0,0.0,
     &STRAN1(M+1),STRAN1(M+2))
      CALL AXIS(0.0,0.0,'P (KPA)',7,4.0,90.0,P(M+1),
     &P(M+2))
      CALL LINE(STRAN1,P,M,1,-1,3)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(6.0,4.0,2)
      CALL PLOT(6.0,0.0,2)
      CALL PLOT(12.0,0.0,999)
      STOP
  120 FORMAT(38H INITIAL HEIGHT OF SAMPLE          = ,F5.2,3H CM)
  121 FORMAT(38H INITIAL VOLUME OF SAMPLE          = ,F6.2,3H CC)
  103 FORMAT(38H EFFECTIVE PRINCIPAL STRESS RATIO  = ,F4.2)
  100 FORMAT(38H INITIAL MOISTURE CONTENT          = ,F5.1,8H PERCENT)
  101 FORMAT(38H SPECIFIC GRAVITY OF SOIL          = ,F4.2)
  102 FORMAT(38H INITIAL VOID RATIO                = ,F6.3)
  104 FORMAT(38H FINAL MOISTURE CONTENT            = ,F5.1,8H PERCENT
     &//)
   60 FORMAT (1H1,////,23H UNIVERSITY OF MANITOBA)
   61 FORMAT (26H SOIL MECHANICS LABORATORY//)
  165 FORMAT(28H TX.  CONSOLIDATION    START,  I10,5H     ,
     113HEND, I10           )
   64 FORMAT(29H TRIAXIAL CONSOLIDATION TEST )
   65 FORMAT(29H ::::::::::::::::::::::::::: ,///)
   69 FORMAT(///,48H  PT  EFFECT   EFFECT  STRAIN1   VOLUME  STRAIN3,
     &45H   EFFECT      Q       VOID      V     SHEAR )
   70 FORMAT(48H      SIGMA1   SIGMA3              STRAIN          ,
```

```
     &45H     P                RATIO            STRAIN//)
  71 FORMAT(///,44H SUMMARY OF ESSENTIAL RESULTS STORED IN FILE)
  72 FORMAT(////////,46H  PT  SIGMA1   SIGMA3   STRAIN1   STRAIN3
     &,1HV//)
 630 FORMAT(15H SAMPLE NO. = T,I4,5X,11H HOLE NO. = ,I4,5X,
     1  9H DEPTH = ,F6.2,11H METRES TO ,F6.2,8H METRES )
 631 FORMAT(15H SAMPLE NO. = T,I4,5X,'(REMOULDED SAMPLE)')
 980 FORMAT(I4,2X,F6.2,3X,F6.2,3X,F6.3,3X,F6.3,3X,F6.3,3X,F6.2,3X,
     &F6.2,3X,F6.3,3X,F6.3,3X,F6.3)
 982 FORMAT(I4,2X,F6.2,3X,F6.2,3X,F6.3,3X,F6.3,3X,F6.3)
 981 FORMAT(1H1)
  63 FORMAT(20H ENERGY CALCULATIONS/)
  66 FORMAT(31H ****  ENGINEERING STRAIN  ****//)
  73 FORMAT(31H ****    NATURAL STRAIN    ****//)
  80 FORMAT(15H SAMPLE NO. = T,I4,5X,11H HOLE NO. = ,I4,5X,
     1  9H DEPTH = ,F6.2,11H METRES TO ,F6.2,8H METRES  //)
  81 FORMAT(47H  PT   EFFECT   EFFECT   DEV     EFFECT   AXIAL,
     150H   RADIAL   VOL      LSSV   LSNV    DELTA     TOTAL)
  82 FORMAT(48H        SIGMA1   SIGMA3   STRESS  OCT       STRAIN,
     151H  STRAIN   STRAIN                    ENERGY   ENERGY )
  83 FORMAT(45H        KPA      KPA      KPA     STRESS     %,
     154H      %        %       KPA     %     KN-M/VOL KN-M/VOL)
  84 FORMAT(36H                                  KPA/)
  90 FORMAT(I4,2X,F6.1,3X,F6.1,2X,F6.1,3X,F6.1,4X,F6.3,2X,F6.3,
     13X,F6.3,2X,F6.1,2X,F4.1,11X,F7.3)
  91 FORMAT(81X,F7.3)
  85 FORMAT(22H TEST RESULTS     START,  I10,5H     ,
     13HEND, I10      ///)
      END
/*
//*
//GO.SYSIN DD *
```

APPENDIX 2B - USHEARP

USHEARP (Undrained Shear with Plots)

2.B.1 Introduction

USHEARP is actually an extension of the program TRIAXIAL (Lew, 1981) which was developed to handle raw data obtained in undrained triaxial shear test. This program plots the reduced data by means of computer graphics techniques. USHEARP produces three plots:

1) Axial strain, ε_1 vs Normalized Half Deviator Stress, $(\sigma_1-\sigma_3)/2\sigma_{1c}'$
2) Axial strain, ε_1 vs Effective Principal Stress Ratio, σ_1'/σ_3'
3) Axial strain, ε_1 vs Normalized Change in Porewater Pressure, $\Delta u/\sigma_{1c}'$

2.B.2 Preparation of Input

The program was written in FORTRAN H. "Free Format" input is used. Input should be presented in the order shown below as Integer or Real. Real numbers require decimal points. Data should be separated either by commas or at least a blank space.

The order of input is as follows:

Card		Input Element Type	Format
1*	JSAMP	Sample No.	Integer
	NHOLE	Hole No.	Integer
	TDPTHM	Depth of Sample (Top)	Real
	BDPTHM	Depth of Sample (Bottom)	Real

(* For remoulded samples: NHOLE=-1, TDPTHM=0, BDPTHM=0)

Card		Input Element Type	Format
2.	SHGHTM	Sample Height after Consolidation	Real
	SVOLM	Sample Volume after Consolidation	Real
	SAREAM	Sample Area after Consoldiation	Real
	RDILOM	Initial Dial Reading	Real

3.	AA	Scale factor for dial gauges not read in units of 0.01 mm	Real

Note: (1) AA = 1.0 for dial gauges read in units of 0.01 mm

(2) AA is positive for dial gauges giving decreasing readings for sample compression

(3) AA is negative for dial gauges giving increasing readings for sample compression

4.	CLOADM	Constant Load (Dead Load)	Real
	PFCTRM	Proving Ring Factor	Real
	APISTM	Piston Area	Real
5.	CONAXM	Consolidated Axial Stress	Real
	PCONPM	Pre-consolidated Stress	Real
	PWPOM	Initial Porewater Pressure	Real
6.	M	Counting Index (Total No. of points in test series)	Integer

Note: Test points for Relaxation Test should not be included.

7.	JDATES	Starting Date of Shear Test	Integer
	JDATEE	Ending Date of Shear Test	Integer
8.	JTIME	Time when reading is taken	Integer
	RDIAL	Dial Reading	Real
	PRING	Proving Ring Reading	Real
	PWP	Porewater Pressure during Shear	Real
	CELLPR	Cell Pressure	Real
	JPT	Point where reading is taken	Integer

Note: (1) If (PWP) is negative - Relaxation Test

(2) If (PWP) is positive - Consolidated Undrained Triaxial

9. (Program Card Deck)

(Data Cards)

(-1 0 0 0 0 0)	indicates end of data pack
(0)	prints calculated results
(0)	searches for new data
(-1 0 0 0)	stops program

3.B.3 Output from the Computer

There will be two outputs from this program. One is obtained from the LINE Printer which contains the program listing, some essential input information and reduced results. Another output is the plots from the CALCOMP Plotter.

2.B.3.1 From the LINE Printer

Following the program listing, the printer will first print out the followings:

1. Essential Input Information

i) For Natural Clay Sample:

Sample No.	JSAMP
Hole No.	NHOLE
Depth of Sample (Top)	TDPTHM
Depth of Sample (Bottom)	BDPTHM

ii) For Remoulded Reconsolidated Sample:

"Sample No. - REMOULDED RECONSOLIDATED SAMPLE" will be printed out

Sample Height after Consolidation	SHGHTM
Sample Volume after Consolidation	SVOLM
Sample Area after Consolidation	SAREAM
Dead Load	GLOADM
Proving Ring Factor	PFCTRM
Piston Area	APISTM
Initial Dial Reading	RDILOM
Starting Date of Shear Test	JDATES
Ending Date of Shear Test	JDATEE
Consolidation Axial Stress	GONAXM
Pre-consolidation Pressure	PCONPM
Normalizing Stress	XNRMSM

2. PRINTOUT OF RESULTS

i) The Calculated Results are printed in the form of a well organizaed table which consists of the following:

Point where reading is taken	JPT
Time when reading is taken	TIME
Dial Reading	RDIAL
Proving Ring Reading	PRING

Porewater Pressure during Shear	PWPRM
Percent (%) Strain	PCSTR
Effective Axial Stress (Eff. Sigma 1.)	EFSTRM
Effective Cell Pressure (Eff. Sigma 3.)	ECELPM
Half Deviator Stress	HDVSTR
Deviator Stress	DVSTRM
Effective Normal Octahedral Stress	OCTSTM
Effective Principal Stress Ratio	RATIO
Porewater Pressure Parameter	A

ii) A table which consists of Normalized stresses is also printed, i.e.,

Normalized Half Deviator Stress	HDVSTN
Normalized Deviator Stress	DEVSNM
Normalized Effective Normal Octahedral Stress	OCTSNM
Normalized Change in Porewater Pressure	DCTONM

2.B.3.2 From the CALCOMP Plotter

The three plots mentioned earlier can be obtained from the input/ouput (I/O) window located on the 6th floor of Engineering Building, University of Manitoba.

'USHEARP' PROGRAM LISTING

```
C
C
C
C
C
C     ******************************
C     *                            *
C     *          USHEARP           *
C     *                            *
C     ******************************
C
C
C
C
C     THIS PROGRAM IS A MODIFICATION OF THE PROGRAM 'TRIAXIAL'
C     WHICH IS ABLE TO REDUCE DATA FROM UNDRAINED SHEAR TEST.
C     'USHEARP' HAS TWO ADDITIONAL FEATURES :
C         (1) HANDLE BOTH NATURAL AND REMOULDED SAMPLES
C         (2) PRODUCE 3 PLOTS :
C               (A)  NOM. HALF DEV.STRESS VS. AXIAL STRAIN
C               (B)  EFF. STRESS RATIO VS. AXIAL STRAIN
C               (C)  PWP CHANGE VS. AXIAL STRAIN
C
C
C
C     TERMS AND DEFINITIONS
C     *********************
C
C
C     NOTE: (1)  IN THIS VERSION OF THE PROGRAM
C
C                 (1)  SAMPLE DIMENSIONS ARE READ IN CENTIMETRES
C
C                 (2)  SAMPLE DEPTHS ARE READ IN METRES
C
C                 (3)  PRESSURES ARE READ IN KPA
C
C                 (4)  CONSTANT (DEAD) LOAD IS READ IN NEWTONS
C
C                 (5)  PROVING RING FACTOR IS READ IN N/DIV
C
C                 (6)  DIAL GAUGE READING IS READ IN UNITS OF 0.01 MM
C
C
C     NOTE: (2)
C
C                 CONTROL CARDS ARE AS FOLLOWS:
C
C                   ***********************
C                   *                     *
C                   *       PROGRAM       *
C                   *                     *
C                   ***********************
C
C                   ***********************
C                   *                     *
C                   *        DATA         *
C                   *                     *
C                   ***********************
C
C                   ***********************
C                   *                     *
C     CONTROL CARDS *  -1  0  0  0  0  0  *   INDICATES END OF DATA PAC
C                   *                     *
```

```
C                   *---------------------*
C                   *                     *
C                   *   0                 *   PRINTS CALCULATED RESULTS
C                   *                     *
C                   *---------------------*
C                   *                     *
C                   *   0                 *   SEARCHES FOR NEW DATA
C                   *                     *
C                   *---------------------*
C                   *  -1  0  0  0        *   STOPS PROGRAM
C                   *                     *
C                   ***********************
C
C
C
C
C     A       =  POREWATER PRESSURE PARAMETER
C     AA      =  SCALE FACTOR FOR DIAL GAUGES NOT READ IN UNITS OF 0.01M
C     APISTM  =  PISTON AREA
C     AREAM   =  CURRENT SAMPLE AREA AT ANY STAGE OF THE TEST
C
C     B       =  COUNTING INDEX ( CONTROL CARD )
C     BDPTHM  =  DEPTH OF SAMPLE (BOTTOM)
C
C     CELLPR  =  CELL PRESSURE
C     CLOADM  =  CONSTANT LOAD (DEAD LOAD)
C     CONAXM  =  CONSOLIDATION AXIAL STRESS
C
C     DEVSNM  =  NORMALIZED DEVIATOR STRESS
C     DEVSNO  =  INITIAL DEVIATOR STRESS ( NORMALIZED )
C     DLTAUM  =  CHANGE IN POREWATER PRESSURE
C     DLTUNM  =  NORMALIZED CHANGE IN POREWATER PRESSURE
C     DVSTRM  =  DEVIATOR STRESS
C
C     ECELPM  =  EFFECTIVE CELL PRESSURE ( EFF. SIGMA 3 )
C     EFSTRM  =  EFFECTIVE AXIAL STRESS (EFF. SIGMA 1 )
C     EFSRTO  =  EFFECTIVE STRESS RATIO
C     F       =  ( 1-APISTM/AREAM )
C
C     HDVSTN  =  NORMALIZED HALF DEVIATOR STRESS
C     HDVSTR  =  HALF DEVIATOR STRESS
C
C     I       =  COUNTING INDEX
C
C     JDATEE  =  ENDING DATE OF SHEAR TEST
C     JDATES  =  STARTING DATE OF SHEAR TEST
C     JPT     =  POINT WHERE READING IS TAKEN
C     JPTX    =  POINT WHERE READING IS TAKEN
C     JSAMP   =  SAMPLE NO.
C     JTIME   =  TIME
C
C     M       =  COUNTING INDEX ( TOTAL NO. OF POINTS IN TEST SERIES )
C
C     NHOLE   =  HOLE NO.
C
C     OCTSNM  =  NORMALIZED EFFECTIVE NORMAL OCTAHEDRAL STRESS
C     OCTSTM  =  EFFECTIVE NORMAL OCTAHEDRAL STRESS
C
C     PCONPM  =  PRE-CONSOLIDATION STRESS
C     PCSTR   =  PERCENT (%) STRAIN
C     PCSTRN  =  PERCENT (%) STRAIN
C     PFCTRM  =  PROVING RING FACTOR
C     PRING   =  PROVING RING READING
C     PWP     =  POREWATER PRESSURE DURING SHEAR
```

```
C      PWPOM    =  INITIAL POREWATER PRESSURE
C      PWPRM    =  POREWATER PRESSURE DURING SHEAR
C
C      RATIO    =  EFFECTIVE PRINCIPAL STRESS RATIO
C      RDIAL    =  DIAL READING
C      RDILOM   =  INITIAL DIAL READING
C
C      SAREAM   =  SAMPLE AREA AFTER CONSOLIDATION
C      SHGHTM   =  SAMPLE HEIGHT AFTER CONSOLIDATION
C      STRAIN   =  AXIAL STRAIN
C      STRESM   =  TOTAL AXIAL STRESS ( SIGMA 1 )
C      SVOLM    =  SAMPLE VOLUME AFTER CONSOLIDATION
C
C      TDPTHM   =  DEPTH OF SAMPLE (TOP)
C
C      X        =  AXIAL STRESS INCREASE DUE TO CHANGE IN CELL PRESSURE
C      XLOAD    =  AXIAL LOAD
C      XNRMSM   =  NORMALIZING STRESS
C
C      Y        =  AXIAL STRESS DUE TO PROVING RING AND DEAD LOADS
C
C
C
C
C      START READING IN ESSENTIAL INFORMATION
C      ======================================
C
       DIMENSION JPTX(90),STRAIN(90),PCSTRN(90),DEVSNM(90),A(90),
      1OCTSNM(90),DLTUNM(90),HDVSTN(90),EFSRTO(90),IBUF(4000),
      &DVSTRM(90),OCTSTM(90)
     1 READ* ,JSAMP,NHOLE,TDPTHM,BDPTHM
       IF (JSAMP)2,3,3
     2 CALL EXIT
     3 WRITE(6,60)
       LLL=JSAMP/100
       NS=JSAMP-LLL*100
       WRITE(6,61)
       READ* ,SHGHTM,SVOLM,SAREAM,RDILOM
       READ* ,AA
       READ* ,CLOADM,PFCTRM,APISTM
       READ* ,CONAXM,PCONPM,PWPOM
       IF (NHOLE.EQ.-1) GO TO 21
       WRITE(6,630)JSAMP,NHOLE,TDPTHM,BDPTHM,SHGHTM,SVOLM,
      &SAREAM,CLOADM,PFCTRM,APISTM,RDILOM
       GO TO 9
    21 WRITE(6,631)  JSAMP,SHGHTM,SVOLM,
      1SAREAM,CLOADM,PFCTRM,APISTM,RDILOM
     9 I=0
       READ* ,M
       IF(M)1,1,10
    10 READ* ,JDATES,JDATEE
       WRITE(6,165)JDATES,JDATEE
       WRITE(6,64)
       WRITE(6,65)
       WRITE(6,69)
       WRITE(6,70)
       WRITE(6,710)
       WRITE(6,720)
C
C
C      INPUT DATA FROM SHEAR TEST
C      ==========================
C
C
     4 READ* ,JTIME,RDIAL,PRING,PWP,CELLPR ,JPT
       IF (JTIME)6,5,5
     5 PWPRM=PWP
       IF (PWPRM)8,7,7
     7 I=I+1
C
C
C      STRESS - STRAIN CALCULATION
C      ===========================
C
C
C      NOTE:
C
C      (1) IF ( PWP ) IS NEGATIVE --- RELAXATION TEST
C
C      (3) IF ( PWP ) IS POSITIVE --- CONSOLIDATED UNDRAINED TRIAXIAL TES
C
C
       STRAIN(I)=(RDILOM-RDIAL)/(1000.*SHGHTM)*AA
       PCSTR=STRAIN(I)*100
       PCSTRN(I)= PCSTR
       JPTX(I)=JPT
       AREAM=SAREAM/(1.-STRAIN(I))
       F=1-APISTM/AREAM
       X=F*CELLPR
       XLOAD=PRING*PFCTRM+CLOADM
       Y=XLOAD/AREAM*10
       STRESM=X+Y
       EFSTRM=STRESM-PWPRM
       ECELPM=CELLPR-PWPRM
       DVSTRM(I)=(STRESM-CELLPR)
       HDVSTR=DVSTRM(I)/2
       OCTSTM(I)=(EFSTRM+2*ECELPM)/3
       RATIO=EFSTRM/ECELPM
C
C
C      NORMALIZATION OF STRESSES
C      =========================
C
C
       XNRMSM=CONAXM
       DEVSNM(I)=DVSTRM(I)/XNRMSM
       HDVSTN(I)=HDVSTR/XNRMSM
       OCTSNM(I)=OCTSTM(I)/XNRMSM
       DLTAUM=PWPRM-PWPOM
       DLTUNM(I)=DLTAUM/XNRMSM
       EFSRTO(I)=RATIO
       IF ( I.EQ.1 ) GO TO 106
       GO TO 107
   106 DEVSNO=DEVSNM(1)
       GO TO 108
   107 A(I)=DLTUNM(I)/(DEVSNM(I)-DEVSNO)
C
C
C      PRINT CALCULATED RESULTS
C      ========================
C
C
   108 WRITE(6,980)JPT,JTIME,RDIAL,PRING,PWPRM,PCSTR,
      1EFSTRM,ECELPM,HDVSTR,DVSTRM(I),OCTSTM(I),RATIO,A(I)
       GO TO 4
     8 WRITE(6,81)JPT     ,JTIME,RDIAL,PRING
       GO TO 4
     6 READ* ,B
       IF (B) 13,13,1
```

```
   13 WRITE(6,99)
      IF (NHOLE.EQ.-1) GO TO 22
      WRITE(6,163) JSAMP,NHOLE,TDPTHM,BDPTHM,CONAXM,PCONPM,
     1XNRMSM
      GO TO 26
   22 WRITE(6,164) JSAMP,CONAXM,PCONPM,XNRMSM
   26 WRITE(6,265) JDATES,JDATEE
      WRITE(6,860)
      DO 50 I=1,M
      WRITE(6,82) JPTX(I),PCSTRN(I),HDVSTN(I),EFSRTO(I),OCTSNM(I),
     1DLTUNM(I)
   50 CONTINUE
C
C
C
C     ****************************************
C     *   PHASE 2 : PLOT THE REDUCED DATA   *
C     ****************************************
C
C
C     NOM. HALF DEV. STRESS VS. AXIAL STRAIN
C     ======================================
C
C
      CALL PLOTS(IBUF,4000)
      CALL PLOT(0.0,-5.0,-3)
      CALL PLOT(0.0,7.0,-3)
      CALL SCALE(PCSTRN,12.0,M,1)
      HDVSTN(M+1)=0.0
      HDVSTN(M+2)=0.1
      CALL FACTOR(0.5)
      CALL AXIS(0.0,0.0,16HAXIAL STRAIN (%),-16,12.0,0.0,
     &PCSTRN(M+1),PCSTRN(M+2))
      CALL AXIS(0.0,0.0,22HNOM. HALF DEV. STRESS ,22,6.0,90.0,
     &HDVSTN(M+1),HDVSTN(M+2))
      CALL LINE(PCSTRN,HDVSTN,M,1,-1,1)
      CALL PLOT(0.0,6.0,3)
      CALL PLOT(12.0,6.0,2)
      CALL PLOT(12.0,0.0,2)
C
C
C     EFF. STRESS RATIO VS. AXIAL STRAIN
C     ==================================
C
C
      CALL PLOT(0.0,-5.0,-3)
      EFSRTO(M+1)=1.0
      EFSRTO(M+2)=1.0
      CALL AXIS(0.0,0.0,16HAXIAL STRAIN (%),-16,12.0,0.0,
     &PCSTRN(M+1),PCSTRN(M+2))
      CALL AXIS(0.0,0.0,22HEFFECTIVE STRESS RATIO,22,4.0,90.0,
     &EFSRTO(M+1),EFSRTO(M+2))
      CALL LINE(PCSTRN,EFSRTO,M,1,-1,1)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(12.0,4.0,2)
      CALL PLOT(12.0,0.0,2)
C
C
C
C     PWP CHANGE VS. AXIAL STRAIN
C     ===========================
C
C
C
      CALL PLOT(0.0,-5.0,-3)
      DLTUNM(M+1)=0.0
      DLTUNM(M+2)=0.2
      CALL AXIS(0.0,0.0,16HAXIAL STRAIN (%),-16,12.0,0.0,
     &PCSTRN(M+1),PCSTRN(M+2))
      CALL AXIS(0.0,0.0,15HNOM. PWP CHANGE,15,4.0,90.0,
     &DLTUNM(M+1),DLTUNM(M+2))
      CALL LINE(PCSTRN,DLTUNM,M,1,-1,1)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(12.0,4.0,2)
      CALL PLOT(12.0,0.0,2)
      CALL PLOT(12.0,0.0,999)
C
C
C
C
      WRITE(6,99)
      GO TO 9
   60 FORMAT (1H1,////,23H UNIVERSITY OF MANITOBA)
   61 FORMAT (26H SOIL MECHANICS LABORATORY//)
   64 FORMAT(37H CONSOLIDATED UNDRAINED TRIAXIAL TEST )
   65 FORMAT(37H ::::::::::::::::::::::::::::::::::::    ///)
  163 FORMAT(15H SAMPLE NO. = T,I4,5X,11H HOLE NO. = ,I4,5X,
     1  9H DEPTH = ,F6.2,11H METRES TO ,F6.2,8H METRES  //
     1        37H CONSOLIDATION AXIAL STRESS         = ,F7.2,
     15H KPA /
     1       37H PRECONSOLIDATION PRESSURE          = ,F7.2,
     15H KPA /
     1       37H NORMALIZING STRESS                 = ,F7.2,
     15H KPA /)
  164 FORMAT(15H SAMPLE NO. = T,I4,5X,'(REMOULDED SAMPLE)' //
     1        37H CONSOLIDATION AXIAL STRESS         = ,F7.2,
     15H KPA /
     1       37H PRECONSOLIDATION PRESSURE        . = ,F7.2,
     15H KPA /
     1       37H NORMALIZING STRESS                 = ,F7.2,
     15H KPA /)
  165 FORMAT(28H SHEAR TEST RESULTS    START,  I10,5H     ,
     13HEND, I10          //)
  265 FORMAT(/  ,39H NORMALIZED SHEAR TEST RESULTS    START,
     1I10,8H     END,I10         //)
   69 FORMAT(46H  PT  TIME      DISPL   PRING   PORE    PER   ,
     162H  EFFECT   EFFECT   HALF     DEV     EFFECT   RATIO OF      A)
   70 FORMAT(46H                  DIAL    DIAL    PRESS   CENT  ,
     157H  SIGMA1   SIGMA3   DEV      STRESS   OCT      EFF SIGMA1)
  980 FORMAT(I4,2X,I4,3X,F7.1,4X,F5.1,2X,F6.1,2X,F5.2,4X,
     1F5.1,4X,F5.1,4X,F5.1,4X,F5.1,4X,F5.1,5X,F6.3,4X,F7.2)
   81 FORMAT(I4,2X,I4,3X,F7.1,4X,F5.1,3X,15HRELAXATION TEST)
   82 FORMAT(I4,3X,F5.2,5X,F6.3,4X,F6.3,3X,F6.3,4X,F6.3)
  631 FORMAT(15H SAMPLE NO. = T,I4,5X,'(REMOULDED SAMPLE)' //
     137H SAMPLE HEIGHT AFTER CONSOLIDATION = ,F7.3,
     112H CENTIMETRES /
     1         37H SAMPLE VOLUME AFTER CONSOLIDATION =  ,F7.3,
     118H CUBIC CENTIMETRES   /
     1 38H SAMPLE AREA AFTER CONSOLIDATION    =  ,F6.3,
     1 19H SQUARE CENTIMETRES //
     137H CONSTANT LOAD                      = ,F7.2,5H  N ./
     1 37H PROVING RING FACTOR               = ,F7.4,
     1 9H   N ./DIV /
     1 37H PISTON AREA                       = ,F7.4,
     119H SQUARE CENTIMETRES  //
     1 37H INITIAL DIAL READING              = ,F7.2,
     110H DIVISIONS //)
  630 FORMAT(15H SAMPLE NO. = T,I4,5X,11H HOLE NO. = ,I4,5X,
```

```
     1  9H DEPTH = ,F6.2,11H METRES TO ,F6.2,8H METRES  //
     137H SAMPLE HEIGHT AFTER CONSOLIDATION = ,F7.3,
     112H CENTIMETRES /
     1        37H SAMPLE VOLUME AFTER CONSOLIDATION =  ,F7.3,
     118H CUBIC CENTIMETRES  /
     1 38H SAMPLE AREA AFTER CONSOLIDATION    =  ,F6.3,
     1 19H SQUARE CENTIMETRES //
     137H CONSTANT LOAD                       = ,F7.2,5H  N ./
     1 37H PROVING RING FACTOR                 = ,F7.4,
     1 9H  N ./DIV /
     1 37H PISTON AREA                         = ,F7.4,
     119H SQUARE CENTIMETRES  //
     1 37H INITIAL DIAL READING                = ,F7.2,
     110H DIVISIONS //)
 710 FORMAT (46H                    RDG      RDG      KPA      PCSTRN
     1,57H  KPA       KPA      STRESS   KPA       STRESS   EFF SIFMA3)
 720 FORMAT (45H
     149H                   KPA                  KPA        /)
 860 FORMAT(53H  PT    PER        NRMLZD    EFFECT   NRMLZD    NRMLZD  /
     1       53H       CENT       HALF      RATIO    OCT       CHANGE  /
     1       53H       PCSTRN     DEV       SIGMA1   STRESS    IN PWP  /
     1       53H                  STRESS    SIGMA3   KPA       KPA     /
     1       52H                  KPA                                 /)
  99 FORMAT(1H1,////)
     END
/*
//*
//GO.SYSIN DD *
```

APPENDIX 2c - OEDOMP

OEDOMP (Oedometer test with Plots)

2.C.1 Introduction

OEDOMP is a computer program written in FORTRAN H for the reduction of data obtained from one-dimensional consolidation test. There are three plots generated:

1) Specific Volume, V vs Log Effective Vertical Stress, Log σ'_v

2) Axial Strain, ε_1 vs Log Effective Vertical Stress, Log σ'_v

3) Specific Volume, V vs Effective Vertical Stress, σ'_v

2.C.2 Input Orders

Card		Input Element Type		Format
1	NSAMP	Sample No.		Integer
2	M	Total No. of Points		Integer
	GS	Specific Gravity of Soil		Real
3	TRSWE	Tare + Ring + Soil + Water (End)	(N)	Real
	TRS	Tare + Ring + Soil	(N)	Real
	T	Tare	(N)	Real
	RSWS	Ring + Soil + Water (Start)	(N)	Real
	R	Ring	(N)	Real
4	FACTOR	Load Multiplication Factor		Real
	CB	Weight of Cap + Ball	(N)	Real
	DIAM	Diameter of Sample	(cm)	Real
	THICK	Average Thickness of Sample	(cm)	Real
5	DIALS	Starting Dial Reading		Real
	DIALE	Ending Dial Reading		Real

6	AA	Scale Factor for Dial Gauges not read in units of 0.01 mm		Real

Note: (1) AA = 1.0 for dial gauges read in units of 0.01 mm

(2) AA is positive for dial gauges giving decreasing readings for sample compression

7	JDATE	Ending Date of Test		Integer
8	PANLO	Pan Load	(N)	Real
	DIAL	The last reading corresponding to the pan load		Real

2.C.3 Output

There are two kinds of output generated, namely, the LINE Printer output and the plots from the CALCOMP Plotter.

