CONVENTIONAL AND CRS ROWE CELL CONSOLIDATION TEST ON SOME HONG KONG CLAYS

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J. Premchitt, K.S. Ho & N.C. Evans

GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING DEPARTMENT
HONG KONG

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PREFACE

In keeping with our policy of releasing information of general technical interest, we make available some of our internal reports in a series of publications termed the GEO Report series. The reports in this series, of which this is one, are selected from a wide range of reports produced by the staff of the Office and our consultants. A charge is made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents and presents the results of research work of general interest in GEO Publications. These publications and the GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these publications is given on the last page of this report.

A.W. Malone
Principal Government Geotechnical Engineer
August 1996

FOREWORD

This report documents two series of Rowe cell consolidation tests completed by the Geotechnical Engineering Office on Hong Kong clays.

Mr N.C. Evans carried out the first test series on a soft marine clay using conventional step-loading tests. Dr Kai S. Ho adopted the constant rate of strain (CRS) approach for the second series of tests on a stiff alluvial clay from the Chek Lap Kok airport site. Both worked under the guidance of Dr J. Premchitt who led the preparation of this report.

The Provisional Airport Authority (PAA) provided the stiff clay samples and requested the CRS tests to be conducted on them. PAA's Mr R. Newman and Mr C. Covil made useful technical suggestions during the testing. Mr Philip W.K. Chung of the Public Works Central Laboratory assisted with the tests. All three reviewed and commented on the draft report. Their contributions are gratefully acknowledged.

Y.C. Chan
Chief Geotechnical Engineer/Special Projects

ABSTRACT

It is often necessary to carry out special laboratory consolidation tests using techniques other than the conventional oedometer testing for the design and construction of reclamation and related projects. In response to this need, two series of Rowe cell consolidation tests were conducted, on two common Hong Kong clays.

The first series was conducted in Phase I work using soft marine clay obtained from seabed near Soko Islands. A step-loading method was used throughout but drainage conditions were varied to obtain both the coefficient of consolidation in the vertical direction and that in the horizontal direction. The results showed that the coefficient of consolidation in horizontal direction for the marine clay samples tested is significantly greater than the coefficient in vertical direction.

The second series was conducted in Phase II work using stiff (alluvial) clay obtained from the site at the new airport at Chek Lap Kok, at the request of the Provisional Airport Authority. The tests were performed employing a Rowe cell which was controlled and monitored by a computerised hydraulic loading system. Constant rate of strain (CRS) test was carried out in this test series principally to determine preconsolidation pressure of the clay. For comparison, small-step loading tests using conventional oedometer were also conducted. For the seven samples tested, it was determined that six of them have low preconsolidation pressures and they are basically normally consolidated. The other sample was estimated to be significantly over-consolidated based on the CRS test results.

The tests indicated that the procedures for the Rowe cell are relatively straightforward, and good results can be readily obtained from the tests. The CRS test offer several advantages over conventional incremental loading test. The time required for a CRS test is considerably less than the conventional test; the test results can be presented in a continuous plot; and the smooth loading procedure reduces sample disturbances. The fully automated Rowe cell system provides reliable and high quality test results, and the overall work is efficient and cost effective.

For stiff clay such as alluvial clays, CRS test may be the only means to find definitive values of preconsolidation pressure. The conventional test on such a clay often results in quite a flat e-log(p) curve and estimation of preconsolidation pressure is uncertain. CRS test is a standard option in many countries, such as USA, Norway and Sweden. Wider usage of CRS test in Hong Kong will be beneficial.

CONTENTS

1. INTRODUCTION

The estimation of settlement of reclamation and other structures which have been built over clay strata may require special laboratory testing which uses techniques other than the standard oedometer testing. It is often necessary to determine coefficient of consolidation in the horizontal direction rather than the normal vertical direction in conventional tests. Accurate determination of preconsolidation pressures is also difficult to be made on the basis of the data obtained from conventional tests particularly for some types of clay. As a result, a number of special equipment and test procedures have been proposed overseas for such special tests since early 1960s. This report describes the use of two of these techniques, namely the conventional Rowe cell and the Constant Rate of Strain (CRS) methods, in two series of consolidation tests to determine the necessary parameters for typical reclamation projects in Hong Kong.

The coefficient of consolidation in horizontal direction is the parameter governing the consolidation settlement of a clay layer with vertical drain installed, as the pore water flows horizontally to the face of the vertical drain. It is known that the values of the coefficient in horizontal direction are commonly greater than those in the vertical direction. To simulate this condition, a special test is required where the load is applied vertically and drainage flows horizontally. This is one of the features of the Rowe cell. In Hong Kong, the vertical drains are mostly installed into the marine clay and the first series of test was carried out on this clay (obtained from soft marine clay layer below seabed near Soko Islands) using a Rowe cell with drainage provided vertically as well as horizontally for comparison.

The compression of the deeper clay layers (usually the 'alluvial clay' in Hong Kong) is often a significant contribution to the long term settlement of reclamation in Hong Kong, whether they were formed by draining or removing the marine clay. It is relatively difficult to predict the settlement in deep clay layers due to limited data available for this type of soil in Hong Kong. One of the important parameters needed for settlement prediction is the preconsolidation pressure (p_c'). The clay is stiff and the e-log(p) curves obtained from conventional tests are quite flat making it hard to determine a reasonably accurate value of the preconsolidation pressure. The deep clay may also consist of many strata ("crust" and normal below "crust") with different values of Overconsolidation Ratio (OCR) and p_c'. For this reason, CRS tests were carried out as the second test series in this study, at the request of the Provisional Airport Authority (PAA), using the clay samples obtained from the new airport site at Chek Lap Kok at approximate elevations of -19 to -27 mPD. CRS tests require special loading system, and automatic recording of data is preferred. These were achieved by deploying the existing computerised digitally controlled and recording system in the Geotechnical Engineering Office (GEO) to connect up with the Rowe cell. This was the only suitable system of this type in Hong Kong at the time. For comparison, small-step loading tests using conventional oedometer were also conducted. Summary of results was provided to PAA in January 1995.

This report documents relevant details of the work for future reference. The background to the tests is outlined and the principles of Rowe cell tests are briefly discussed. The characteristics of the two Rowe cells and the automatic loading system used in this study are then described. The basic properties of the soil samples used are given, and the sample preparation and testing procedures are explained. The test results are presented and the interpretation procedures are described.

2. BACKGROUND

2.1 Rowe Cell

The Rowe cell was developed at Manchester University, UK, by Professor P.W. Rowe (Rowe & Barden, 1966). A detailed description of the principles and practice of Rowe cell testing is given in Head (1985).

In the Rowe cell, the test sample is loaded hydraulically by water pressure acting on a flexible diaphragm. Drainage of the sample can be controlled and pore water pressure measured. Back pressure can be applied to simulate the in situ condition, whilst the conventional oedometer cannot provide such back pressure. The application of hydraulic pressure and measurement of the variation of pore water pressure and volume change of the sample can either be handled by a conventional pressure panel or by an automatic system.

Several drainage conditions are possible, allowing a variety of test types to be performed. Rowe cells are available in different nominal diameters as follows: 76 mm, 150 mm and 250 mm. The basic configuration of the Rowe cell is shown in Figure 1. The different types of test and drainage conditions are illustrated schematically in Figure 2.

Head (1985) summarised the advantages of the Rowe cell over traditional oedometers as follows:

(a) Minimum vibration effects.

(b) Application of pressures of up to 1,000 kPa.

(c) Negligible deformations of the loading system.

(d) Control of various sample drainage conditions.

(e) Measurement of pore water pressure.

(f) Measurement of the volume of water expelled from the sample.

(g) Saturation of sample under back pressure condition.

(h) Application of back pressure to simulate in situ condition.

(i) Variation of load conditions between "equal strain" (rigid platen) and "free strain" (flexible platen).

(j) Control of loading condition.

Eight different types of drainage and load conditions can be applied in the Rowe cell, as follows:

(a) Free strain, vertical single drainage - Figure 2(a).

(b) Equal strain, vertical single drainage - Figure 2(b).

(c) Free strain, vertical double drainage - no pore pressure measurement Figure 2(c).

(d) Equal strain, vertical double drainage - no pore pressure measurement Figure 2(d).

(e) Free strain, horizontal outward drainage - requires Rowe cell to have a peripheral porous rim drain - Figure 2(e).

(f) Equal strain, horizontal outward drainage - requires Rowe cell to have a peripheral porous rim drain - Figure 2(f).

(g) Free strain, horizontal inward drainage - requires Rowe cell to have a central cylindrical porous drain - Figure 2(g).

(h) Equal strain, horizontal inward drainage - requires Rowe cell to have a central cylindrical porous drain - Figure 2(h).

Head (1985) provided the following comments regarding the choice of test type:

(a) For the determination of c_v, the most usual test is free strain, vertical single drainage.

(b) Equal strain, vertical single drainage, is the type of test most analogous to traditional oedometer testing.

(c) For the determination of c_h, the preferred test is free strain, horizontal outward drainage.

(d) Horizontal outward drainage tests theoretically drain nine times more quickly than horizontal inward drainage tests.

There are other factors that should be considered when selecting the test type. Head (1985) noted that the decrease in sample volume during equal strain tests can be determined both by vertical displacement (as in traditional oedometer tests) and by measurement of the volume of water drained from the sample. For free strain tests the volume decrease cannot be determined from the vertical displacement.

Rowe and Barden (1966) also noted that a flexible platen and a uniformly distributed load (free strain) offer the advantage of localising the effects of side friction and of providing a greater knowledge of the total stress acting on the major part of the sample. Horizontal drainage using a rigid plate (equal strain) can give an uneven distribution of stresses across the sample as a result of initial rapid dissipation of pore pressure adjacent to the central or peripheral drains (Head, 1985).

In Hong Kong, Rowe cell consolidation tests have not been commonly carried out. Much of the available data are related to the work for the new airport at Chek Lap Kok.

Such Rowe cell tests have been carried out at various times since early 1980s up to now. Of the limited number of tests that have been done, it is relevant to note the results obtained for marine clay at Chek Lap Kok Test Embankment site reported in CESD (1986). Three values of coefficient of consolidation in horizontal direction, 2.0, 4.4 and 8.2 sq m/yr were obtained from Rowe cell tests in comparison with the values for vertical direction of 0.7 to 1.4 sq m/yr. The ratio of these two parameter was about 3 to 6. Recent work under the direction of the PAA include determination of c_h values from dissipation tests during Cone Penetration Tests (CPT) and from back calculation using field measurement results.

2.2 Constant Rate of Strain Tests

The CRS test was first described by Hamilton and Crawford (1959) as a rapid means of determining preconsolidation pressure (p_c'). This parameter was originally defined by Casagrande in 1930s who correlated it to the change in slope of the curve in the e - log(p) plot. Practically, engineers are interested in this threshold beyond which relatively large deformation can take place. There are disadvantages associated with using the e - log(p) curve from conventional oedometer tests to determine p_c', including (Leroueil et al, 1983a):

(a) Test results are widely spaced making it difficult to draw e - log(p) curve and estimate p_c'.

(b) Step loading is applied every 24 hours and the amount of secondary compression varies with each loading and soil sample.

(c) One to two weeks are required to complete the test.

The CRS test can overcome these problems. The load is applied continuously while keeping the rate of strain constant, so continuous record of stress and deformation can be made. With suitable choice of strain rate, there is little secondary compression and the test can be completed in a few days.

Theoretical solutions have been established to allow proper determination of soil parameters, such as coefficient of consolidation (c_v) and coefficient of volume compressibility (m_v), from the test results. Approximate solution was given by Smith & Wahls (1969) and a rigorous solution based on small strain theories was provided by Wissa et al (1971). Subsequently a number of solutions based on large strain theories were published. These were reviewed in Lee et al (1993).

A noteworthy series of CRS tests was reported by Gorman et al (1978). The tests were conducted on samples from three sites, and the results of CRS tests were compared with those obtained from conventional oedometer tests and controlled hydraulic gradient tests (Section 3.2). The CRS test results showed a clear break in the rise of pore pressure when applied effective stress exceeded p_c, Figure 3. Therefore p_c' can be readily identified from the u - log(p) curve obtained from CRS tests. It was concluded that the results were comparable for all three types of test but CRS required the least time (average 1.9 days) and was the least difficult to perform.

From these test results, Gorman et al also concluded that a considerable range of strain rates could be used in CRS tests without significant difference in results. They provided some guidance on the selection of strain rate on the basis of liquid limits, with values of the order of 0.01 - 0.005 %/min. With regard to the estimation of c_v, they cautioned that at pressures below p_c' very little or no pore pressure is generated. Therefore the estimated c_v values are erratic and too high, and the values in this pressure range may not be valid.

A number of laboratory consolidation test series, using various test methods, and back analyses of case histories were conducted by Leroueil and his colleagues (Leroueil et al, 1983a&b, Morin et al, 1983), in order to compare p_c' estimated from these laboratory tests with those estimated from monitoring records of actual earth structures. There were variations of estimated p_c' with the strain rate used in laboratory tests, and there were differences between laboratory and field estimated values. For normally consolidated or slightly overconsolidated clay, these deviations were opposite and tended to cancel out. It was finally concluded by Leroueil (1983b) that p_c' is preferably determined from CRS tests rather than any other types of test. Further discussion on CRS tests and comparison of results with conventional and other tests may be found in Leroueil et al (1985) and Leroueil (1988).

A recent work by Lee et al (1993) provided detailed estimation of variation of parameters within the test specimen. They also proposed a criterion for strain rate selection. Three series of CRS tests were carried out using undisturbed and reconstituted soft marine clay samples. The main conclusions were that detailed information can be obtained by comparing estimated parameters at different parts of a test specimen, and that the rate of test should have an upper bound β value of 0.1, where $\beta = rh_o^2/c_v$, r = strain rate and h_o = initial sample height. However, the criterion needs an estimate of c_v value before the test. Also, for relatively thin specimen used in this study detailed estimation of parameters on different parts may not be fruitful.

Because of its many advantages, the CRS test has now been a standard option in many countries for determination of consolidation properties of clay. It has been adopted by the Swedish Geotechnical Institute, the Norwegian Geotechnical Institute, the French Laboratoires des Ponts et Chaussees, and the American Society for Testing and Materials (ASTM)(Lee et al, 1993). The test was described in adequate detail in Head (1985), which was based largely on ASTM test method no. D 4186-82. Head suggested that preconsolidation pressure may be estimated from the break in curve of e, c_v, D ($=1/m_v$), and u plotted against log(p), see Figure 4. Figure 4c shows possible different results if very different strain rates (r) are used.

The values of c_v and m_v can be calculated using Wissa et al (1971) solutions as follows:

$$c_v = (\frac{\delta p'}{\delta t}) \times (\frac{H^2}{2\Delta u})$$

$$m_v = \frac{r \times \delta t}{\log_e(\frac{p_2}{p_1}) \times p'}$$

where p' = effective applied stress

t = time

$\delta p'$ and δt are increments during a time interval

H = mean height of sample during δt

Δu = excess pore water pressure

r = strain rate

p_1, p_2 = total applied stress at the start and end of time interval δt

The CRS tests in this study followed the procedures for conducting the test and interpreting the results as outlined by Head. There were no published results of any previous CRS tests in Hong Kong before 1994, when the PAA initiated a programme for this type of tests on soil obtained from the new airport at Chek Lap Kok.

3. TEST EQUIPMENT AND CALIBRATION

In the Phase I tests, the test equipment includes a Rowe cell, pore water pressure transducer and readout unit, dial gauge, volume change measurement device and a compressed air system for pressure application (Plate 1). The test equipment set-up allows the application of step loading, and monitoring of pore pressure variation and settlement during consolidation.

The GDS consolidation testing system for the Phase II tests consists of a Rowe cell, pore water pressure transducer, two digital controllers, transducer interface, system controller card and desktop computer (Plate 2, Figures 5 and 6). This system enables the automation of test control, application of continuous loading, data logging, data reduction and on-line screen graphics.

3.1 Rowe Cell

Two 76 mm nominal diameter (3") Rowe cells, Cell A and Cell B, have been studied. Cell A (Plates 3a and 3b) was supplied by Arnfield Engineering, UK. This cell has an internal diameter of 76.2 mm and it can accommodate a sample height of 25 mm. This Rowe cell does not provide for a peripheral porous rim drain and therefore cannot perform horizontal outward drainage test.

Cell B (Plates 4a and 4b) was obtained from ELE International, UK. This Rowe cell incorporates a rim drain and can therefore carry out the full range of tests as outline in Section 2.1. The internal diameter of this cell is 75.7 mm, reducing to 72.7 mm when the peripheral drainage layer is inserted for horizontal outward drainage test. Maximum sample height is 30 mm.

3.2 Automatic System

The automatic consolidation testing system was supplied by GDS Instrument Ltd. The system provides personal computer automation of test control, data logging, data reduction and on-line screen graphics. As shown in Plate 2 and Figure 5, the test cell is linked to a digital controller for back pressure and measurement of volume change and another digital controller for axial stress application. The controller may have one of the two available capacities, 200 cm^3 and 2000 cm^3, and both can sustain a maximum pressure of 2 MPa. The two digital controllers are in turn connected by cables to the personal computer. The pore water pressure variation is measured by a pore pressure transducer mounted on the cell and linked to the computer through a digital pressure interface (DPI). The system is driven by a software "GDSCTS Version 3.1".

Average axial stress is computed from the pressure applied to the top membrane by the axial stress controller. This stress is automatically corrected for the area of the top drainage tube passing through the top of the Rowe cell. Axial deformation is computed from the volume change of the back pressure controller or from volume change of the axial stress controller. Additionally, axial deformation can also be measured directly by a digital gauge.

The following tests can be carried out using the above software:

(a) Conventional step loading.

(b) Constant rate of strain (CRS).

(c) Constant rate of loading.

(d) Controlled hydraulic gradient.

(e) Swelling pressure.

(f) Cyclic loading.

The tests can be readily carried out employing this easy to use software. Continuous loading, i.e. constant rate of strain, constant rate of loading, controlled hydraulic gradient, consolidation tests can be performed using this system. The continuous loading consolidation testing causes the pore water to flow into or out of the test specimen at a more or less steady rate. This is in direct contrast to the conventional step loading test where the hydraulic gradient causing the flow is itself reduced by the flow thus giving rise to the decaying flow rate.

Another major feature of the system is the digital controller. As shown in Plate 2 and Figure 6, the digital controller is a microprocessor controlled hydraulic pump for the precise regulation and measurement of water pressure and water volume change. The volumetric capacity is 200 cm^3 or 2000 cm^3 and the pressure range is 0-2000 kPa. Pressure measurement is resolved to within 0.2 kPa and the pressure is controlled with deviations less than 0.5 kPa.

The principles of operation of the digital controller are shown schematically in Figure 6. De-aired water in a cylinder is pressurised and displaced by a piston pump using a stepper motor. The pressure is detected by means of a solid state pressure transducer. Control mechanism is built into the programmable memory to activate the controller either to adjust to achieve a target pressure or to change to attain a target volume change. Volume change is measured by counting the steps of the stepper motor. The pump was constructed such that one step of the motor will cause a volume change of 1 mm^3.

In stand alone mode, the digital controller can perform one or more functions of a general purpose constant pressure source, a volume change gauge, a pore pressure measuring system, a flow pump and a digital pipette. As a constant pressure source, it can be used to replace mercury column, compressed air, pumped oil or dead weight devices. It can be programmed through its own control panel to ramp and change pressure or volume linearly with respect to time. In computer control mode it is a computer peripheral receiving control signals via the standard IEEE-488 computer interface.

3.3 Calibration of Rowe Cell

3.3.1 Trapped Water Calibration

The volume of water trapped between the side of the diaphragm and the Rowe cell wall, and the time required for its removal through the rim drain valve, have been measured at various applied effective stresses. These data provide a guide to the time required to drain off the surplus water at each effective stress before starting the next loading step. The results of this calibration are given in Table 1. The details of the procedure are as follows:

The Rowe cell was set up with several porous plastic plates (spacers) placed inside to simulate a test specimen. The cell was then filled with water and it was ensured that there was no air trapped inside. The diaphragm stem was set to rest on the porous plates. Diaphragm pressures were applied in stages as shown in Table 1. The rim drain valve was opened to allow drainage of water to a measuring cylinder. The volume of water expelled and the time for completion were then recorded. On completion of all diaphragm pressure increments, pressure was released and the diaphragm and cell pressure valves were opened to a common water tank such that the diaphragm recovered its original state. The above steps were then repeated twice to give average values which are presented in Table 1.

3.3.2 Diaphragm Load Calibration

The force exerted by the diaphragm on a soil sample may be less than that calculated from the hydraulic pressure and cross-sectional area of the Rowe cell, due to diaphragm stiffness and wall friction. The difference between actual and calculated forces has been determined for both Rowe cells, at various applied pressures using a variation of trapped water test set up above. The results of this calibration are given in Table 2. The details of the procedure are as follows:

A pressure transducer was connected to the diaphragm and another pressure transducer was connected to the pore water pressure measuring point at the cell base. Both transducers were adjusted to indicate the same readings when subject to the same initial pressure. The diaphragm and cell were filled with water to ensure there was no air trapped inside. Soft porous spacers were placed inside the cell to simulate a sample. All the drainage valves were closed. A pressure of 600 kPa was gradually introduced into the diaphragm and then released. The transducers were checked to ensure that both still indicated the same value. Diaphragm pressures from 50 kPa to 800 kPa, at 50 kPa increments, were then applied and the reaction pressure at the base was recorded. Several trials were performed and an average value was taken as shown in Table 2.

4. TEST PROCEDURES AND RESULTS

4.1 Sample Preparation

Specimens for the present Rowe cells cannot be prepared from 76 mm diameter tube or piston samples, as the actual diameter of these samples is inevitably less than 76 mm. They must be prepared from 100 mm tube or piston samples. Specimen preparation techniques for the two Rowe cells are slightly different and they are discussed below.

For Cell A, the cell was modified previously to improve handling. A cutting ring of 25 mm height and 76.2 mm internal diameter was constructed and the internal wall of the cell body was machined to provide space to accept the ring. The cutting ring is pushed into the soil sample, and the excess is trimmed off as for a conventional oedometer cutting ring. The ring containing the trimmed specimen is inserted into the cell body. Plates 5 and 6 show the system. Due to this modification, very high pressure testing should not be carried out in this Rowe cell.

For Cell B, the required specimen is prepared by means of specially constructed cutting shoes which are bolted to the cell body. The cell/cutting shoe assembly is then mounted in a sample extrusion frame and the soil sample is extruded from the tube or piston liner directly into the cell body, in accordance with the recommendations contained in the ELE Operating Instructions. Two sizes of cutting ring assembly have been prepared for producing samples of 72.7 mm and 75.7 mm diameter (for horizontal outward drainage and vertical drainage tests respectively). The cutting shoe assembly for producing 72.7 mm diameter samples is identified by red marks. Plate 7 illustrates the cutting shoe assemblies and Plate 8 shows one of the cutting shoe assemblies bolted to the cell body.

For both cells, the specimen at the base of the cell was carefully trimmed with a wire saw, after it has been placed in the cell body. De-aired water was spread over the base of the cell and the cell body (with soil specimen) was placed on the cell base and bolted to it. After the cell body and base were bolted, the specimen was carefully trimmed to the required thickness at the top. The whole cell was then flooded with de-aired water. The diaphragm and the lid were then securely bolted. The diaphragm was filled with de-aired water and a small bedding pressure was applied to allow for the priming of the system while draining against zero back-pressure. The specimen was then saturated by the common saturation procedures under a specified back pressure to a "B" value greater than 0.97.

Step-loading tests were carried out in the Phase I tests using both Rowe cells. CRS tests were carried out in the Phase II Tests using cell B only. The test procedures are described in detail in BS1377:Part 6 (1990b) for step-loading tests using Rowe cell, and in Head (1985) for both step-loading and CRS tests. The Phase II tests were controlled and monitored by the automatic system with the procedures as described in the manufacturer's operation manuals (GDS, 1992a and b).

4.2 Phase I Tests

4.2.1 Sample Characteristics

The specimens were obtained from a 100 mm diameter piston sample from borehole no. SKMD 2/20 of the Fill Management Study advance marine site investigation in the seabed near the Soko Islands.

The sample was obtained at depth of about 17-18 m. The stratum sampled comprised soft to firm, dark greenish grey slightly sandy marine silt/clay, with traces of shell fragments. The log of borehole SKMD 2/20 is presented in Appendix A.

Standard classification tests were carried out on the sample. The material is a silty clay with 34 % to 39 % clay content. Atterberg limits are : liquid limit 44 %, plastic limit 22 %, plasticity index 22 %. Specific gravity was measured at 2.69. Natural moisture contents were measured for each consolidation test and ranged from 50.4 % to 62.0 %, with an average value of 54.6 %.

4.2.2 Test Schedule

The schedule of tests is shown in Table 3. All the tests in Phase I were conducted at the Public Works Central Laboratory. Four tests were performed, one using Cell A and three using Cell B. The first pair of tests compared results from similar samples in the two cells using free strain, vertical drainage conditions. The second pair of tests compared free strain and equal strain conditions under lateral drainage (horizontal, outwards) in Cell B, using specimens from the same piston sample.

The specimens were saturated under a back-pressure of 200 kPa prior to loading, and the 200 kPa back pressure was maintained during the testing. Diaphragm loads of 220, 240, 280, 360 and 520 kPa (step loading) were used for the tests, giving effective pressures of 20, 40, 80, 160 and 320 kPa.

4.2.3 Test Results

For Phase I tests readings were taken at time zero, and at intervals commencing with 0.25 minutes, increasing as consolidation proceeded. The data output allowed plots of pore pressure, volume change and vertical settlement against time to be prepared for each load/unload stage. The data were interpreted in accordance with the recommendations contained in Head (1985) and in the ELE Operating Instructions. The time parameters to be used in the plots for the different test types are as follows:

(a) Free strain, vertical drainage; use $\sqrt{t}$.

(b) Free strain, lateral drainage; use $(t)^{0.465}$.

(c) Equal strain, lateral drainage; use $\sqrt{t}$.

From the test results, it is apparent that pore pressure dissipation during loading stages was rapid, due to the sandy/silty nature of the material being tested. For this reason the estimation of consolidation times was based on the plots of volume change for these Phase I tests. In practice the volume change plots were found to be most useful as difficulties were experienced with axial strain measurements at low effective stresses.

The plots of volume change versus appropriate time parameter are presented in Appendix C. A summary of the calculated values of c_v, c_h and m_v is given in Table 4. These were estimated from time-volume change relationship and use t_{50}. It can be seen that the ratio c_h/c_v is of the order of 3 or 4, i.e. the coefficient of consolidation in horizontal direction is about three to four times that in vertical direction.

4.3 Phase II Tests

4.3.1 Sample Characteristics

Six 100 mm diameter piston (P100) samples were collected from boreholes 519B08, 519B09 and 519B12, at the Chek Lap Kok airport site. The boreholes were drilled soon after dredging of the marine clay and completion of filling. Borehole logs are attached in Appendix C. Table 5 summarizes the soil samples received for testing.

As described in the borehole logs, the samples tested are in general firm to stiff grey clayey silt (alluvium) with trace of sand to some sand. As shown in Table 6, the moisture content of the soil samples tested vary from 20 % to 57 % with the measured bulk unit weight ranging from 17 kN/m^3 to 20 kN/m^3. The average liquid limit and plastic limit are about 50 % and 25 %, respectively.

4.3.2 Test Schedule

Seven constant rate of strain (CRS) consolidation tests were carried out using a computer controlled hydraulic loading system in Engineer's Laboratory, Civil Engineering Building. In addition, seven small step loading consolidation (OED) tests were carried out by the Public Works Central Laboratory using the conventional oedometer. Table 6 summarizes the schedule of testing.

For the CRS tests, only the equal strain, vertical single drainage condition were used. The specimens were saturated under a back pressure similar to the in situ hydrostatic pressure. The strain rate used was 0.01 %/min. This was selected following the recommendation of Head (1985) on the basis of the relationship between acceptable strain rate and liquid limit. To examine the sensitivity of test results to the strain rate, three tests with strain rates of 0.005, 0.01 and 0.1 %/min (numbered TRIAL-1, -2 & -3) were carried out at the beginning of the test series. Additionally, two repeat tests were conducted, numbered CRS-2a and CRS-5a, to examine repeatability of the tests and to confirm the test results. The control programme was set so that the test will terminate when total applied pressure reached 1200 kPa. For strain rate of 0.01 %/min, this took about 3 days in comparison with more than a week for conventional tests.

In the small step loading consolidation test, the loading sequence for each sample tested was: 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 200 and 400 kPa. A new loading step was applied after completion of primary consolidation due to the previous loading.

4.3.3 Test Results

The consolidation curves for the CRS and OED tests for all the samples tested are given in Appendices D and E, respectively. The curves for c_v and D were calculated from other measured parameters, as discussed in Section 2.2. Readings were taken at short intervals and as a result the calculated values of these two parameters were occasionally subject to short term fluctuations, particularly where the dividing term was very small. Therefore where necessary the plots were drawn on the basis of moving 10-point average for these two parameters. For c_v, the calculation was made when excess pore pressure was greater than 3 kPa, as recommended by Head (1985). This is to avoid the errors due to the division by a very small number (value of excess pore pressure). The test results are also summarized in Table 6.

Examples of test results are given in Figures 7 & 8. These show the plot of void ratio, excess pore water pressure, coefficient of consolidation and constrained modulus against the logarithm of applied effective stress. For these examples, a clear break in the curves can be seen, and estimation

of preconsolidation pressure can be made according to Head (1985), see also Figure 4. At this pressure, the pore pressure and constrained modulus ($1/m_v$) began to rise rapidly, whilst c_v dropped from a high to a low value. The sample for CRS-5a was found to be significantly overconsolidated. The D - log(p) curve showed rising D value at low pressures but in the vicinity of preconsolidation pressure, considerable variations occurred, see Figure 8. This behaviour was not found in other samples, except the TRIAL series, see Figure 9..

Figure 9 provides comparison of tests results obtained at three different strain rates. All three produced similar trends for c_v and D plots. The differences in the e plots are due to different initial void ratios, but the break in the curves still occurred at about the same pressure. The tests at 0.005 and 0.01 %/min produced similar pore pressures but the one at 0.1 %/min generated much higher pore pressure. Therefore the strain rates within the adopted range would still produce similar satisfactory results except for pore pressure at 0.1 %/min. It can be seen that rates higher than 0.1 %/min will produce too high pore pressures for meaningful interpretation whilst those much lower than 0.005 % may not generate any pore pressure. However, some small deviations in the strain rate in the vicinity of 0.01 % should still give satisfactory results. For the range of c_v of this clay, it was found that the criterion for the upper limit of strain rate, $\beta < 0.1$ as defined by Lee et al (1993) and reviewed in Section 2.2 above, was also satisfied.

Figure 10 shows the results of a set of repeat tests carried out on two samples which were only 0.3 m apart in depth at the same borehole and the using the same strain rate. There is a good similarity in the parameters obtained, in particular the constrained modulus. The results demonstrate that the test is repeatable and the derived preconsolidation pressure does not vary between tests.

The pre-consolidation pressure (p_c') as shown in Table 6 is estimated using different plots of consolidation curves. For the CRS test, the curves of e-log(p) and Δu-log(p) plots are used to estimate p_c'. This was determined from the point of intersection of the extrapolations of the two straight portions of the curves. Some variation in the estimated value may occur in this relatively subjective procedure. It can be seen from the test results that the e-log(p) curves for sample CRS-1 and CRS-3 are too flat for a reasonable estimation of p_c'. It is also noted that the p_c' of CRS-2 estimated from the e-log(p) curve is different from that estimated from the Δu-log(p) curve. For samples CRS-4, CRS-5, CRS-6 and CRS-7, the values of the estimated p_c' using e-log(p) curves are consistent with those estimated using Δu-log(p) curves.

For the OED test, the curves of e-log(p) and c_v-log(p) plots are used to estimate p_c'. It can be seen from the test results that the c_v-log(p) curve for samples OED-5 and OED-6 are too flat for a reasonable interpretation of p_c'. It is also noted that the p_c' values using the e-log(p) curves are in general lower than those estimated from the c_v-log(p) curves.

It is observed from the test results that, for the sample tested, the soil is normally consolidated to slightly over-consolidated (except for only one sample CRS-5). Sample CRS-5 has a relatively high p_c' of 320 kPa indicating that the soil is significantly over-consolidated, with OCR about 3 to 4.

5. CONCLUSIONS

This study indicates that the test procedures for the Rowe cell are relatively straightforward, and good results can be readily obtained from the tests. The derived parameters at applied pressures between loading steps cannot be determined by the conventional tests. The interpretation of the test results required more effort than for standard oedometer testing, due to the greater number of parameters measured and differences in analytical techniques for the different loading and drainage conditions. However, the measurement of more parameters allows cross-checking of results to detect any anomaly. For consistency, it is suggested that the test data be interpreted as given by Head (1985) and ELE Operating Instruction.

Based on the Phase I test results, it can be concluded that the coefficient of consolidation in horizontal direction for the marine clay samples tested is significantly greater than the coefficient in vertical direction.

The Phase II tests show that, with the aid of the computer controlled hydraulic loading system, constant rate of strain (CRS) tests in a Rowe cell can be readily performed. The CRS test offers several advantages over conventional incremental loading test. The time required for a CRS test is considerably less than conventional test, and the test results can be presented in a continuous plot. More importantly, the smooth loading process is also favourable to reduce sample disturbance. The computer controlled hydraulic loading system provides reliable and high quality test results. As the system is fully automatic, the laboratory work is efficient and cost effective.

For stiffer clay, u-log(p) plots obtained from CRS test provide a clear indication of preconsolidation pressure. In contrast, the conventional test on such a clay commonly results in quite a flat e-log(p) curve and estimation of preconsolidation pressure is uncertain.

On the basis of the results from the tests conducted on seven stiff clay samples obtained from the site at new airport at Chek Lap Kok, it was determined that six of them have low preconsolidation pressures and they are basically normally consolidated. The other sample was estimated to be significantly over-consolidated.

CRS test is a standard option in many countries, such as the USA, Norway and Sweden. Wider usage of CRS test in Hong Kong will be beneficial.

6. REFERENCES

BSI (1990a). BS1377:1990 Methods of Tests for Soils for Civil Engineering Purposes, Part 5. Compressibility, Permeability and Durability Tests. British Standards Institution, London, 1990, 36p.

BSI (1990b). BS1377:1990 Methods of Tests for Soils for Civil Engineering Purposes, Part 6. Consolidation and Permeability Tests in Hydraulic Cells and with Pore Pressure Measurement. British Standards Institution, London, 1990, 64p.

CESD (1986). Replacement Airport at Chek Lap Kok, Civil Engineering Design Studies, Study Report No. 2B, Vol.1 - Main Report. Civil Engineering Services Department, Hong Kong Government.

ELE International (1990). Operating Instructions for ELE Hydraulic Consolidation Cells EL 28-351 to EL 28-361. ELE International Ltd., 30p.

GDS (1992a). The GDS Users Handbook, Part I, Introducing the GDS Digital Controller (Mark III), Firmware Revision 3.5. GDS Instruments Ltd., 33p.

GDS (1992b). The GDS Users Handbook, Part III, Introducing the GDS Consolidation Testing System, GDSCTS. GDS Instruments Ltd., 41p.

Gorman, C.T., Hopkins, T.C., Deen, R.C. & Drnevich, V.P. (1978). Constant-rate-of-strain and controlled-gradient consolidation testing. Geotechnical Testing Journal, Vol.1, No.1, pp.3-15.

Hamilton, J.J. & Crawford, C.B. (1959). Improved determination of preconsolidation pressure of a sensitive clay. American Society for Testing and Materials STP 254, pp. 254-270.

Head, K.H. (1985). Manual of Soil Laboratory Testing, Vol. 3. Effective Stress Tests, pp.1129-1225.

Janbu, N., Tokheim, O. & Senneset, K. (1981). Consolidation test with continuous loading. Proceedings, 10th International Conference on Soil Mechanics and Foundation Engineering, Stockholm, Vol. 3, pp.645-654.

Lee, K., Choa, V., Lee, S.H. & Quek, S.H. (1993). Constant rate of strain consolidation of Singapore marine clay. Géotechnique, Vol. 43, No. 3, pp.471-488.

Leroueil, S. (1988). Recent developments in consolidation of natural clays. Canadian Geotechnical Journal, Vol. 25, No.1, pp.85-107.

Leroueil, S., Kabbaj, M., Tavenas, F. & Bouchard, R. (1985). Stress-strain rate relation for the compressibility of sensitive natural clays. Géotechnique, Vol. 35 No.2, pp.159-180.

Leroueil, S., Samson, L. & Bozozuk, M. (1983a). Laboratory and field determination of preconsolidation pressures at Gloucester. Canadian Geotechnical Journal, Vol.20, No.3, pp.446-453.

Leroueil, S., Tavenas, F., Samson, L. & Morin, P. (1983). Preconsolidation pressure of Champlain clays. Part II. Laboratory determination. Canadian Geotechnical Journal, Vol.20, No.4, pp.803-816.

Morin, P., Leroueil, S. & Samson, L. (1983). Preconsolidation pressure of Champlain clays. Part I. *In-situ* determination. Canadian Geotechnical Journal, Vol.20, No.4, pp.782-802.

Rowe, P.W. & Barden, L. (1966). A new consolidation cell. Géotechnique, Vol.16, No.2, pp.162-170.

Smith, R.E. & Wahls, H.E. (1969). Consolidation under constant rate of strain. Journal of Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol.95, No.SM2, pp.519-539.

Wissa, A.E.Z., Christian, J.T., Davis, E.H. & Heinberg, S. (1971). Consolidation at constant rate of strain. Journal of Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol.97, No.SM10, pp.1393-1413.

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Table 1 - Trapped Water (Rim Drain) Calibration Results

Diaphragm Pressure (kPa)	Cell A		Cell B	
	Volume Change (ml)	Time (min)	Volume Change (ml)	Time (min)
0	0	---	0	3.5
20	26.1	3.5	31.2	1.0
50	27.1	0.5	38.5	0.5
100	27.7	0.2	39.8	0.2
200	28.2	0.2	41.2	0.2
300	28.4	0.2	42.9	0.2
400	28.5	0.2	44.3	0.2
500	28.6	0.2	45.4	0.2
600	28.7	0.2	46.0	0.2
700	28.7	---	46.7	0.2
800	28.7	---	47.5	0.2

Table 2 - Diaphragm Load Calibration Results

Diaphragm Pressure (kPa)	Cell A		Cell B	
	Reactionary Pressure (kPa)	Percentage Error (%)	Reactionary Pressure (kPa)	Percentage Error (%)
50	50	0	50	0
100	99	-1.0	99	-1.0
150	148	-1.3	148	-1.3
200	198	-1.0	198	-1.0
250	247	-1.2	246	-1.6
300	296	-1.3	295	-1.7
350	345	-1.4	344	-1.7
400	394	-1.5	393	-1.8
450	444	-1.3	442	-1.8
500	493	-1.4	491	-1.8
550	543	-1.3	540	-1.8
600	592	-1.3	589	-1.8
650	642	-1.2	638	-1.8
700	690	-1.4	687	-1.9
750	740	-1.3	736	-1.9
800	790	-1.3	785	-1.9

Table 3 - Schedule of Phase I Tests

Test No.	Cell	Test Type		Borehole	Sample Depth (m)
		Strain Condition	Drainage		
2A	B	free strain	vertical	SKMD 2/20	17 - 18
2B	A	free strain	vertical	SKMD 2/20	17 - 18
3A	B	free strain	lateral	SKMD 2/20	17 - 18
3B	B	equal strain	lateral	SKMD 2/20	17 - 18
Note: Test no. 1 is excluded due to large inclusion of shell fragments in the soil sample.					

Table 4 - Summary of Test Results for Phase I Tests

Test No.	Sample Depth (m)	Test Type		Cell	Average m_v (m^2/MN)	Average[(2)] c_v or c_h (m^2/year)
		Strain Condition	Drainage			
2A	17.74 - 17.99	free strain	vertical	B	1.22	2.6
2B	17.49 - 17.59	free strain	vertical	A	1.04	4.6
3A	17.69 - 17.74	free strain	lateral	B	1.61	10.6
3B	17.34 - 17.49	equal strain	lateral	B	0.98	13.3
Notes : (1) Test no.1 is excluded because of large inclusion of shell fragments in the soil sample. (2) Average for pressure range 80-320 kPa estimated from volume change curves.						

Table 5 - Summary of Soil Samples Received for Phase II Tests

Borehole No.	Sample No.	Depth (m)	Reduced Level (mPD)
519B08	20	31.0-32.0	-23.22 to -24.22
519B08	24	34.0-35.0	-26.22 to -27.22
519B09	19	29.5-30.5	-21.50 to -22.50
519B09	23	32.5-33.5	-24.50 to -25.50
519B12	13	27.0-28.0	-20.83 to -21.83
519B12	17	30.5-31.5	-24.33 to -25.33
TBM15	---	10.4	-11.9
TBM15	---	10.3	-11.8
TBM15	---	10.1	-11.6
Note : Sample type: 100 mm diameter piston tube sample.			

Table 6 - Summary of Test Results for Phase II Tests

Test No.	Borehole No.	Sample No.	Specimen Location		Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Bulk Unit Weight (kN/m^3)	Estimated Probable p_c' (kPa)				
									Constant Rate of Strain Test			Small Loading Oedometer Test	
			Depth (m)	Reduced Level (mPD)					strain rate (%/min)	using e-log(p) curve(1)	using Δu-log(p) curve	using e-log(p) curve(1)	using c_v-log(p) curve
CRS-1	519B08	20	31.0-31.1	-23.2 to -23.3	28.0	---	---	---	0.01	f(2)	100	---	---
OED-1	519B08	20	31.37-31.47	-23.59 to -23.69	28.4	46	20	19.57	---	---	---	85	135
CRS-2	519B08	24	34.3-34.5	-26.5 to -26.7	21.8	---	---	---	0.01	25	120	---	---
CRS-2a(3)	519B08	24	34.4	-26.6	23.4	---	---	---	0.01	f(2)	120	---	---
CRS-3	519B08	24	34.7-35.0	-26.9 to -27.2	29.4	---	---	---	0.01	f(2)	110	---	---
OED-2	519B08	24	34.12-34.22	-26.34 to -26.44	24.5	40	18	19.82	---	---	---	75	135
LTT-1(4)	519B08	24	34.22-34.32	-26.44 to -26.54	20.5	---	---	20.21	---	---	---	100	105
CRS-4	519B09	19	29.5-29.8	-21.5 to -21.8	53.9	---	---	---	0.01	110	110	---	---
CRS-5	519B09	19	30.3-30.5	-22.3 to -22.5	55.0	---	---	---	0.01	320	320	---	---
CRS-5a(3)	519B09	19	29.8-30.0	-21.8 to -22.0	56.4	---	---	---	0.01	320	320	---	---
OED-3	519B09	19	29.87-29.97	-21.87 to -21.97	56.8	65	30	16.48	---	---	---	75	120
OED-4	519B09	19	30.38-30.48	-22.38 to -22.48	55.2	---	---	16.58	---	---	---	80	105
CRS-6	519B09	23	33.0-33.2	-25.0 to -25.2	30.4	---	---	---	0.005	100	120	---	---
OED-5	519B09	23	32.97-33.05	-24.97 to -25.05	25.2	42	20	19.91	---	---	---	80	f(2)
OED-6	519B12	13	27.60-27.70	-19.43 to -19.53	44.2	54	23	17.27	---	---	---	65	f(2)
CRS-7	519B12	17	31.1-31.3	-24.9 to -25.1	41.6	---	---	---	0.01	150	100	---	---
OED-7	519B12	17	30.97-31.03	-22.80 to -22.86	42.4	48	24	17.56	---	---	---	55	105
TRIAL1	TBM15	---	10.4	-11.9	46.0	---	---	16.29	0.005	300	300	---	---
TRIAL2	TBM15	---	10.3	-11.8	59.2	---	---	16.25	0.01	310	310	---	---
TRIAL3	TBM15	---	10.1	-11.6	58.4	---	---	15.82	0.1	320	300	---	---

Notes:
(1) Most of these e-log(p) curves are very flat and the estimated p_c' is much less certain than the others.
(2) f indicates curves too flat to estimate the probable p_c'.
(3) Repeated test.
(4) Consolidation test, applied load = 450 kPa.
(5) Only cell B was used in the Phase II Tests.