2.C.3.1 From the LINE Printer

From the program listing, the printer will print out background information about the test in the following order:

1) Sample No.
2) Starting Date of Test
3) Initial Moisture Content
4) Final Moisture Content
5) Specific Gravity of Soil

The results are printed in a well organized table which consists of the following:

1) Load
2) Dial Reading
3) Axial Stress
4) Specific Volume
5) Axial Strain

2.C.3.2 From the CALCOMP Plotter

The three plots mentioned earlier can be obtained from the Input/ Output (I/O) window located on the 6th floor of Engineering Building, University of Manitoba.

'OEDOMP' PROGRAM LISTING

```
C
C
C
C     *****************************
C     *                           *
C     *         OEDOMP            *
C     *                           *
C     *****************************
C
C
C     THIS PROGRAM 'OEDOMP' REDUCES DATA FROM 1 DIMENSIONAL
C     OEDOMETER TEST AND ALSO PRODUCES 3 PLOTS :
C
C       1)  AXIAL CONSOLIDATION PRESSURE VS. SPECIFIC VOLUME
C
C       2)  LOG AXIAL CONS. PRESSURE VS. SPECIFIC VOLUME
C
C       3)  LOG AXIAL CONS. PRESSURE VS. AXIAL STRAIN
C
C
C
      DIMENSION PANLO(90),DIAL(90),STRESS(90),SPV(90),STRAIN(90),
     &IBUF(4000),VR(90),SIGMAV(90),SPVOL(90)
C
C
C
C     REQUIRED INFORMATION
C     --------------------
C
C
      READ* ,NSAMP
      READ* ,P1,P2,P3
      READ* ,M,SPGRV
      READ* ,TRSWE,TRS,T,RSWS,R
      READ* ,FACTOR,CB,DIAM,THICKS
      READ* ,DIALS,DIALE
      READ* ,AA
      READ* ,JDATE
C
C
C     CALCULATE SAMPLE MOISTURE CONTENTS
C     ----------------------------------
C
C
      WE=TRSWE-TRS
      RS=TRS-T
      SS=RS-R
      WS=RSWS-RS
      WACONS=WS/SS*100
      WACONE=WE/SS*100
C
C
C     SAMPLE CROSS-SECTIONAL AREA
C     ---------------------------
C
C
      PI=4.*ATAN(1.0)
      XSA=DIAM*DIAM*PI/4
C
C
C     CALCULATE VERTICAL PRESSURE
C     ---------------------------
C
C
      I=1
    1 IF(I.GT.M) GOTO 2
      READ* ,PANLO(I),DIAL(I)
      TOLO=PANLO(I)*FACTOR+(CB/1000*9.81)
      STRESS(I)=TOLO/XSA*10
C
C
C     CALCULATE SPECIFIC VOLUME
C     -------------------------
C
C
      DEFLN=(DIAL(I)-DIALE)/1000*AA
      HSS=SS/(SPGRV*XSA)
      DELVR=DEFLN/HSS
      VF=WACONE*SPGRV/100
      VR(I)=VF+DELVR
      SPV(I)=1+VR(I)
C
C
C     CALCULATE VERTICAL STRAIN
C     -------------------------
C
C
      STRAIN(I)=(DIALS-DIAL(I))/1000*AA*(1/THICKS)*100
      I=I+1
      GOTO 1
C
C
C     PRINT CALCULATED RESULTS
C     ------------------------
C
C
    2 WRITE(6,60)
      WRITE(6,61)
      WRITE(6,63)NSAMP
      WRITE(6,64)
      WRITE(6,65)JDATE
      WRITE(6,66)WACONS
      WRITE(6,67)WACONE
      WRITE(6,68)SPGRV
      WRITE(6,102)
      I=1
    3 IF (I.GT.M) GOTO 4
      WRITE(6,101)I,PANLO(I),DIAL(I),STRESS(I),SPV(I),STRAIN(I)
      I=I+1
      GOTO 3
    4 CALL PLOTS(IBUF,4000)
      CALL PLOT(0.0,-5.0,-3)
      CALL PLOT(0.0,1.25,-3)
      IF(P1.EQ.0) GOTO 5
C
C
C     PLOT AXIAL CONSOLIDATION PRESSURE VS.SPECIFIC VOLUME
C     ----------------------------------------------------
C
C
      N=0
      DO 10 I=1,M
      IF (STRESS(I).LT.10.0) GOTO 11
      N=N+1
      SIGMAV(N)=STRESS(I)
      SPVOL(N)=SPV(I)
   11 CONTINUE
```

```
   10 CONTINUE
      SIGMAV(N+1)=0.0
      SIGMAV(N+2)=150.0
C
C
C
C
C
      CALL SCALE(SPVOL,6.9,N,1)
      CALL AXIS(0.0,0.0,'SPECIFIC VOLUME',-15,6.9,0,
     &SPVOL(N+1),SPVOL(N+2))
      CALL AXIS (0.0,0.0,'AXIAL CONSOLIDATION PRESSURE (KPA)',34,
     &8.0,90.0,SIGMAV(N+1),SIGMAV(N+2))
      CALL AXIS(0.0,8.0,'    ',3,6.9,0,
     &SPVOL(N+1),SPVOL(N+2))
      CALL AXIS(6.9,0.0,'    ',-3,8.0,90.0,
     &SIGMAV(N+1),SIGMAV(N+2))
      CALL LINE(SPVOL,SIGMAV,N,1,-1,1)
C
C
    5 IF(P2.EQ.0) GO TO 6
C
C
C     PLOT LOG AXIAL CONSOLIDATION PRESSURE VS. SPECIFIC VOLUME
C     ---------------------------------------------------------
C
C
      CALL PLOT(12.0,0.0,-3)
      CALL SCALG(SIGMAV,8.0,N,1)
      CALL AXIS(0.0,0.0,'SPECIFIC VOLUME',-15,6.9,0,
     &SPVOL(N+1),SPVOL(N+2))
      CALL LGAXS(0.0,0.0,'AXIAL CONSOLIDATION PRESSURE (KPA)',
     &34,8.0,90.0,SIGMAV(N+1),SIGMAV(N+2))
      CALL AXIS(0.0,8.0,'    ',3,6.9,0,
     &SPVOL(N+1),SPVOL(N+2))
      CALL LGAXS(6.9,0.0,'    ',-3,8.0,90.0,
     &SIGMAV(N+1),SIGMAV(N+2))
      CALL LGLIN(SPVOL,SIGMAV,N,1,-1,2,1)
C
C
C
C
C
C
    6 IF(P3.EQ.0) GO TO 7
C
C
C     PLOT LOG AXIAL CONSOLIDATION PRESSURE VS. AXIAL STRAIN
C     -----------------------------------------------------
C
C
      N=0
      DO 20 I=1,M
      IF(STRAIN(I).LT.0.0) GO TO 8
      IF(STRESS(I).LT.10.0) GO TO 8
      N=N+1
      SIGMAV(N)=STRESS(I)
      STRAIN(N)=STRAIN(I)
    8 CONTINUE
   20 CONTINUE
      STRAIN(N+1)=0.0
      STRAIN(N+2)=5.0
      CALL PLOT(12.0,0.0,-3)
      CALL SCALG(SIGMAV,8.0,N,1)
      CALL AXIS(0.0,0.0,'AXIAL STRAIN (%)',-16,5.7,0,
     &STRAIN(N+1),STRAIN(N+2))
      CALL LGAXS (0.0,0.0,'AXIAL CONSOLIDATION PRESSURE (KPA)',34,
     &8.0,90.0,SIGMAV(N+1),SIGMAV(N+2))
      CALL AXIS (0.0,8.0,'    ',3,5.7,0,
     &STRAIN(N+1),STRAIN(N+2))
      CALL LGAXS(5.7,0.0,'    ',-3,8.0,90.0,
     &SIGMAV(N+1),SIGMAV(N+2))
      CALL LGLIN(STRAIN,SIGMAV,N,1,-1,5,1)
      CALL PLOT(12.0,0.0,999)
C
C
    7 WRITE(6,99)
   60 FORMAT(1H1,////,23H UNIVERSITY OF MANITOBA)
   61 FORMAT(26H SOIL MECHANICS LABORATORY//)
   63 FORMAT(47H ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE  C,I5)
   64 FORMAT(52H ---------------------------------------------------- //)
   65 FORMAT(31H DATE STARTED LOADING         :,I7)
   66 FORMAT(31H INITIAL MOISTURE CONTENT     =,F6.2,'%')
   67 FORMAT(31H FINAL   MOISTURE CONTEMT     =,F6.2,'%')
   68 FORMAT(31H SPECIFIC GRAVITY OF SOIL     =,F5.2///)
  101 FORMAT(I4,2X,F6.1,3X,F7.1,3X,F6.1,3X,F7.4,3X,F5.1)
  102 FORMAT(2H  ,3X,'LOAD (N)',4X,'DIAL',3X,'STRESS (KPA)',
     &2X,'V',4X,'STRAIN (%)' //)
   99 FORMAT(1H1)
      STOP
      END
/*
//*
//GO.SYSIN DD *
```

A P P E N D I X 3

TABULATED LABORATORY TEST RESULTS

TRIAXIAL CONSOLIDATION TESTS

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 601 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES
INITIAL MOISTURE CONTENT = 66.8 PERCENT
SPECIFIC GRAVITY OF SOIL = 2.72
INITIAL VOID RATIO = 1.817
INITIAL HEIGHT OF SAMPLE = 13.02 CM
INITIAL VOLUME OF SAMPLE = 585.84 CC
EFFECTIVE PRINCIPAL STRESS RATIO = 0.62
FINAL MOISTURE CONTENT = 50.9 PERCENT

TX. CONSOLIDATION START 131282 END 211282
TRIAXIAL CONSOLIDATION TEST
::::::::::::::::::::::::::::

PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	74.36	52.50	2.611	4.960	1.175	59.79	21.86	1.677	2.677	0.958
2	85.17	55.00	3.518	6.454	1.468	65.06	30.17	1.635	2.635	1.366
3	97.89	61.50	4.247	7.394	1.573	73.63	36.39	1.609	2.609	1.783
4	113.60	71.90	5.116	8.546	1.715	85.80	41.70	1.576	2.576	2.266
5	131.07	81.20	6.459	9.929	1.735	97.82	49.87	1.537	2.537	3.150
6	161.21	99.70	9.063	11.978	1.458	120.20	61.51	1.480	2.480	5.070
7	184.98	114.40	10.960	13.788	1.414	137.93	70.58	1.429	2.429	6.364
8	212.30	131.60	12.550	15.308	1.379	158.50	80.70	1.386	2.386	7.447

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	74.36	52.50	2.611	1.175	2.677
2	85.17	55.00	3.518	1.468	2.635
3	97.89	61.50	4.247	1.573	2.609
4	113.60	71.90	5.116	1.715	2.576
5	131.07	81.20	6.459	1.735	2.537
6	161.21	99.70	9.063	1.458	2.480
7	184.98	114.40	10.960	1.414	2.429
8	212.30	131.60	12.550	1.379	2.386

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 501 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 131282 END 211282

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	74.4	52.5	21.9	59.8	2.611	1.175	4.960	0.0	0.0		0.0
										1.039	
2	85.2	55.0	30.2	65.1	3.518	1.468	6.454	11.4	1.0		1.039
										0.790	
3	97.9	61.5	36.4	73.6	4.247	1.573	7.394	26.8	1.7		1.829
										1.108	
4	113.6	71.9	41.7	85.8	5.115	1.715	8.546	47.9	2.6		2.936
										1.674	
5	131.1	81.2	49.9	97.8	6.459	1.735	9.929	69.7	3.9		4.611
										3.303	
6	161.2	99.7	61.5	120.2	9.063	1.458	11.978	109.5	6.5		7.914
										3.191	
7	185.0	114.4	70.6	137.9	10.960	1.414	13.788	141.1	8.4		11.104
										3.072	
8	212.3	131.6	80.7	158.5	12.550	1.379	15.308	177.6	9.9		14.176

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 501 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 131282 END 211282

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	74.4	52.5	21.9	59.8	2.646	1.220	5.087	0.0	0.0		0.0
										1.095	
2	85.2	55.0	30.2	65.1	3.581	1.545	6.671	11.4	1.0		1.095
										0.840	
3	97.9	61.5	36.4	73.6	4.340	1.670	7.680	26.8	1.8		1.935
										1.191	
4	113.6	71.9	41.7	85.8	5.251	1.841	8.932	47.9	2.7		3.126
										1.820	
5	131.1	81.2	49.9	97.8	6.677	1.890	10.456	69.7	4.1		4.946
										3.653	
6	161.2	99.7	61.5	120.2	9.500	1.629	12.757	109.5	6.9		8.599
										3.616	
7	185.0	114.4	70.6	137.9	11.608	1.614	14.835	141.1	9.0		12.215
										3.550	
8	212.3	131.6	80.7	158.5	13.410	1.602	16.614	177.6	10.8		15.765

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SOIL MECHANICS LABORATORY

SAMPLE NO. = T 502   HOLE NO. = 0   DEPTH = 0.0 METRES TO 0.0 METRES
INITIAL MOISTURE CONTENT = 64.6 PERCENT
SPECIFIC GRAVITY OF SOIL = 2.72
INITIAL VOID RATIO = 1.763
INITIAL HEIGHT OF SAMPLE = 12.33 CM
INITIAL VOLUME OF SAMPLE = 554.40 CC
EFFECTIVE PRINCIPAL STRESS RATIO = 0.62
FINAL MOISTURE CONTENT = 41.7 PERCENT

TX. CONSOLIDATION START 130183 END 280183
TRIAXIAL CONSOLIDATION TEST
::::::::::::::::::::::::::::

PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	40.43	25.60	1.580	2.038	0.229	30.54	14.83	1.706	2.706	0.900
2	54.00	33.50	2.187	3.238	0.525	40.33	20.50	1.673	2.673	1.108
3	67.11	41.50	2.959	4.401	0.721	50.04	25.61	1.641	2.641	1.492
4	80.66	50.10	3.739	5.541	0.901	60.29	30.56	1.609	2.609	1.892
5	92.90	57.30	4.712	6.764	1.026	69.17	35.60	1.576	2.576	2.457
6	106.85	66.20	5.949	8.171	1.111	79.75	40.65	1.537	2.537	3.225
7	121.87	75.40	7.531	9.823	1.146	90.89	46.47	1.491	2.491	4.257
8	139.96	86.60	9.261	11.499	1.119	104.39	53.36	1.445	2.445	5.428
9	160.78	99.65	11.185	13.321	1.068	120.03	61.13	1.395	2.395	6.745
10	184.87	114.80	13.188	15.152	0.982	138.16	70.07	1.344	2.344	8.138
11	212.22	131.70	15.270	16.973	0.852	158.54	80.52	1.294	2.294	9.612
12	243.43	151.10	17.264	18.669	0.703	181.88	92.33	1.247	2.247	11.041
13	279.50	173.60	19.427	20.391	0.482	208.90	105.90	1.199	2.199	12.630
14	318.98	197.50	21.648	22.078	0.215	237.99	121.48	1.153	2.153	14.289
15	319.37	197.50	22.062	22.738	0.337	238.12	121.87	1.134	2.134	14.484

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	40.43	25.60	1.580	0.229	2.706
2	54.00	33.50	2.187	0.525	2.673
3	67.11	41.50	2.959	0.721	2.641
4	80.66	50.10	3.739	0.901	2.609
5	92.90	57.30	4.712	1.026	2.576
6	106.85	66.20	5.949	1.111	2.537
7	121.87	75.40	7.531	1.146	2.491
8	139.96	86.60	9.261	1.119	2.445
9	160.78	99.65	11.185	1.068	2.395
10	184.87	114.80	13.188	0.982	2.344
11	212.22	131.70	15.270	0.852	2.294
12	243.43	151.10	17.264	0.703	2.247
13	279.50	173.60	19.427	0.482	2.199
14	318.98	197.50	21.648	0.215	2.153
15	319.37	197.50	22.062	0.337	2.134

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 502 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 130183 END 280183

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	40.4	25.6	14.8	30.5	1.580	0.229	2.038	0.0	0.0		0.0
										0.482	
2	54.0	33.5	20.5	40.3	2.187	0.525	3.238	17.6	0.7		0.482
										0.614	
3	67.1	41.5	25.6	50.0	2.959	0.721	4.401	34.9	1.5		1.076
										0.741	
4	80.7	50.1	30.6	60.3	3.739	0.901	5.541	53.1	2.4		1.817
										0.979	
5	92.9	57.3	35.6	69.2	4.712	1.026	6.764	69.0	3.3		2.796
										1.340	
6	106.9	66.2	40.7	79.8	5.949	1.111	8.171	87.8	4.5		4.136
										1.859	
7	121.9	75.4	46.5	90.9	7.531	1.146	9.823	107.7	6.1		5.995
										2.221	
8	140.0	86.6	53.4	104.4	9.261	1.119	11.499	131.7	7.8		8.216
										2.798	
9	160.8	99.6	61.1	120.0	11.185	1.068	13.321	159.5	9.7		11.014
										3.277	
10	184.9	114.8	70.1	138.2	13.188	0.982	15.152	191.8	11.7		14.291
										3.813	
11	212.2	131.7	80.5	158.5	15.270	0.852	16.973	228.1	13.7		18.104
										4.120	
12	243.4	151.1	92.3	181.9	17.264	0.703	18.669	269.6	15.7		22.224
										4.941	
13	279.5	173.6	105.9	208.9	19.427	0.482	20.391	317.7	17.9		27.165
										5.654	
14	319.0	197.5	121.5	238.0	21.648	0.215	22.078	369.7	20.1		32.819
										1.805	
15	319.4	197.5	121.9	238.1	22.062	0.337	22.738	370.0	20.5		34.624

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 502 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 130183 END 280183

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	40.4	25.6	14.8	30.5	1.592	0.233	2.058	0.0	0.0		0.0
										0.473	
2	54.0	33.5	20.5	40.3	2.212	0.540	3.291	17.6	0.8		0.473
										0.636	
3	67.1	41.5	25.6	50.0	3.003	0.749	4.501	34.9	1.6		1.110
										0.776	
4	80.7	50.1	30.6	60.3	3.810	0.945	5.700	53.1	2.4		1.886
										1.036	
5	92.9	57.3	35.6	69.2	4.827	1.088	7.004	69.0	3.5		2.922
										1.437	
6	106.9	66.2	40.7	79.8	6.133	1.195	8.524	87.8	4.7		4.359
										2.025	
7	121.9	75.4	46.5	90.9	7.830	1.255	10.340	107.7	6.4		6.383
										2.462	
8	140.0	86.6	53.4	104.4	9.718	1.248	12.215	131.7	8.3		8.845
										3.164	
9	160.8	99.6	61.1	120.0	11.861	1.217	14.295	159.5	10.4		12.008
										3.785	
10	184.9	114.8	70.1	138.2	14.142	1.144	16.430	191.8	12.6		15.794
										4.503	
11	212.2	131.7	80.5	158.5	16.570	1.015	18.600	228.1	15.0		20.297
										4.975	
12	243.4	151.1	92.3	181.9	18.950	0.857	20.663	269.6	17.4		25.271
										6.102	
13	279.5	173.6	105.9	208.9	21.600	0.602	22.804	317.7	20.0		31.373
										7.150	
14	319.0	197.5	121.5	238.0	24.395	0.275	24.945	369.7	22.6		38.523
										2.321	
15	319.4	197.5	121.9	238.1	24.926	0.434	25.794	370.0	23.3		40.844

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 503 (REMOULDED SAMPLE)
INITIAL MOISTURE CONTENT = 59.5 PERCENT
SPECIFIC GRAVITY OF SOIL = 2.72
INITIAL VOID RATIO = 1.618
INITIAL HEIGHT OF SAMPLE = 13.27 CM
INITIAL VOLUME OF SAMPLE = 587.00 CC
EFFECTIVE PRINCIPAL STRESS RATIO = 0.62
FINAL MOISTURE CONTENT = 45.0 PERCENT

TX. CONSOLIDATION START 250183 END 70283
TRIAXIAL CONSOLIDATION TEST
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PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	40.56	25.30	1.329	2.010	0.340	30.39	15.26	1.566	2.566	0.659
2	46.75	28.90	1.860	3.400	0.770	34.85	17.85	1.529	2.529	0.726
3	54.03	33.50	2.298	4.405	1.054	40.34	20.53	1.503	2.503	0.829
4	62.35	38.60	2.734	5.260	1.263	46.52	23.75	1.481	2.481	0.981
5	72.05	44.60	3.325	6.298	1.487	53.75	27.45	1.453	2.453	1.225
6	83.05	51.40	4.030	7.286	1.628	61.95	31.65	1.428	2.428	1.601
7	95.62	59.10	5.024	8.518	1.747	71.27	36.52	1.395	2.395	2.185
8	109.39	68.50	6.397	9.966	1.785	82.13	40.89	1.357	2.357	3.074
9	125.65	77.90	8.191	11.449	1.629	93.82	47.75	1.319	2.319	4.374
10	144.18	89.60	10.528	13.241	1.358	107.79	54.58	1.272	2.272	6.112
11	166.18	102.80	13.196	14.891	0.847	123.93	63.38	1.228	2.228	8.233
12	139.20	86.00	13.313	15.486	1.086	103.73	53.20	1.213	2.213	8.151
13	83.22	51.60	12.787	15.109	1.171	62.14	31.62	1.223	2.223	7.730

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	40.56	25.30	1.329	0.340	2.566
2	46.75	28.90	1.860	0.770	2.529
3	54.03	33.50	2.298	1.054	2.503
4	62.35	38.60	2.734	1.263	2.481
5	72.05	44.60	3.325	1.487	2.453
6	83.05	51.40	4.030	1.628	2.428
7	95.62	59.10	5.024	1.747	2.395
8	109.39	68.50	6.397	1.785	2.357
9	125.65	77.90	8.191	1.629	2.319
10	144.18	89.60	10.528	1.358	2.272
11	166.18	102.80	13.196	0.847	2.228
12	139.20	86.00	13.313	1.086	2.213
13	83.22	51.60	12.787	1.171	2.223

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 503 HOLE NO. = -1 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 250183 END 70283

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	40.6	25.3	15.3	30.4	1.329	0.340	2.010	0.0	0.0		0.0
2	46.8	28.9	17.9	34.8	1.860	0.770	3.400	8.0	0.8	0.485	0.485
3	54.0	33.5	20.5	40.3	2.298	1.054	4.405	17.8	1.4	0.398	0.882
4	62.4	38.6	23.8	46.5	2.734	1.263	5.260	28.8	1.9	0.405	1.287
5	72.1	44.6	27.4	53.8	3.325	1.487	6.298	41.7	2.6	0.563	1.850
6	83.1	51.4	31.7	61.9	4.030	1.628	7.286	56.3	3.3	0.683	2.533
7	95.6	59.1	36.5	71.3	5.024	1.747	8.518	72.9	4.2	1.018	3.552
8	109.4	68.5	40.9	82.1	6.397	1.785	9.966	92.0	5.5	1.455	5.007
9	125.6	77.9	47.8	93.8	8.191	1.629	11.449	113.0	7.1	1.880	6.888
10	144.2	89.6	54.6	107.8	10.528	1.358	13.241	137.9	9.3	2.696	9.584
11	166.2	102.8	63.4	123.9	13.196	0.847	14.891	166.7	11.9	3.162	12.746
12	139.2	86.0	53.2	103.7	13.313	1.086	15.486	130.8	12.0	0.628	13.375
13	83.2	51.6	31.6	62.1	12.767	1.171	15.109	56.6	11.5	-0.491	12.884

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 503 HOLE NO. = -1 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 250183 END 70283

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	40.6	25.3	15.3	30.4	1.338	0.346	2.030	0.0	0.0		0.0
2	46.8	28.9	17.9	34.8	1.877	0.791	3.459	8.0	0.8	0.477	0.477
3	54.0	33.5	20.5	40.3	2.325	1.090	4.505	17.8	1.4	0.412	0.889
4	62.4	38.6	23.8	46.5	2.772	1.315	5.403	28.8	2.0	0.423	1.311
5	72.1	44.6	27.4	53.8	3.381	1.562	6.505	41.7	2.7	0.614	1.925
6	83.1	51.4	31.7	61.9	4.114	1.726	7.565	56.3	3.4	0.725	2.651
7	95.6	59.1	36.5	71.3	5.155	1.874	8.902	72.9	4.4	1.094	3.745
8	109.4	68.5	40.9	82.1	6.610	1.944	10.499	92.0	5.7	1.582	5.326
9	125.6	77.9	47.8	93.8	8.545	1.807	12.159	113.0	7.5	2.073	7.399
10	144.2	89.6	54.6	107.8	11.122	1.541	14.204	137.9	9.9	3.031	10.430
11	166.2	102.8	63.4	123.9	14.152	0.986	16.124	166.7	12.8	3.634	14.064
12	139.2	86.0	53.2	103.7	14.288	1.269	16.825	130.8	13.0	0.740	14.804
13	83.2	51.6	31.6	62.1	13.658	1.361	16.380	56.6	12.4	-0.573	14.232

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 504 (REMOULDED SAMPLE)
INITIAL MOISTURE CONTENT = 63.2 PERCENT
SPECIFIC GRAVITY OF SOIL = 2.72
INITIAL VOID RATIO = 1.718
INITIAL HEIGHT OF SAMPLE = 13.27 CM
INITIAL VOLUME OF SAMPLE = 597.20 CC
EFFECTIVE PRINCIPAL STRESS RATIO = 0.61
FINAL MOISTURE CONTENT = 36.1 PERCENT

TX. CONSOLIDATION START 280183 END 110283
TRIAXIAL CONSOLIDATION TEST
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PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	37.01	23.50	3.402	5.760	1.179	28.00	13.51	1.562	2.562	1.482
2	42.59	26.20	3.900	7.133	1.617	31.66	16.39	1.525	2.525	1.522
3	48.94	30.10	4.213	8.423	2.105	36.38	18.84	1.490	2.490	1.405
4	56.21	34.60	4.549	9.695	2.573	41.80	21.61	1.455	2.455	1.318
5	64.74	39.90	4.774	10.926	3.076	48.18	24.84	1.421	2.421	1.132
6	73.60	44.80	5.217	12.298	3.541	54.40	28.80	1.384	2.384	1.117
7	82.64	53.80	5.862	13.957	4.047	63.41	28.84	1.339	2.339	1.210
8	95.50	59.00	6.956	15.857	4.451	71.17	36.50	1.287	2.287	1.670
9	111.32	68.90	8.222	17.959	4.869	83.04	42.42	1.230	2.230	2.235
10	128.50	79.20	9.635	20.219	5.292	95.63	49.30	1.168	2.168	2.895
11	148.88	91.90	11.161	22.698	5.769	110.89	56.98	1.101	2.101	3.595
12	171.99	105.80	12.782	25.343	6.281	127.86	66.19	1.030	2.030	4.314
13	173.00	105.60	13.265	27.101	6.918	128.07	67.40	0.982	1.982	4.231

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	37.01	23.50	3.402	1.179	2.562
2	42.59	26.20	3.900	1.617	2.525
3	48.94	30.10	4.213	2.105	2.490
4	56.21	34.60	4.549	2.573	2.455
5	64.74	39.90	4.774	3.076	2.421
6	73.60	44.80	5.217	3.541	2.384
7	82.64	53.80	5.862	4.047	2.339
8	95.50	59.00	6.956	4.451	2.287
9	111.32	68.90	8.222	4.869	2.230
10	128.50	79.20	9.635	5.292	2.168
11	148.88	91.90	11.161	5.769	2.101
12	171.99	105.80	12.782	6.281	2.030
13	173.00	105.60	13.265	6.918	1.982

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. : T 504 HOLE NO. : -1 DEPTH : 0.0 METRES TO 0.0 METRES

TEST RESULTS START 280183 END 110283

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	37.0	23.5	13.5	28.0	3.402	1.179	5.760	0.0	0.0		0.0
										0.418	
2	42.6	26.2	16.4	31.7	3.900	1.617	7.133	6.8	0.8		0.418
										0.418	
3	48.9	30.1	18.8	36.4	4.213	2.105	8.423	15.1	1.5		0.834
										0.480	
4	56.2	34.6	21.6	41.8	4.549	2.573	9.695	24.8	2.3		1.313
										0.511	
5	64.7	39.9	24.8	48.2	4.774	3.076	10.926	36.2	3.0		1.824
										0.700	
6	73.6	44.8	28.8	54.4	5.217	3.541	12.299	47.4	3.8		2.524
										1.003	
7	82.6	53.8	28.8	63.4	5.862	4.047	13.957	62.6	4.7		3.528
										1.429	
8	95.5	59.0	36.5	71.2	6.956	4.451	15.857	77.1	5.8		4.957
										1.843	
9	111.3	68.9	42.4	83.0	8.222	4.869	17.959	98.2	7.1		6.800
										2.322	
10	128.5	79.2	49.3	95.6	9.635	5.292	20.219	120.7	8.5		9.122
										2.931	
11	148.9	91.9	57.0	110.9	11.161	5.769	22.698	147.9	10.1		12.053
										3.601	
12	172.0	105.8	66.2	127.9	12.782	6.281	25.343	178.2	11.8		15.654
										2.194	
13	173.0	105.6	67.4	128.1	13.265	6.918	27.101	178.8	12.8		17.848

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. : T 504 HOLE NO. : -1 DEPTH : 0.0 METRES TO 0.0 METRES

TEST RESULTS START 280183 END 110283

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	37.0	23.5	13.5	28.0	3.461	1.235	5.931	0.0	0.0		0.0
										0.442	
2	42.6	26.2	16.4	31.7	3.978	1.711	7.399	6.8	0.8		0.442
										0.451	
3	48.9	30.1	18.8	36.4	4.303	2.247	8.797	15.1	1.7		0.893
										0.524	
4	56.2	34.6	21.6	41.8	4.656	2.770	10.196	24.8	2.5		1.417
										0.566	
5	64.7	39.9	24.8	48.2	4.891	3.339	11.568	36.2	3.3		1.983
										0.783	
6	73.6	44.8	28.8	54.4	5.358	3.882	13.122	47.4	4.2		2.766
										1.138	
7	82.6	53.8	28.8	63.4	6.041	4.495	15.030	62.6	5.3		3.903
										1.641	
8	95.5	59.0	36.5	71.2	7.209	5.027	17.264	77.1	6.5		5.545
										2.158	
9	111.3	68.9	42.4	83.0	8.579	5.607	19.793	98.2	8.0		7.703
										2.780	
10	128.5	79.2	49.3	95.6	10.130	6.228	22.587	120.7	9.7		10.483
										3.604	
11	148.9	91.9	57.0	110.9	11.833	6.954	25.742	147.9	11.6		14.087
										4.562	
12	172.0	105.8	66.2	127.9	13.652	7.786	29.224	178.2	13.8		18.649
										2.905	
13	173.0	105.6	67.4	128.1	14.230	8.688	31.607	178.8	15.1		21.554

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 505 (REMOULDED SAMPLE)
INITIAL MOISTURE CONTENT = 58.9 PERCENT
SPECIFIC GRAVITY OF SOIL = 2.72
INITIAL VOID RATIO = 1.603
INITIAL HEIGHT OF SAMPLE = 13.14 CM
INITIAL VOLUME OF SAMPLE = 580.86 CC
EFFECTIVE PRINCIPAL STRESS RATIO = 0.98
FINAL MOISTURE CONTENT = 27.3 PERCENT

TX. CONSOLIDATION START 100283 END 240283
TRIAXIAL CONSOLIDATION TEST
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PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	40.36	39.40	0.538	2.843	1.153	39.72	0.96	1.529	2.529	-0.410
2	46.28	45.40	0.685	4.671	1.993	45.69	0.88	1.481	2.481	-0.872
3	53.53	52.40	0.818	6.262	2.722	52.78	1.13	1.440	2.440	-1.269
4	61.82	60.60	0.965	7.971	3.503	61.01	1.22	1.395	2.395	-1.692
5	70.79	69.30	1.151	9.985	4.417	69.80	1.49	1.343	2.343	-2.177
6	81.30	79.60	1.347	11.983	5.318	80.17	1.70	1.291	2.291	-2.647
7	93.70	91.80	1.597	14.225	6.314	92.43	1.90	1.232	2.232	-3.144
8	108.15	106.00	1.896	16.611	7.358	106.72	2.15	1.170	2.170	-3.641
9	124.20	121.70	2.273	19.209	8.468	122.53	2.50	1.103	2.103	-4.131
10	142.66	139.90	2.831	21.782	9.476	140.82	2.76	1.038	2.038	-4.430
11	163.80	160.30	3.148	24.490	10.671	161.47	3.50	0.965	1.965	-5.015
12	188.27	184.40	3.639	27.248	11.805	185.69	3.87	0.893	1.893	-5.444
13	216.56	212.00	4.177	30.109	12.966	213.52	4.56	0.819	1.819	-5.859
14	249.28	244.10	4.727	33.053	14.163	245.82	5.18	0.742	1.742	-6.291

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	40.36	39.40	0.538	1.153	2.529
2	46.28	45.40	0.685	1.993	2.481
3	53.53	52.40	0.818	2.722	2.440
4	61.82	60.60	0.965	3.503	2.395
5	70.79	69.30	1.151	4.417	2.343
6	81.30	79.60	1.347	5.318	2.291
7	93.70	91.80	1.597	6.314	2.232
8	108.15	106.00	1.896	7.358	2.170
9	124.20	121.70	2.273	8.468	2.103
10	142.66	139.90	2.831	9.476	2.038
11	163.80	160.30	3.148	10.671	1.965
12	188.27	184.40	3.639	11.805	1.893
13	216.56	212.00	4.177	12.966	1.819
14	249.28	244.10	4.727	14.163	1.742

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 505 HOLE NO. = -1 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 100283 END 240283

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	40.4	39.4	1.0	39.7	0.538	1.153	2.843	0.0	0.0		0.0
										0.776	
2	46.3	45.4	0.9	45.7	0.685	1.993	4.671	10.3	1.2		0.776
										0.779	
3	53.5	52.4	1.1	52.8	0.818	2.722	6.262	22.6	2.2		1.556
										0.968	
4	61.8	60.6	1.2	61.0	0.965	3.503	7.971	36.9	3.4		2.523
										1.311	
5	70.8	69.3	1.5	69.8	1.161	4.417	9.985	52.1	4.7		3.834
										1.490	
6	81.3	79.6	1.7	80.2	1.347	5.318	11.983	70.1	5.9		5.324
										1.926	
7	93.7	91.8	1.9	92.4	1.597	6.314	14.225	91.3	7.4		7.250
										2.366	
8	108.1	106.0	2.1	106.7	1.898	7.358	16.611	116.0	8.9		9.616
										2.966	
9	124.2	121.7	2.5	122.5	2.273	8.468	19.209	143.4	10.5		12.583
										3.380	
10	142.7	139.9	2.8	140.8	2.831	9.476	21.782	175.1	12.0		15.962
										4.075	
11	163.8	160.3	3.5	161.5	3.148	10.671	24.490	210.9	13.7		20.037
										4.773	
12	188.3	184.4	3.9	185.7	3.639	11.805	27.248	252.8	15.4		24.809
										5.692	
13	216.6	212.0	4.6	213.5	4.177	12.966	30.109	301.0	17.1		30.501
										6.742	
14	249.3	244.1	5.2	245.8	4.727	14.163	33.053	357.0	18.9		37.244

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 505 HOLE NO. = -1 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 100283 END 240283

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	40.4	39.4	1.0	39.7	0.540	1.172	2.884	0.0	0.0		0.0
										0.807	
2	46.3	45.4	0.9	45.7	0.688	2.048	4.784	10.3	1.2		0.807
										0.824	
3	53.5	52.4	1.1	52.8	0.822	2.822	6.466	22.6	2.4		1.631
										1.042	
4	61.8	60.6	1.2	61.0	0.970	3.668	8.307	36.9	3.6		2.672
										1.440	
5	70.8	69.3	1.5	69.8	1.158	4.681	10.519	52.1	5.0		4.112
										1.673	
6	81.3	79.6	1.7	80.2	1.358	5.704	12.763	70.1	6.5		5.786
										2.216	
7	93.7	91.8	1.9	92.4	1.610	6.867	15.344	91.3	8.1		8.002
										2.786	
8	108.1	106.0	2.1	106.7	1.914	8.126	18.165	116.0	9.9		10.788
										3.612	
9	124.2	121.7	2.5	122.5	2.299	9.515	21.330	143.4	11.9		14.410
										4.247	
10	142.7	139.9	2.8	140.8	2.871	10.847	24.565	175.1	13.9		18.658
										5.298	
11	163.8	160.3	3.5	161.5	3.199	12.445	28.088	210.9	16.2		23.956
										6.432	
12	188.3	184.4	3.9	185.7	3.707	14.051	31.810	252.8	18.5		30.388
										7.972	
13	216.6	212.0	4.6	213.5	4.267	15.776	35.820	301.0	21.0		38.360
										9.844	
14	249.3	244.1	5.2	245.8	4.842	17.641	40.124	357.0	23.7		48.204

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. : T 506 (REMOULDED SAMPLE)
INITIAL MOISTURE CONTENT : 64.5 PERCENT
SPECIFIC GRAVITY OF SOIL : 2.72
INITIAL VOID RATIO : 1.755
INITIAL HEIGHT OF SAMPLE : 13.14 CM
INITIAL VOLUME OF SAMPLE : 596.86 CC
EFFECTIVE PRINCIPAL STRESS RATIO : 0.98
FINAL MOISTURE CONTENT : 45.3 PERCENT

TX. CONSOLIDATION START 190283 END 30383
TRIAXIAL CONSOLIDATION TEST
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PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	59.20	57.90	2.083	8.107	3.012	58.33	1.30	1.531	2.531	-0.819
2	67.78	66.30	2.427	9.393	3.483	66.79	1.48	1.496	2.496	-0.704
3	77.37	75.70	2.790	10.670	3.940	76.26	1.67	1.461	2.461	-0.767
4	88.65	86.80	3.217	12.073	4.428	87.42	1.85	1.422	2.422	-0.808
5	101.80	99.70	3.729	13.509	4.890	100.40	2.10	1.383	2.383	-0.774
6	117.45	115.10	4.256	14.995	5.370	115.88	2.35	1.342	2.342	-0.743
7	134.88	132.10	4.874	16.596	5.862	133.03	2.78	1.297	2.297	-0.659
8	155.10	152.00	5.531	18.161	6.310	153.03	3.10	1.255	2.255	-0.519
9	178.29	174.70	6.151	19.654	6.752	175.90	3.59	1.213	2.213	-0.401
10	126.26	123.80	5.947	19.395	6.724	124.62	2.46	1.220	2.220	-0.518
11	89.56	87.80	5.587	18.953	6.683	88.39	1.76	1.233	2.233	-0.731

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	59.20	57.90	2.083	3.012	2.531
2	67.78	66.30	2.427	3.483	2.496
3	77.37	75.70	2.790	3.940	2.461
4	88.65	86.80	3.217	4.428	2.422
5	101.80	99.70	3.729	4.890	2.383
6	117.45	115.10	4.256	5.370	2.342
7	134.88	132.10	4.874	5.862	2.297
8	155.10	152.00	5.531	6.310	2.255
9	178.29	174.70	6.151	6.752	2.213
10	126.26	123.80	5.947	6.724	2.220
11	89.56	87.80	5.587	6.683	2.233

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 508 HOLE NO. = -1 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 180283 END 30383

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	59.2	57.9	1.3	58.3	2.083	3.012	8.107	0.0	0.0		0.0
										0.803	
2	67.8	66.3	1.5	66.8	2.427	3.483	9.393	14.7	0.7		0.803
										0.913	
3	77.4	75.7	1.7	76.3	2.790	3.940	10.670	31.0	1.5		1.716
										1.147	
4	88.6	86.8	1.8	87.4	3.217	4.428	12.073	50.4	2.3		2.863
										1.349	
5	101.8	99.7	2.1	100.4	3.729	4.890	13.509	72.9	3.1		4.212
										1.608	
6	117.4	115.1	2.3	115.9	4.255	5.370	14.995	98.7	4.0		5.820
										1.997	
7	134.9	132.1	2.8	133.0	4.874	5.862	16.598	129.4	4.9		7.817
										2.225	
8	155.1	152.0	3.1	153.0	5.531	6.310	18.151	164.0	5.8		10.043
										2.475	
9	178.3	174.7	3.6	175.9	6.151	6.752	19.654	203.6	6.7		12.518
										-0.392	
10	126.3	123.8	2.5	124.6	5.947	6.724	19.395	114.8	6.5		12.126
										-0.476	
11	89.6	87.8	1.8	88.4	5.587	6.683	18.953	52.1	6.3		11.650

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 508 HOLE NO. = -1 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 180283 END 30383

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	59.2	57.9	1.3	58.3	2.105	3.172	8.450	0.0	0.0		0.0
										0.880	
2	67.8	66.3	1.5	66.8	2.457	3.701	9.859	14.7	0.8		0.880
										1.014	
3	77.4	75.7	1.7	76.3	2.830	4.224	11.278	31.0	1.7		1.894
										1.294	
4	88.6	86.8	1.8	87.4	3.269	4.796	12.861	50.4	2.6		3.188
										1.546	
5	101.8	99.7	2.1	100.4	3.800	5.354	14.508	72.9	3.5		4.734
										1.874	
6	117.4	115.1	2.3	115.9	4.349	5.946	16.241	98.7	4.5		6.607
										2.370	
7	134.9	132.1	2.8	133.0	4.997	6.574	18.145	129.4	5.6		8.977
										2.690	
8	155.1	152.0	3.1	153.0	5.650	7.187	20.024	164.0	6.7		11.667
										3.049	
9	178.3	174.7	3.6	175.9	6.348	7.765	21.877	203.6	7.8		14.716
										-0.487	
10	126.3	123.8	2.5	124.6	6.132	7.712	21.556	114.8	7.6		14.230
										-0.587	
11	89.6	87.8	1.8	88.4	5.749	7.630	21.008	52.1	7.3		13.642

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 507 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES
INITIAL MOISTURE CONTENT = 69.4 PERCENT
SPECIFIC GRAVITY OF SOIL = 2.72
INITIAL VOID RATIO = 1.887
INITIAL HEIGHT OF SAMPLE = 13.14 CM
INITIAL VOLUME OF SAMPLE = 590.86 CC
EFFECTIVE PRINCIPAL STRESS RATIO = 0.62
FINAL MOISTURE CONTENT = 37.9 PERCENT

TX. CONSOLIDATION START 30383 END 230383
TRIAXIAL CONSOLIDATION TEST
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PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	41.17	25.90	1.769	2.877	0.554	30.99	15.27	1.804	2.804	0.810
2	53.85	33.30	2.477	4.536	1.030	40.15	20.55	1.756	2.756	0.965
3	67.11	41.40	3.364	6.228	1.432	49.97	25.71	1.707	2.707	1.287
4	80.87	50.10	4.494	8.073	1.789	60.36	30.77	1.654	2.654	1.803
5	94.14	58.30	5.928	10.121	2.097	70.25	35.84	1.595	2.595	2.553
6	107.57	66.30	7.355	12.033	2.339	80.06	41.27	1.539	2.539	3.344
7	124.10	76.60	9.096	14.242	2.573	92.43	47.50	1.476	2.476	4.349
8	142.80	88.30	10.906	16.422	2.758	106.47	54.50	1.413	2.413	5.431
9	164.25	101.70	12.790	18.558	2.884	122.55	62.55	1.351	2.351	6.604
10	137.30	84.90	12.724	18.896	3.086	102.37	52.40	1.341	2.341	6.425
11	82.38	51.40	12.046	18.075	3.014	61.73	30.98	1.365	2.365	6.021
12	101.96	63.00	12.241	18.608	3.184	75.99	38.96	1.350	2.350	6.039
13	122.21	75.60	12.498	19.280	3.391	91.14	46.61	1.330	2.330	6.071
14	142.00	87.70	12.812	20.039	3.613	105.80	54.30	1.308	2.308	6.133
15	162.26	100.30	13.265	20.978	3.857	120.95	61.96	1.281	2.281	6.272
16	182.34	112.70	13.890	22.053	4.081	135.91	69.64	1.250	2.250	6.540
17	209.80	129.80	15.110	23.593	4.241	156.47	80.00	1.208	2.208	7.246
18	240.56	148.70	17.017	25.585	4.284	179.32	91.86	1.148	2.148	8.489
19	276.95	171.60	19.229	27.670	4.221	206.72	105.35	1.088	2.088	10.005
20	319.57	197.20	20.490	29.636	4.573	237.99	122.37	1.031	2.031	10.611

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	41.17	25.90	1.769	0.554	2.804
2	53.85	33.30	2.477	1.030	2.756
3	67.11	41.40	3.364	1.432	2.707
4	80.87	50.10	4.494	1.789	2.654
5	94.14	58.30	5.928	2.097	2.595
6	107.57	66.30	7.355	2.339	2.539
7	124.10	76.60	9.096	2.573	2.476
8	142.80	88.30	10.906	2.758	2.413
9	164.25	101.70	12.790	2.884	2.351
10	137.30	84.90	12.724	3.086	2.341
11	82.38	51.40	12.046	3.014	2.365
12	101.96	63.00	12.241	3.184	2.350
13	122.21	75.60	12.498	3.391	2.330
14	142.00	87.70	12.812	3.613	2.308
15	162.26	100.30	13.265	3.857	2.281
16	182.34	112.70	13.890	4.081	2.250
17	209.80	129.80	15.110	4.241	2.208
18	240.56	148.70	17.017	4.284	2.148
19	276.95	171.60	19.229	4.221	2.088
20	319.57	197.20	20.490	4.573	2.031

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 507 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 30383 END 230383

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	41.2	25.9	15.3	31.0	1.769	0.554	2.877	0.0	0.0		0.0
										0.618	
2	53.9	33.3	20.6	40.1	2.477	1.030	4.536	18.4	1.0		0.618
										0.837	
3	67.1	41.4	25.7	50.0	3.384	1.432	6.228	34.0	2.0		1.455
										1.163	
4	80.9	50.1	30.8	60.4	4.494	1.789	8.073	52.4	3.2		2.618
										1.587	
5	94.1	58.3	35.8	70.2	5.926	2.097	10.121	70.0	4.7		4.205
										1.742	
6	107.6	66.3	41.3	80.1	7.355	2.339	12.033	87.6	6.1		5.948
										2.351	
7	124.1	76.6	47.5	92.4	9.096	2.573	14.242	109.6	7.9		8.298
										2.720	
8	142.8	88.3	54.5	106.5	10.905	2.758	16.422	134.9	9.7		11.018
										3.132	
9	164.2	101.7	62.5	122.5	12.790	2.884	18.558	163.2	11.6		14.151
										0.276	
10	137.3	84.9	52.4	102.4	12.724	3.086	18.896	127.3	11.5		14.428
										-0.842	
11	82.4	51.4	31.0	61.7	12.046	3.014	18.075	54.8	10.9		13.586
										0.373	
12	102.0	63.0	39.0	76.0	12.241	3.184	18.608	80.3	11.1		13.960
										0.575	
13	122.2	75.6	46.6	91.1	12.498	3.391	19.280	107.3	11.5		14.535
										0.778	
14	142.0	87.7	54.3	105.8	12.812	3.613	20.038	133.4	11.9		15.313
										1.146	
15	162.3	100.3	62.0	121.0	13.265	3.857	20.978	160.4	12.4		16.459
										1.556	
16	182.3	112.7	69.6	135.9	13.890	4.081	22.053	187.1	13.1		18.015
										2.780	
17	208.8	128.8	80.0	155.5	15.110	4.241	23.593	223.7	14.3		20.795