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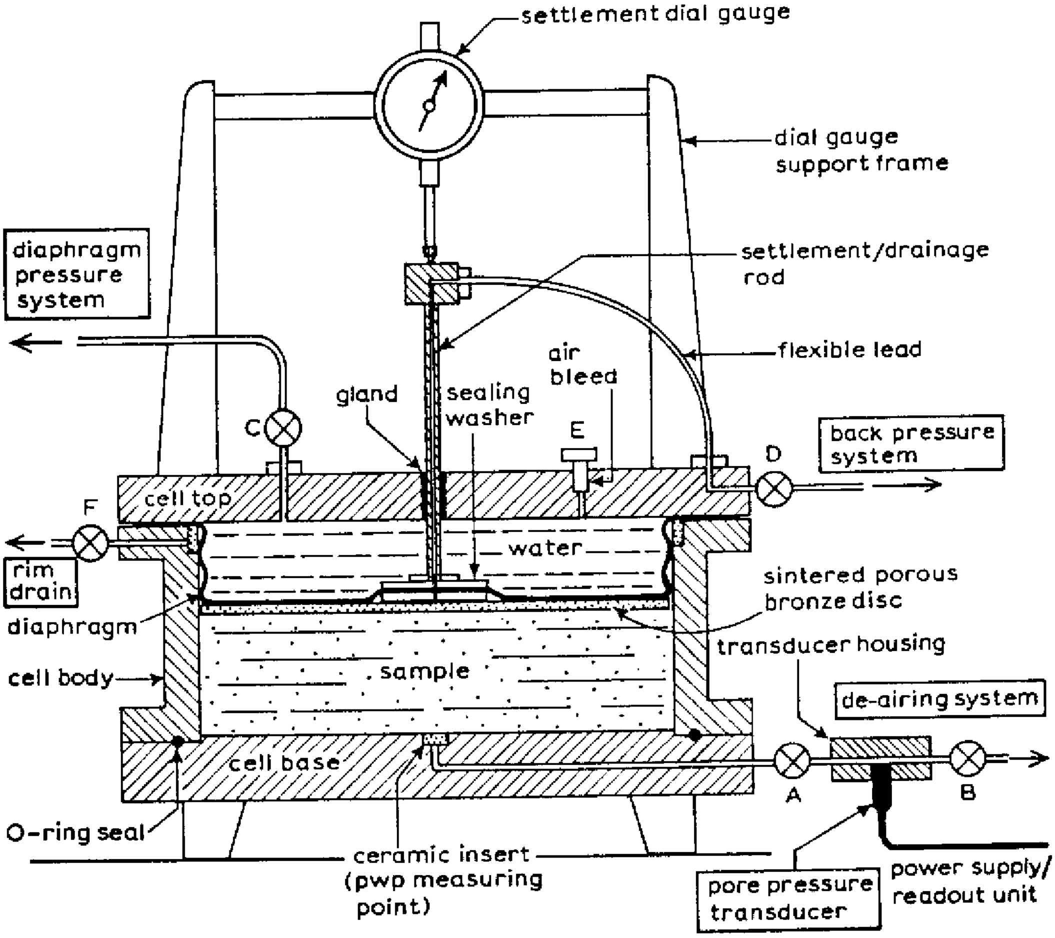
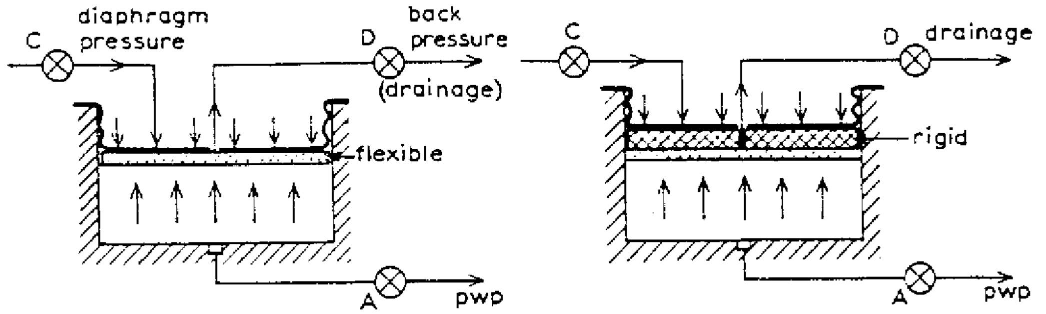
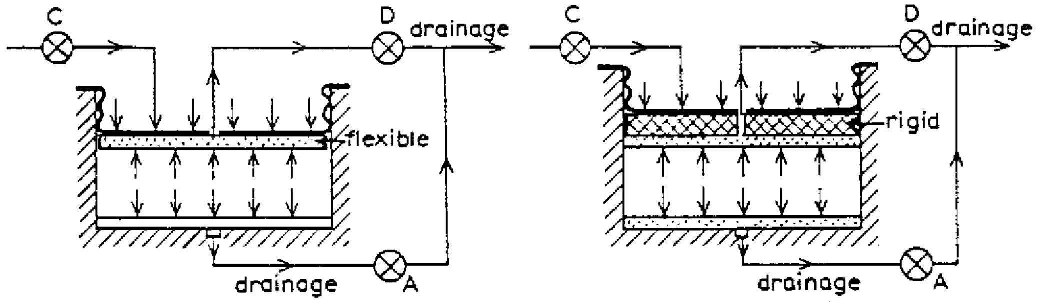


Figure 1 - Basic Configuration of the Rowe Cell (after ELE, 1990)



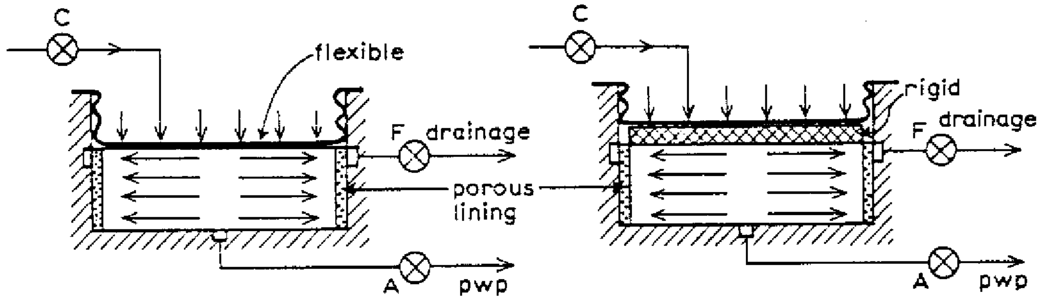
(a) Free Strain - Vertical Single Drainage

(b) Equal Strain - Vertical Single Drainage



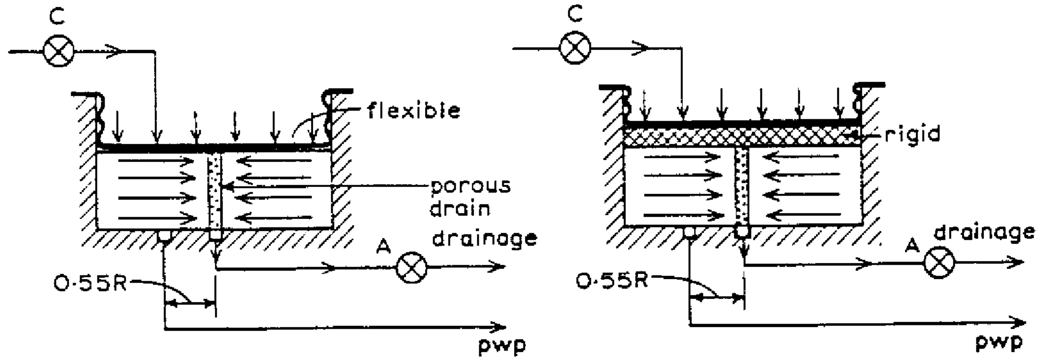
(c) Free Strain - Vertical Double Drainage

(d) Equal Strain - Vertical Double Drainage



(e) Free Strain - Horizontal outward Drainage

(f) Equal Strain - Horizontal outward Drainage



(g) Free Strain - Horizontal inward Drainage

(h) Equal Strain - Horizontal inward Drainage

Figure 2 - Different Types of Drainage and Loading Conditions in the Rowe Cell (after Head, 1985)

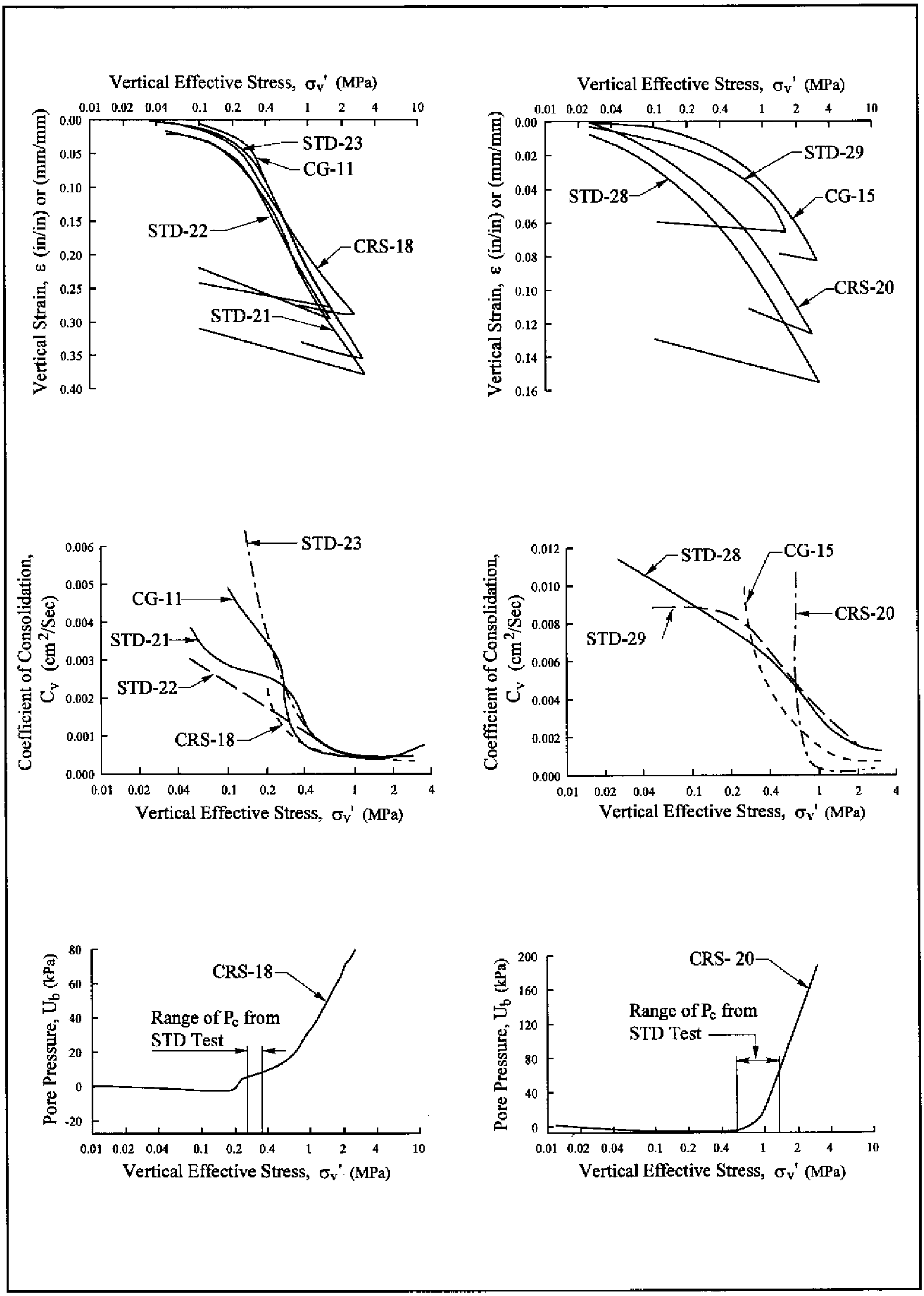


Figure 3- Comparison of Conventional (STD), Controlled Gradient(CG) and Constant Rate of Strain (CRS) Consolidation Test Results (after Gorman et al, 1978)

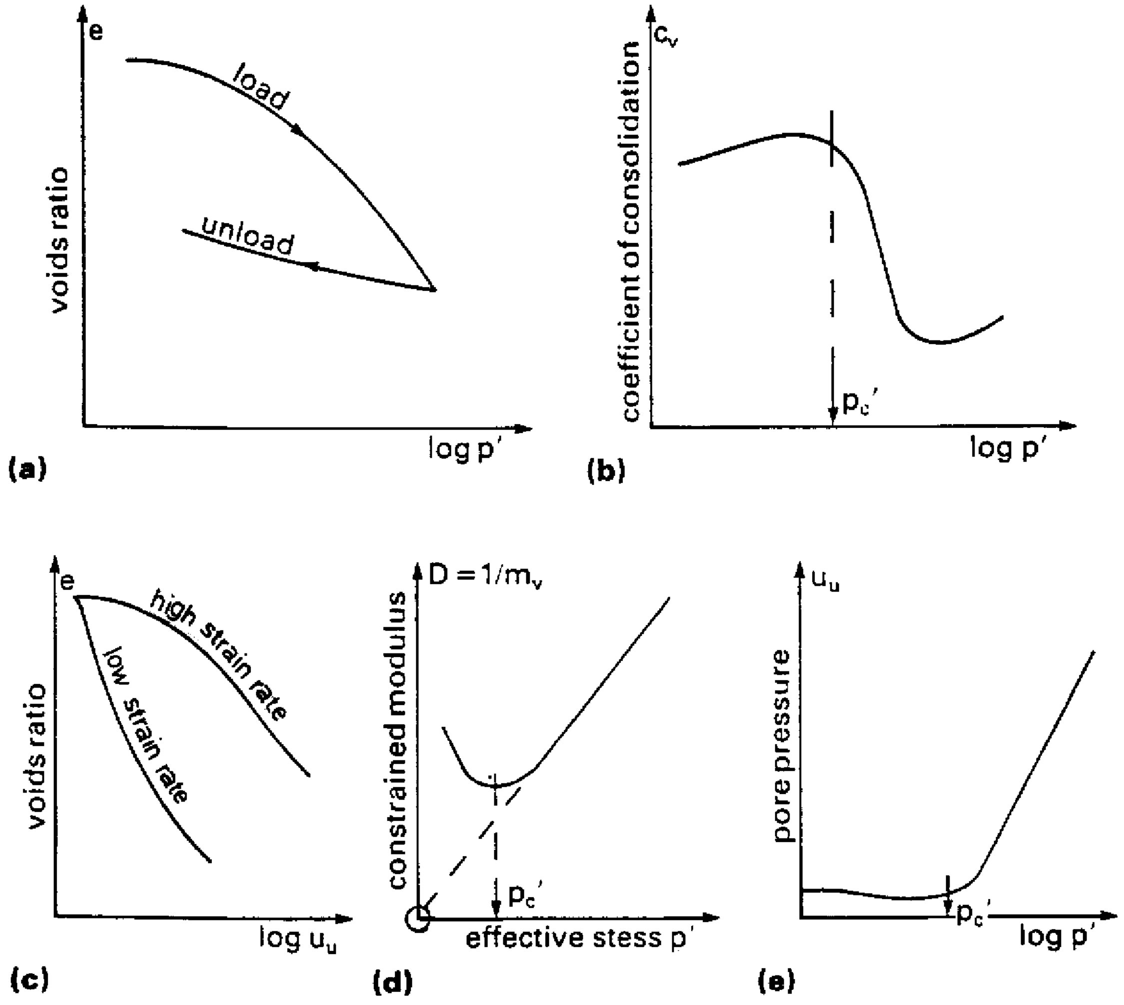


Figure 4 - Typical Graphical Plots Obtained from CRS Test (after Head, 1985)

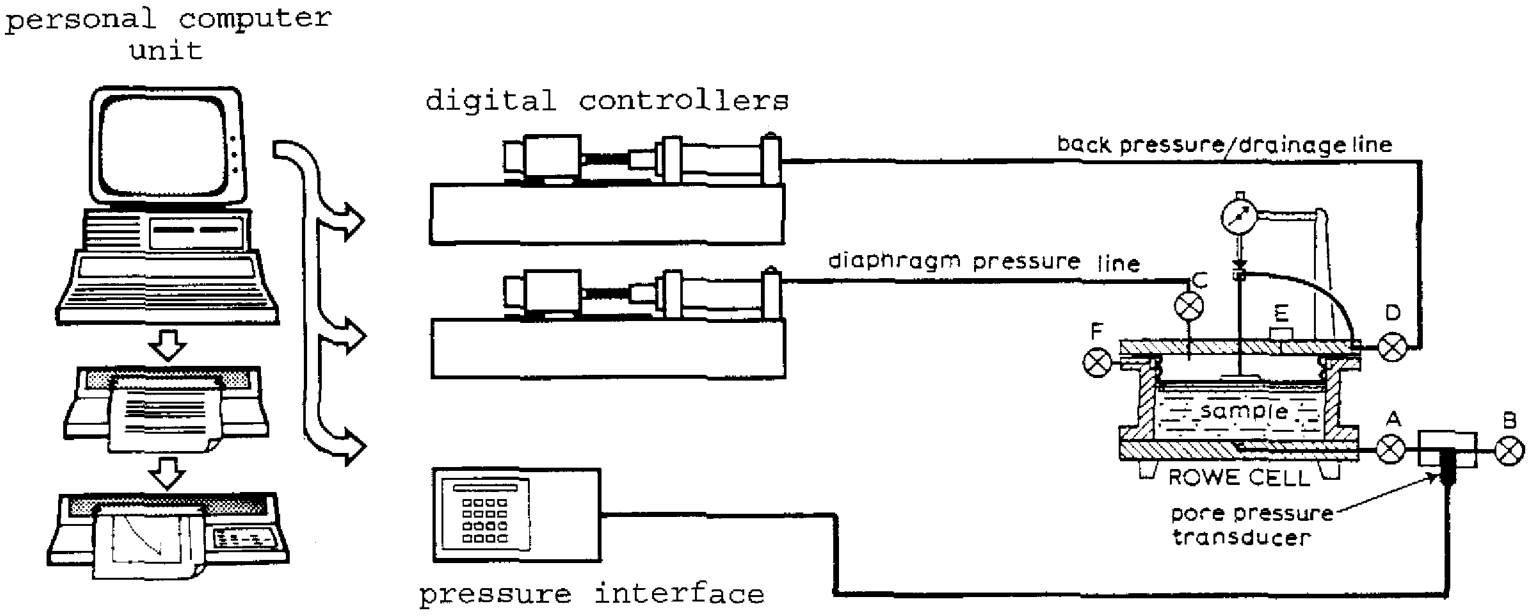


Figure 5 - Layout of GDS-Rowe Cell Testing System

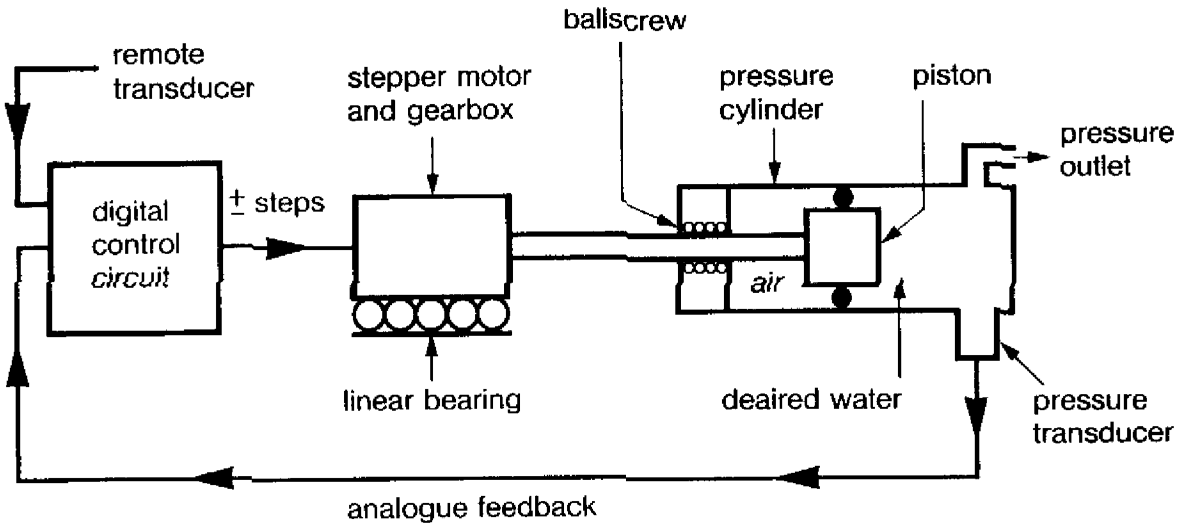


Figure 6 - Diagrammatic Layout of GDS Digital Controller (after GDS 1992a)

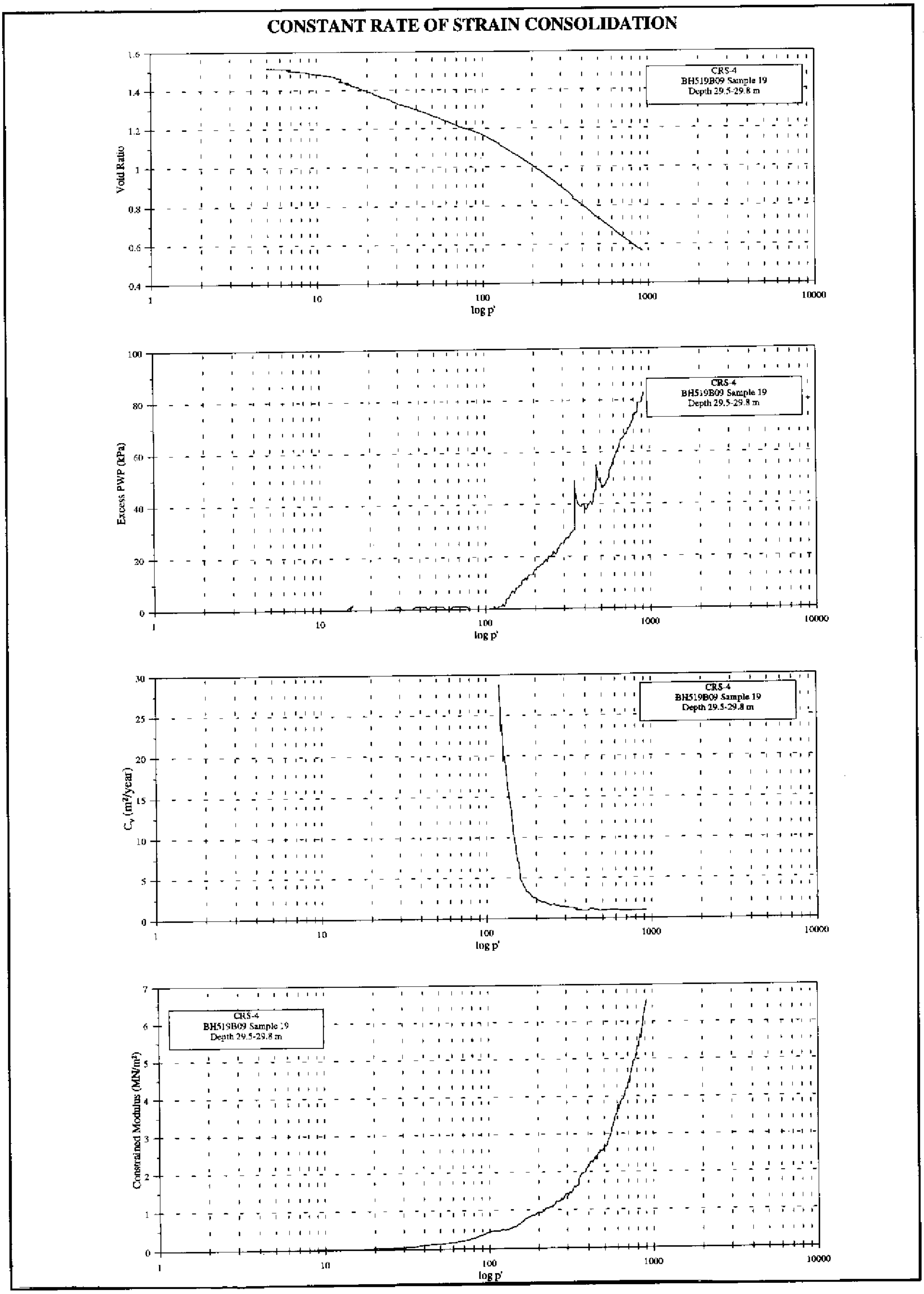


Figure 7 - Example of CRS Test Results, Low Preconsolidation Pressure (Test No. CRS-4)

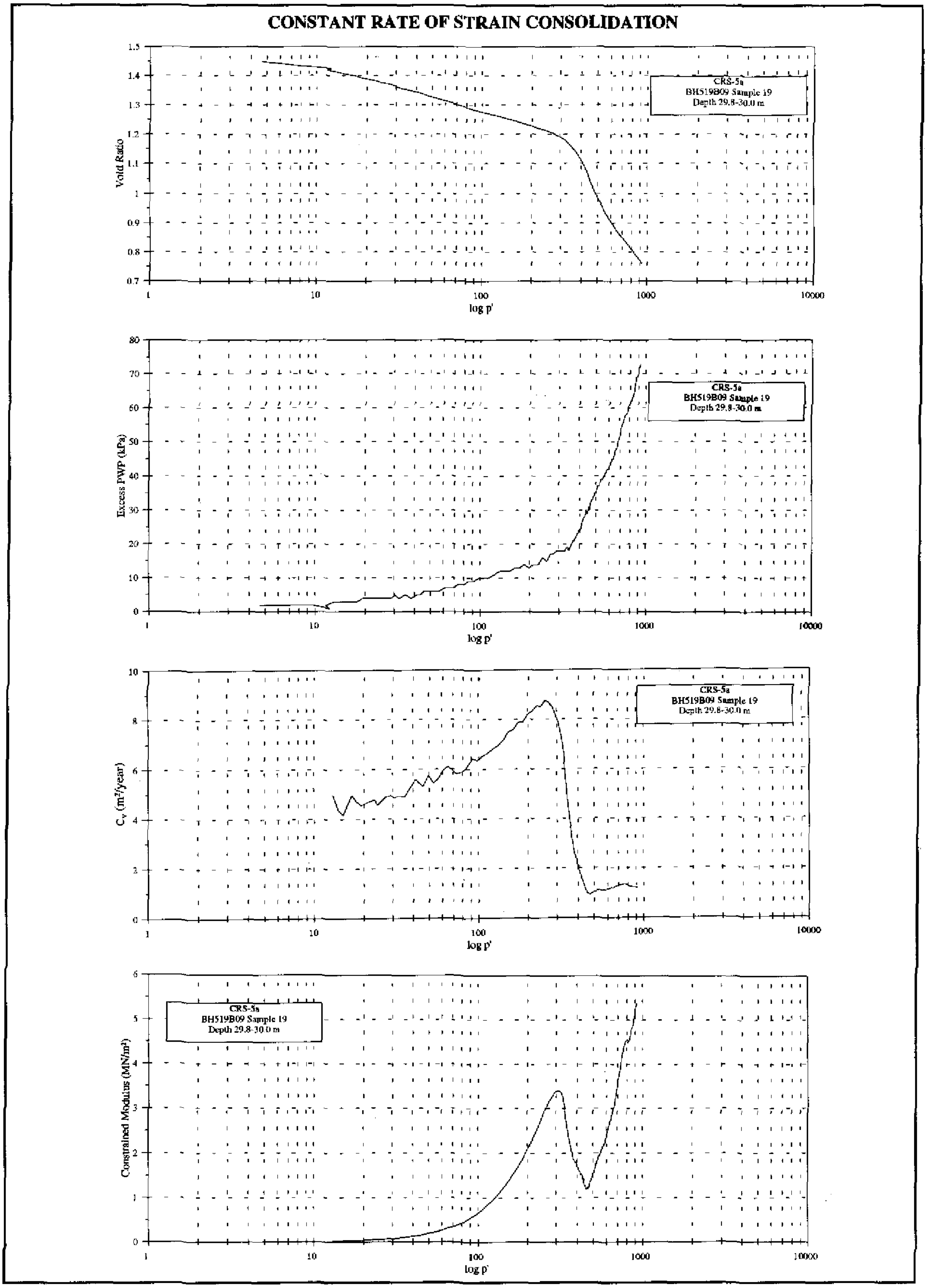


Figure 8 - Example of CRS Test Results, High Preconsolidation Pressure (Test No. CRS-5a)

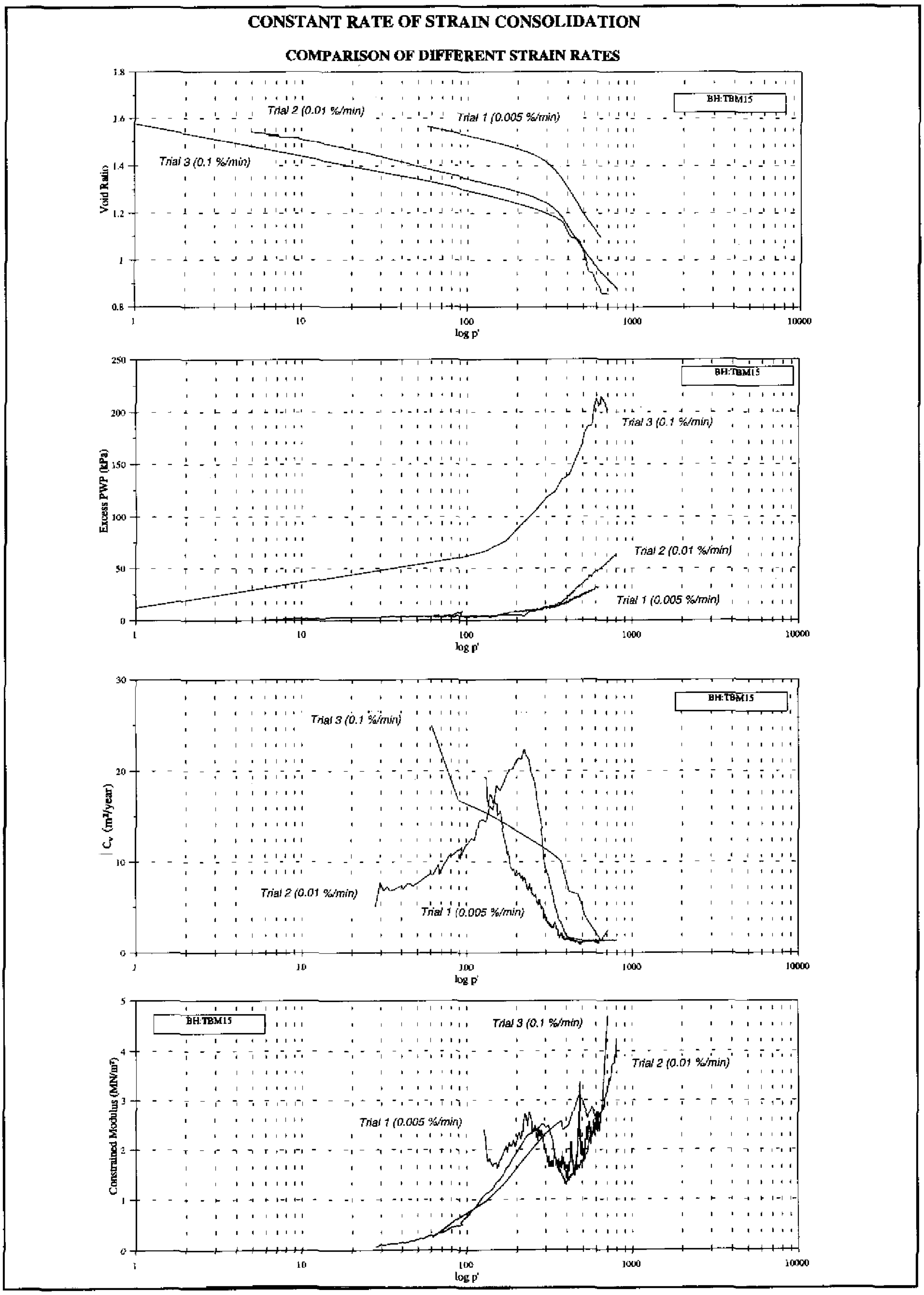
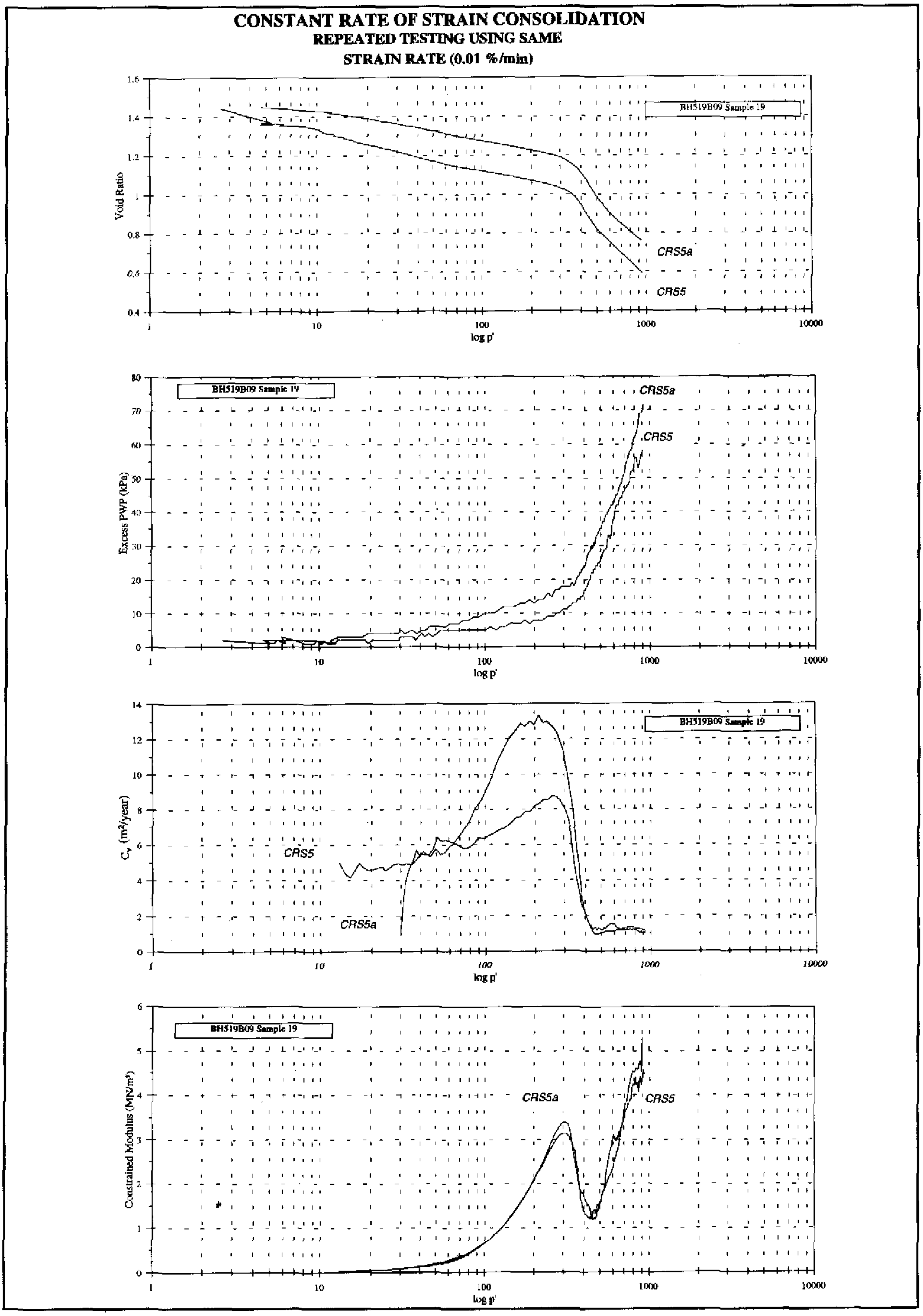


Figure 9 - Comparison of Three CRS Tests at Different Strain Rates
(Tests No. TRIAL-1, 2 & 3)



CONSTANT RATE OF STRAIN CONSOLIDATION
REPEATED TESTING USING SAME
STRAIN RATE (0.01 %/min)

Figure 10 - Results of a Set of Repeated Tests (Tests No. CRS-5 & 5a)

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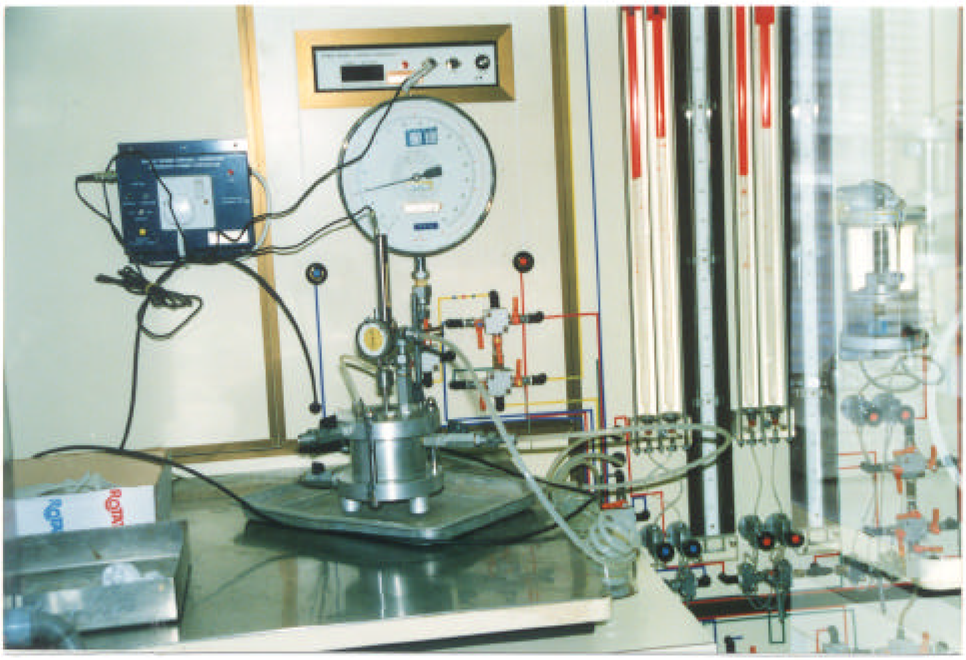
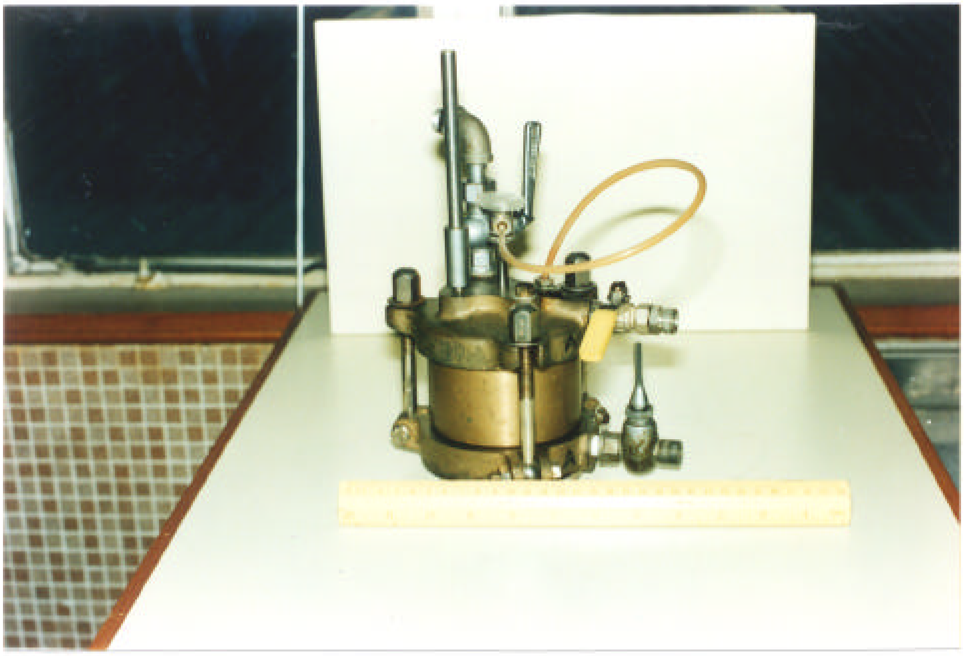


Plate 1 - Test Equipment for Rowe Cell Consolidation Test for Phase I Tests (Negative No. SP9226431)

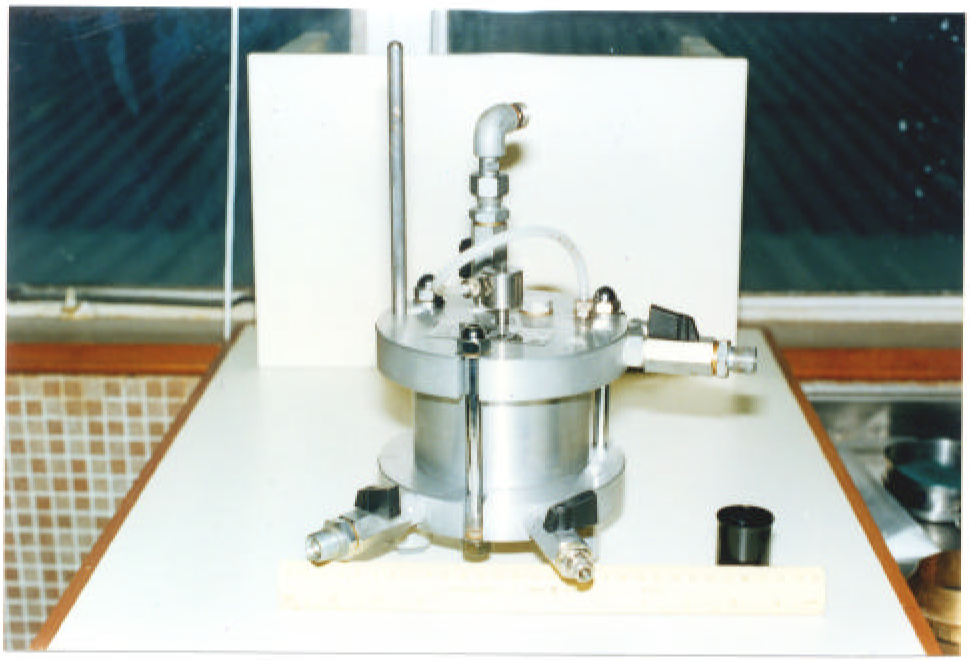
Plate 2 - Setup of the GDS Equipment for Continuous Loading Consolidation Test for Phase II Tests (Negative No. SP9411806)



(a) Rowe Cell Assembled

(b) Rowe Cell Disassembled

Plate 3 - Rowe Cell A Supplied by Arnfield Engineering, U.K.
(Negative Nos. SP9202716 & 11)



(a) Rowe Cell Assembled

(b) Rowe Cell Disassembled

Plate 4 - Rowe Cell B Supplied by ELE International, U.K.
(Negative Nos. SP9202706 & 09)

Plate 5 - Sample Cutting Ring for Rowe Cell A
(Negative No. SP9202718)

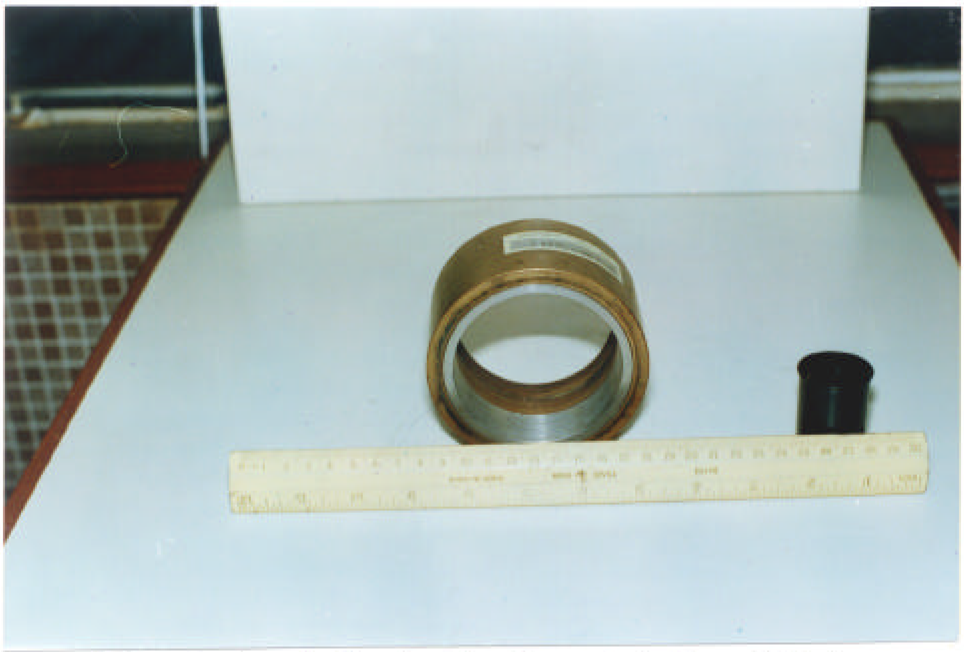


Plate 6 - Sample Cutting Ring Inserted in Rowe Cell A
(Negative No. SP9202720)

Plate 7 - Sample Cutting Shoe for Rowe Cell B
(Negative No. SP9202700)

Plate 8 - Sample Cutting Shoe Assembly Bolted to Rowe Cell B
(Negative No. SP9202703)

APPENDIX A

LOGS OF BOREHOLES FOR PHASE I TESTS

Gammon Construction Limited
Geotechnical Contracting Department

BOREHOLE RECORD

JOB NO. J1076
HOLE NO. SKMD2/20
SHEET 1 of 5
DATE from 16/04 to 17/04/91

PROJECT W.O PW7/2/29.57 FILL MANAGEMENT STUDY ADVANCE MARINE SITE INVESTIGATION IN SOKO ISLANDS

METHOD CABLE TOOL BORING	CO-ORDINATES E 805441.90 N 804750.30	ROCK COREBIT – –
MACHINE & No. HELEN POWER SWIVEL		HOLE DIA. 168mm 0.00m ------ 40.20m
FLUSHING MEDIUM /	ORIENTATION VERTICAL	SEABED LEVEL -6.20 mPD

Drilling Progress	Casing depth/size	Total core Recovery %	Solid core Recovery %	R. Q. D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Particle Size Distribution % Gravel	Sand	Silt	Clay	Shell Carbonate %	Description
16/04	SX	100				1 bl /0.45m	1			1	58	19	12		Very loose, dark greenish grey, very silty/clayey fine to medium SAND with some shell fragments. (MARINE DEPOSIT)
									0.45						
							2		1.00						
						(0,0 0,0,0,0) N=0	3		1.45						
							4		2.00						
		100				3 bls /0.45m	5		2.45	1	70	19	10		
							6	-9.20	3.00						
						(0,0 0,0,0,0) N=0	7		3.45	2	68	20	10		Very loose, olive grey, very silty/clayey fine to coarse SAND with some shell fragments. (MARINE DEPOSIT)
							8	-10.20	4.00						
		100				1 bl /0.45m	9		4.45						Very soft, olive grey, sandy SILT/CLAY with some shell fragments. (MARINE DEPOSIT)
							10		5.00						
						(0,0 0,0,0,0) N=0	11		5.45						
							12		6.00						
		100				4 bls /0.45m	13		6.45	7	51	31	11		
							14		7.00						
						(0,0 0,0,0,0) N=0	15		7.45						
							16		8.00						
		100				5 bls /0.45m	17		8.45						
							18		9.00						
						(0,0 0,0,0,0) N=0	19		9.45						
	10.00m						20	-16.20	10.00						

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	⧗	Water level
▮	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	⊥	Permeability test
■	U100 undisturbed sample	≙	Piezometer tip
■	Mazier sample	✓	In-situ vane shear test
P/S	Piston sample		

LOGGED S O CHAN
DATE 18/04/91
CHECKED S HUNG
DATE 29/04/91

REMARKS

Gammon Construction Limited
Geotechnical Contracting Department

BOREHOLE RECORD

JOB NO. J1076
HOLE NO. SKMD2/20
SHEET 2 of 5
DATE from 16/04 to 17/04/91

PROJECT W.O PW7/2/29.57 FILL MANAGEMENT STUDY ADVANCE MARINE SITE INVESTIGATION IN SOKO ISLANDS

METHOD CABLE TOOL BORING	CO-ORDINATES E 805441.90 N 804750.30	ROCK COREBIT – –
MACHINE & No. HELEN POWER SWIVEL		HOLE DIA. 0.00m 168mm 40.20m
FLUSHING MEDIUM /	ORIENTATION VERTICAL	SEABED LEVEL -6.20 mPD

Drilling Progress	Casing depth/size	Total core Recovery %	Solid core Recovery %	R. Q. D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Particle Size Distribution % Gravel	Sand	Silt	Clay	Shell Carbonate %	Description
18/04	SX	100				4 bls /0.45m	21		10.45							As sheet 1 of 5. (MARINE DEPOSIT)
							22	-17.20	11.00							
						(0,0 0,0,0,0) N=0	23		11.45		2	65	33			Dark greenish grey, very silty/clayey fine to medium SAND with some shell fragments. (MARINE DEPOSIT)
							24		12.00							
		100				1 bls /0.45m	25		12.45		1	70	29			
							26	-19.20	13.00							
						(0,0 0,0,0,0) N=0	27		13.45							Very soft, dark greenish grey, sandy SILT/CLAY with traces of shell fragments. (MARINE DEPOSIT)
							28		14.00							
		100				3 bls /0.45m	29		14.45							
							30		15.00							
		100					P/S 31		16.00							
							32		17.00							
		100					P/S 33	-24.20	18.00							
							34		19.00							Soft to firm, dark greenish grey, sandy SILT/CLAY with traces of shell fragments. (MARINE DEPOSIT)
	20.00m	100					P/S 35		20.00							

•	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	▼	Water level
▮	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	⌶	Permeability test
■	U100 undisturbed sample	▲	Piezometer tip
■	Mazier sample	∨	In-situ vane shear test
P/S	Piston sample		