										4.413	
18	240.6	148.7	91.9	179.3	17.017	4.284	25.585	264.4	16.1		25.207
										5.520	
19	276.9	171.6	105.3	206.7	19.228	4.221	27.670	313.1	18.2		30.727
										5.053	
20	319.6	197.2	122.4	238.0	20.490	4.573	29.636	368.0	19.6		35.780

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 507 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 30383 END 230383

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	41.2	25.9	15.3	31.0	1.784	0.567	2.919	0.0	0.0		0.0
										0.639	
2	53.9	33.3	20.6	40.1	2.508	1.067	4.642	18.4	1.0		0.639
										0.879	
3	67.1	41.4	25.7	50.0	3.421	1.504	6.430	34.0	2.1		1.518
										1.241	
4	80.9	50.1	30.8	60.4	4.598	1.909	8.417	52.4	3.4		2.760
										1.724	
5	94.1	58.3	35.8	70.2	6.108	2.281	10.670	70.0	5.0		4.484
										1.930	
6	107.6	66.3	41.3	80.1	7.640	2.591	12.821	87.6	6.5		6.414
										2.659	
7	124.1	76.6	47.5	92.4	9.537	2.913	15.363	109.6	8.4		9.073
										3.148	
8	142.8	88.3	54.5	106.5	11.547	3.195	17.936	134.9	10.4		12.221
										3.711	
9	164.2	101.7	62.5	122.5	13.685	3.421	20.527	163.2	12.8		15.932
										0.345	
10	137.3	84.9	52.4	102.4	13.609	3.667	20.943	127.3	12.6		16.277
										-1.009	
11	82.4	51.4	31.0	61.7	12.836	3.550	19.936	54.8	11.8		15.268
										0.451	
12	102.0	63.0	39.0	76.0	13.058	3.756	20.569	80.3	12.1		15.719
										0.700	
13	122.2	75.6	46.6	91.1	13.350	4.034	21.418	107.3	12.6		16.419
										0.952	
14	142.0	87.7	54.3	105.8	13.710	4.326	22.362	133.4	13.1		17.371
										1.413	
15	162.3	100.3	62.0	121.0	14.230	4.656	23.543	160.4	13.7		18.784
										1.935	
16	182.3	112.7	69.6	135.9	14.955	4.979	24.912	187.1	14.6		20.719
										3.487	
17	208.8	128.8	80.0	155.5	16.381	5.264	26.908	223.7	16.0		24.206
										5.631	
18	240.6	148.7	91.9	179.3	18.653	5.448	29.550	264.4	18.2		29.836
										7.215	
19	276.9	171.6	105.3	206.7	21.364	5.519	32.391	313.1	20.6		37.051
										6.875	
20	319.6	197.2	122.4	238.0	22.928	6.110	35.148	368.0	22.8		43.926

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 508 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES
INITIAL MOISTURE CONTENT = 60.5 PERCENT
SPECIFIC GRAVITY OF SOIL = 2.72
INITIAL VOID RATIO = 1.645
INITIAL HEIGHT OF SAMPLE = 13.14 CM
INITIAL VOLUME OF SAMPLE = 590.65 CC
EFFECTIVE PRINCIPAL STRESS RATIO = 0.62
FINAL MOISTURE CONTENT = 33.0 PERCENT

TX. CONSOLIDATION START 50383 END 250383
TRIAXIAL CONSOLIDATION TEST
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PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	36.16	22.90	1.257	2.014	0.379	27.32	13.26	1.592	2.592	0.585
2	61.13	38.00	2.292	4.189	0.949	45.71	23.13	1.534	2.534	0.895
3	80.62	49.70	3.074	5.966	1.446	60.01	30.92	1.487	2.487	1.085
4	93.80	57.80	3.720	7.354	1.817	69.80	36.00	1.450	2.450	1.269
5	108.41	67.10	4.699	9.114	2.207	80.87	41.31	1.404	2.404	1.661
6	124.78	77.30	5.963	11.043	2.540	93.13	47.48	1.353	2.353	2.282
7	143.20	88.60	7.584	13.259	2.837	106.80	54.60	1.294	2.294	3.165
8	163.63	100.80	9.270	15.477	3.104	121.74	62.83	1.235	2.235	4.111
9	114.64	70.80	8.955	15.559	3.302	85.41	43.84	1.233	2.233	3.769
10	80.46	49.10	8.521	15.266	3.373	59.55	31.36	1.241	2.241	3.432
11	100.55	68.20	8.659	16.198	3.770	78.98	32.35	1.218	2.218	3.259
12	114.30	82.90	8.799	17.029	4.115	93.37	31.40	1.194	2.194	3.122
13	130.65	100.80	8.931	18.185	4.627	110.75	29.85	1.164	2.164	2.869
14	144.25	115.90	9.057	19.404	5.174	125.35	28.35	1.132	2.132	2.589
15	158.80	131.40	9.190	20.716	5.763	140.53	27.40	1.097	2.097	2.285
16	173.35	147.00	9.353	22.181	6.414	155.78	26.35	1.058	2.058	1.959
17	186.93	162.00	9.518	23.655	7.069	170.31	24.93	1.019	2.019	1.633
18	200.41	177.60	9.686	25.133	7.724	185.20	22.81	0.980	1.980	1.308
19	213.85	192.40	9.863	26.649	8.393	199.55	21.45	0.940	1.940	0.980
20	233.09	213.70	10.148	28.299	9.076	220.16	19.39	0.898	1.898	0.715

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	36.16	22.90	1.257	0.379	2.592
2	61.13	38.00	2.292	0.949	2.534
3	80.62	49.70	3.074	1.446	2.487
4	93.80	57.80	3.720	1.817	2.450
5	108.41	67.10	4.699	2.207	2.404
6	124 78	77.30	5.963	2.540	2.353
7	143.20	88.60	7.584	2.837	2.294
8	163.63	100.80	9.270	3.104	2.235
9	114.64	70.80	8.955	3.302	2.233
10	80.46	49.10	8.521	3.373	2.241
11	100.55	68.20	8.659	3.770	2.218
12	114.30	82.90	8.799	4.115	2.194
13	130.65	100.80	8.931	4.627	2.164
14	144.25	115.90	9.057	5.174	2.132
15	158.80	131.40	9.190	5.763	2.097
16	173.35	147.00	9.353	6.414	2.058
17	186.93	162.00	9.518	7.069	2.019
18	200.41	177.60	9.686	7.724	1.980
19	213.85	192.40	9.863	8.393	1.940
20	233.09	213.70	10.148	9.076	1.898

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 508 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 50383 END 250383

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	36.2	22.9	13.3	27.3	1.257	0.378	2.014	0.0	0.0		0.0
										0.850	
2	61.1	38.0	23.1	45.7	2.292	0.949	4.188	32.9	1.3		0.850
										0.991	
3	80.6	49.7	30.9	60.0	3.074	1.446	5.966	58.4	2.4		1.841
										0.962	
4	93.8	57.8	36.0	69.8	3.720	1.817	7.354	75.9	3.2		2.803
										1.478	
5	108.4	67.1	41.3	80.9	4.699	2.207	9.114	95.5	4.3		4.281
										1.954	
6	124.8	77.3	47.5	93.1	5.963	2.540	11.043	117.4	5.6		6.235
										2.665	
7	143.2	88.6	54.6	106.8	7.584	2.837	13.258	141.7	7.2		8.900
										3.081	
8	163.6	100.8	62.8	121.7	9.270	3.104	15.477	168.5	8.9		11.981
										-0.098	
9	114.6	70.8	43.8	85.4	8.955	3.302	15.559	103.7	8.7		11.883
										-0.339	
10	80.5	49.1	31.4	59.6	8.521	3.373	15.268	57.8	8.4		11.554
										0.591	
11	100.6	68.2	32.4	79.0	8.658	3.770	16.198	90.8	8.8		12.145
										0.672	
12	114.3	82.9	31.4	93.4	8.799	4.115	17.029	115.4	9.2		12.817
										1.102	
13	130.6	100.8	29.8	110.8	8.931	4.627	18.185	145.1	9.7		13.920
										1.357	
14	144.2	115.8	28.4	125.3	9.057	5.174	19.404	170.2	10.3		15.276
										1.659	
15	158.8	131.4	27.4	140.5	9.150	5.783	20.716	198.4	11.0		16.935
										2.084	
16	173.4	147.0	26.4	155.8	9.353	6.414	22.181	222.8	11.8		19.019
										2.320	
17	186.9	162.0	24.9	170.3	9.518	7.069	23.656	247.8	12.6		21.339
										2.549	
18	200.4	177.6	22.8	185.2	9.685	7.724	25.133	273.6	13.4		23.888
										2.845	
19	213.9	192.4	21.5	199.6	9.863	8.393	26.649	298.4	14.2		26.733
										3.408	
20	233.1	213.7	19.4	220.2	10.146	9.076	28.298	334.1	15.2		30.141

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 508 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 50383 END 250383

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	36.2	22.9	13.3	27.3	1.265	0.385	2.034	0.0	0.0		0.0
										0.875	
2	61.1	38.0	23.1	45.7	2.318	0.980	4.279	32.9	1.3		0.875
										1.038	
3	80.6	49.7	30.9	60.0	3.122	1.514	6.151	58.4	2.4		1.913
										1.023	
4	93.8	57.8	36.0	69.8	3.791	1.924	7.638	75.9	3.3		2.936
										1.593	
5	108.4	67.1	41.3	80.9	4.813	2.372	9.558	95.5	4.5		4.529
										2.142	
6	124.8	77.3	47.5	93.1	6.149	2.776	11.702	117.4	5.9		6.671
										2.979	
7	143.2	88.6	54.6	106.8	7.887	3.168	14.223	141.7	7.7		9.650
										3.535	
8	163.6	100.8	62.8	121.7	9.728	3.543	16.814	168.5	9.6		13.185
										-0.102	
9	114.6	70.8	43.8	85.4	9.381	3.765	16.911	103.7	9.4		13.083
										-0.385	
10	80.5	49.1	31.4	59.6	8.908	3.828	16.564	57.8	9.1		12.698
										0.697	
11	100.6	68.2	32.4	79.0	9.056	4.307	17.671	90.8	9.8		13.393
										0.802	
12	114.3	82.9	31.4	93.4	9.210	4.729	18.668	115.4	10.0		14.195
										1.333	
13	130.6	100.8	29.8	110.8	9.355	5.358	20.071	145.1	10.7		15.528
										1.666	
14	144.2	115.8	28.4	125.3	9.493	6.039	21.571	170.2	11.5		17.194
										2.070	
15	158.8	131.4	27.4	140.5	9.640	6.786	23.212	198.4	12.3		19.264
										2.646	
16	173.4	147.0	26.4	155.8	9.819	7.628	25.078	222.8	13.3		21.910
										3.001	
17	186.9	162.0	24.9	170.3	10.002	8.494	26.990	247.8	14.4		24.911
										3.362	
18	200.4	177.6	22.8	185.2	10.187	9.379	28.944	273.6	15.5		28.273
										3.829	
19	213.9	192.4	21.5	199.6	10.384	10.304	30.991	298.4	16.7		32.102
										4.684	
20	233.1	213.7	19.4	220.2	10.700	11.283	33.266	334.1	18.1		36.787

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SAMPLE NO. : T 509   HOLE NO. : 0   DEPTH : 0.0 METRES TO 0.0 METRES
INITIAL MOISTURE CONTENT : 64.5 PERCENT
SPECIFIC GRAVITY OF SOIL : 2.72
INITIAL VOID RATIO : 1.755
INITIAL HEIGHT OF SAMPLE : 13.34 CM
INITIAL VOLUME OF SAMPLE : 600.06 CC
EFFECTIVE PRINCIPAL STRESS RATIO : 0.45
FINAL MOISTURE CONTENT : 49.6 PERCENT

TX. CONSOLIDATION   START 170383   END 10483
TRIAXIAL CONSOLIDATION TEST
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PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	41.13	25.90	0.966	1.750	0.392	30.98	15.23	1.707	2.707	0.383
2	53.93	33.50	1.890	2.946	0.528	40.31	20.43	1.674	2.674	0.908
3	66.57	41.00	3.012	3.999	0.494	49.52	25.57	1.645	2.645	1.679
4	80.47	49.70	3.840	5.339	0.749	59.96	30.77	1.608	2.608	2.061
5	92.80	56.80	4.761	6.657	0.948	68.80	36.00	1.572	2.572	2.542
6	108.02	66.80	5.956	8.262	1.153	80.54	41.22	1.527	2.527	3.202
7	123.45	76.10	7.370	9.945	1.288	91.88	47.35	1.481	2.481	4.055
8	143.87	89.60	9.126	11.957	1.415	107.69	54.27	1.426	2.426	5.140
9	164.67	102.20	10.894	13.873	1.489	123.02	62.47	1.373	2.373	6.270
10	82.52	51.50	10.068	12.990	1.461	61.84	31.02	1.397	2.397	5.738
11	97.15	56.10	10.199	13.175	1.488	69.78	41.05	1.392	2.392	5.807
12	107.54	57.40	10.374	13.423	1.525	74.11	50.14	1.385	2.385	5.900
13	121.00	61.00	10.645	13.728	1.541	81.00	60.00	1.377	2.377	6 070
14	133.50	63.60	11.104	14.098	1.497	86.90	69.90	1.367	2.367	6.405
15	144.30	65.90	12.212	14.590	1.189	92.03	78.40	1.353	2.353	7.349
16	153.53	69.70	16.330	14.726	-0.802	97.64	83.83	1.349	2.349	11.421

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	41.13	25.90	0.966	0.392	2.707
2	53.93	33.50	1.890	0.528	2.674
3	66.57	41.00	3.012	0.494	2.645
4	80.47	49.70	3.840	0.749	2.608
5	92.80	56.80	4.761	0.948	2.572
6	108.02	66.80	5.956	1.153	2.527
7	123.45	76.10	7.370	1.288	2.481
8	143.87	89.60	9.126	1.415	2.426
9	164.67	102.20	10.894	1.489	2.373
10	82.52	51.50	10.068	1.461	2.397
11	97.15	56.10	10.199	1.488	2.392
12	107.54	57.40	10.374	1.525	2.385
13	121.00	61.00	10.645	1.541	2.377
14	133.50	63.60	11.104	1.497	2.367
15	144.30	65.90	12.212	1.189	2.353
16	153.53	69.70	16.330	-0.802	2.349

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 609 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 170383 END 10483

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	41.1	25.9	15.2	31.0	0.966	0.392	1.750	0.0	0.0		0.0
2	53.9	33.5	20.4	40.3	1.890	0.528	2.946	16.7	0.9	0.520	0.520
3	66.6	41.0	25.6	49.5	3.012	0.494	3.999	33.2	2.1	0.650	1.170
4	80.5	49.7	30.8	60.0	3.840	0.749	5.339	51.8	2.9	0.841	2.011
5	92.6	56.6	36.0	68.6	4.761	0.948	6.657	67.3	3.9	1.008	3.019
6	108.0	66.8	41.2	80.5	5.956	1.153	8.262	88.4	5.1	1.452	4.471
7	123.4	76.1	47.3	91.9	7.370	1.288	9.945	108.7	6.5	1.829	6.300
8	143.9	89.6	54.3	107.7	9.126	1.415	11.957	136.6	8.3	2.558	8.858
9	164.7	102.2	62.5	123.0	10.894	1.489	13.873	164.0	10.0	2.870	11.728
10	82.5	51.5	31.0	61.8	10.068	1.461	12.990	55.0	9.2	-1.065	10.663
11	97.1	56.1	41.0	69.8	10.199	1.488	13.175	70.4	9.4	0.147	10.810
12	107.5	57.4	50.1	74.1	10.374	1.525	13.423	80.0	9.5	0.221	11.031
13	121.0	61.0	60.0	81.0	10.645	1.541	13.726	94.0	9.8	0.329	11.360
14	133.5	63.6	69.9	86.9	11.104	1.497	14.098	106.7	10.3	0.529	11.889
15	144.3	65.9	78.4	92.0	12.212	1.189	14.590	117.7	11.3	1.140	13.029
16	153.5	69.7	83.8	97.6	16.330	-0.802	14.726	128.3	15.5	3.433	16.462

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 609 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 170383 END 10483

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	41.1	25.9	15.2	31.0	0.971	0.397	1.765	0.0	0.0		0.0
2	53.9	33.5	20.4	40.3	1.908	0.541	2.990	16.7	1.0	0.531	0.531
3	66.6	41.0	25.6	49.5	3.058	0.512	4.082	33.2	2.1	0.671	1.202
4	80.5	49.7	30.8	60.0	3.916	0.786	5.487	51.8	3.0	0.879	2.081
5	92.6	56.6	36.0	68.6	4.878	1.006	6.889	67.3	4.0	1.066	3.147
6	108.0	66.8	41.2	80.5	6.140	1.241	8.623	88.4	5.3	1.557	4.705
7	123.4	76.1	47.3	91.9	7.656	1.410	10.475	108.7	6.8	1.994	6.699
8	143.9	89.6	54.3	107.7	9.569	1.582	12.734	136.6	8.8	2.844	9.543
9	164.7	102.2	62.5	123.0	11.534	1.700	14.934	164.0	10.7	3.257	12.800
10	82.5	51.5	31.0	61.8	10.612	1.651	13.914	55.0	9.8	-1.215	11.585
11	97.1	56.1	41.0	69.8	10.757	1.686	14.127	70.4	10.0	0.167	11.751
12	107.5	57.4	50.1	74.1	10.952	1.731	14.413	80.0	10.2	0.252	12.003
13	121.0	61.0	60.0	81.0	11.258	1.764	14.784	94.0	10.5	0.375	12.378
14	133.5	63.6	69.9	86.9	11.770	1.713	15.196	106.7	11.0	0.603	12.981
15	144.3	65.9	78.4	92.0	13.024	1.373	15.770	117.7	12.1	1.302	14.283
16	153.5	69.7	83.8	97.6	17.828	-0.949	15.930	128.3	17.0	4.005	18.287

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 610 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES
INITIAL MOISTURE CONTENT = 59.3 PERCENT
SPECIFIC GRAVITY OF SOIL = 2.72
INITIAL VOID RATIO = 1.612
INITIAL HEIGHT OF SAMPLE = 13.35 CM
INITIAL VOLUME OF SAMPLE = 600.53 CC
EFFECTIVE PRINCIPAL STRESS RATIO = 0.63
FINAL MOISTURE CONTENT = 47.3 PERCENT

TX. CONSOLIDATION START 290383 END 90483
TRIAXIAL CONSOLIDATION TEST
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PT	EFFECT SIGMA1	EFFECT SIGMA3	STRAIN1	VOLUME STRAIN	STRAIN3	EFFECT P	Q	VOID RATIO	V	SHEAR STRAIN
1	26.88	16.60	0.596	1.307	0.356	20.03	10.28	1.578	2.578	0.160
2	40.06	24.60	1.170	2.491	0.661	29.75	15.46	1.547	2.547	0.340
3	53.40	32.60	1.700	3.475	0.887	39.53	20.80	1.521	2.521	0.542
4	67.85	42.30	2.271	4.493	1.111	50.82	25.55	1.495	2.495	0.774
5	80.24	49.50	2.897	5.520	1.311	59.75	30.74	1.468	2.468	1.057
6	93.80	58.00	3.738	6.707	1.485	69.93	35.80	1.437	2.437	1.502
7	107.83	66.70	4.937	8.218	1.640	80.41	41.13	1.397	2.397	2.198
8	123.90	76.70	6.398	9.883	1.742	92.43	47.20	1.354	2.354	3.104
9	142.95	88.70	8.058	11.710	1.826	106.78	54.25	1.306	2.306	4.155
10	164.08	101.70	9.730	13.442	1.856	122.49	62.38	1.261	2.261	5.250
11	82.77	51.80	8.901	12.431	1.765	62.12	30.97	1.287	2.287	4.758

SUMMARY OF ESSENTIAL RESULTS STORED IN FILE

PT	SIGMA1	SIGMA3	STRAIN1	STRAIN3	V
1	26.88	16.60	0.596	0.356	2.578
2	40.06	24.60	1.170	0.661	2.547
3	53.40	32.60	1.700	0.887	2.521
4	67.85	42.30	2.271	1.111	2.495
5	80.24	49.50	2.897	1.311	2.468
6	93.80	58.00	3.738	1.485	2.437
7	107.83	66.70	4.937	1.640	2.397
8	123.90	76.70	6.398	1.742	2.354
9	142.95	88.70	8.058	1.826	2.306
10	164.08	101.70	9.730	1.856	2.261
11	82.77	51.80	8.901	1.765	2.287

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** ENGINEERING STRAIN ****

SAMPLE NO. = T 510 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 290383 END 90483

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	26.9	16.6	10.3	20.0	0.586	0.358	1.307	0.0	0.0		0.0
										0.318	
2	40.1	24.6	15.5	29.8	1.170	0.661	2.491	17.4	0.7		0.318
										0.378	
3	53.4	32.6	20.8	39.5	1.700	0.887	3.475	34.9	1.3		0.695
										0.513	
4	67.9	42.3	25.6	50.8	2.271	1.111	4.493	54.8	2.0		1.209
										0.648	
5	80.2	49.5	30.7	59.7	2.897	1.311	5.520	70.8	2.7		1.857
										0.918	
6	93.8	58.0	35.8	69.9	3.738	1.485	6.707	88.9	3.5		2.774
										1.403	
7	107.8	66.7	41.1	80.4	4.937	1.640	8.218	107.6	4.7		4.177
										1.839	
8	123.9	76.7	47.2	92.4	6.398	1.742	9.883	129.0	6.1		6.017
										2.353	
9	142.9	88.7	54.3	106.8	8.058	1.826	11.710	154.5	7.7		8.389
										2.624	
10	164.1	101.7	62.4	122.5	9.730	1.858	13.442	182.5	9.4		10.983
										-1.163	
11	82.8	51.8	31.0	62.1	8.901	1.765	12.431	74.8	8.5		9.830

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

ENERGY CALCULATIONS

**** NATURAL STRAIN ****

SAMPLE NO. = T 510 HOLE NO. = 0 DEPTH = 0.0 METRES TO 0.0 METRES

TEST RESULTS START 290383 END 90483

PT	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	AXIAL STRAIN %	RADIAL STRAIN %	VOL STRAIN %	LSSV KPA	LSNV %	DELTA ENERGY KN-M/VOL	TOTAL ENERGY KN-M/VOL
1	26.9	16.6	10.3	20.0	0.587	0.359	1.316	0.0	0.0		0.0
										0.323	
2	40.1	24.6	15.5	29.8	1.177	0.673	2.523	17.4	0.7		0.323
										0.388	
3	53.4	32.6	20.8	39.5	1.715	0.911	3.537	34.9	1.4		0.711
										0.532	
4	67.9	42.3	25.6	50.8	2.297	1.150	4.587	54.8	2.0		1.243
										0.677	
5	80.2	49.5	30.7	59.7	2.940	1.369	5.678	70.8	2.7		1.920
										0.969	
6	93.8	58.0	35.8	69.9	3.809	1.567	6.943	88.9	3.6		2.889
										1.500	
7	107.8	66.7	41.1	80.4	5.063	1.756	8.575	107.6	4.8		4.389
										1.997	
8	123.9	76.7	47.2	92.4	6.612	1.897	10.406	129.0	6.4		6.386
										2.601	
9	142.9	88.7	54.3	106.8	8.402	2.026	12.454	154.5	8.2		8.987
										2.856	
10	164.1	101.7	62.4	122.5	10.237	2.099	14.435	182.5	9.9		11.843
										-1.318	
11	82.8	51.8	31.0	62.1	9.322	1.878	13.274	74.8	9.0		10.525

UNDRAINED SHEAR TESTS

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 501 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION = 11.386 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION = 485.990 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION = 43.560 SQUARE CENTIMETRES

CONSTANT LOAD = 14.30 N .