LOGGED S O CHAN
DATE 18/04/91
CHECKED S HUNG
DATE 29/04/91

REMARKS

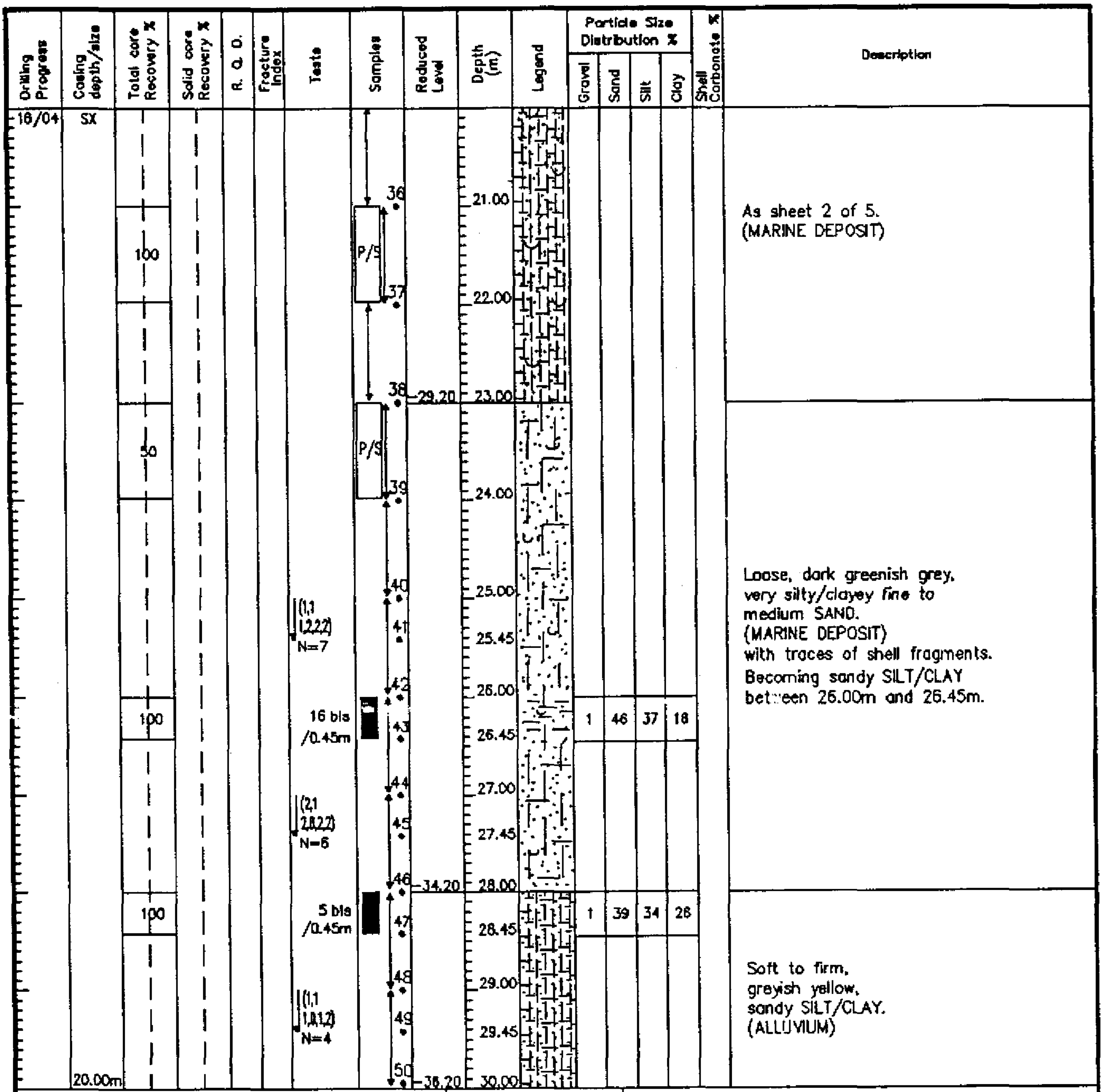
Gammon Construction Limited
Geotechnical Contracting Department

BOREHOLE RECORD

JOB NO. J1076
HOLE NO. SKMD2/20
SHEET 3 of 5
DATE from 16/04 to 17/04/91

PROJECT W.O PW7/2/29.57 FILL MANAGEMENT STUDY ADVANCE MARINE SITE INVESTIGATION IN SOKO ISLANDS

METHOD CABLE TOOL BORING	CO-ORDINATES E 805441.90 N 804750.30	ROCK COREBIT – –
MACHINE & No. HELEN POWER SWIVEL		HOLE DIA. 168mm 0.00m ----- 40.20m
FLUSHING MEDIUM /	ORIENTATION VERTICAL	GROUND-LEVEL -6.20 mPD



Drilling Progress	Casing depth/size	Total core Recovery %	Tests	Samples	Reduced Level	Depth (m)	Gravel	Sand	Silt	Clay	Description
16/04	SX			36		21.00					As sheet 2 of 5. (MARINE DEPOSIT)
		100		P/S, 37		22.00					
				38	-29.20	23.00					
		50		P/S, 39		24.00					Loose, dark greenish grey, very silty/clayey fine to medium SAND. (MARINE DEPOSIT) with traces of shell fragments. Becoming sandy SILT/CLAY between 26.00m and 26.45m.
			(1,1 1,2,2,2) N=7	40, 41		25.00 25.45					
		100	16 bls /0.45m	42, 43		26.00 26.45	1	46	37	18	
			(2,1 2,0,2,2) N=6	44, 45		27.00 27.45					
		100	5 bls /0.45m	46, 47	-34.20	28.00 28.45	1	39	34	26	Soft to firm, greyish yellow, sandy SILT/CLAY. (ALLUVIUM)
	20.00m		(1,1 1,0,1,2) N=4	48, 49, 50	-36.20	29.00 29.45 30.00					

● Small disturbed sample	▲ Water sample
↕ Large disturbed sample	⌅ Water level
▮ SPT liner sample	↓ Standard penetration test
▮ U76 undisturbed sample	⟂ Permeability test
■ U100 undisturbed sample	≜ Piezometer tip
■ Mazier sample	∨ In-situ vane shear test
P/S Piston sample	

LOGGED S O CHAN
DATE 18/04/91
CHECKED S HUNG
DATE 29/04/91

REMARKS

Gammon Construction Limited
Geotechnical Contracting Department

BOREHOLE RECORD

JOB NO. J1076
HOLE NO. SKMD2/20
SHEET 4 of 5
DATE from 16/04 to 17/04/91

PROJECT W.O PW7/2/29.57 FILL MANAGEMENT STUDY ADVANCE MARINE SITE INVESTIGATION IN SOKO ISLANDS

METHOD CABLE TOOL BORING	CO-ORDINATES E 805441.90 N 804750.30	ROCK COREBIT - -
MACHINE & No. HELEN POWER SWIVEL		HOLE DIA. 168mm 0.00m ------ 40.20m
FLUSHING MEDIUM	ORIENTATION VERTICAL	GROUND-LEVEL -6.20 mPD

Drilling Progress	Casing depth/size	Total core Recovery %	Solid core Recovery %	R. Q. D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Particle Size Distribution % Gravel	Sand	Silt	Clay	Shell Carbonate %	Description
16/04	SX	100				8 bls	51									As sheet 3 of 5. (ALLUVIUM)
									30.45							
						(1,1 2,2,2,3) N=9	52		31.00							
							53		31.45							
		100				6 bls	54		32.00							
							55		32.45							
						(1,1 2,2,4,3) N=11	56	-39.20	33.00							Medium dense, greyish yellow blue, gravelly silty/clayey fine to coarse SAND. (ALLUVIUM)
17/04							57		33.45							
		100				13 bls	58		34.00							
							59		34.45		6	82	12			
						(2,2 3,4,6,9) N=22	60	-41.20	35.00							Medium dense, greyish bluish yellow, very silty/clayey fine to coarse SAND. (ALLUVIUM)
							61		35.45							
		100				9 bls	62	-42.20	36.00							Medium dense, light grey, very silty/clayey fine to coarse SAND. (ALLUVIUM)
							63		36.45		1	[illegible]	25			
						(1,2 2,2,3,3) N=10	64	-43.20	37.00							Light grey, sandy SILT/CLAY. (ALLUVIUM)
							65		37.45		1	59	26	14		
		100				10 bls	66		38.00							
							57		38.45							
						(1,2 2,2,3,3) N=10	68		39.00							
							69		39.45							
	40.00m						70	-46.20	40.00							

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	⌅	Water level
▨	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	⊤	Permeability test
■	U100 undisturbed sample	≑	Piezometer tip
▦	Mazier sample	∨	In-situ vane shear test
P/S	Piston sample		

LOGGED SOC
DATE 18/04/91
CHECKED SH
DATE 29/04/91

REMARKS
Descriptions provided by Binnie Consultants Ltd.

Gammon Construction Limited
Geotechnical Contracting Department

BOREHOLE RECORD

JOB NO. J1076
HOLE NO. SKMD2/20
SHEET 5 of 5
DATE from 16/04 to 17/04/91

PROJECT W.O PW7/2/29.57 FILL MANAGEMENT STUDY ADVANCE MARINE SITE INVESTIGATION IN SOKO ISLANDS

METHOD CABLE TOOL BORING	CO-ORDINATES E 805441.90 N 804750.30	ROCK COREBIT - -
MACHINE & No. HELEN POWER SWIVEL		HOLE DIA. 0.00m 168mm 40.20m
FLUSHING MEDIUM /	ORIENTATION VERTICAL	GROUND-LEVEL -6.20 mPD

Drilling Progress	Casing depth/size	Total core Recovery %	Solid core Recovery %	R. Q. D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Particle Size Distribution %				Shell Carbonate %	Description
											Gravel	Sand	Silt	Clay		
17/04	SX		D			30 bls /0.08m	■ ↕ 71 72	-46.40	40.20	∴						Extremely weak to weak greenish black completely decomposed GRANITE. (Fine to coarse SAND) End of Hole at 40.20m.

•	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	⌅	Water level
▮	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	⌶	Permeability test
■	U100 undisturbed sample	⁑	Piezometer tip
■	Mazier sample	∨	In-situ vane shear test
P/S	Piston sample		