PROVING RING FACTOR = 1.2350 N ./DIV
PISTON AREA = 5.1100 SQUARE CENTIMETRES

INITIAL DIAL READING = 1500.00 DIVISIONS

SHEAR TEST RESULTS START 221282 END 231282

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	940	1500.0	342.0	149.5	0.00	190.2	121.5	34.3	68.7	144.4	1.565	UUUUUUU
2	945	1499.8	359.0	150.9	0.00	193.4	119.9	36.8	73.5	144.4	1.613	0.29
3	950	1498.6	372.5	153.0	0.01	195.2	117.8	38.7	77.4	143.6	1.657	0.40
4	955	1497.3	385.2	154.9	0.02	197.1	116.2	40.5	80.9	143.2	1.697	0.44
5	1000	1496.0	398.2	156.7	0.04	198.9	114.3	42.3	84.6	142.5	1.740	0.45
6	1005	1494.5	410.5	158.2	0.05	200.8	112.7	44.1	88.1	142.1	1.782	0.45
7	1010	1492.5	421.2	159.8	0.07	202.2	111.0	45.6	91.2	141.4	1.821	0.46
8	1015	1490.5	431.8	161.1	0.08	203.8	109.6	47.1	94.2	141.0	1.859	0.46
9	1020	1488.2	441.8	162.7	0.10	205.1	108.2	48.5	96.9	140.5	1.896	0.47
10	1025	1486.0	451.0	163.9	0.12	206.6	107.0	49.8	99.6	140.2	1.930	0.47
11	1030	1483.3	459.5	164.8	0.15	208.0	106.1	51.0	101.9	140.1	1.961	0.46
12	1035	1480.2	466.5	165.9	0.17	208.7	104.8	52.0	103.9	139.4	1.992	0.47
13	1040	1477.5	473.0	166.7	0.20	209.7	104.0	52.9	105.7	139.2	2.017	0.48
14	1045	1474.2	478.5	167.8	0.23	210.4	103.1	53.6	107.3	138.9	2.040	0.47
15	1050	1470.5	483.0	168.5	0.26	210.9	102.4	54.2	108.5	138.6	2.060	0.48
16	1100	1466.0	488.9	168.9	0.30	212.3	101.9	55.2	110.4	138.7	2.084	0.46
21	1140	1459.0	483.0	172.3	0.36	207.0	98.6	54.2	108.4	134.7	2.099	0.57
22	1150	1445.5	502.0	173.3	0.48	211.0	97.3	56.8	113.7	135.2	2.168	0.53
23	1200	1434.5	514.0	175.0	0.58	212.7	95.8	58.5	116.9	134.8	2.220	0.53
24	1210	1423.5	514.5	175.6	0.67	212.0	95.0	58.5	117.0	134.0	2.231	0.54
25	1220	1397.0	512.5	176.1	0.90	210.9	94.8	58.0	116.1	133.5	2.225	0.56
26	1242	1368.0	511.5	177.9	1.16	208.4	92.9	57.8	115.5	131.4	2.244	0.61
27	1307	1331.0	511.3	180.2	1.46	205.7	90.6	57.5	115.1	129.0	2.270	0.66
28	1325	1288.0	508.0	180.8	1.86	203.6	89.8	56.9	113.8	127.7	2.267	0.69
29	1352	1246.0	506.2	183.6	2.24	199.9	87.1	56.4	112.8	124.7	2.295	0.77
30	1424	1208.0	507.5	186.0	2.56	197.3	84.5	56.4	112.8	122.1	2.335	0.83
31	1450	1156.5	504.5	188.6	3.02	193.3	81.8	55.7	111.5	119.0	2.363	0.91
101	1455	1147.5	505.0	RELAXATION TEST								
102	1457	1146.7	502.0	RELAXATION TEST								
103	1458	1140.5	497 8	RELAXATION TEST								
104	1500	1132 7	492.8	RELAXATION TEST								
105	1504	1164.2	488.1	RELAXATION TEST								
106	1511	1163.2	480.0	RELAXATION TEST								
107	1517	1123.5	474.2	RELAXATION TEST								
108	1526	1127.0	469.0	RELAXATION TEST								
109	1552	1123.0	462.3	RELAXATION TEST								
110	1556	1123.1	453.5	RELAXATION TEST								
111	830	1106.2	429.1	RELAXATION TEST								
112	833	1110.7	428.0	RELAXATION TEST								
32	835	1110.7	428.0	194.8	3.42	165.9	75.9	45.0	90.0	105.9	2.186	2.13
33	836	1110.9	433.0	194.9	3.42	167.1	75.7	45.7	91.4	106.2	2.207	2.00
34	837	1110.8	439.5	194.9	3.42	168.9	75.7	46.6	93.2	106.8	2.231	1.86
35	838	1110.8	445.0	195.0	3.42	170.2	75.5	47.3	94.7	107.1	2.254	1.75
36	840	1109.0	448.0	197.7	3.43	168.6	72.9	47.9	95.7	104.8	2.313	1.78
37	843	1108.5	462.5	199.1	3.44	171.1	71.7	49.7	99.4	104.8	2.387	1.61
38	845	1107.5	470.0	200.1	3.45	172.1	70.6	50.7	101.5	104.4	2.437	1.54
39	847	1106.8	477.5	200.2	3.45	174.0	70.5	51.8	103.5	105.0	2.468	1.48
40	851	1100.2	489.0	201.3	3.51	176.0	69.4	53.3	106.6	104.9	2.536	1.37
41	853	1100.1	494.8	201.7	3.51	177.1	68.9	54.1	108.2	105.0	2.571	1.32
42	855	1097.5	499.1	202.0	3.54	178.0	68.6	54.7	109.4	105.1	2.594	1.29
43	857	1096.0	504.3	202.4	3.56	179.0	68.2	55.4	110.8	105.1	2.624	1.26
44	859	1088.0	510.2	202.4	3.62	180.5	68.2	56.2	112.3	105.6	2.647	1.21
45	901	1082.1	511.2	202.4	3.67	180.7	68.2	56.3	112.5	105.7	2.650	1.21
46	903	1079.8	513.0	202.6	3.69	180.9	67.9	56.5	113.0	105.6	2.664	1.20
47	905	1077.5	514.1	202.7	3.71	181.2	67.9	56.6	113.3	105.7	2.668	1.19
48	907	1073.8	515.0	202.9	3.74	181.2	67.7	56.7	113.5	105.5	2.676	1.18
49	909	1064.0	516.8	202.4	3.83	182.0	68.4	56.8	113.6	106.3	2.661	1.16
50	914	1053.2	520.1	202.5	3.92	182.9	68.2	57.3	114.7	106.4	2.681	1.15
51	920	1046.5	525.0	202.0	3.98	184.6	68.7	58.0	115.9	107.3	2.687	1.11
52	925	1036.5	525.5	201.4	4.07	185.2	69.2	58.0	116.0	107.9	2.676	1.10
53	930	1029.4	525.5	201.2	4.13	185.3	69.4	57.9	115.9	108.0	2.670	1.10
54	939	1011.0	525.0	200.5	4.29	185.9	70.4	57.8	115.5	108.9	2.641	1.09
55	955	988.2	524.5	200.0	4.48	185.8	70.6	57.6	115.2	109.0	2.631	1.09
56	1031	935.3	523.1	199.9	4.96	185.2	71.0	57.1	114.2	109.1	2.608	1.11
57	1124	940.6	515.2	200.0	4.91	182.9	70.7	56.1	112.2	108.1	2.586	1.16
58	1222	878.0	512.6	200.7	5.46	180.8	70.0	55.4	110.8	106.9	2.583	1.22
59	1314	667.0	503.0	200.9	7.32	175.8	69.7	53.1	106.1	105.1	2.522	1.37
60	1501	495.0	498.0	202.7	8.83	171.3	68.2	51.6	103.1	102.6	2.511	1.55
61	1555	409.3	482.5	203.5	9.58	165.6	67.4	49.1	98.2	100.1	2.457	1.83
62	1631	346.0	476.8	204.3	10.14	162.7	66.5	48.1	96.2	98.6	2.446	1.99

SAMPLE NO. : T 501 HOLE NO. : -1 DEPTH : 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS : 212.30 KPA
PRECONSOLIDATION PRESSURE : 80.00 KPA
NORMALIZING STRESS : 212.30 KPA

NORMALIZED SHEAR TEST RESULTS START 221282 END 231282

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.162	1.565	0.680	0.000
2	0.00	0.173	1.613	0.680	0.007
3	0.01	0.182	1.657	0.678	0.016
4	0.02	0.191	1.697	0.674	0.025
5	0.04	0.199	1.740	0.671	0.034
6	0.05	0.208	1.782	0.669	0.041
7	0.07	0.215	1.821	0.666	0.049
8	0.08	0.222	1.859	0.664	0.055
9	0.10	0.228	1.896	0.662	0.062
10	0.12	0.234	1.930	0.660	0.068
11	0.15	0.240	1.961	0.660	0.072
12	0.17	0.245	1.992	0.657	0.077
13	0.20	0.249	2.017	0.656	0.081
14	0.23	0.253	2.040	0.654	0.086
15	0.26	0.256	2.060	0.653	0.089
16	0.30	0.260	2.084	0.653	0.091
21	0.36	0.265	2.099	0.635	0.107
22	0.46	0.268	2.168	0.637	0.112
23	0.58	0.275	2.220	0.635	0.120
24	0.67	0.275	2.231	0.631	0.123
25	0.90	0.273	2.225	0.629	0.125
26	1.16	0.272	2.244	0.619	0.134
27	1.46	0.271	2.270	0.607	0.145
28	1.86	0.268	2.267	0.602	0.147
29	2.24	0.266	2.295	0.587	0.161
30	2.56	0.266	2.335	0.575	0.172
31	3.02	0.263	2.363	0.560	0.184
32	3.42	0.212	2.186	0.499	0.213
33	3.42	0.215	2.207	0.500	0.214
34	3.42	0.219	2.231	0.503	0.214
35	3.42	0.223	2.254	0.504	0.214
36	3.43	0.225	2.313	0.494	0.227
37	3.44	0.234	2.387	0.494	0.234
38	3.45	0.239	2.437	0.492	0.238
39	3.46	0.244	2.489	0.495	0.239
40	3.51	0.251	2.536	0.494	0.244
41	3.51	0.255	2.571	0.494	0.246
42	3.54	0.258	2.594	0.495	0.247
43	3.55	0.261	2.624	0.495	0.249
44	3.62	0.265	2.647	0.498	0.249
45	3.67	0.265	2.650	0.498	0.249
46	3.69	0.266	2.664	0.497	0.250
47	3.71	0.267	2.668	0.498	0.251
48	3.74	0.267	2.679	0.497	0.252
49	3.83	0.268	2.661	0.501	0.249
50	3.92	0.270	2.681	0.501	0.250
51	3.98	0.273	2.687	0.505	0.247
52	4.07	0.273	2.678	0.508	0.244
53	4.13	0.273	2.670	0.509	0.244
54	4.29	0.272	2.641	0.513	0.240
55	4.49	0.271	2.631	0.513	0.238
56	4.66	0.269	2.609	0.514	0.237
57	4.91	0.264	2.586	0.509	0.238
58	5.46	0.261	2.583	0.504	0.241
59	7.32	0.250	2.522	0.495	0.242
60	8.83	0.243	2.511	0.483	0.251
61	9.58	0.231	2.457	0.472	0.254
62	10.14	0.227	2.446	0.484	0.258

UNIVERSITY OF MANITOBA
SOIL MECHANICS LABORATORY

SAMPLE NO. = T 502 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION = 9.610 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION = 428.350 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION = 44.570 SQUARE CENTIMETRES

CONSTANT LOAD = 14.87 N .
PROVING RING FACTOR = 1.2370 N ./DIV
PISTON AREA = 5.0700 SQUARE CENTIMETRES

INITIAL DIAL READING = 1958.50 DIVISIONS

SHEAR TEST RESULTS START 290183 END 300183

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	847	1958.5	552.0	126.0	0.00	313.4	193.2	60.1	120.2	233.3	1.622	UUUUUUU
2	852	1958.1	588.0	132.9	0.00	316.4	186.2	65.1	130.2	229.6	1.699	0.59
3	857	1955.5	619.0	138.5	0.03	319.5	180.7	69.4	138.8	227.0	1.768	0.67
4	902	1952.3	647.0	143.2	0.06	322.5	176.0	73.3	146.5	224.8	1.832	0.65
5	907	1948.7	674.0	147.5	0.10	325.5	171.6	77.0	153.9	222.9	1.897	0.64
6	912	1943.0	697.0	150.8	0.16	328.5	168.3	80.1	160.2	221.7	1.952	0.62
7	917	1939.7	715.0	153.7	0.20	330.6	165.4	82.6	165.2	220.5	1.999	0.62
8	922	1932.1	729.0	155.8	0.27	332.2	163.3	84.4	168.9	219.6	2.034	0.61
9	927	1924.5	739.0	157.3	0.35	333.3	161.8	85.8	171.5	219.0	2.060	0.61
10	932	1915.9	746.0	158.5	0.44	334.0	160.7	86.6	173.3	218.5	2.078	0.61
11	937	1906.1	748.0	159.2	0.55	333.7	160.0	86.8	173.7	217.9	2.086	0.62
12	942	1897.0	750.0	160.0	0.64	333.3	159.2	87.0	174.1	217.2	2.093	0.63
13	947	1885.5	749.5	160.7	0.76	332.2	158.5	86.9	173.7	216.4	2.096	0.65
14	952	1875.3	747.8	161.2	0.87	331.1	158.0	86.5	173.1	215.7	2.095	0.67
15	957	1864.2	747.0	162.1	0.98	329.8	157.2	86.3	172.6	214.7	2.098	0.69
16	1002	1854.1	745.2	162.2	1.09	329.0	157.1	86.0	171.9	214.4	2.095	0.70
17	1034	1784.7	735.0	167.9	1.81	319.2	151.3	84.0	167.9	207.3	2.110	0.88
18	1100	1728.6	730.0	172.6	2.39	312.2	146.6	82.8	165.6	201.8	2.129	1.03
19	1133	1657.5	725.2	178.2	3.13	304.0	141.0	81.5	163.0	195.3	2.156	1.22
20	1200	1601.7	723.0	182.2	3.71	298.5	137.0	80.7	161.5	190.8	2.179	1.36
21	1233	1530.0	719.6	186.7	4.46	291.8	132.4	79.7	159.4	185.5	2.204	1.55
22	1300	1472.5	717.5	190.0	5.06	286.9	129.1	78.9	157.8	181.7	2.222	1.70
23	1333	1403.9	714.3	193.6	5.77	281.2	125.5	77.9	155.7	177.4	2.241	1.90
24	1403	1341.5	710.1	196.2	6.42	276.5	122.9	76.8	153.6	174.1	2.250	2.10
25	1533	1148.5	686.5	201.1	8.43	262.3	118.0	72.1	144.3	166.1	2.223	3.12
26	1603	1085.4	679.8	202.1	9.09	258.6	117.0	70.8	141.6	164.2	2.210	3.57
27	1705	947.0	665.0	204.6	10.53	250.2	114.6	67.8	135.6	159.8	2.184	5.10
28	1725	905.0	658.8	205.1	10.96	247.5	114.1	66.7	133.4	158.6	2.169	5.99

SAMPLE NO. = T 502   HOLE NO. = -1   DEPTH = 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS = 319.37 KPA
PRECONSOLIDATION PRESSURE = 80.00 KPA
NORMALIZING STRESS = 319.37 KPA

NORMALIZED SHEAR TEST RESULTS   START 290183   END 300183

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.188	1.622	0.730	0.000
2	0.00	0.204	1.699	0.719	0.022
3	0.03	0.217	1.768	0.711	0.039
4	0.06	0.229	1.832	0.704	0.054
5	0.10	0.241	1.897	0.698	0.067
6	0.16	0.251	1.952	0.694	0.078
7	0.20	0.259	1.999	0.690	0.087
8	0.27	0.264	2.034	0.688	0.093
9	0.35	0.269	2.060	0.686	0.098
10	0.44	0.271	2.078	0.684	0.102
11	0.55	0.272	2.085	0.682	0.104
12	0.64	0.273	2.093	0.680	0.106
13	0.76	0.272	2.098	0.678	0.109
14	0.87	0.271	2.095	0.675	0.110
15	0.98	0.270	2.098	0.672	0.113
16	1.09	0.269	2.095	0.671	0.113
17	1.61	0.263	2.110	0.649	0.131
18	2.39	0.259	2.129	0.632	0.146
19	3.13	0.255	2.156	0.612	0.163
20	3.71	0.253	2.179	0.597	0.176
21	4.46	0.250	2.204	0.581	0.190
22	5.06	0.247	2.222	0.569	0.200
23	5.77	0.244	2.241	0.558	0.212
24	6.42	0.240	2.250	0.545	0.220
25	8.43	0.226	2.223	0.520	0.235
26	9.09	0.222	2.210	0.514	0.238
27	10.53	0.212	2.184	0.500	0.246
28	10.96	0.209	2.169	0.497	0.248

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SAMPLE NO. = T 503 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION = 11.571 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION = 506.800 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION = 43.797 SQUARE CENTIMETRES

CONSTANT LOAD = 14.90 N .
PROVING RING FACTOR = 1.2370 N ./DIV
PISTON AREA = 5.0870 SQUARE CENTIMETRES

INITIAL DIAL READING = 1883.80 DIVISIONS

SHEAR TEST RESULTS START 90283 END 110283

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	935	1883.8	207.5	209.6	0.00	82.4	50.6	15.9	31.8	61.2	1.628	UUUUUUU
2	940	1880.2	215.0	212.3	0.03	81.8	47.9	16.9	33.9	59.2	1.708	1.28
3	945	1878.0	236.5	216.5	0.05	83.7	43.7	20.0	40.0	57.0	1.914	0.84
4	950	1875.0	254.2	219.5	0.08	85.6	40.7	22.5	44.9	55.7	2.104	0.75
5	955	1871.9	270.5	220.1	0.10	89.6	40.1	24.8	49.5	56.6	2.235	0.59
6	1000	1867.5	285.2	221.6	0.14	92.3	38.6	26.8	53.7	56.5	2.390	0.55
7	1005	1863.6	298.0	222.6	0.17	94.8	37.6	28.6	57.2	56.7	2.523	0.51
8	1010	1858.5	309.3	223.6	0.22	97.0	36.6	30.2	60.4	56.7	2.650	0.49
9	1015	1853.8	319.0	224.6	0.26	98.7	35.6	31.6	63.1	56.6	2.773	0.48
10	1020	1847.5	328.5	224.8	0.31	101.2	35.4	32.9	65.8	57.3	2.857	0.45
11	1025	1842.0	335.0	225.0	0.36	102.8	35.2	33.8	67.6	57.7	2.919	0.43
12	1030	1835.6	340.5	225.6	0.42	103.7	34.6	34.5	69.1	57.6	2.998	0.43
13	1035	1829.8	345.9	225.8	0.47	104.9	34.4	35.3	70.5	57.9	3.051	0.42
14	1040	1823.0	350.2	225.7	0.53	106.2	34.5	35.9	71.7	58.4	3.079	0.40
15	1045	1816.5	354.2	225.6	0.58	107.4	34.6	36.4	72.8	58.9	3.104	0.39
16	1050	1809.7	357.2	225.4	0.64	108.3	34.7	36.8	73.6	59.2	3.121	0.38
17	1055	1802.1	360.0	225.0	0.71	109.4	35.1	37.2	74.3	59.9	3.118	0.36
18	1100	1794.8	361.8	224.9	0.77	110.0	35.2	37.4	74.8	60.1	3.125	0.36
19	1105	1787.2	363.5	224.5	0.83	110.8	35.6	37.6	75.2	60.7	3.113	0.35
20	1110	1780.4	364.9	224.2	0.89	111.6	36.0	37.8	75.6	61.2	3.099	0.33
21	1115	1773.0	365.4	224.0	0.96	111.9	36.2	37.8	75.7	61.4	3.090	0.33
22	1120	1765.5	366.0	223.8	1.02	112.1	36.3	37.9	75.8	61.6	3.088	0.32
23	1125	1757.5	367.0	223.6	1.09	112.5	36.5	38.0	76.0	61.8	3.082	0.32
24	1130	1749.7	367.5	223.4	1.16	112.8	36.7	38.0	76.1	62.1	3.073	0.31
25	1135	1741.0	367.5	223.1	1.23	113.0	37.0	38.0	76.0	62.3	3.055	0.31
26	1140	1734.0	367.5	222.7	1.29	113.3	37.3	38.0	76.0	62.6	3.038	0.30
28	1150	1718.2	366.8	222.0	1.43	113.7	38.0	37.9	75.7	63.2	2.992	0.28
29	1250	1623.0	363.0	220.7	2.25	113.2	39.2	37.0	74.0	63.9	2.888	0.26
31	1450	1431.8	354.8	221.3	3.91	109.0	38.4	35.3	70.6	61.9	2.838	0.30
32	1550	1338.0	349.0	221.1	4.72	106.9	38.5	34.2	68.4	61.3	2.777	0.31
33	1650	1239.5	339.0	221.6	5.57	103.2	38.0	32.6	65.2	59.7	2.715	0.36
34	1900	1228.0	309.3	222.3	5.67	94.6	37.4	28.6	57.2	56.5	2.528	0.50
35	1905	1225.0	323.0	224.0	5.69	96.5	35.7	30.4	60.8	56.0	2.703	0.50
36	1910	1219.7	330.5	225.1	5.74	97.4	34.6	31.4	62.8	55.5	2.814	0.50
37	1915	1213.0	334.8	225.3	5.80	98.3	34.4	31.9	63.9	55.7	2.857	0.49
38	1920	1203.8	336.0	225.0	5.88	98.7	34.6	32.1	64.1	56.0	2.854	0.48
39	1925	1195.9	335.0	225.0	5.94	98.4	34.6	31.9	63.8	55.9	2.845	0.48
40	1930	1188.0	334.8	224.8	6.01	98.5	34.8	31.9	63.7	56.0	2.831	0.48
41	2000	1140.9	328.6	223.4	6.42	98.1	36.2	30.9	61.9	56.8	2.709	0.46
42	2110	1027.7	312.5	223.3	7.40	93.3	36.3	28.5	57.0	55.3	2.569	0.54
43	2200	945.3	303.5	223.4	8.11	90.2	36.0	27.1	54.2	54.1	2.506	0.62
44	2400	751.5	278.5	223.4	9.78	83.1	36.0	23.6	47.1	51.7	2.308	0.90

SAMPLE NO. : T 503 HOLE NO. : -1 DEPTH : 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS : 83.22 KPA
PRECONSOLIDATION PRESSURE : 166.18 KPA
NORMALIZING STRESS : 83.22 KPA

NORMALIZED SHEAR TEST RESULTS START 90283 END 110283

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.191	1.828	0.735	0.000
2	0.03	0.204	1.708	0.711	0.032
3	0.05	0.240	1.914	0.685	0.083
4	0.08	0.270	2.104	0.669	0.119
5	0.10	0.298	2.235	0.660	0.128
6	0.14	0.322	2.390	0.679	0.144
7	0.17	0.344	2.523	0.661	0.158
8	0.22	0.363	2.650	0.662	0.168
9	0.26	0.379	2.773	0.661	0.180
10	0.31	0.395	2.857	0.689	0.183
11	0.36	0.408	2.919	0.694	0.185
12	0.42	0.415	2.996	0.692	0.192
13	0.47	0.424	3.051	0.698	0.195
14	0.53	0.431	3.079	0.702	0.193
15	0.58	0.437	3.104	0.707	0.192
16	0.64	0.442	3.121	0.712	0.190
17	0.71	0.447	3.118	0.720	0.185
18	0.77	0.449	3.125	0.723	0.184
19	0.83	0.452	3.113	0.729	0.179
20	0.89	0.454	3.099	0.735	0.175
21	0.95	0.455	3.090	0.738	0.173
22	1.02	0.455	3.088	0.740	0.171
23	1.09	0.457	3.082	0.743	0.168
24	1.16	0.457	3.073	0.746	0.166
25	1.23	0.457	3.055	0.749	0.162
26	1.29	0.457	3.038	0.753	0.157
28	1.43	0.455	2.992	0.760	0.149
29	2.25	0.445	2.889	0.768	0.133
31	3.91	0.424	2.838	0.744	0.141
32	4.72	0.411	2.777	0.737	0.138
33	5.57	0.391	2.715	0.718	0.144
34	5.67	0.343	2.528	0.678	0.153
35	5.69	0.365	2.703	0.672	0.173
36	5.74	0.377	2.814	0.667	0.186
37	5.80	0.384	2.857	0.669	0.189
38	5.86	0.385	2.854	0.673	0.185
39	5.94	0.384	2.845	0.671	0.185
40	6.01	0.383	2.831	0.673	0.183
41	6.42	0.372	2.709	0.663	0.166
42	7.40	0.342	2.569	0.664	0.165
43	8.11	0.326	2.506	0.650	0.168
44	9.79	0.283	2.306	0.621	0.166

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SAMPLE NO. = T 504 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION = 11.510 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION = 435.350 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION = 37.820 SQUARE CENTIMETRES

CONSTANT LOAD = 9.95 N .
PROVING RING FACTOR = 1.2370 N ./DIV
PISTON AREA = 2.9100 SQUARE CENTIMETRES

INITIAL DIAL READING = 1746.00 DIVISIONS

SHEAR TEST RESULTS START 120283 END 130283

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	1018	1746.0	272.7	209.5	0.00	172.5	104.9	33.8	67.6	127.4	1.645	UUUUUUU
2	1020	1745.0	280.5	210.9	0.01	173.6	103.4	35.1	70.2	126.8	1.679	0.55
3	1025	1742.7	302.0	220.4	0.03	171.1	93.9	38.6	77.2	119.6	1.822	1.14
4	1030	1739.8	320.0	224.9	0.05	172.5	89.4	41.5	83.1	117.1	1.929	1.00
5	1035	1735.6	336.2	228.0	0.09	174.6	86.3	44.2	88.3	115.7	2.024	0.89
6	1040	1731.4	349.0	230.6	0.13	176.2	83.7	46.2	92.5	114.5	2.105	0.85
7	1045	1726.0	358.9	232.5	0.17	177.3	81.8	47.8	95.7	113.5	2.173	0.82
8	1050	1720.0	365.9	234.1	0.23	178.0	80.1	49.0	97.9	112.7	2.222	0.81
9	1055	1713.9	370.1	235.1	0.28	178.5	79.3	49.6	99.2	112.4	2.251	0.81
10	1100	1707.0	373.2	235.5	0.34	179.1	78.9	50.1	100.2	112.3	2.270	0.80
11	1105	1699.8	375.5	236.6	0.40	178.7	77.8	50.4	100.9	111.4	2.296	0.82
12	1110	1692.0	376.9	237.4	0.47	178.3	77.1	50.6	101.2	110.8	2.313	0.83
13	1115	1685.0	377.7	238.2	0.53	177.7	76.3	50.7	101.4	110.1	2.329	0.85
14	1120	1677.2	378.0	238.8	0.60	177.2	75.7	50.7	101.5	109.5	2.340	0.87
15	1125	1669.4	378.3	239.4	0.67	176.6	75.1	50.7	101.5	108.9	2.351	0.88
16	1130	1661.9	378.5	240.0	0.73	176.0	74.5	50.8	101.5	108.3	2.363	0.90
17	1135	1653.4	378.6	240.6	0.80	175.4	74.0	50.7	101.4	107.8	2.371	0.92
18	1140	1645.2	378.6	241.1	0.88	174.9	73.5	50.7	101.4	107.3	2.379	0.94
19	1150	1629.2	378.7	242.2	1.01	173.7	72.4	50.6	101.3	106.2	2.399	0.97
20	1200	1614.0	378.3	243.2	1.15	172.4	71.4	50.5	101.0	105.1	2.414	1.01
21	1352	1437.0	372.3	252.2	2.68	159.8	62.3	48.8	97.5	94.8	2.565	1.43
22	1442	1366.0	370.1	254.7	3.30	156.1	59.9	48.1	96.2	92.0	2.606	1.56
23	1611	1217.5	365.0	259.0	4.59	148.5	55.2	46.7	93.3	86.3	2.691	1.93
24	1753	1057.0	359.2	262.5	5.99	142.1	51.9	45.1	90.2	82.0	2.738	2.35
25	1820	1024.8	318.0	279.4	6.27	112.2	34.9	38.6	77.3	60.7	3.215	7.24
26	1825	1020.0	329.5	280.3	6.31	114.8	34.0	40.4	80.8	60.9	3.376	5.39
27	1830	1013.8	335.0	280.4	6.36	116.3	33.9	41.2	82.4	61.4	3.431	4.80
28	1835	1006.7	337.5	280.2	6.42	117.2	34.1	41.6	83.1	61.8	3.438	4.56
29	1840	999.0	338.7	279.9	6.49	117.8	34.4	41.7	83.4	62.2	3.426	4.45
30	1845	992.0	339.0	279.6	6.55	118.3	34.8	41.7	83.5	62.6	3.399	4.43
31	1850	983.2	339.0	279.1	6.63	118.7	35.3	41.7	83.4	63.1	3.363	4.41
32	1855	976.0	338.5	278.7	6.69	119.0	35.8	41.6	83.2	63.5	3.324	4.45
33	1700	968.0	338.0	278.3	6.76	119.1	36.1	41.5	83.0	63.8	3.299	4.48
34	1731	916.0	333.0	276.5	7.21	119.1	38.0	40.5	81.1	65.0	3.133	4.89
35	1800	872.0	328.8	275.9	7.59	118.2	38.8	39.7	79.4	65.3	3.047	5.63
36	1853	786.0	321.5	275.2	8.34	116.1	39.5	38.3	76.6	65.0	2.939	7.33
37	1956	684.5	314.3	275.1	9.22	113.3	39.6	36.9	73.7	64.2	2.862	10.77
38	2113	570.6	308.0	275.3	10.21	110.5	39.4	35.5	71.1	63.1	2.804	19.13
39	2213	466.8	301.8	275.2	11.11	108.0	39.4	34.3	68.6	62.3	2.740	70.89

SAMPLE NO. = T 504   HOLE NO. = -1   DEPTH = 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS = 173.00 KPA
PRECONSOLIDATION PRESSURE = 80.00 KPA
NORMALIZING STRESS = 173.00 KPA

NORMALIZED SHEAR TEST RESULTS   START 120283   END 130283

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.195	1.645	0.737	0.000
2	0.01	0.203	1.679	0.733	0.008
3	0.03	0.223	1.822	0.692	0.063
4	0.05	0.240	1.929	0.677	0.089
5	0.09	0.255	2.024	0.669	0.107
6	0.13	0.267	2.105	0.662	0.122
7	0.17	0.277	2.173	0.656	0.134
8	0.23	0.283	2.222	0.652	0.142
9	0.28	0.287	2.251	0.650	0.148
10	0.34	0.289	2.270	0.649	0.150
11	0.40	0.291	2.295	0.644	0.157
12	0.47	0.293	2.313	0.641	0.161
13	0.53	0.293	2.329	0.636	0.166
14	0.60	0.293	2.340	0.633	0.169
15	0.67	0.293	2.351	0.630	0.173
16	0.73	0.293	2.363	0.626	0.176
17	0.80	0.293	2.371	0.623	0.180
18	0.88	0.293	2.379	0.620	0.183
19	1.01	0.293	2.399	0.614	0.189
20	1.15	0.292	2.414	0.607	0.195
21	2.68	0.282	2.565	0.548	0.247
22	3.30	0.278	2.606	0.532	0.261
23	4.59	0.270	2.691	0.499	0.288
24	5.99	0.261	2.738	0.474	0.308
25	6.27	0.223	3.215	0.351	0.404
26	6.31	0.233	3.376	0.352	0.409
27	6.36	0.238	3.431	0.355	0.410
28	6.42	0.240	3.438	0.357	0.409
29	6.49	0.241	3.426	0.360	0.407
30	6.55	0.241	3.395	0.362	0.405
31	6.63	0.241	3.383	0.365	0.402
32	6.69	0.240	3.324	0.367	0.400
33	6.78	0.240	3.298	0.369	0.398
34	7.21	0.234	3.133	0.376	0.387
35	7.59	0.230	3.047	0.377	0.384
36	8.34	0.221	2.939	0.376	0.380
37	9.22	0.213	2.862	0.371	0.379
38	10.21	0.205	2.804	0.365	0.380
39	11.11	0.198	2.740	0.360	0.380

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SAMPLE NO. = T 505 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION = 12.514 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION = 395.560 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION = 31.609 SQUARE CENTIMETRES

CONSTANT LOAD = 14.93 N .
PROVING RING FACTOR = 1.2370 N ./DIV
PISTON AREA = 5.1100 SQUARE CENTIMETRES

INITIAL DIAL READING = 1443.00 DIVISIONS

SHEAR TEST RESULTS START 830226 END 830226

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	931	1443.0	164.0	151.0	0.00	247.3	241.9	2.7	5.4	243.7	1.022	UUUUUUU
2	935	1441.2	191.1	168.9	0.01	240.2	224.2	8.0	16.0	229.5	1.071	1.69
3	940	1438.1	222.0	180.8	0.04	240.1	212.0	14.0	28.1	221.4	1.132	1.31
4	945	1435.9	250.0	189.2	0.06	242.8	203.8	19.5	39.0	216.8	1.191	1.14
5	950	1433.0	275.5	196.3	0.08	245.8	196.9	24.5	48.9	213.2	1.249	1.04
6	955	1430.5	298.5	202.3	0.10	248.5	190.5	29.0	58.0	209.8	1.304	0.98
7	1000	1426.3	319.9	207.5	0.13	251.8	185.5	33.1	66.3	207.6	1.357	0.93
8	1005	1420.9	337.0	211.5	0.18	254.4	181.5	36.5	72.9	205.8	1.402	0.90
9	1010	1415.5	352.1	215.7	0.22	256.0	177.2	39.4	78.8	203.5	1.445	0.88
10	1015	1410.0	366.2	219.7	0.26	257.6	173.3	42.1	84.3	201.4	1.486	0.87
11	1020	1403.0	378.0	222.6	0.32	259.1	170.2	44.4	88.9	199.8	1.522	0.86
13	1030	1390.1	397.3	228.7	0.42	260.6	164.3	48.1	96.3	196.4	1.585	0.86
14	1035	1383.2	405.5	231.0	0.48	261.2	161.8	49.7	99.4	194.9	1.615	0.85
15	1040	1375.3	413.0	233.4	0.54	261.9	159.6	51.1	102.3	193.7	1.641	0.85
16	1045	1369.2	419.1	235.2	0.59	262.0	157.4	52.3	104.6	192.3	1.665	0.85
17	1050	1357.6	424.5	237.7	0.68	261.8	155.2	53.3	106.6	190.7	1.687	0.86
18	1055	1348.8	430.0	240.0	0.75	261.6	153.0	54.3	108.6	189.2	1.710	0.86
19	1100	1339.8	434.1	241.6	0.82	261.4	151.2	55.1	110.2	187.9	1.729	0.86
20	1105	1331.0	438.0	243.7	0.89	260.7	149.1	55.8	111.6	186.3	1.749	0.87
21	1110	1321.5	442.1	24[illegible].4	0.97	260.7	147.6	56.5	113.1	185.3	1.768	0.88
22	1120	1302.9	449.2	248.8	1.12	259.9	144.2	57.8	115.7	182.8	1.802	0.89
23	1130	1283.5	456.2	251.8	1.27	258.9	141.1	58.9	117.8	180.4	1.835	0.90
24	1140	1264.1	461.0	254.8	1.43	258.1	138.2	59.9	119.9	178.2	1.868	0.90
25	1150	1245.1	465.2	257.4	1.58	256.6	135.2	60.7	121.4	175.7	1.898	0.92
26	1200	1224.1	469.8	260.3	1.75	255.5	132.6	61.4	122.9	173.6	1.927	0.93
27	1210	1205.0	473.3	262.5	1.90	254.4	130.4	62.0	124.0	171.7	1.951	0.94
28	1220	1184.0	476.5	264.8	2.07	253.0	127.9	62.5	125.1	169.6	1.978	0.95
29	1230	1163.5	479.5	266.8	2.23	251.8	125.8	63.0	126.0	167.8	2.002	0.96
30	1240	1143.0	482.0	269.3	2.40	250.4	123.7	63.4	126.7	165.9	2.024	0.98
31	1255	1113.0	485.3	271.8	2.64	248.5	120.8	63.9	127.7	163.4	2.057	0.99
32	1310	1084.2	487.7	274.7	2.87	246.3	118.0	64.2	128.3	160.8	2.087	1.01
33	1325	1052.7	490.3	277.4	3.12	244.2	115.2	64.5	129.0	158.2	2.120	1.02
34	1340	1022.1	492.0	279.7	3.36	242.4	113.1	64.6	129.3	156.2	2.143	1.04
35	1400	976.8	493.2	282.6	3.71	239.1	109.8	64.7	129.3	152.9	2.178	1.06
36	1430	915.0	494.5	286.5	4.22	234.9	105.8	64.6	129.1	148.8	2.221	1.09
37	1530	789.5	496.9	293.4	5.22	227.8	99.2	64.3	128.6	142.1	2.297	1.16
38	1630	622.9	500.3	299.3	6.55	221.2	93.1	64.0	128.1	135.8	2.376	1.21
39	1730	534.5	501.1	303.8	7.26	215.9	88.5	63.7	127.4	131.0	2.440	1.25
41	1830	382.3	494.0	311.6	8.48	204.0	80.8	61.6	123.2	121.9	2.525	1.36
42	2030	154.5	488.9	314.5	10.30	197.1	77.8	59.7	119.3	117.6	2.534	1.43

SAMPLE NO. = T 505 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS = 249.33 KPA
PRECONSOLIDATION PRESSURE = 80.00 KPA
NORMALIZING STRESS = 249.33 KPA

NORMALIZED SHEAR TEST RESULTS START 830226 END 830228

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.011	1.022	0.977	0.000
2	0.01	0.032	1.071	0.921	0.072
3	0.04	0.056	1.132	0.888	0.120
4	0.06	0.078	1.191	0.870	0.153
5	0.08	0.098	1.249	0.855	0.182
6	0.10	0.116	1.304	0.842	0.206
7	0.13	0.133	1.357	0.833	0.227
8	0.18	0.146	1.402	0.825	0.243
9	0.22	0.158	1.445	0.818	0.259
10	0.26	0.169	1.486	0.808	0.276
11	0.32	0.178	1.522	0.801	0.287
13	0.42	0.193	1.585	0.788	0.312
14	0.48	0.199	1.615	0.782	0.321
15	0.54	0.205	1.641	0.777	0.330
16	0.59	0.210	1.665	0.771	0.338
17	0.66	0.214	1.687	0.765	0.348
18	0.75	0.218	1.710	0.759	0.357
19	0.82	0.221	1.729	0.754	0.363
20	0.89	0.224	1.749	0.747	0.372
21	0.97	0.227	1.766	0.743	0.379
22	1.12	0.232	1.802	0.733	0.392
23	1.27	0.236	1.835	0.723	0.404
24	1.43	0.240	1.868	0.715	0.416
25	1.58	0.243	1.898	0.704	0.427
26	1.75	0.246	1.927	0.696	0.438
27	1.90	0.249	1.951	0.689	0.447
28	2.07	0.251	1.978	0.680	0.456
29	2.23	0.253	2.002	0.673	0.464
30	2.40	0.254	2.024	0.666	0.474
31	2.64	0.256	2.057	0.655	0.484
32	2.87	0.257	2.087	0.645	0.496
33	3.12	0.259	2.120	0.634	0.507
34	3.36	0.259	2.143	0.628	0.516
35	3.71	0.259	2.178	0.613	0.528
36	4.22	0.259	2.221	0.597	0.543
37	5.22	0.258	2.297	0.570	0.571
38	6.55	0.257	2.376	0.545	0.595
39	7.26	0.256	2.440	0.525	0.613
41	8.48	0.247	2.525	0.489	0.644
43	10.30	0.239	2.634	0.472	0.656

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SOIL MECHANICS LABORATORY

SAMPLE NO. = T 506 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION = 12.408 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION = 484.660 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION = 39.060 SQUARE CENTIMETRES

CONSTANT LOAD = 14.80 N .