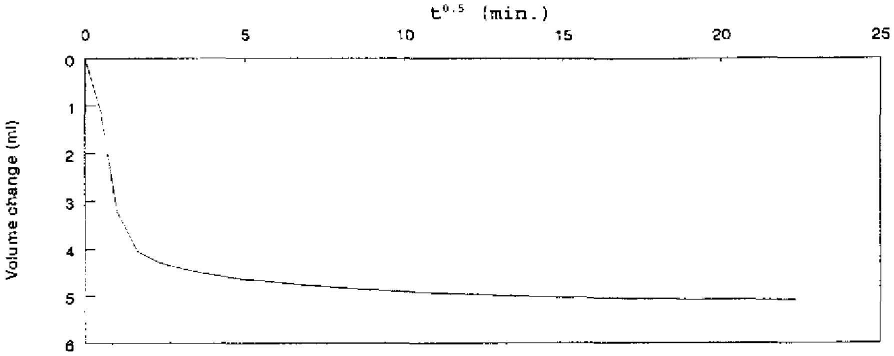
LOGGED S O CHAN
DATE 18/04/91
CHECKED S HUNG
DATE 29/04/91

REMARKS

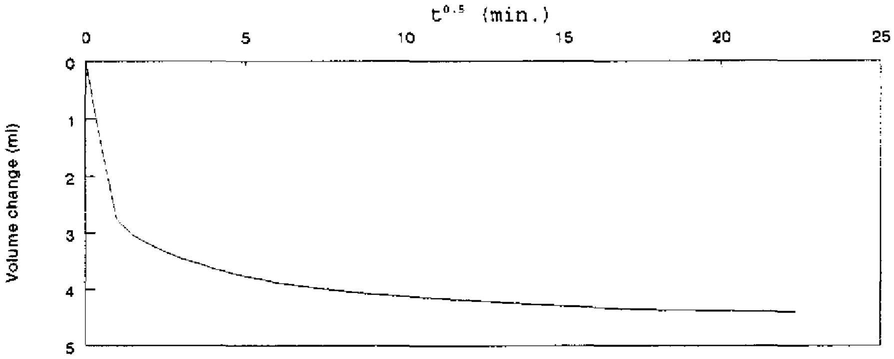
APPENDIX B

ROWE CELL CONSOLIDATION CURVES FROM PHASE I TESTS

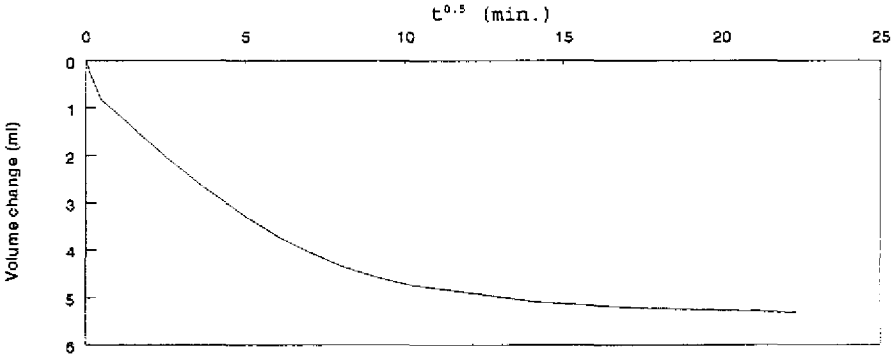
ROWE CELL TEST NO.2A – VOLUME CHANGE



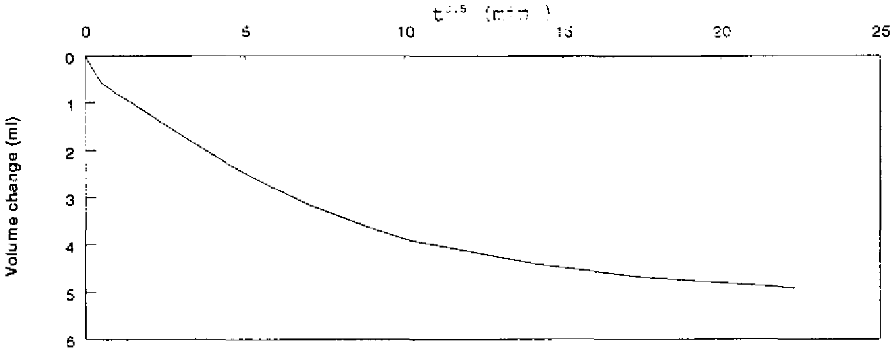
Load stage 1
Effective pressure 20 kPa



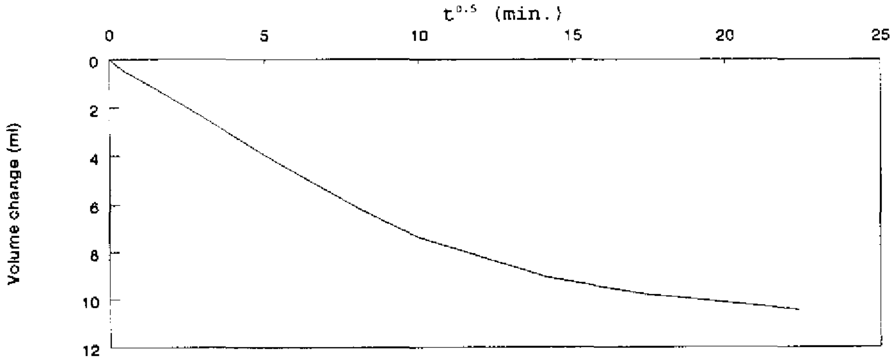
Load stage 2
Effective pressure 40 kPa



Load stage 3
Effective pressure 80 kPa

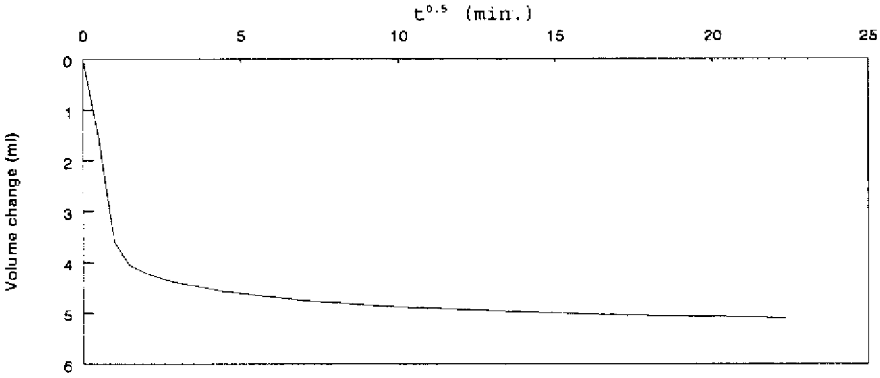


Load stage 4
Effective pressure 160 kPa

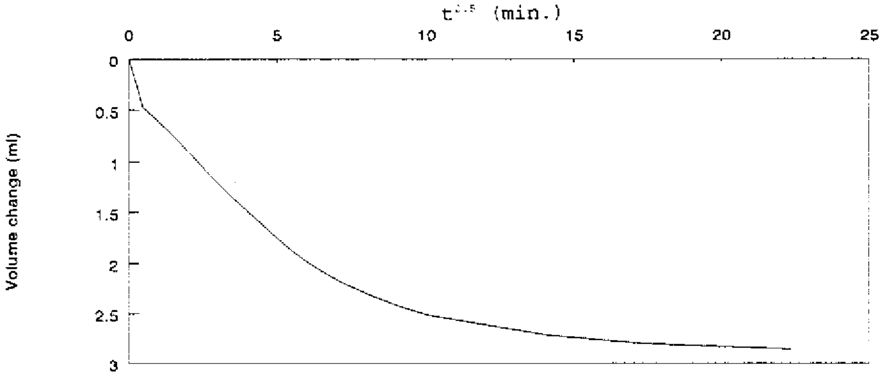


Load stage 5
Effective pressure 320 kPa

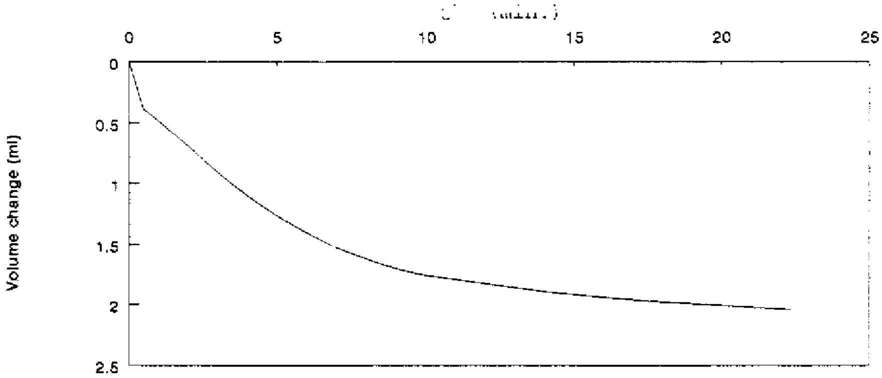
ROWE CELL TEST NO.2B – VOLUME CHANGE



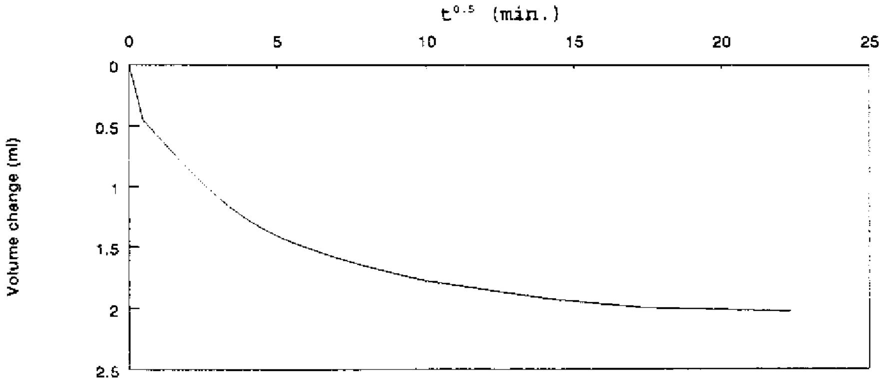
Load stage 1
Effective pressure 20 kPa



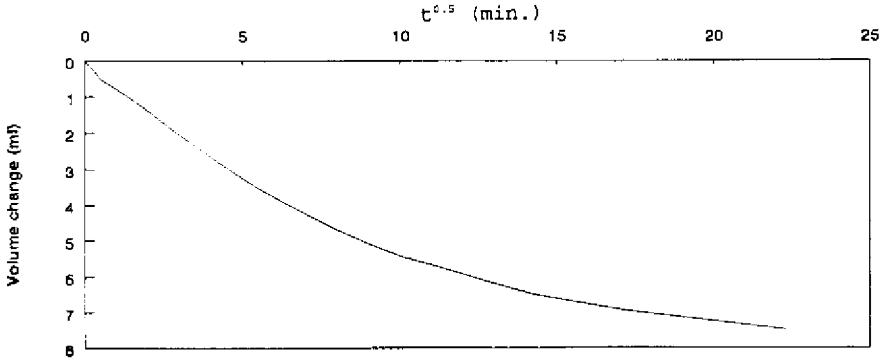
Load stage 2
Effective pressure 40 kPa



Load stage 3
Effective pressure 80 kPa

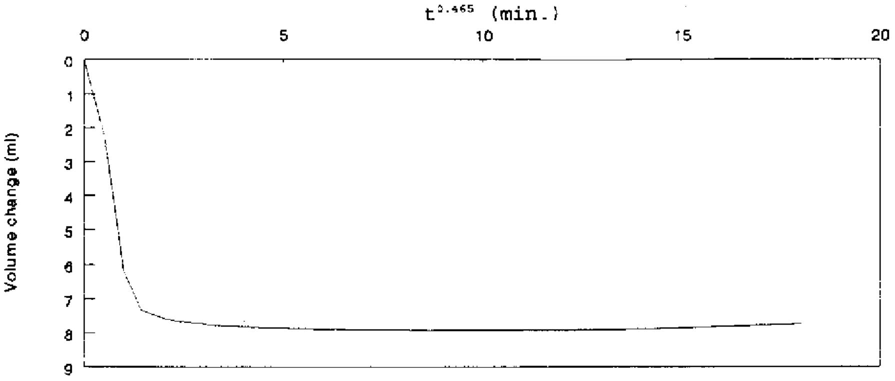


Load stage 4
Effective pressure 160 kPa

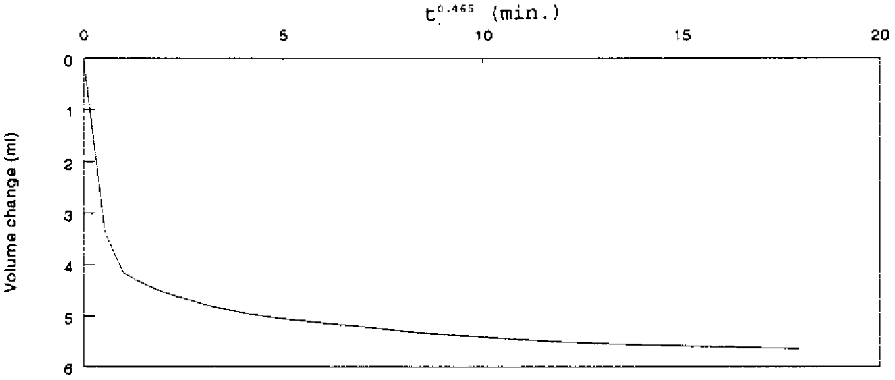


Load stage 5
Effective pressure 320 kPa

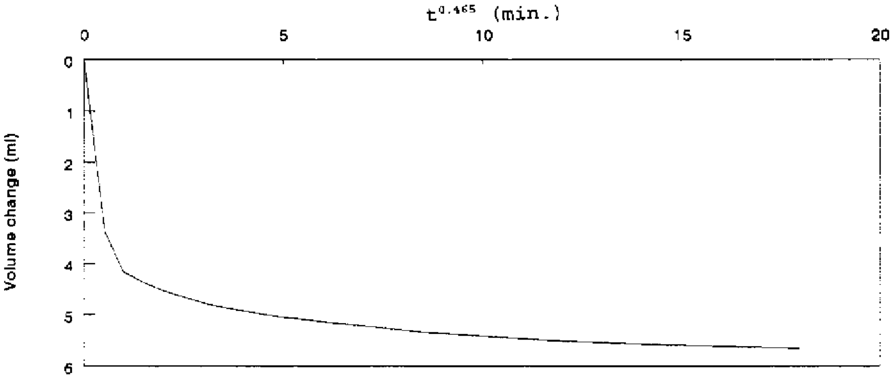
ROWE CELL TEST NO.3A – VOLUME CHANGE



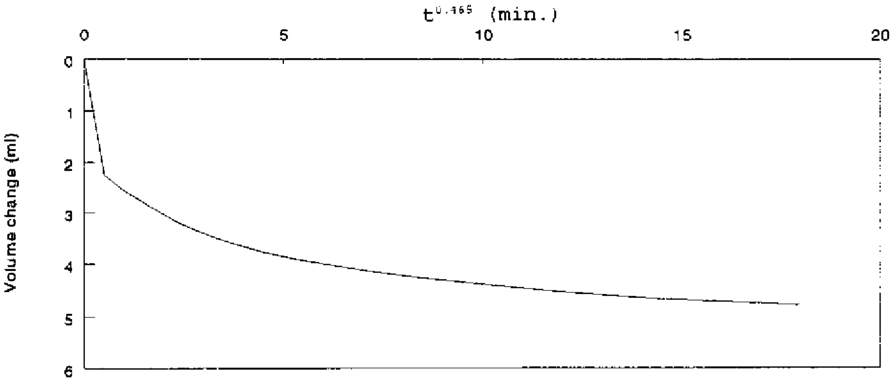
Load stage 1
Effective pressure 20 kPa



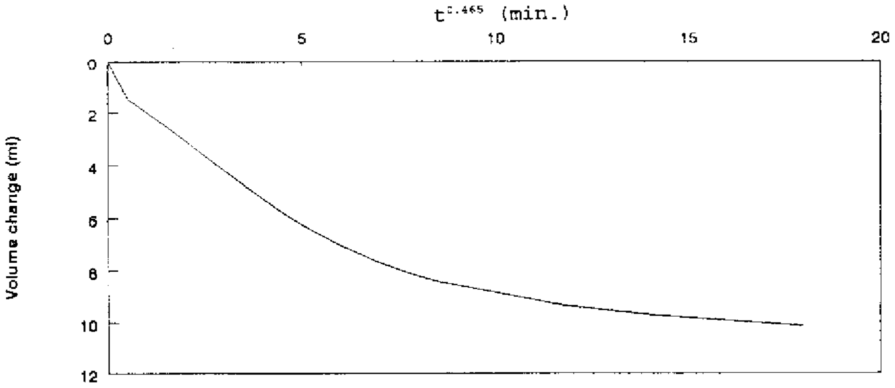
Load stage 2
Effective pressure 40 kPa



Load stage 3
Effective pressure 80 kPa

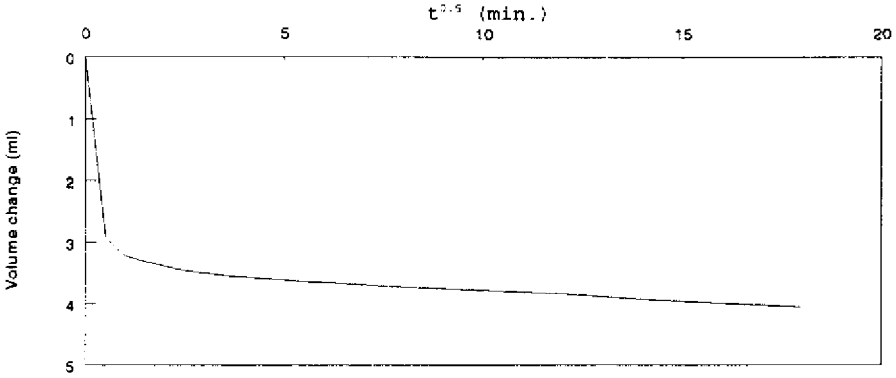


Load stage 4
Effective pressure 160 kPa

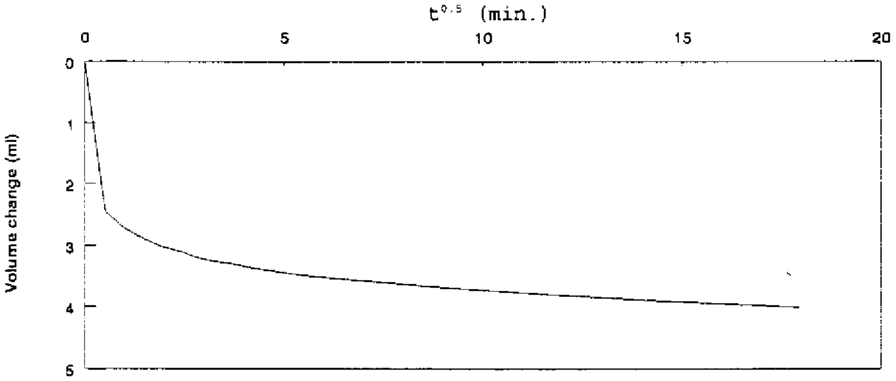


Load stage 5
Effective pressure 320 kPa

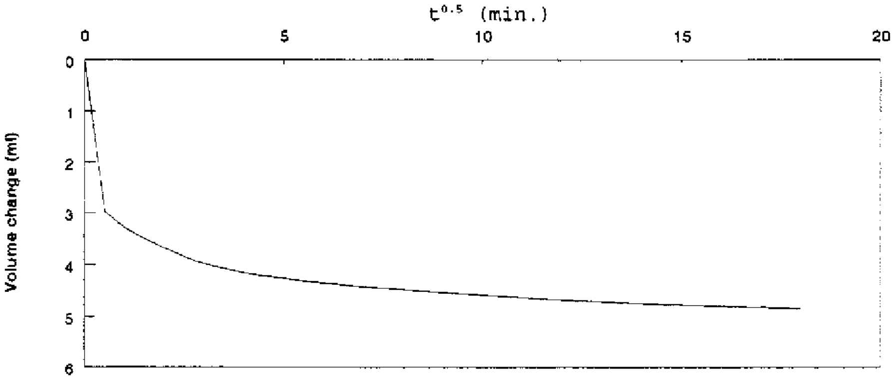
ROWE CELL TEST NO.3B - VOLUME CHANGE



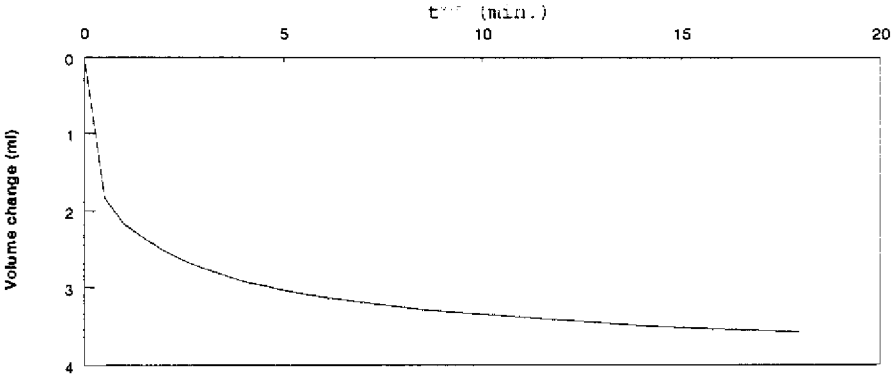
Load stage 1
Effective pressure 20 kPa



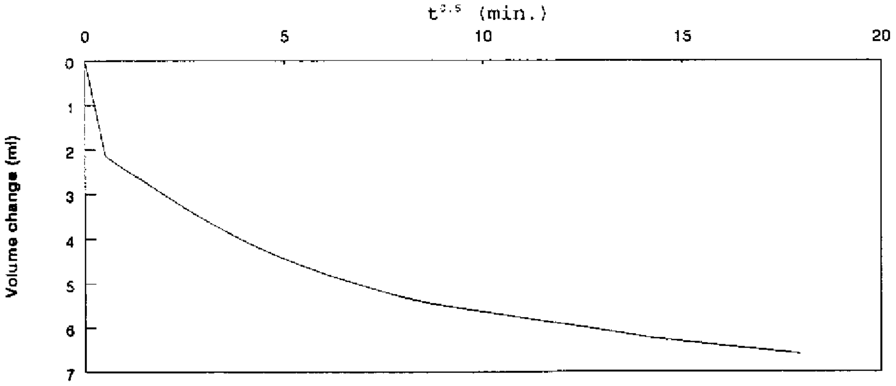
Load stage 2
Effective pressure 40 kPa



Load stage 3
Effective pressure 80 kPa



Load stage 4
Effective pressure 160 kPa



Load stage 5
Effective pressure 320 kPa

APPENDIX C

LOGS OF BOREHOLES FOR PHASE II TESTS

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B08
SHEET 1 of 5
DATE from 16/07/94 to 30/07/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY
MACHINE & No. ACKER D90 /ACKER 20
FLUSHING MEDIUM AIR / WATER
CO-ORDINATES E 808174.15 N 817722.95
ORIENTATION Vertical
ROCK COREBIT T2101
HOLE DIA. 140mm 114mm 0.00m-21.00-42.35m
GROUND-LEVEL 7.67 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level 7.67	Depth (m) 0.00	Legend	Grade	Zone	Description
16/7	PX														Rock (FILL)

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample		Standpipe tip
‖	SPT liner sample	↓	Standard penetration test
▌	U76 undisturbed sample		Permeability test
█	U100 undisturbed sample		Piezometer tip
▨	Mazier sample	IP	Impression Packer test
▤	Piston sample	HV/V	Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 01/08/94
CHECKED CBT
DATE 02/08/94

REMARKS
Designated fill type A placed above -13.33mPD
Percussive drilling from 0.00m-19.00m

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B08
SHEET 2 of 5
DATE from 16/07/94 to 30/07/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 808174.15 N 817722.95	ROCK COREBIT T2101
MACHINE & No. ACKER D90 /ACKER 20		HOLE DIA. 140mm 114mm 0.00m-21.00-42.35m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 7.67 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
										-2.33	10.00				
16/7		3.05m								-11.33	19.00				
18/7		1.85m							T2101						Yellowish brown coarse angular *GRAVEL and COBBLES of granite with* a matrix of fine to medium sand (FILL)

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	♁	Standpipe tip
‖	SPT liner sample	↓	Standard penetration test
▌	U76 undisturbed sample	⊥	Permeability test
█	U100 undisturbed sample	♁	Piezometer tip
▨	Mazier sample	IP	Impression Packer test
▤	Piston sample	HV / V	Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 30/07/94
CHECKED CBT
DATE 02/08/94

REMARKS

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B08
SHEET 3 of 5
DATE from 16/07/94 to 30/07/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 808174.15 N 817722.95	ROCK COREBIT T2101
MACHINE & No. ACKER D90 /ACKER 20		HOLE DIA. 140mm 114mm 0.00m-21.00-42.35m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 7.67 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
										-12.33	20.00				
	PX			13					T2101	-13.33	21.00				AS SHEET 2 OF 5
	21.00m HX			100				49bls	1 ●		21.45				Firm to very stiff, light grey mottled reddish brown streaked yellowish brown sandy clayey SILT (ALLUVIUM)
								(4,4,6,7,11,18) N=42	2 ●		21.95				
18/7 19/7		3.50m 2.10m		100				34bls	3 ●		22.45				
								(3,3,5,5,7,8) N=25	4 ●		22.95				
				100				36bls ♁	5 ●	-15.83	23.45 23.50				
								(3,3,4,6,7,10) N=27	6 ●	-16.33	23.95 24.00				Very stiff, grey slightly sandy very clayey SILT with occasional black organic fragments (ALLUVIUM)
				100				43bls	7 ●	-16.83	24.45 24.50				Firm to stiff, light grey silty CLAY (ALLUVIUM)
								(2,2,2,3,5,7) N=17	8 ●		24.95				Firm to stiff, yellowish brown streaked dark brown slightly clayey to clayey SILT with occasional dark brown silt nodules (<4mm) (ALLUVIUM)
19/7 20/7		2.00m 1.95m		100				48bls	9 ●		25.45				
								(2,3,3,4,6,9) N=22	10 ●		25.95				
				100				36bls	11 ●	-18.83	26.45 26.50				
								(2,2,3,3,4,4) N=14	12 ●		26.95				Soft to firm, dark grey silty CLAY (ALLUVIUM)
20/7 21/7		2.70m 2.50m		100				46bls	13 ●		27.45				
								(3,3,3,4,3,3) N=13	14 ●		27.95				
				100				23bls	15 ●		28.45				28.50-31.00: very silty
								(1,2,2,3,3,4) N=12	16 ●		28.95				
21/7 22/7		3.10m 2.65m		100				33bls	17 ●		29.45				229.50-31.00: with occasional black organic fragments

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	♁	Standpipe tip
▯	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	⌶	Permeability test
■	~~U100~~ undisturbed sample	♁	Piezometer tip
▨	Mazier sample	ℙ	Impression Packer test
☰	Piston sample	HV/V	Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 30/07/94
CHECKED CBT
DATE 02/08/94

REMARKS
Vibrating wire piezometer installed at 25.37m

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B08
SHEET 4 of 5
DATE from 16/07/94 to 30/07/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 808174.15 N 817722.95	ROCK COREBIT T2101
MACHINE & No. ACKER D90 /ACKER 20		HOLE DIA. 140mm 114mm 0.00m-21.00-42.35m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 7.67 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level -22.33	Depth (m) 30.00	Legend	Grade	Zone	Description
				100					▤						AS SHEET 3 OF 5
22/7		3.50m							18 ●		30.50				
23/7		2.10m													
								V	19 ●	-23.33	30.95 31.00				
				100					▤						Firm, yellowish brown streaked light grey clayey SILT (ALLUVIUM)
									20 ●		32.00				32.00-33.50: stiff
23/7		3.70m						V	21 ●		32.50				
25/7		2.00m		100					▤						
									22 ●		33.50				
25/7		3.50m						V Ô	23 ●		34.00				
26/7		2.30m		100					▤						
									24 ●		35.00				
26/7		3.59m						V	25 ●		35.50				35.50-35.00: slightly clayey slightly sandy
27/7		1.73m		100					▤						
									26 ●		36.50				
27/7		3.17m						V	27 ●	-29.33	37.00				Firm, light grey clayey SILT (ALLUVIUM)
28/7		0.59m		100					▤						
									28 ●		38.00				
28/7		3.67m						V 171bls	29 ●	-30.83	38.50				Grey and whitish grey, slightly clayey silty sandy subangular locally subrounded coarse GRAVEL of granite and dolerite (COLLUVIUM)
29/7		1.03m		0					■						
								(4,7, 7,10, 14,20) N=51	30 ●		38.95				
								270bls	31 ●		39.45				
				0					■ 32 ●		39.95				

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	≙	Standpipe tip
‖	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	⊥	Permeability test
■	U100 undisturbed sample	Ô	Piezometer tip
▨	Mazier sample	⌶	Impression Packer test
▤	Piston sample	HV/V	Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 30/07/94
CHECKED CBT
DATE 02/08/94

REMARKS

Vibrating wire piezometer installed at 34.17m
In situ vane shear tests at 31.00m (61.40kPa) 32.50m (78.39kPa), 34.00m (56.73kPa), 35.50m (61.40kPa), 37.00m (41.91kPa) and at 38.50m (75.54kPa)

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.:	255
HOLE NO.:	519808
SHEET	5 of 5
DATE from	16/07/94 to 30/07/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 808174.15 N 817722.95	ROCK COREBIT T2101
MACHINE & No. ACKER D90 /ACKER 20		HOLE DIA. 140mm 114mm 0.00m-21.00-42.35m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 7.67 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
										-32.33	40.00				AS SHEET 4 OF 5
								(17,29, 31,39, 52,71) N=193	● 33 ●		40.45 40.50				
29/7		3.72m		75							41.80				40.50-41.80: gravel and cobbles
30/7	HX 42.35M	1.67m		86					T2101	-34.68	42.35				
30/7				100	100	100	1.3			-36.28	43.95		II		Strong, greyish pink spotted black slightly decomposed coarse grained slightly chloritised GRANITE with medium spaced rough undulating rough stepped clean joints, dipping at 10° and 75°
															END OF HOLE AT 43.95m

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	♁	Standpipe tip
▯	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	Ι	Permeability test
■	U100 undisturbed sample	♁	Piezometer tip
▨	Mazier sample	ℙ	Impression Packer test
▤	Piston sample	HV/V	Hand Vane/in situ Vane shear test

LOGGED YKY

DATE 01/08/94

CHECKED CBT

DATE 02/08/94

REMARKS

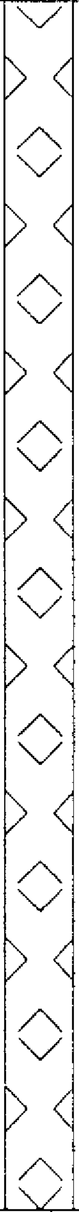
INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B09
SHEET 1 of 5
DATE from 03/08/94 to 16/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 808062.09 N 817681.98	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 0.00m-46.75m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 8.22 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level 8.22	Depth (m) 0.00	Legend	Grade	Zone	Description
3/8	PX	1.89m													Rock (FILL)

● Small disturbed sample
Large disturbed sample
SPT liner sample
U76 undisturbed sample
U100 undisturbed sample
Mazier sample
Piston sample

▲ Water sample
Standpipe tip
Standard penetration test
Permeability test
Piezometer tip
Impression Packer test
HV/V Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 16/08/94
CHECKED CBT
DATE 16/08/94

REMARKS
Designated fill type A placed above -11.28mPD
Percussive drilling from 0.00m-19.50m

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B09
SHEET 2 of 5
DATE from 03/08/94 to 16/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD	PERCUSSIVE / ROTARY	CO-ORDINATES E 808062.09 N 817681.98	ROCK COREBIT T2101
MACHINE & No.	ACKER D90/LYEAR D69		HOLE DIA. 140mm 0.00m-46.75m
FLUSHING MEDIUM	AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 8.22 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
										-1.78	10.00				AS SHEET 2 OF 5
				50					T2101	-10.28	18.50				Yellowish brown and grey speckled black, angular to subangular coarse GRAVEL (FILL)
								(4,4, 6,6,3,4) N=27	1	-11.28	19.50 19.95				Very stiff, yellowish brown clayey SILT with occasionally subangular fine to

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample		Standpipe tip
	SPT liner sample	↓	Standard penetration test
	U76 undisturbed sample		Permeability test
■	U100 undisturbed sample		Piezometer tip
▨	Mazier sample		Impression Packer test
▤	Piston sample	HV/V	Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 16/08/94
CHECKED CBT
DATE 18/08/94

REMARKS

	INTRUSION-PREPAKT (FAR EAST) LIMITED DRILL / BORE HOLE LOG	CONTRACT NO.: 255 HOLE NO.: 519B09 SHEET 3 of 5 DATE from 03/08/94 to 16/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 808062.09 N 817681.98	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 0.00m-46.75m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 8.22 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
									●	-11.78	20.00				
				50				23bls	■ 2 ●	-12.28	20.45 20.50				medium grained gravel sized rock fragments (ALLUVIUM)
3/8 4/8		3.59m 2.17m		100 100				(2,2, 2,3,3,3) N=11 27bls (2,3, 3,3,3,4) N=13 30bls	▯ 3 ● ■ 4 ● ▯ 5 ● ■ 6 ●	-14.28	20.95 21.45 21.95 22.45 22.50				Firm, light grey mottled yellowish brown clayey SILT (ALLUVIUM) 22.00-22.50: slightly sandy
				80					▤ 7 ●	-14.78	23.00				Light grey, slightly clayey silty medium to coarse SAND (ALLUVIUM)
				100				49bls (3,3, 4,6,6,7) N=23	■ 8 ● ▯ 9 ●	-15.78	23.45 23.95 24.00				Medium dense, greyish brown very clayey silty locally coarse SAND (ALLUVIUM)
				100				33bls (3,4, 4,4,5,7) N=20	■ 10 ● 11 ●	-16.78	24.45 24.95 25.00				Dark grey, silty coarse locally medium SAND (ALLUVIUM)
				0				34bls	■ 12 ●	-17.28	25.40 25.50				Firm to stiff, light grey locally mottled yellowish brown slightly sandy clayey SILT with occasional subangular fine gravel (ALLUVIUM)
4/8 5/8 5/8 6/8 6/8		3.74m 1.63m 3.19m 1.97m 3.34m		100 90 90				(2,2, 2,3,4,4) N=13 24bls ô V V	▯ 13 ● ■ 14 ● ▤ 15 ● 16 ● ▤ 17 ● 18 ●	-21.28	25.95 26.45 27.42 27.50 28.00 29.00 29.50				Soft, dark grey clayey SILT with occasional black organic fragments (ALLUVIUM)
8/8		2.17m							▤						Stiff to very stiff, dark greenish grey slightly clayey SILT (ALLUVIUM)

● Small disturbed sample	▲ Water sample	LOGGED YKY
↕ Large disturbed sample	ô Standpipe tip	DATE 16/08/94
▯ SPT liner sample	↓ Standard penetration test	CHECKED CBT
▮ U76 undisturbed sample	⊥ Permeability test	DATE 18/08/94
■ U100 undisturbed sample	ô Piezometer tip	
▨ Mazier sample	P Impression Packer test	
▤ Piston sample	HV/V Hand Vane/in situ Vane shear test	

REMARKS

In situ vane shear tests at 28.00m(34.69kPa) and at 29.50m(>80.40kPa)

Dual piezometer installed at 27.42m and 32.22m

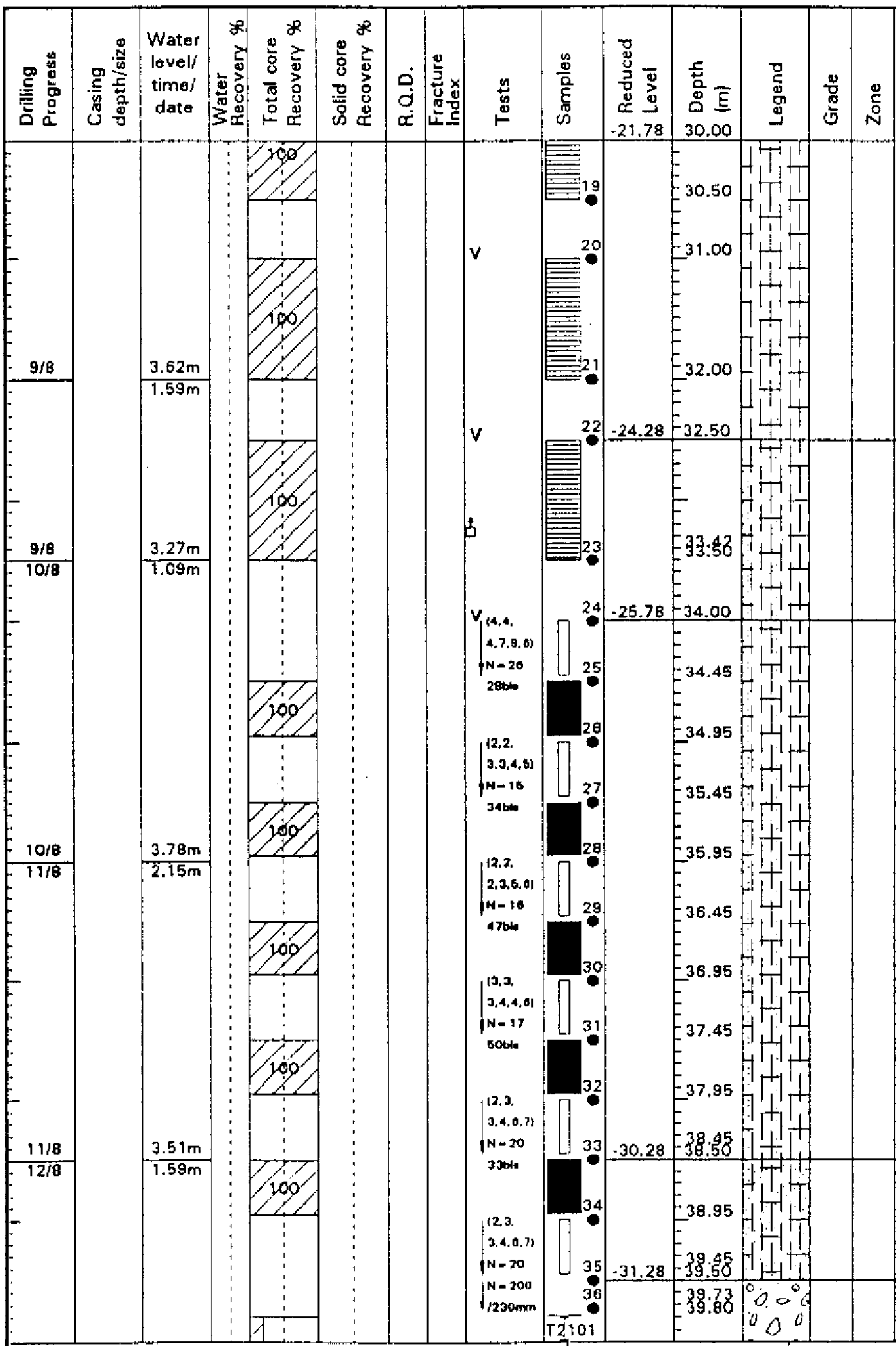
INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B09
SHEET 4 of 5
DATE from 03/08/94 to 16/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 808062.09 N 817681.98	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 0.00m-46.75m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 8.22 mP.D.