PROVING RING FACTOR = 1.2370 N ./DIV
PISTON AREA = 5.0700 SQUARE CENTIMETRES

INITIAL DIAL READING = 2056.00 DIVISIONS

SHEAR TEST RESULTS START 30383 END 40383

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	838	2055.7	115.8	209.5	0.00	89.4	87.5	0.9	1.9	88.1	1.021	UUUUUUU
2	835	2056.0	120.5	208.7	0.00	91.7	88.3	1.7	3.4	89.4	1.039	-0.52
3	840	2053.1	147.5	213.0	0.02	96.1	84.2	6.0	11.9	88.2	1.142	0.35
4	850	2034.0	155.2	212.8	0.18	98.0	83.5	7.2	14.5	88.3	1.173	0.26
5	855	2028.5	176.1	217.2	0.22	100.6	79.6	10.5	21.0	86.6	1.264	0.40
6	1000	2021.8	189.5	219.8	0.28	102.7	77.5	12.6	25.2	85.9	1.325	0.44
7	1005	2017.0	211.0	222.0	0.31	107.0	75.0	16.0	32.0	85.7	1.426	0.42
8	1010	2012.0	230.0	224.5	0.35	110.0	72.0	19.0	38.0	84.7	1.528	0.41
9	1015	2005.5	247.2	226.9	0.41	113.3	69.9	21.7	43.4	84.4	1.621	0.42
10	1020	1999.0	262.9	228.5	0.46	116.9	68.6	24.1	48.3	84.7	1.704	0.41
11	1025	1991.5	274.8	229.8	0.52	119.2	67.2	26.0	52.0	84.5	1.774	0.40
12	1035	1977.2	296.2	231.4	0.64	124.1	65.4	29.4	58.7	85.0	1.898	0.39
13	1040	1968.8	305.2	232.3	0.70	126.2	64.7	30.7	61.5	85.2	1.950	0.38
14	1045	1960.5	314.2	233.0	0.77	128.7	64.5	32.1	64.2	85.9	1.995	0.38
15	1050	1952.5	320.5	232.5	0.83	130.1	63.8	33.1	66.3	85.9	2.039	0.36
16	1055	1943.5	326.5	233.8	0.91	131.5	63.4	34.1	68.1	86.1	2.074	0.37
17	1100	1934.0	333.0	234.2	0.98	132.8	62.8	35.0	70.0	86.1	2.115	0.36
18	1105	1924.5	348.0	234.3	1.06	137.6	63.0	37.3	74.6	87.9	2.185	0.34
19	1110	1916.0	342.2	234.2	1.13	135.1	62.2	36.4	72.9	86.5	2.172	0.35
20	1115	1906.0	346.5	235.0	1.21	136.1	62.0	37.0	74.1	86.7	2.195	0.35
21	1120	1897.0	351.0	235.6	1.28	137.5	62.2	37.7	75.3	87.3	2.211	0.36
22	1125	1888.0	354.5	235.9	1.35	138.1	61.7	38.2	76.4	87.2	2.238	0.35
23	1135	1868.7	360.6	233.8	1.51	139.9	61.4	39.2	78.5	87.6	2.278	0.32
24	1145	1848.9	365.5	236.4	1.67	140.7	60.7	40.0	80.0	87.4	2.317	0.34
25	1155	1829.8	370.5	235.3	1.82	141.9	60.7	40.6	81.2	87.8	2.338	0.33
26	1205	1809.0	375.0	237.4	1.99	142.5	60.2	41.1	82.3	87.6	2.367	0.35
27	1215	1790.0	378.2	238.1	2.14	143.0	59.9	41.5	83.1	87.6	2.387	0.35
28	1230	1759.9	383.0	239.5	2.39	143.7	59.5	42.1	84.2	87.6	2.416	0.36
29	1245	1729.1	387.8	238.5	2.63	144.5	58.8	42.9	85.7	87.4	2.458	0.35
30	1315	1669.0	393.5	238.6	3.12	144.3	57.0	43.6	87.3	86.1	2.531	0.34
31	1345	1607.0	398.5	240.0	3.62	144.8	56.6	44.1	88.2	86.0	2.558	0.35
32	1417	1540.0	402.5	242.0	4.16	144.4	55.6	44.4	88.8	85.2	2.597	0.37
33	1445	1480.0	405.5	242.5	4.64	143.9	54.6	44.7	89.3	84.4	2.636	0.38
34	1515	1421.0	408.0	242.6	5.12	144.0	54.4	44.8	89.6	84.3	2.648	0.38
35	1615	1297.0	410.8	240.3	6.12	146.4	56.9	44.8	89.5	86.7	2.574	0.35
36	1715	1173.7	412.1	247.7	7.11	139.2	50.4	44.4	88.8	80.0	2.762	0.44
37	1815	1029.5	412.6	248.0	8.27	137.2	49.2	44.0	88.0	78.5	2.788	0.45
38	2015	917.8	412.5	250.9	9.17	134.4	47.5	43.5	86.9	76.5	2.830	0.49

SAMPLE NO. = T 506 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS = 89.74 KPA
PRECONSOLIDATION PRESSURE = 178.29 KPA
NORMALIZING STRESS = 89.74 KPA

NORMALIZED SHEAR TEST RESULTS START 30383 END 40383

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.010	1.021	0.982	0.000
2	0.00	0.019	1.039	0.997	-0.009
3	0.02	0.067	1.142	0.983	0.039
4	0.15	0.081	1.173	0.984	0.037
5	0.22	0.117	1.264	0.965	0.066
6	0.28	0.140	1.325	0.957	0.115
7	0.31	0.178	1.428	0.955	0.139
8	0.35	0.212	1.528	0.944	0.167
9	0.41	0.242	1.621	0.940	0.194
10	0.46	0.269	1.704	0.944	0.212
11	0.52	0.290	1.774	0.942	0.226
12	0.64	0.327	1.898	0.947	0.244
13	0.70	0.343	1.950	0.949	0.254
14	0.77	0.358	1.995	0.957	0.282
15	0.83	0.369	2.039	0.957	0.256
16	0.91	0.379	2.074	0.959	0.271
17	0.98	0.390	2.115	0.960	0.275
18	1.06	0.416	2.185	0.979	0.278
19	1.13	0.406	2.172	0.964	0.275
20	1.21	0.413	2.195	0.966	0.284
21	1.28	0.420	2.211	0.973	0.291
22	1.35	0.426	2.238	0.971	0.294
23	1.51	0.437	2.278	0.978	0.271
24	1.67	0.445	2.317	0.973	0.300
25	1.82	0.453	2.338	0.975	0.287
26	1.99	0.458	2.367	0.975	0.311
27	2.14	0.463	2.387	0.976	0.319
28	2.39	0.469	2.418	0.976	0.334
29	2.63	0.478	2.458	0.974	0.323
30	3.12	0.486	2.531	0.959	0.324
31	3.62	0.491	2.558	0.958	0.340
32	4.16	0.495	2.597	0.949	0.362
33	4.64	0.498	2.636	0.940	0.368
34	5.12	0.499	2.648	0.939	0.389
35	6.12	0.499	2.674	0.967	0.343
36	7.11	0.495	2.762	0.892	0.426
37	8.27	0.490	2.788	0.875	0.429
38	9.17	0.484	2.830	0.852	0.461

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SAMPLE NO. : T 507 HOLE NO. : -1 DEPTH : 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION : 10.440 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION : 415.750 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION : 39.810 SQUARE CENTIMETRES

CONSTANT LOAD : 14.97 N .
PROVING RING FACTOR : 1.2370 N ./DIV
PISTON AREA : 5.1100 SQUARE CENTIMETRES

INITIAL DIAL READING : 1939.50 DIVISIONS

SHEAR TEST RESULTS START 240383 END 240383

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	907	1939.5	553.0	221.6	0.00	308.5	185.1	61.7	123.4	226.2	1.667	UUUUUUU
2	910	1938.7	567.0	224.5	0.01	309.8	182.0	63.9	127.8	224.6	1.702	0.66
3	915	1936.6	589.0	229.3	0.03	312.0	177.5	67.3	134.5	222.3	1.758	0.69
4	920	1934.5	609.8	232.6	0.05	314.8	173.8	70.5	141.0	220.8	1.811	0.62
5	925	1931.5	627.0	236.3	0.08	316.6	170.3	73.1	146.3	219.1	1.859	0.64
6	930	1927.4	643.0	239.2	0.12	318.5	167.3	75.6	151.2	217.7	1.904	0.63
7	935	1924.0	656.5	241.3	0.15	320.7	165.4	77.7	155.3	217.2	1.939	0.62
8	940	1919.0	667.5	243.3	0.20	321.8	163.1	79.3	158.7	216.0	1.973	0.61
9	945	1913.5	675.5	244.8	0.25	322.9	161.8	80.5	161.1	215.5	1.995	0.62
10	950	1908.1	683.0	245.8	0.30	323.8	160.5	81.7	163.3	214.9	2.018	0.61
11	955	1901.0	688.0	247.2	0.37	324.1	159.3	82.4	164.8	214.2	2.034	0.62
12	1000	1894.0	691.0	248.1	0.44	323.8	158.2	82.8	165.6	213.4	2.047	0.63
13	1005	1887.0	694.0	249.0	0.50	323.8	157.4	83.2	166.4	212.9	2.057	0.64
14	1015	1872.5	695.3	250.7	0.64	322.3	155.7	83.3	166.6	211.2	2.070	0.67
15	1030	1849.0	696.6	253.1	0.87	320.0	153.4	83.3	166.6	208.9	2.086	0.73
16	1045	1823.6	694.9	254.9	1.11	316.8	151.1	82.9	165.7	206.3	2.097	0.79
17	1100	1800.9	692.8	257.4	1.33	313.6	148.9	82.3	164.7	203.8	2.106	0.87
18	1135	1744.2	688.0	262.3	1.87	306.3	144.0	81.1	162.3	198.1	2.127	1.05
19	1200	1704.3	685.2	265.6	2.25	301.4	140.6	80.4	160.8	194.2	2.144	1.18
20	1300	1608.0	679.8	273.0	3.18	291.1	133.4	78.8	157.7	186.0	2.182	1.50
21	1400	1510.2	671.9	278.7	4.11	281.4	127.6	76.9	153.8	178.9	2.205	1.86
22	1430	1481.9	667.1	280.6	4.57	277.0	125.4	75.8	151.6	175.9	2.209	2.10
103	1430	1459.2	665.0	RELAXATION TEST								
104	1430	1458.6	663.0	RELAXATION TEST								
105	1432	1458.3	661.2	RELAXATION TEST								
106	1433	1457.4	658.9	RELAXATION TEST								
107	1435	1456.0	653.9	RELAXATION TEST								
108	1439	1453.9	645.8	RELAXATION TEST								
109	1446	1451.5	637.2	RELAXATION TEST								
110	1501	1448.5	628.8	RELAXATION TEST								
111	1531	1445.4	614.8	RELAXATION TEST								
112	1630	1443.5	604.0	RELAXATION TEST								
23	1635	1441.0	624.5	289.1	4.77	256.1	117.4	69.3	138.7	163.6	2.181	4.41
24	1640	1437.0	639.6	291.3	4.81	258.4	115.3	71.6	143.1	163.0	2.241	3.53
25	1645	1432.1	651.2	292.4	4.86	260.6	114.2	73.2	146.4	163.0	2.282	3.07
26	1650	1428.6	659.1	292.7	4.91	262.9	114.2	74.3	148.7	163.8	2.302	2.81
27	1655	1420.0	664.3	292.8	4.98	264.0	113.9	75.1	150.1	163.9	2.318	2.86
28	1700	1413.6	666.9	292.5	5.04	264.7	113.9	75.4	150.8	164.2	2.324	2.58
29	1710	1398.2	668.2	292.3	5.18	265.2	114.3	75.5	150.9	164.6	2.321	2.57
30	1725	1373.0	658.0	292.1	5.43	264.8	114.9	74.9	149.9	164.9	2.304	2.66
31	1745	1340.1	614.0	291.9	5.74	249.1	114.9	67.1	134.2	159.6	2.168	5.53
32	1815	1282.3	654.5	292.5	6.20	259.5	114.2	72.7	145.3	162.6	2.273	3.23
33	1900	1217.9	640.5	293.5	6.91	253.8	113.7	70.1	140.1	160.4	2.232	4.30
34	2000	1114.8	608.8	293.7	7.90	242.2	113.2	64.5	129.0	156.2	2.140	12.82
35	2105	999.2	561.3	294.1	9.01	228.1	113.6	57.3	114.5	151.8	2.008	-6.16

SAMPLE NO. : T 507 HOLE NO. : -1 DEPTH : 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS : 319.57 KPA
PRECONSOLIDATION PRESSURE : 164.25 KPA
NORMALIZING STRESS : 319.57 KPA

NORMALIZED SHEAR TEST RESULTS START 240383 END 240383

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.193	1.667	0.708	0.000
2	0.01	0.200	1.702	0.703	0.009
3	0.03	0.210	1.758	0.696	0.024
4	0.05	0.221	1.811	0.691	0.034
5	0.08	0.229	1.859	0.685	0.046
6	0.12	0.237	1.904	0.681	0.055
7	0.15	0.243	1.939	0.680	0.062
8	0.20	0.248	1.973	0.676	0.068
9	0.25	0.252	1.995	0.674	0.073
10	0.30	0.256	2.016	0.673	0.076
11	0.37	0.258	2.034	0.670	0.080
12	0.44	0.259	2.047	0.668	0.083
13	0.50	0.260	2.057	0.665	0.086
14	0.64	0.261	2.070	0.661	0.091
15	0.87	0.261	2.088	0.654	0.099
16	1.11	0.259	2.097	0.646	0.104
17	1.33	0.258	2.106	0.638	0.112
18	1.67	0.254	2.127	0.620	0.127
19	2.25	0.252	2.144	0.608	0.138
20	3.16	0.247	2.162	0.582	0.161
21	4.11	0.241	2.205	0.560	0.179
22	4.57	0.237	2.209	0.551	0.185
23	4.77	0.217	2.161	0.512	0.211
24	4.81	0.224	2.241	0.510	0.218
25	4.86	0.229	2.282	0.510	0.222
26	4.91	0.233	2.302	0.512	0.222
27	4.96	0.235	2.318	0.513	0.223
28	5.04	0.236	2.324	0.514	0.222
29	5.18	0.236	2.321	0.515	0.221
30	5.43	0.234	2.304	0.516	0.221
31	5.74	0.210	2.168	0.499	0.220
32	6.20	0.227	2.273	0.509	0.222
33	6.91	0.219	2.232	0.502	0.225
34	7.90	0.202	2.140	0.489	0.226
35	9.01	0.179	2.008	0.475	0.227

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SAMPLE NO. = T 606 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION = 11.812 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION = 423.650 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION = 35.865 SQUARE CENTIMETRES

CONSTANT LOAD = 10.11 N .
PROVING RING FACTOR = 1.2370 N ./DIV
PISTON AREA = 2.9100 SQUARE CENTIMETRES

INITIAL DIAL READING = 1929.90 DIVISIONS

SHEAR TEST RESULTS START 260383 END 270383

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	948	1929.9	148.0	222.0	0.00	218.2	198.5	9.9	19.7	205.1	1.099	UUUUUUU
2	950	1929.7	148.5	224.0	0.00	216.7	196.8	9.9	19.9	203.4	1.101	13.86
3	955	1929.3	171.5	229.7	0.01	219.0	191.2	13.9	27.8	200.5	1.145	0.96
4	1000	1927.2	194.0	235.7	0.02	220.8	185.2	17.8	35.6	197.1	1.192	0.87
5	1005	1924.8	215.5	241.1	0.04	222.7	179.7	21.5	43.0	194.0	1.239	0.82
6	1010	1922.8	234.8	246.0	0.06	225.1	175.5	24.8	49.6	192.0	1.282	0.80
7	1015	1919.2	254.0	250.3	0.09	227.6	171.5	28.1	56.1	190.2	1.327	0.78
8	1022	1914.3	279.0	255.0	0.13	231.2	166.4	32.4	64.8	188.0	1.389	0.73
9	1030	1908.9	301.3	259.1	0.18	234.2	161.7	36.2	72.5	185.C	1.448	0.70
10	1035	1904.8	315.2	262.4	0.21	235.9	158.7	38.6	77.2	184.4	1.486	0.70
11	1040	1900.1	328.0	265.5	0.25	237.9	156.4	40.8	81.5	183.6	1.521	0.70
12	1045	1895.2	339.0	268.8	0.29	238.2	152.9	42.6	85.3	181.3	1.558	0.71
13	1050	1890.7	350.0	270.9	0.33	238.8	149.7	44.6	89.1	179.4	1.595	0.70
14	1055	1884.9	360.1	271.6	0.38	241.3	148.7	46.3	92.6	179.6	1.622	0.68
15	1100	1879.3	369.0	274.4	0.43	242.0	146.5	47.8	95.5	178.3	1.652	0.69
16	1105	1873.8	377.0	276.8	0.47	242.7	144.5	49.1	98.2	177.2	1.680	0.70
17	1110	1867.4	384.4	279.3	0.53	243.0	142.4	50.3	100.6	175.9	1.707	0.71
18	1115	1861.9	391.3	280.7	0.58	243.9	140.9	51.5	103.0	175.2	1.731	0.71
19	1120	1855.7	397.9	281.6	0.63	244.1	138.9	52.6	105.2	174.0	1.757	0.70
20	1125	1849.3	403.5	283.2	0.68	244.5	137.4	53.6	107.1	173.1	1.780	0.70
21	1130	1842.9	408.9	285.0	0.74	244.8	135.9	54.4	108.9	172.2	1.801	0.71
22	1135	1836.5	413.9	286.6	0.79	245.2	134.7	55.3	110.5	171.5	1.820	0.71
23	1140	1830.2	418.6	288.8	0.84	245.0	133.0	56.0	112.0	170.3	1.842	0.72
24	1145	1823.5	422.6	289.8	0.90	245.1	131.8	56.7	113.3	169.6	1.860	0.72
25	1150	1811.4	426.8	290.0	1.00	245.7	131.1	57.3	114.6	169.3	1.874	0.72
26	1155	1809.5	429.8	291.7	1.02	244.7	129.0	57.8	115.7	167.6	1.897	0.73
27	1200	1802.8	433.0	293.4	1.08	244.6	127.9	58.4	116.7	166.8	1.913	0.74
28	1210	1788.7	438.9	296.5	1.20	244.5	126.0	59.2	118.5	165.5	1.940	0.75
29	1220	1774.7	444.0	297.1	1.31	244.0	123.8	60.1	120.2	163.9	1.971	0.75
30	1230	1759.8	448.5	300.0	1.44	243.3	121.8	60.8	121.5	162.3	1.998	0.77
31	1245	1737.8	454.5	302.5	1.63	241.9	118.5	61.7	123.4	159.6	2.041	0.78
32	1300	1715.3	459.6	305.6	1.82	241.2	116.4	62.4	124.8	158.0	2.072	0.80
33	1330	1670.3	467.4	310.8	2.20	238.4	111.5	63.5	126.9	153.8	2.138	0.83
34	1400	1625.0	473.1	314.8	2.58	235.9	107.6	64.2	128.3	150.4	2.193	0.85
35	1500	1533.2	481.1	322.1	3.36	230.3	100.3	65.0	130.0	143.6	2.296	0.91
36	1600	1440.3	486.5	326.7	4.14	225.7	95.0	65.4	130.7	138.6	2.376	0.94
37	1700	1340.0	489.8	332.0	4.99	220.3	89.6	65.3	130.7	133.2	2.458	0.99
38	1800	1253.4	492.0	335.8	5.73	216.2	85.8	65.2	130.4	129.3	2.520	1.03
39	1900	1159.0	492.5	339.1	6.53	211.9	82.5	64.7	129.4	125.6	2.569	1.07
101	1902	1158.2	492.7	RELAXATION TEST								
102	1902	1155.5	490.8	RELAXATION TEST								
103	1903	1154.9	489.0	RELAXATION TEST								
104	1904	1154.0	486.5	RELAXATION TEST								
105	1906	1152.6	482.5	RELAXATION TEST								
106	1910	1151.3	476.9	RELAXATION TEST								
107	1917	1149.5	470.2	RELAXATION TEST								
108	1932	1147.6	461.9	RELAXATION TEST								
109	2002	1145.0	452.8	RELAXATION TEST								
110	2102	1142.8	444.1	RELAXATION TEST								
111	941	1138.3	427.0	RELAXATION TEST								
112	1529	1138.0	425.8	RELAXATION TEST								
40	1535	1135.8	446.0	362.7	6.72	173.5	59.3	57.1	114.2	97.4	2.926	1.49
41	1540	1132.3	462.5	364.0	6.75	178.2	58.8	59.7	119.4	98.6	3.030	1.43
42	1545	1127.4	474.1	364.3	6.79	180.1	56.9	61.6	123.2	98.0	3.165	1.38
43	1551	1120.1	483.6	364.5	6.86	183.0	56.9	63.1	126.1	98.9	3.217	1.34
44	1555	1115.2	488.0	365.5	6.90	184.4	57.0	63.7	127.4	99.5	3.235	1.33
45	1600	1108.1	492.0	365.9	6.96	185.2	56.6	64.3	128.6	99.5	3.272	1.32
46	1606	1099.6	494.7	364.2	7.03	186.6	57.1	64.7	129.5	100.3	3.267	1.30
47	1610	1094.1	496.0	364.2	7.08	187.7	57.9	64.9	129.8	101.2	3.241	1.29
48	1615	1086.6	496.8	364.2	7.14	188.8	58.9	64.9	129.9	102.2	3.205	1.29
49	1620	1079.0	496.8	362.8	7.20	188.5	58.6	64.9	129.9	101.9	3.217	1.28
50	1625	1070.9	496.8	362.7	7.27	189.1	59.3	64.9	129.8	102.6	3.188	1.28
51	1630	1063.2	496.6	362.7	7.34	189.5	60.0	64.8	129.5	103.2	3.158	1.28
52	1635	1055.0	496.0	362.0	7.41	190.0	60.7	64.6	129.3	103.8	3.129	1.28
53	1645	1038.9	494.3	361.3	7.54	189.5	60.9	64.3	128.6	103.8	3.111	1.28
54	1700	1014.8	491.1	360.5	7.75	189.1	61.9	63.6	127.2	104.3	3.056	1.29
55	1730	965.2	483.5	358.9	8.17	187.8	63.5	62.1	124.3	104.9	2.957	1.31
57	1830	867.5	469.1	358.6	8.99	183.0	64.3	59.4	118.7	103.9	2.847	1.38
58	1900	819.5	463.3	357.7	9.40	181.3	65.0	58.1	116.3	103.8	2.789	1.41
59	2000	723.0	453.2	357.1	10.22	176.9	64.8	56.1	112.1	102.2	2.730	1.46
60	2100	626.0	444.3	357.1	11.04	173.0	64.6	54.2	108.4	100.7	2.678	1.52

SAMPLE NO. = T 808 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS = 233.09 KPA
PRECONSOLIDATION PRESSURE = 163.63 KPA
NORMALIZING STRESS = 233.09 KPA

NORMALIZED SHEAR TEST RESULTS START 260383 END 270383

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.042	1.099	0.880	0.000
2	0.00	0.043	1.101	0.873	0.008
3	0.01	0.060	1.146	0.860	0.033
4	0.02	0.076	1.192	0.845	0.059
5	0.04	0.092	1.239	0.832	0.082
6	0.06	0.108	1.282	0.824	0.103
7	0.09	0.120	1.327	0.818	0.121
8	0.13	0.139	1.389	0.807	0.142
9	0.18	0.155	1.448	0.797	0.159
10	0.21	0.166	1.486	0.791	0.173
11	0.25	0.175	1.521	0.788	0.187
12	0.29	0.183	1.558	0.778	0.201
13	0.33	0.191	1.595	0.770	0.210
14	0.38	0.199	1.622	0.770	0.213
15	0.43	0.205	1.652	0.765	0.225
16	0.47	0.211	1.680	0.760	0.235
17	0.53	0.216	1.707	0.755	0.246
18	0.58	0.221	1.731	0.752	0.252
19	0.63	0.226	1.757	0.748	0.257
20	0.68	0.230	1.780	0.743	0.263
21	0.74	0.234	1.801	0.739	0.270
22	0.79	0.237	1.820	0.736	0.277
23	0.84	0.240	1.842	0.731	0.287
24	0.90	0.243	1.860	0.728	0.291
25	1.00	0.246	1.874	0.726	0.292
26	1.02	0.248	1.897	0.719	0.299
27	1.08	0.250	1.913	0.716	0.306
28	1.20	0.254	1.940	0.710	0.320
29	1.31	0.258	1.971	0.703	0.322
30	1.44	0.261	1.998	0.696	0.335
31	1.63	0.265	2.041	0.685	0.345
32	1.82	0.268	2.072	0.678	0.359
33	2.20	0.272	2.138	0.660	0.380
34	2.58	0.275	2.193	0.645	0.398
35	3.38	0.279	2.296	0.616	0.429
36	4.14	0.280	2.376	0.595	0.449
37	4.99	0.280	2.458	0.571	0.472
38	5.73	0.280	2.520	0.555	0.488
39	6.53	0.278	2.569	0.539	0.502
40	6.72	0.245	2.925	0.418	0.604
41	6.75	0.256	3.030	0.423	0.609
42	6.79	0.264	3.165	0.420	0.610
43	6.85	0.271	3.217	0.424	0.611
44	6.90	0.273	3.235	0.427	0.616
45	6.96	0.276	3.272	0.427	0.617
46	7.03	0.276	3.267	0.430	0.610
47	7.08	0.278	3.241	0.434	0.610
48	7.14	0.279	3.205	0.436	0.610
49	7.20	0.279	3.217	0.437	0.604
50	7.27	0.278	3.188	0.440	0.604
51	7.34	0.278	3.159	0.443	0.604
52	7.41	0.277	3.129	0.445	0.601
53	7.54	0.276	3.111	0.445	0.598
54	7.75	0.273	3.056	0.448	0.594
55	8.17	0.267	2.957	0.450	0.586
57	8.99	0.255	2.847	0.448	0.577
58	9.40	0.249	2.789	0.445	0.582
59	10.22	0.241	2.730	0.438	0.580
60	11.04	0.233	2.678	0.432	0.580

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SAMPLE NO. : T 510 HOLE NO. : -1 DEPTH : 0.00 METRES TO 0.00 METRES

SAMPLE HEIGHT AFTER CONSOLIDATION : 12.162 CENTIMETRES
SAMPLE VOLUME AFTER CONSOLIDATION : 525.880 CUBIC CENTIMETRES
SAMPLE AREA AFTER CONSOLIDATION : 43.241 SQUARE CENTIMETRES

CONSTANT LOAD : 14.90 N .
PROVING RING FACTOR : 1.2370 N ./DIV
PISTON AREA : 5.0700 SQUARE CENTIMETRES

INITIAL DIAL READING : 1992.70 DIVISIONS

SHEAR TEST RESULTS START 100483 END 110483

CONSOLIDATED UNDRAINED TRIAXIAL TEST
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PT	TIME	DISPL DIAL RDG	PRING DIAL RDG	PORE PRESS KPA	PER CENT STRAIN	EFFECT SIGMA1 KPA	EFFECT SIGMA3 KPA	HALF DEV STRESS KPA	DEV STRESS KPA	EFFECT OCT STRESS KPA	RATIO OF EFF SIGMA1 EFF SIFMA3	A
1	1534	1992.7	208.5	206.1	0.00	86.0	53.3	16.3	32.7	64.2	1.613	UUUUUUU
2	1537	1991.8	221.5	208.7	0.01	86.9	50.5	18.2	36.4	62.6	1.721	0.70
3	1540	1990.0	232.1	210.8	0.02	88.1	48.7	19.7	39.4	61.8	1.809	0.71
4	1545	1988.5	250.7	213.2	0.05	90.7	46.0	22.4	44.7	60.9	1.973	0.59
5	1550	1983.0	267.0	215.6	0.08	93.4	44.1	24.7	49.3	60.5	2.119	0.57
6	1555	1978.5	279.9	216.7	0.12	95.7	42.6	26.5	53.1	60.3	2.245	0.52
7	1600	1974.0	291.5	218.3	0.15	97.8	41.5	28.1	56.3	60.3	2.356	0.52
8	1605	1969.1	302.0	218.8	0.19	99.8	40.5	29.7	59.3	60.3	2.465	0.48
9	1610	1963.1	311.1	219.6	0.24	101.9	40.0	30.9	61.9	60.6	2.548	0.46
10	1615	1957.0	319.1	219.7	0.29	103.8	39.7	32.1	64.1	61.1	2.615	0.43
11	1620	1950.5	326.0	220.2	0.35	105.4	39.4	33.0	66.0	61.4	2.675	0.42
12	1625	1944.9	331.5	220.1	0.39	106.9	39.3	33.8	67.6	61.8	2.720	0.40
13	1630	1938.0	336.9	220.1	0.45	108.4	39.3	34.5	69.1	62.3	2.758	0.38
14	1635	1932.0	341.5	220.1	0.50	109.7	39.3	35.2	70.4	62.8	2.791	0.37
15	1640	1925.2	345.1	220.0	0.56	110.8	39.4	35.7	71.4	63.2	2.811	0.36
16	1650	1911.0	351.8	219.5	0.67	112.9	39.7	36.6	73.2	64.1	2.844	0.33
17	1700	1895.0	356.5	219.0	0.80	114.5	40.0	37.2	74.5	64.8	2.862	0.31
18	1715	1875.0	361.8	218.6	0.97	116.6	40.8	37.9	75.8	66.1	2.858	0.29
19	1730	1851.4	364.5	217.4	1.16	118.1	41.6	38.2	76.5	67.1	2.838	0.26
20	1800	1804.0	367.5	216.5	1.55	119.6	42.6	38.5	77.0	68.3	2.807	0.23
21	1830	1756.9	367.8	215.9	1.94	120.1	43.4	38.4	76.7	69.0	2.766	0.22
22	1900	1710.1	366.2	215.8	2.32	119.7	43.7	38.0	76.0	69.0	2.739	0.22
23	1930	1662.6	363.1	215.1	2.72	119.1	44.3	37.4	74.8	69.2	2.689	0.21
101	1932	1658.4	363.0	RELAXATION TEST								
102	30	1658.1	361.5	RELAXATION TEST								
103	1933	1657.9	360.3	RELAXATION TEST								
104	1934	1657.4	358.0	RELAXATION TEST								
105	1936	1656.5	354.1	RELAXATION TEST								
106	1940	1655.2	350.0	RELAXATION TEST								
107	1947	1654.0	344.5	RELAXATION TEST								
108	2002	1652.5	338.4	RELAXATION TEST								
109	2032	1650.8	332.5	RELAXATION TEST								
110	2132	1649.0	326.0	RELAXATION TEST								
111	810	1644.8	310.0	RELAXATION TEST								
24	810	1644.8	310.0	214.8	2.86	104.5	44.6	30.0	59.9	64.6	2.344	0.32
25	815	1641.8	328.1	217.7	2.89	107.2	42.3	32.4	64.9	63.9	2.534	0.36
26	820	1637.2	341.6	219.0	2.92	109.2	40.6	34.3	68.6	63.5	2.690	0.36
27	825	1632.3	351.5	220.0	2.96	111.3	40.0	35.7	71.3	63.8	2.783	0.36
28	830	1626.5	357.8	219.7	3.01	113.1	40.0	36.5	73.1	64.4	2.827	0.34
29	835	1619.5	362.5	220.0	3.07	114.3	40.0	37.2	74.3	64.8	2.858	0.33
30	840	1611.7	364.5	219.5	3.13	115.0	40.2	37.4	74.8	65.1	2.862	0.32
31	850	1596.8	365.0	218.4	3.26	116.1	41.2	37.5	74.9	66.2	2.818	0.29
32	900	1580.5	364.7	217.6	3.39	116.6	41.9	37.4	74.7	66.8	2.783	0.28
33	915	1555.5	362.0	217.4	3.59	116.4	42.6	36.9	73.8	67.2	2.732	0.28
34	930	1532.2	358.2	216.6	3.79	115.8	43.2	36.3	72.6	67.4	2.681	0.26
35	1000	1483.0	352.4	216.5	4.19	114.0	43.3	35.4	70.7	66.9	2.633	0.27
36	1105	1378.1	341.2	216.8	5.05	109.7	42.6	33.5	67.1	65.0	2.574	0.31
37	1220	1264.0	332.0	217.9	5.99	106.0	42.1	31.9	63.9	63.4	2.517	0.38
38	1320	1168.2	323.1	217.5	6.78	102.7	41.7	30.5	61.0	62.0	2.464	0.40
39	1420	1072.5	316.1	218.1	7.57	100.1	41.5	29.3	58.6	61.0	2.413	0.46
40	1520	976.2	310.0	218.7	8.36	97.3	40.7	28.3	56.6	59.6	2.390	0.53
41	1620	876.0	307.0	219.0	9.17	95.6	40.3	27.6	55.3	58.7	2.372	0.57

SAMPLE NO. = T 510 HOLE NO. = -1 DEPTH = 0.00 METRES TO 0.00 METRES

CONSOLIDATION AXIAL STRESS = 82.77 KPA
PRECONSOLIDATION PRESSURE = 184.08 KPA
NORMALIZING STRESS = 82.77 KPA

NORMALIZED SHEAR TEST RESULTS START 100483 END 110483

PT	PER CENT STRAIN	NRMLZD HALF DEV STRESS KPA	EFFECT RATIO SIGMA1 SIGMA3	NRMLZD OCT STRESS KPA	NRMLZD CHANGE IN PWP KPA
1	0.00	0.197	1.613	0.776	0.000
2	0.01	0.220	1.721	0.757	0.031
3	0.02	0.238	1.809	0.747	0.058
4	0.05	0.270	1.973	0.738	0.086
5	0.08	0.298	2.119	0.731	0.115
6	0.12	0.320	2.245	0.728	0.128
7	0.15	0.340	2.356	0.728	0.147
8	0.19	0.358	2.465	0.728	0.153
9	0.24	0.374	2.546	0.732	0.163
10	0.29	0.387	2.615	0.738	0.164
11	0.35	0.399	2.676	0.742	0.170
12	0.39	0.408	2.720	0.747	0.169
13	0.45	0.417	2.758	0.753	0.169
14	0.50	0.425	2.791	0.758	0.169
15	0.58	0.431	2.811	0.763	0.168
16	0.67	0.442	2.844	0.774	0.162
17	0.80	0.450	2.862	0.783	0.156
18	0.97	0.458	2.858	0.798	0.151
19	1.16	0.462	2.838	0.810	0.137
20	1.55	0.465	2.807	0.825	0.128
21	1.94	0.464	2.768	0.833	0.118
22	2.32	0.459	2.739	0.834	0.115
23	2.72	0.452	2.689	0.837	0.109
24	2.86	0.362	2.344	0.780	0.108
25	2.89	0.392	2.534	0.772	0.140
26	2.92	0.415	2.690	0.767	0.158
27	2.96	0.431	2.783	0.771	0.168
28	3.01	0.441	2.827	0.778	0.164
29	3.07	0.449	2.858	0.783	0.158
30	3.13	0.452	2.862	0.787	0.152
31	3.26	0.452	2.818	0.799	0.149
32	3.39	0.451	2.783	0.807	0.141
33	3.59	0.445	2.732	0.812	0.137
34	3.79	0.439	2.681	0.814	0.127
35	4.19	0.427	2.633	0.808	0.126
36	5.06	0.405	2.574	0.785	0.129
37	5.99	0.386	2.517	0.768	0.143
38	6.78	0.369	2.464	0.750	0.138
39	7.57	0.354	2.413	0.738	0.145
40	8.38	0.342	2.390	0.719	0.152
41	9.17	0.334	2.372	0.710	0.156

OEDOMETER TESTS

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ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE C 501

DATE STARTED LOADING : 820727
INITIAL MOISTURE CONTENT = 52.02%
FINAL MOISTURE CONTEMT = 48.41%
SPECIFIC GRAVITY OF SOIL = 2.72

	LOAD (N)	DIAL	STRESS (KPA)	V	STRAIN (%)
1	1.8	1770.0	5.6	2.5152	-2.7
2	21.8	1721.0	51.2	2.4693	-0.8
3	41.8	1676.0	96.8	2.4271	0.9
4	61.8	1641.0	142.4	2.3943	2.3
5	81.1	1614.5	186.4	2.3694	3.3
6	101.8	1589.5	233.7	2.3460	4.3
7	121.8	1562.8	279.3	2.3210	5.3
8	141.8	1528.1	324.9	2.2884	6.7
9	161.8	1495.0	370.5	2.2574	8.0
10	181.8	1456.0	416.1	2.2208	9.5
11	201.8	1424.0	461.7	2.1908	10.7
12	221.8	1391.5	507.3	2.1604	12.0
13	241.8	1360.7	552.9	2.1316	13.2
14	261.8	1328.5	598.5	2.1013	14.5
15	281.8	1305.0	644.2	2.0793	15.4
16	301.8	1282.3	689.8	2.0580	16.3
17	321.8	1262.7	735.4	2.0396	17.0
18	341.8	1244.2	781.0	2.0222	17.7
19	361.8	1218.4	826.6	1.9982	18.8
20	401.8	1196.2	917.8	1.9772	19.6
21	301.8	1208.3	689.8	1.9887	19.2
22	201.8	1225.7	461.7	2.0049	18.5
23	101.8	1272.5	233.7	2.0488	16.6
24	1.8	1558.2	5.6	2.3167	5.5

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ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE C 502

DATE STARTED LOADING : 270782
INITIAL MOISTURE CONTENT = 49.80%
FINAL MOISTURE CONTEMT = 46.80%
SPECIFIC GRAVITY OF SOIL = 2.72

	LOAD (N)	DIAL	STRESS (KPA)	V	STRAIN (%)
1	1.8	1781.0	5.6	2.4953	-3.2
2	21.8	1717.8	50.8	2.4361	-0.7
3	41.8	1668.8	96.1	2.3903	1.2
4	61.8	1634.2	141.3	2.3579	2.6
5	81.8	1603.0	186.6	2.3287	3.8
6	101.8	1577.8	231.8	2.3051	4.8
7	121.8	1550.6	277.1	2.2796	5.9
8	141.8	1520.3	322.3	2.2513	7.1
9	161.8	1488.0	367.6	2.2210	8.3
10	181.8	1452.0	412.8	2.1873	9.8
11	201.8	1421.2	458.1	2.1585	11.0
12	221.8	1390.9	503.3	2.1301	12.2
13	241.8	1363.2	548.6	2.1042	13.3
14	261.8	1332.2	593.8	2.0752	14.5
15	281.8	1309.9	639.1	2.0543	15.4
16	301.8	1289.5	684.3	2.0352	16.2
17	321.8	1273.1	729.6	2.0198	16.8
18	341.8	1256.1	774.8	2.0039	17.5
19	361.8	1229.0	820.1	1.9785	18.5
20	401.8	1211.2	910.6	1.9619	19.2
21	301.2	1221.2	683.0	1.9712	18.9
22	201.8	1241.9	458.1	1.9906	18.0
23	101.8	1287.8	231.8	2.0338	16.2
24	1.8	1543.5	5.6	2.2730	6.2

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ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE C 503

DATE STARTED LOADING : 100882
INITIAL MOISTURE CONTENT = 55.45%
FINAL MOISTURE CONTEMT = 42.42%
SPECIFIC GRAVITY OF SOIL = 2.72

	LOAD (N)	DIAL	STRESS (KPA)	V	STRAIN (%)
1	20.0	1747.5	46.9	2.2739	6.1
2	40.0	1652.0	92.2	2.1795	9.9
3	60.0	1593.0	137.6	2.1212	12.2
4	80.0	1551.0	183.0	2.0797	13.9
5	100.0	1521.2	228.3	2.0502	15.1
6	120.0	1496.4	273.7	2.0257	16.1
7	140.0	1472.3	319.1	2.0019	17.0
8	160.0	1458.3	364.4	1.9881	17.6
9	180.0	1436.5	409.8	1.9665	18.5
10	200.0	1422.0	455.2	1.9522	19.0
11	220.0	1408.3	500.6	1.9387	19.6
12	240.0	1395.5	545.9	1.9260	20.1
13	260.0	1377.5	591.3	1.9082	20.8
14	280.0	1367.4	636.7	1.8982	21.2
15	300.0	1358.2	682.0	1.8892	21.6
16	320.0	1350.2	727.4	1.8812	21.9
17	340.0	1342.2	772.8	1.8733	22.2
18	360.0	1328.8	818.1	1.8601	22.8
19	400.0	1318.6	908.9	1.8500	23.2
20	300.0	1327.7	682.0	1.8590	22.8
21	200.0	1345.9	455.2	1.8770	22.1
22	100.0	1384.7	228.3	1.9153	20.5
23	0.0	1626.1	1.5	2.1539	10.9

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ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE C 504

DATE STARTED LOADING : 100882
INITIAL MOISTURE CONTENT = 50.99%
FINAL MOISTURE CONTEMT = 36.93%
SPECIFIC GRAVITY OF SOIL = 2.72

	LOAD (N)	DIAL	STRESS (KPA)	V	STRAIN (%)
1	20.0	1705.0	47.1	2.2337	7.5
2	45.0	1595.2	104.1	2.1327	11.7
3	60.0	1559.8	138.3	2.1001	13.1
4	80.0	1520.5	183.9	2.0640	14.6
5	100.0	1491.0	229.5	2.0368	15.7
6	120.0	1466.1	275.2	2.0139	16.7
7	140.0	1443.8	320.8	1.9934	17.5
8	160.0	1426.4	366.4	1.9774	18.2
9	180.0	1400.0	412.0	1.9531	19.2
10	200.0	1383.8	457.6	1.9382	19.8
11	220.0	1371.0	503.2	1.9265	20.3
12	240.0	1358.4	548.8	1.9149	20.8
13	260.0	1340.3	594.4	1.8982	21.5
14	280.0	1330.0	640.0	1.8887	21.9
15	300.0	1320.9	685.7	1.8804	22.3
16	320.0	1313.3	731.3	1.8734	22.6
17	340.0	1304.9	776.9	1.8657	22.9
18	360.0	1291.8	822.5	1.8536	23.4
19	400.0	1281.3	913.7	1.8440	23.8
20	300.0	1289.1	685.7	1.8511	23.5
21	200.0	1305.6	457.6	1.8663	22.9
22	100.0	1339.4	229.5	1.8974	21.6
23	0.0	1455.8	1.5	2.0045	17.1

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ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE C 512

DATE STARTED LOADING : 130183
INITIAL MOISTURE CONTENT = 64.19%
FINAL MOISTURE CONTEMT = 42.33%
SPECIFIC GRAVITY OF SOIL = 2.72

	LOAD (N)	DIAL	STRESS (KPA)	V	STRAIN (%)
1	22.3	1890.8	51.7	2.8325	1.0
2	27.3	1874.8	63.0	2.8149	1.6
3	37.3	1818.6	86.6	2.7529	3.6
4	45.0	1768.2	102.9	2.6974	5.8
5	50.4	1729.3	116.2	2.6545	7.3
6	75.4	1577.9	171.5	2.4875	13.3
7	113.1	1442.0	256.5	2.3377	18.7
8	128.1	1412.8	290.3	2.3055	19.8
9	138.1	1393.9	312.9	2.2847	20.5
10	148.1	1378.1	335.4	2.2673	21.2
11	153.1	1369.6	346.7	2.2579	21.5
12	158.1	1363.4	358.0	2.2511	21.8
13	163.1	1357.1	369.2	2.2441	22.0
14	168.1	1351.2	380.5	2.2376	22.2
15	173.1	1344.5	391.8	2.2302	22.5
16	178.1	1336.7	403.0	2.2216	22.8
17	158.1	1338.8	358.0	2.2239	22.7
18	135.0	1342.7	305.6	2.2282	22.6
19	110.0	1349.5	249.4	2.2357	22.3
20	85.0	1359.4	193.1	2.2466	21.9
21	60.0	1376.2	135.7	2.2652	21.2
22	35.0	1408.3	80.4	2.3006	20.0
23	60.0	1392.6	135.7	2.2832	20.6
24	85.0	1382.3	193.1	2.2718	21.0
25	110.0	1366.1	249.4	2.2540	21.6
26	135.0	1351.0	305.8	2.2374	22.2
27	160.0	1334.6	362.1	2.2193	22.9
28	175.0	1322.6	398.0	2.2061	23.4
29	190.0	1309.0	429.8	2.1911	23.9
30	220.0	1273.0	497.4	2.1514	25.3

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ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE C 513

DATE STARTED LOADING : 210183
INITIAL MOISTURE CONTENT = 58.56%
FINAL MOISTURE CONTEMT = 47.50%
SPECIFIC GRAVITY OF SOIL = 2.72

	LOAD (N)	DIAL	STRESS (KPA)	V	STRAIN (%)
1	25.0	1964.8	58.2	2.6412	1.8
2	30.0	1950.7	69.5	2.6266	2.3
3	35.0	1933.2	80.9	2.6085	3.0
4	40.0	1907.7	92.2	2.5821	4.0
5	45.0	1871.4	103.6	2.5445	5.5
6	50.0	1837.9	114.9	2.5099	6.8
7	55.0	1808.1	126.2	2.4790	8.0
8	60.0	1779.0	137.6	2.4489	9.1
9	65.0	1752.2	148.9	2.4212	10.2
10	70.0	1731.2	160.3	2.3995	11.0
11	75.0	1709.9	171.6	2.3774	11.9
12	60.0	1716.0	137.6	2.3837	11.6
13	45.0	1723.0	103.6	2.3910	11.3
14	30.0	1739.4	69.5	2.4079	10.7
15	45.0	1730.9	103.6	2.3991	11.0
16	60.0	1719.9	137.6	2.3876	11.5
17	75.0	1698.6	171.6	2.3657	12.3
18	86.3	1667.4	197.3	2.3334	13.6
19	98.6	1627.3	225.1	2.2918	15.1

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ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE C 514

DATE STARTED LOADING : 280183
INITIAL MOISTURE CONTENT = 64.49%
FINAL MOISTURE CONTEMT = 43.17%
SPECIFIC GRAVITY OF SOIL = 2.72

	LOAD (N)	DIAL	STRESS (KPA)	V	STRAIN (%)
1	25.0	1970.9	58.4	2.7903	1.5
2	30.0	1958.3	69.7	2.7768	2.0
3	35.0	1937.9	81.1	2.7550	2.8
4	40.0	1903.3	92.5	2.7179	4.2
5	45.0	1867.8	103.9	2.6798	5.5
6	50.0	1831.1	115.2	2.6406	7.0
7	55.0	1797.8	126.6	2.6049	8.3
8	60.0	1773.7	138.0	2.5791	9.2
9	75.0	1645.5	172.1	2.4418	14.2
10	86.3	1613.2	197.9	2.4072	15.4
11	98.6	1580.2	225.7	2.3719	16.7
12	113.6	1544.1	259.8	2.3332	18.1
13	137.7	1512.8	314.6	2.2997	19.3
14	110.0	1517.2	251.7	2.3044	19.2
15	80.0	1526.7	183.5	2.3146	18.8
16	55.0	1542.3	126.6	2.3313	18.2
17	25.0	1585.2	58.4	2.3772	16.5
18	55.0	1566.1	126.6	2.3568	17.3
19	80.0	1546.0	183.5	2.3352	18.1
20	110.0	1521.8	251.7	2.3093	19.0
21	140.0	1494.1	319.9	2.2796	20.1
22	160.0	1468.4	365.4	2.2521	21.1
23	185.0	1433.5	422.3	2.2147	22.4
24	212.7	1395.7	485.2	2.1742	23.9

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ONE DIMENSIONAL CONSOLIDATION TEST - SAMPLE C 515

DATE STARTED LOADING : 100283
INITIAL MOISTURE CONTENT = 60.77%
FINAL MOISTURE CONTEMT = 38.73%
SPECIFIC GRAVITY OF SOIL = 2.72

	LOAD (N)	DIAL	STRESS (KPA)	V	STRAIN (%)
1	25.0	1785.1	58.5	2.7137	2.2
2	30.0	1775.5	69.9	2.7036	2.6
3	35.0	1762.1	81.3	2.6896	3.1
4	40.0	1741.2	92.7	2.6678	3.9
5	45.0	1713.6	104.1	2.6389	5.0
6	51.8	1667.9	119.6	2.5911	6.8
7	59.4	1619.1	137.1	2.5401	8.7
8	68.1	1571.5	156.8	2.4903	10.6
9	78.1	1521.9	179.6	2.4385	12.5
10	90.0	1474.5	206.7	2.3889	14.4
11	103.1	1428.1	236.6	2.3414	16.2
12	118.9	1387.6	271.9	2.2980	17.8
13	136.2	1343.0	312.2	2.2514	19.5
14	156.7	1304.2	358.6	2.2108	21.0
15	179.9	1264.9	411.7	2.1697	22.6
16	206.8	1226.2	473.0	2.1293	24.1
17	237.7	1188.3	543.5	2.0897	25.6
18	273.1	1153.8	624.3	2.0536	26.9