Description

AS SHEET 3 OF 5

Stiff to very stiff, light greenish grey clayey sandy SILT (ALLUVIUM)

Medium dense, dark orangish brown locally mottled light grey clayey SILT (ALLUVIUM)

35.50-36.50: slightly sandy to sandy

Medium dense, dark grey silty clayey fine to medium SAND with occasional to some black organic fragments (ALLUVIUM)
39.00-39.50: fine grained

Yellowish brown and grey speckled black, medium to coarse subangular

●	Small disturbed sample	▲	Water sample
↨	Large disturbed sample	♁	Standpipe tip
▯	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	⌶	Permeability test
■	U100 undisturbed sample	♁	Piezometer tip
▨	Mazier sample	ℙ	Impression Packer test
▤	Piston sample	HV/V	Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 16/08/94
CHECKED CBT
DATE 18/08/94

REMARKS
In situ vane shear tests at 31.00m(>80.40kPa), 32.50m(>80.40kPa) and at 34.00m(69.18kPa)

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B09
SHEET 5 of 5
DATE from 03/08/94 to 16/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 808062.09 N 817681.98	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 0.00m-46.75m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 8.22 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
										-31.78	40.00				
				20							40.30				GRAVEL locally COBBLES of granite and rhyolite with a matrix of yellowish brown silty fine sand (COLLUVIUM)
12/8		3.27m		20							40.85				
13/8		0.58m		80							42.00				
13/8		3.59m		90							42.35				
15/8		1.09m		67							42.70				
				60					T2101		44.20				
				35							45.25				
15/8	PX	3.59m		34							46.75				
16/8	46.75m	1.09m						N=200 /230mm	37 ●		47.23				
				37					T2101		47.50				
				0				280bls /230mm	38 ●		47.73				
				63					T2101	-39.83	48.05				
16/8				100	85	85			T2101	-41.33	49.55	+ + +	II		Very strong, pinkish grey spotted black speckled white slightly decomposed slightly chloritised and kaolinitised GRANITE with medium spaced smooth stepped kaolinite and chlorite locally iron stained and clean joints, dipping at 55°
															END OF HOLE AT 49.55m

● Small disturbed sample
Large disturbed sample
SPT liner sample
U76 undisturbed sample
U100 undisturbed sample
▨ Mazier sample
Piston sample

▲ Water sample
Standpipe tip
Standard penetration test
Permeability test
Piezometer tip
Impression Packer test
HV/V Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 16/08/94
CHECKED CBT
DATE 18/08/94

REMARKS

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B12
SHEET 1 of 5
DATE from 27/07/94 to 05/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 807839.86 N 817822.92	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 114mm 0.00-37.00m-48.60m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 6.05 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level 6.05	Depth (m) 0.00	Legend	Grade	Zone	Description
27/7	PX	2.55m													Rock (FILL)

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	♁	Standpipe tip
▯	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	I	Permeability test
█	U100 undisturbed sample	♁	Piezometer tip
▨	Mazier sample	P	Impression Packer test
▤	Piston sample	HV/V	Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 05/08/94
CHECKED CBT
DATE 10/08/94

REMARKS
Designated fill type A placed above -14.75mPD
Percussive drilling from 0.00m-17.20m

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B12
SHEET 2 of 5
DATE from 27/07/94 to 05/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 807839.86 N 817822.92	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 114mm 0.00-37.00m-48.60m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 6.05 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
										-3.95	10.00				AS SHEET 1 OF 5
				30					T2101	-11.15	17.20				Pinkish grey, subangular coarse GRAVELS and COBBLES of granite (FILL)
				35							18.00				
											19.50				

● Small disturbed sample	▲ Water sample
↕ Large disturbed sample	Standpipe tip
▯ SPT liner sample	↓ Standard penetration test
▮ U76 undisturbed sample	Permeability test
█ U100 undisturbed sample	Piezometer tip
▨ Mazier sample	Impression Packer test
▤ Piston sample	HV / V Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 05/08/94
CHECKED CBT
DATE 10/08/94

REMARKS

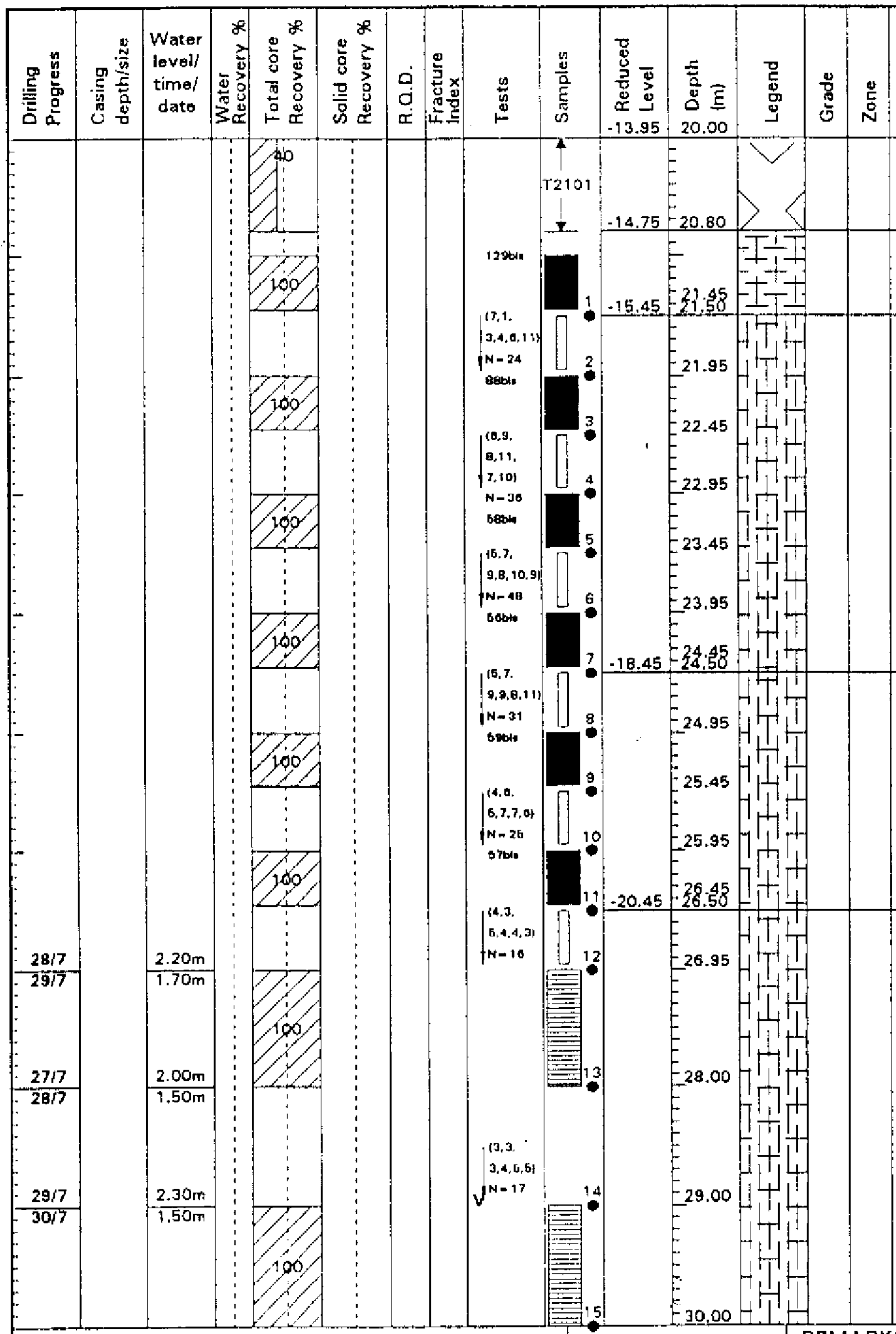
INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519812
SHEET 3 of 5
DATE from 27/07/94 to 05/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 807839.86 N 817822.92	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 114mm 0.00-37.00m-48.60m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 6.05 mP.D.



Drilling Progress	Water level/ time/ date
28/7	2.20m
29/7	1.70m
27/7	2.00m
28/7	1.50m
29/7	2.30m
30/7	1.50m

Reduced Level	Depth (m)	Description
-13.95	20.00	AS SHEET 2 OF 5
-14.75	20.80	Firm, light yellowish brown slightly silty to silty sandy CLAY (ALLUVIUM)
-15.45	21.45 21.50	Firm to very stiff, yellowish brown striped light grey mottled reddish brown clayey SILT with occasional dark yellowish brown silt pockets (<5mm) (ALLUVIUM)
-18.45	24.45 24.50	Very stiff to stiff, light grey clayey SILT with occasional dark yellowish brown silt pockets (<5mm) and occasional black organic fragments (ALLUVIUM) 25.50-26.00: mottled dark brown in colour
-20.45	26.45 26.50	Stiff, grey to dark grey clayey SILT (ALLUVIUM)

● Small disturbed sample	▲ Water sample
↕ Large disturbed sample	Standpipe tip
▯ SPT liner sample	↓ Standard penetration test
▮ U76 undisturbed sample	Permeability test
■ U100 undisturbed sample	Piezometer tip
▨ Mazier sample	Impression Packer test
▤ Piston sample	HV/V Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 05/08/94
CHECKED CBT
DATE 10/08/94

REMARKS
In situ vane shear test at 29.00m(68.89kPa)

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519812
SHEET 4 of 5
DATE from 27/07/94 to 05/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 807839.86 N 817822.92	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 114mm 0.00-37.00m-48.60m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 6.05 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
									●	-23.95	30.00				AS SHEET 3 OF 5 30.00-31.50: stiff
30/7		2.65m						V	16 ●		30.50				
1/8		1.85m		100					▤						
									17 ●		31.50				31.50-32.00: very stiff
								V	18 ●	-25.95	32.00				Stiff, greyish black clayey SILT with occasional to some black organic fragments (ALLUVIUM)
				100					▤						
1/8		2.60m							19 ●		33.00				33.00-33.50: slightly sandy
2/8		1.75m													
								V S'ble	20 ●	-27.45	33.50				Medium dense, light grey silty very clayey fine SAND (ALLUVIUM) 34.00-43.00: slightly clayey to clayey
				100					■						
									21 ●		33.95				
								(3,3, 4,2,3,3) N=12	▯ 22 ●		34.45				
								(2,4, 4,4,4,4) N=16	▯ 23 ●		35.95				
2/8	PX	2.75m													
3/8	37.00m HX	1.95m													
								(2,2, 4,4,4,4) N=16	▯ 24 ●		37.45				
								(3,3, 3,4,5,5) N=17	▯ 25 ●		38.95				

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	♁	Standpipe tip
▯	SPT liner sample	↓	Standard penetration test
▮	U76 undisturbed sample	⌶	Permeability test
■	U100 undisturbed sample	♁	Piezometer tip
▨	Mazier sample	ℙ	Impression Packer test
▤	Piston sample	HV / V	Hand Vane/in situ Vane shear test

LOGGED YKY
DATE 06/08/94
CHECKED CBT
DATE 10/08/94

REMARKS

In situ vane shear tests at 30.50m(>80.40kPa), 32.00m(>80.40kPa) and at 33.50m(>80.40kPa).

INTRUSION-PREPAKT
(FAR EAST) LIMITED

DRILL / BORE HOLE LOG

CONTRACT NO.: 255
HOLE NO.: 519B12
SHEET 5 of 5
DATE from 27/07/94 to 05/08/94

W.O.No.& LOC. 255/019 SITE INVESTIGATION FOR AREA D3, WEST OF LAM CHAU

METHOD PERCUSSIVE / ROTARY	CO-ORDINATES E 807839.86 N 817822.92	ROCK COREBIT T2101
MACHINE & No. ACKER D90/LYEAR D69		HOLE DIA. 140mm 114mm 0.00-37.00m-48.60m
FLUSHING MEDIUM AIR / WATER	ORIENTATION Vertical	GROUND-LEVEL 6.05 mP.D.

Drilling Progress	Casing depth/size	Water level/ time/ date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
										-33.95	40.00				AS SHEET 4 OF 5
								(3,4, 3,3,5,5) N=16	26		40.45				
								(4,4, 4,3,5,5) N=17	27		41.95				
										-36.95	43.00				
3/8		2.75m						(4,7,6, 7,11,12) N=36	28		43.45				Very stiff, light grey silty very sandy CLAY (ALLUVIUM)
4/8		1.70m													
										-37.95	44.00				
				60					T2101						Dark grey, and greyish green subangular to subrounded medium to coarse GRAVELS of granite with a matrix of greyish black clayey silt (COLLUVIUM)
										-39.45	45.50				
								(6,9, 12,17, 24,29) N=82	29		46.00		V		Extremely weak, white mottled dark green and grey completely decomposed GRANITE (very dense, silty fine to coarse SAND with occasional to some *subangular fine locally medium gravel sized rock fragments)*
				100					30		47.00				
4/8		2.20m						(12,16, 23,39, 68,75) N=205	31	-41.45	47.50				
5/8				100									V		Extremely weak, yellowish brown spotted pink and white completely decomposed GRANITE (very dense, silty fine to coarse SAND with occasional medium to coarse gravel sized rock fragments)
5/8	HX							N=201 /100mm	32	-42.55	48.60				
															END OF HOLE AT 48.60m

●	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	△	Standpipe tip
▯	SPT liner sample	↓	Standard penetration test
▮	*U76 undisturbed sample*	⌶	*Permeability test*
█	U100 undisturbed sample	♁	Piezometer tip
▨	Mazier sample	ℙ	Impression Packer test
▤	Piston sample	HV / V	Hand Vane/in situ Vane shear test

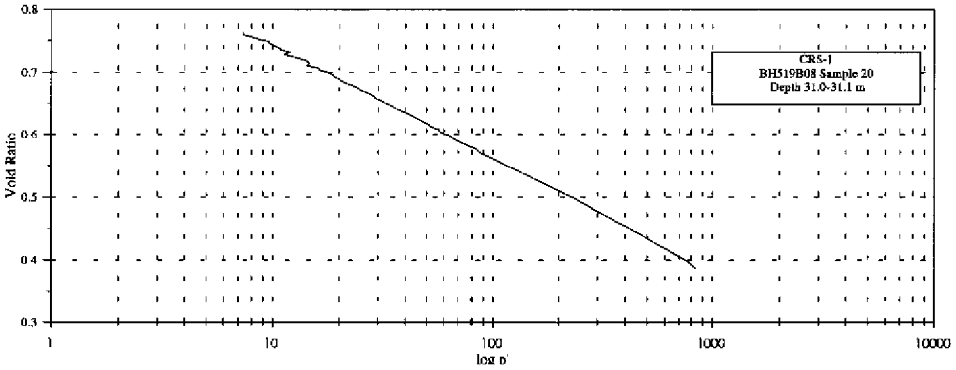
LOGGED YKY
DATE 06/08/94
CHECKED CBT
DATE 10/08/94

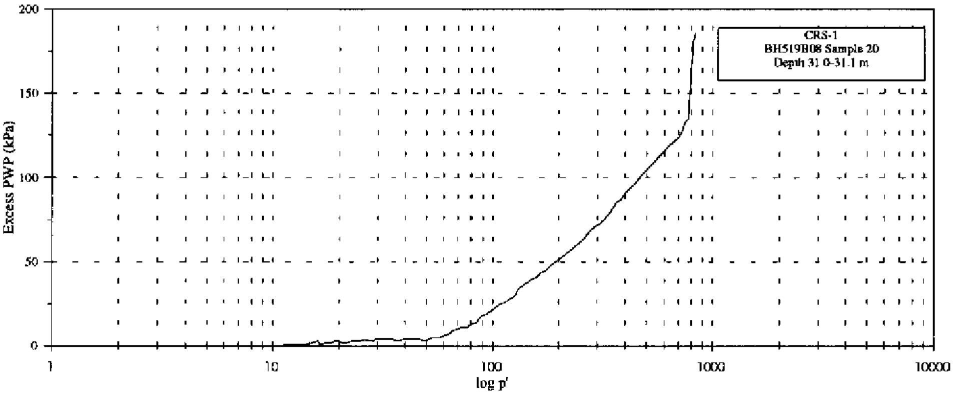
REMARKS

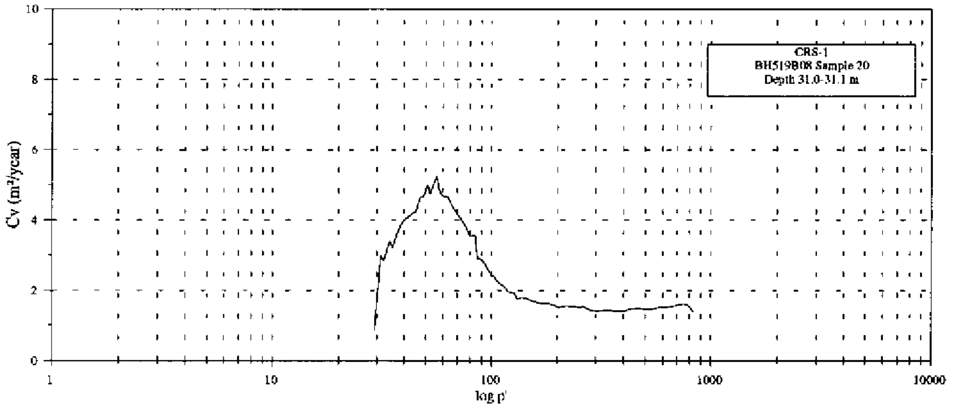
APPENDIX D

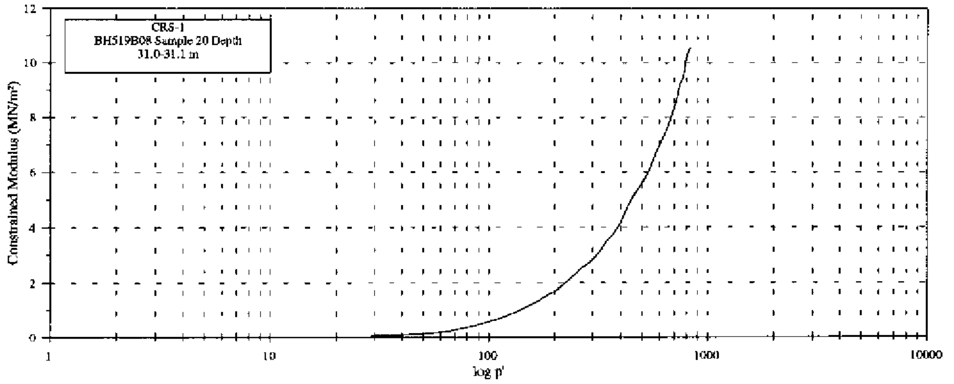
ROWE CELL CONSOLIDATION CURVES FROM PHASE II TESTS

CONSTANT RATE OF STRAIN CONSOLIDATION









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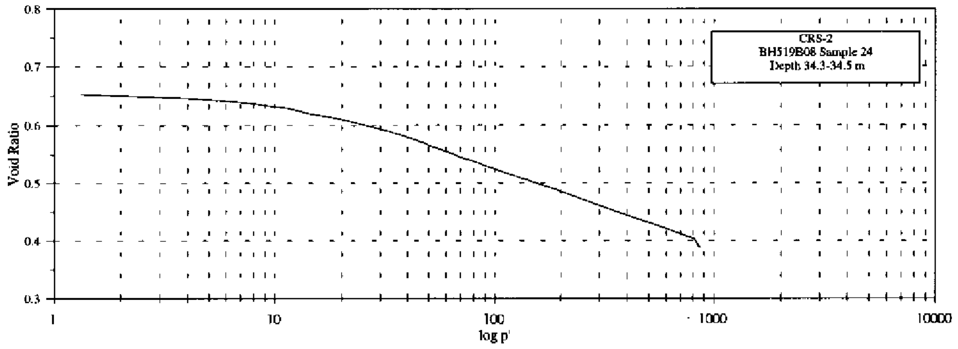

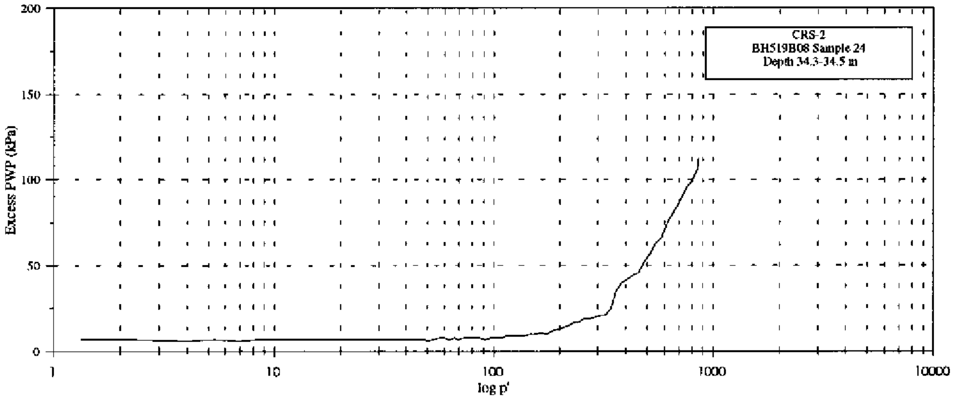

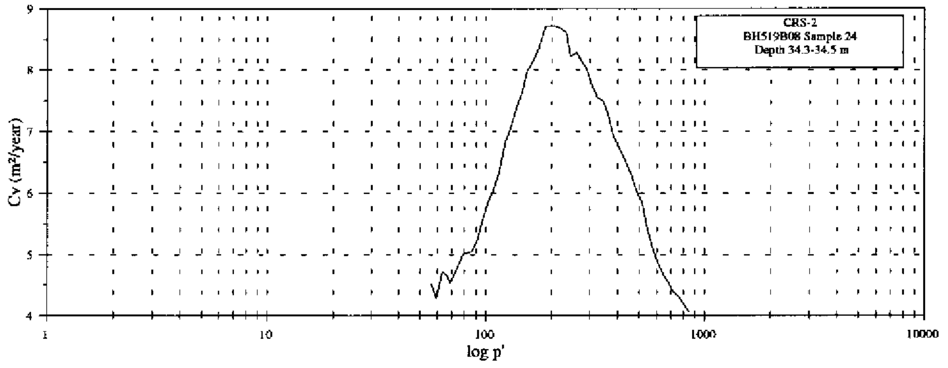

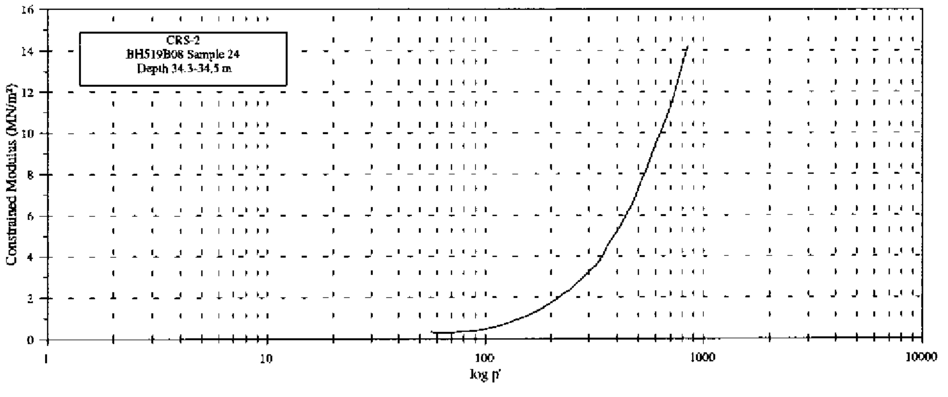

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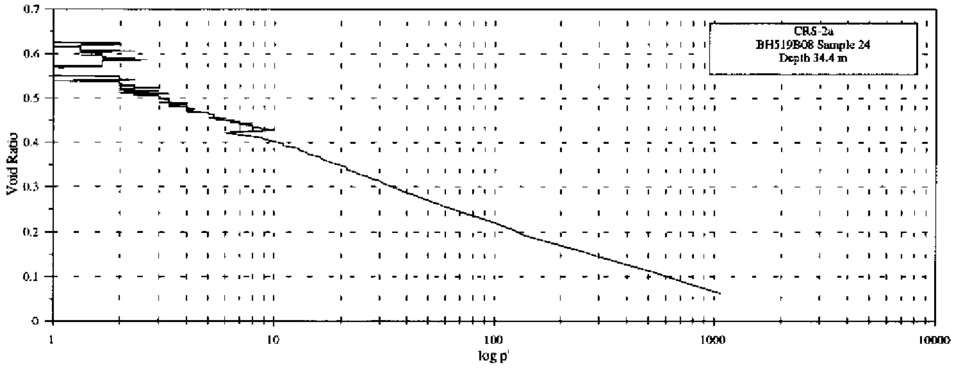

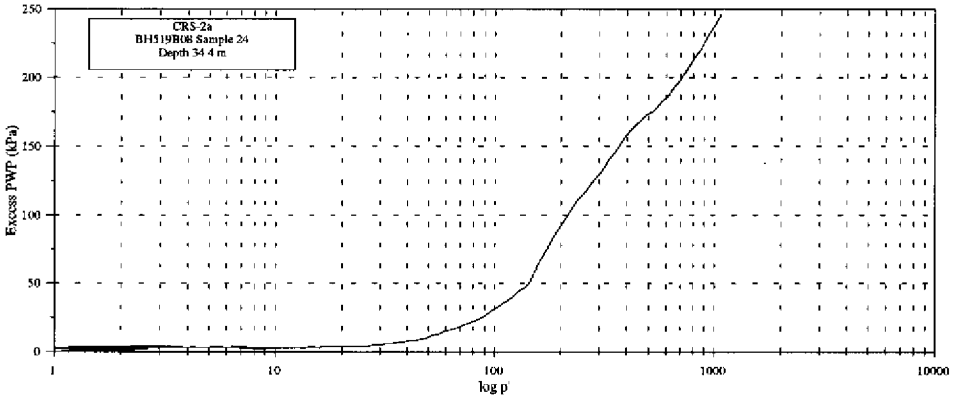

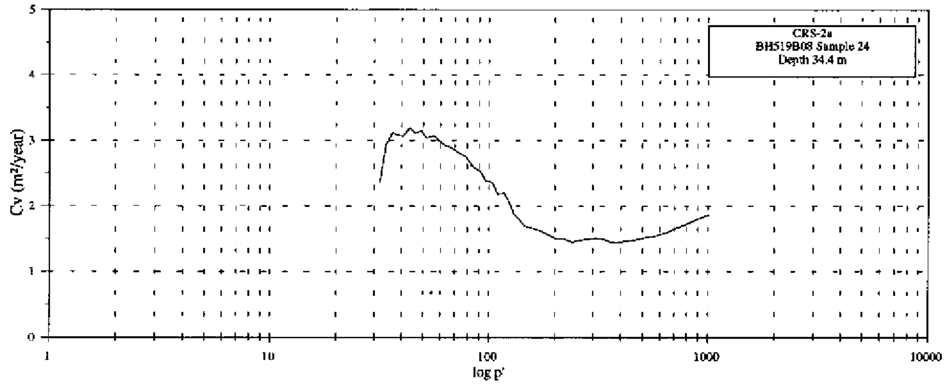

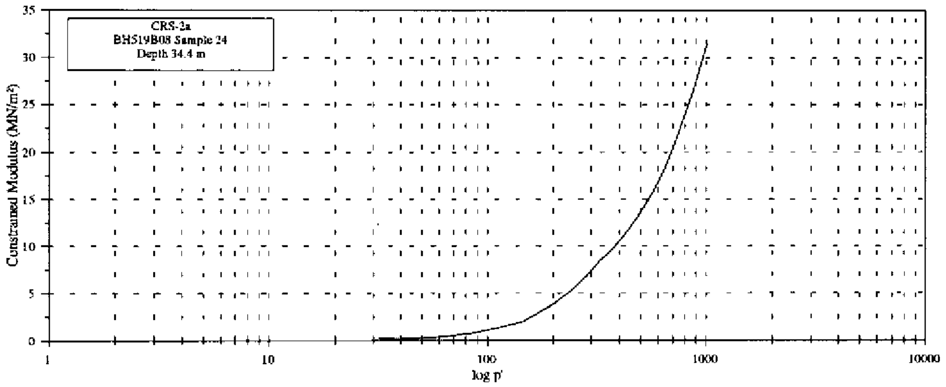

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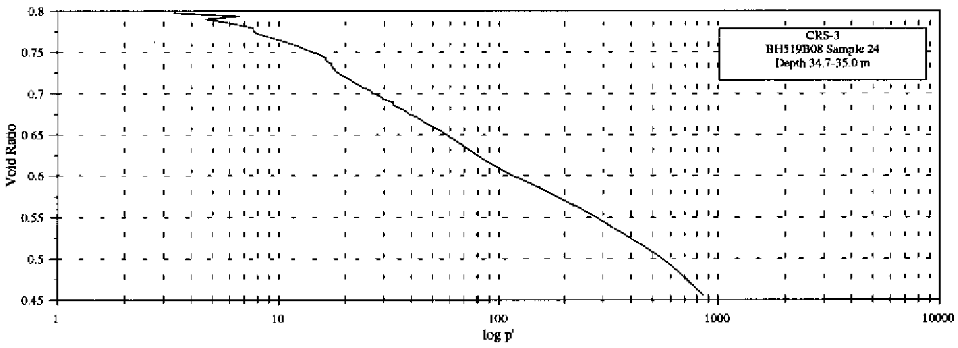

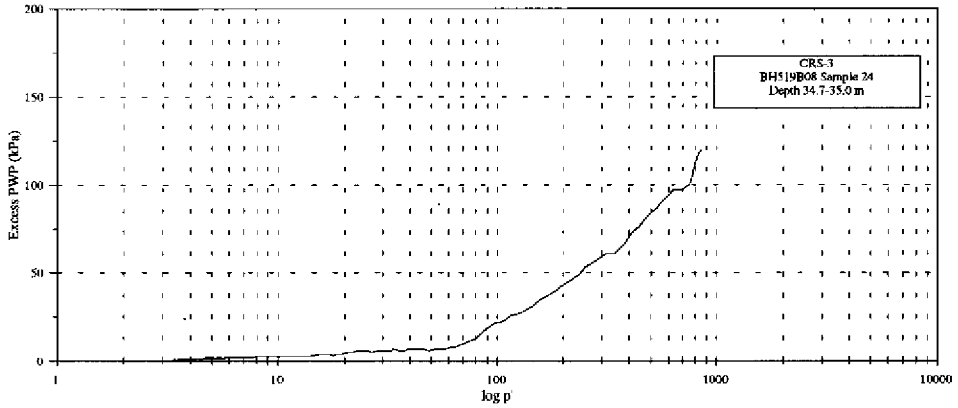

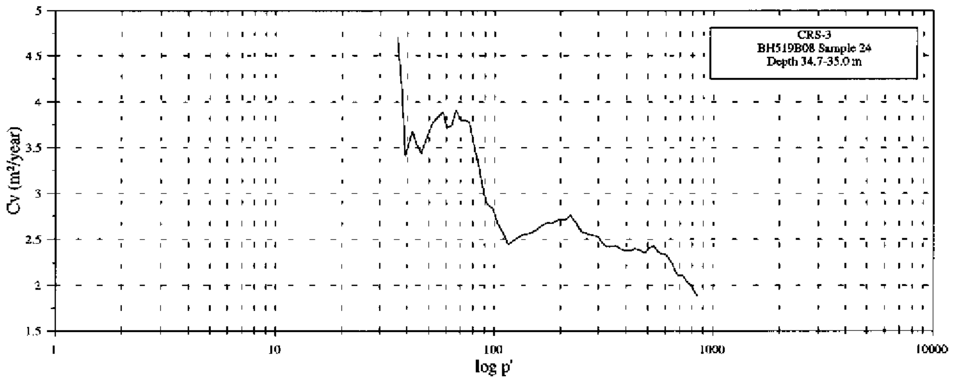

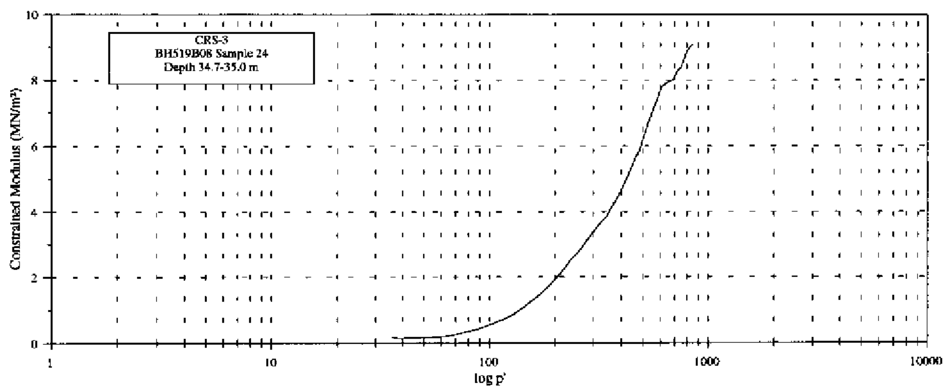

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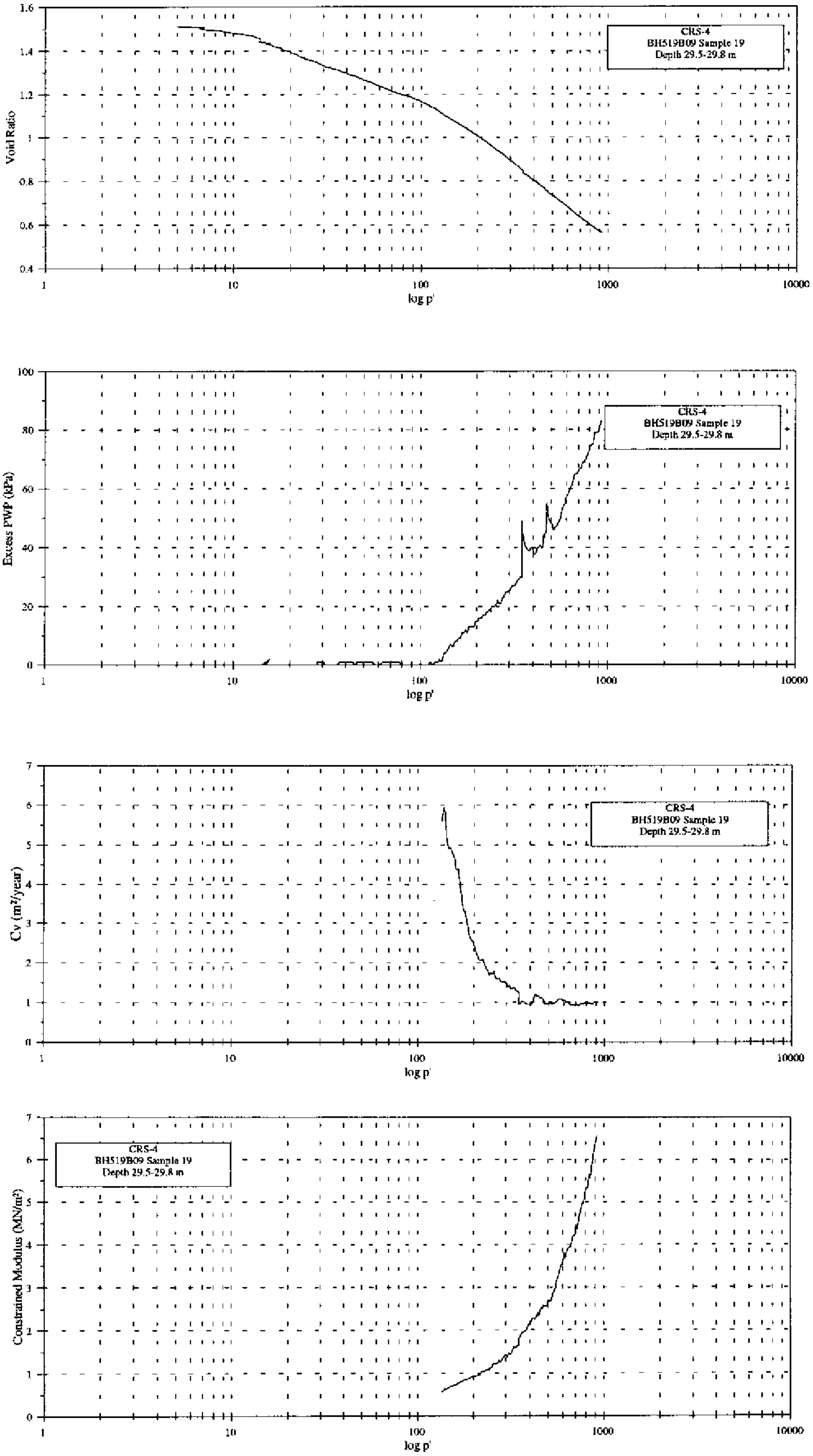

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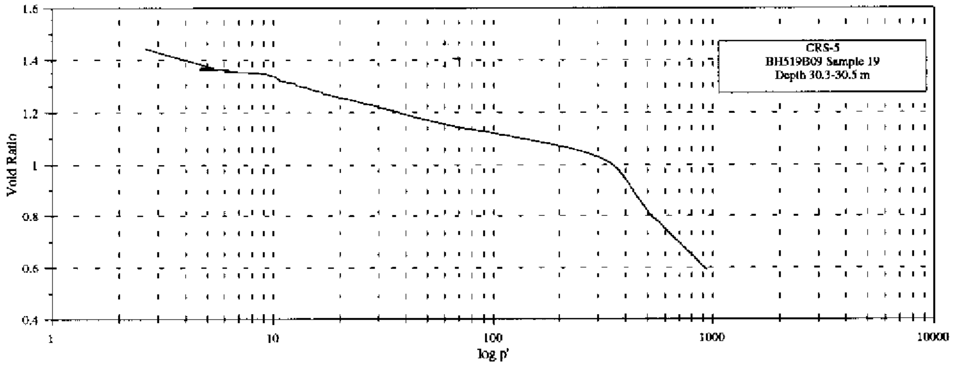

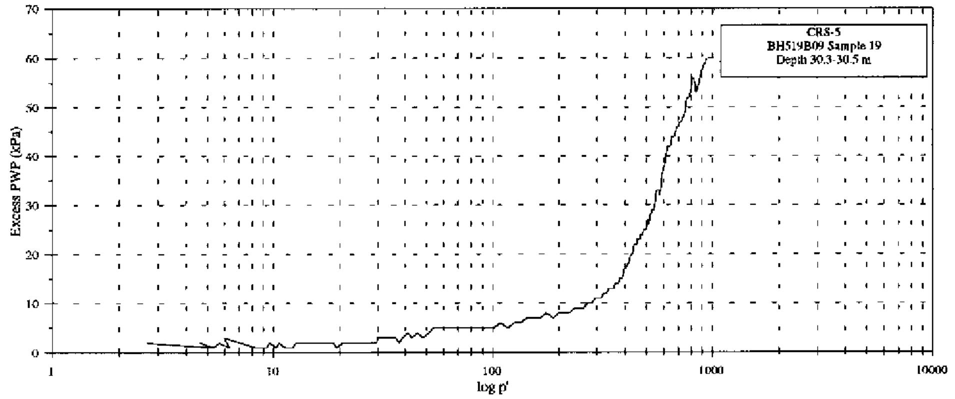

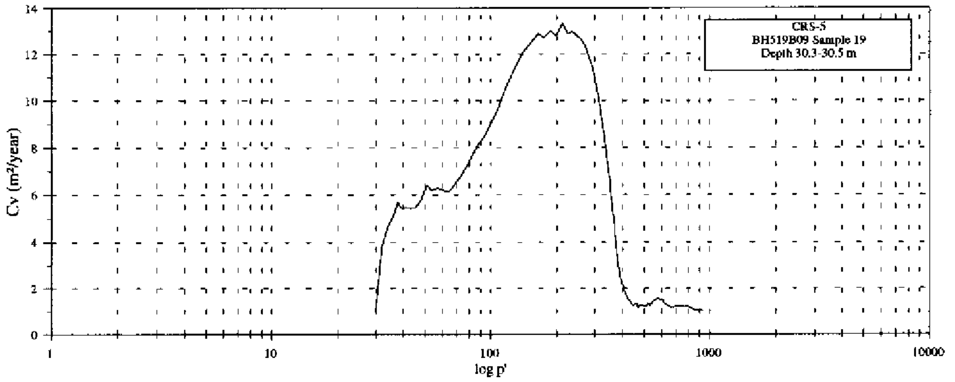

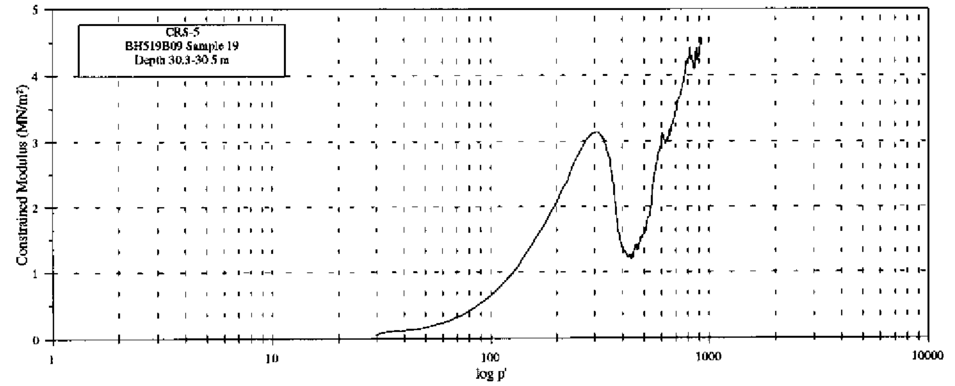

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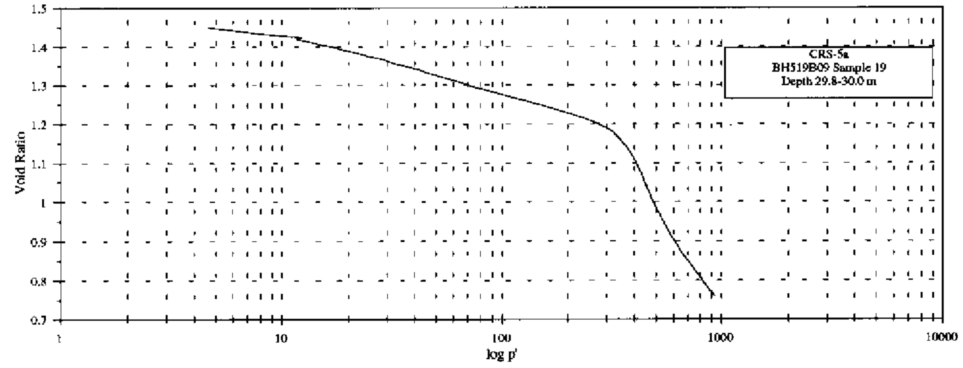

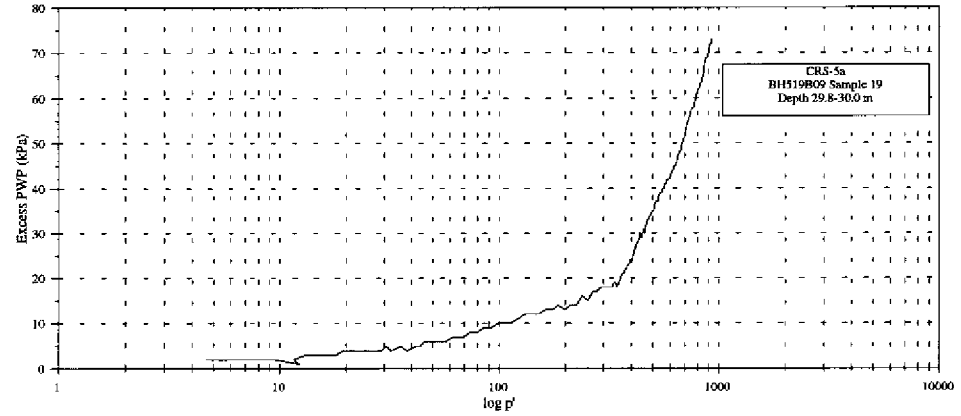

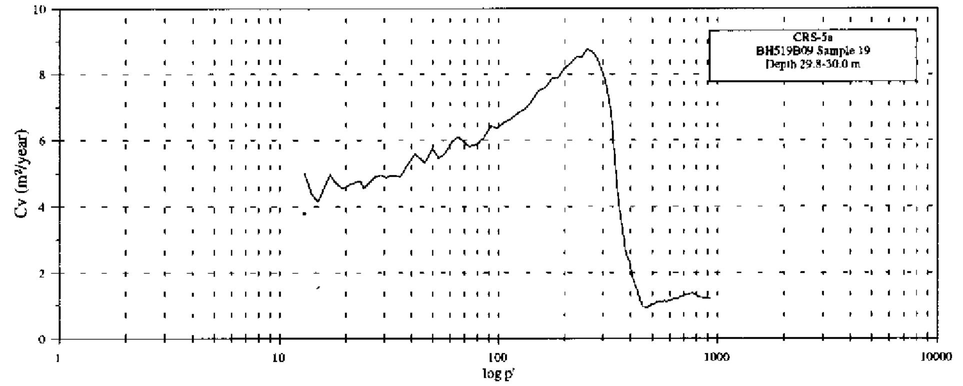

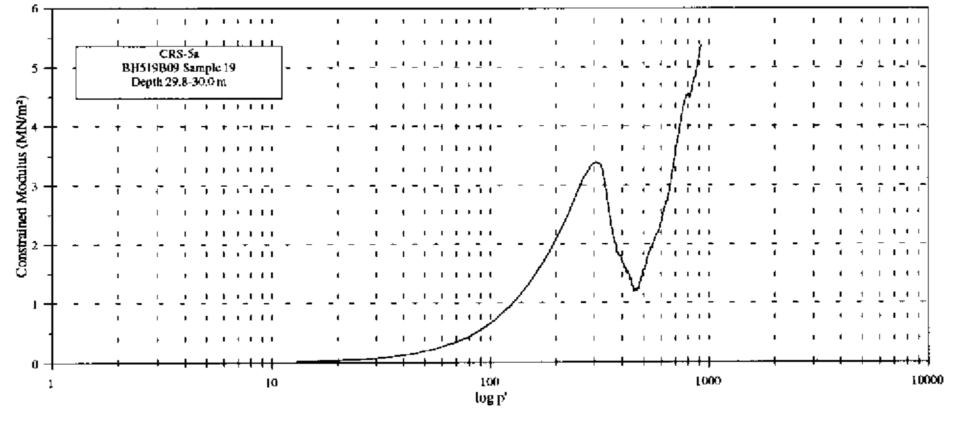

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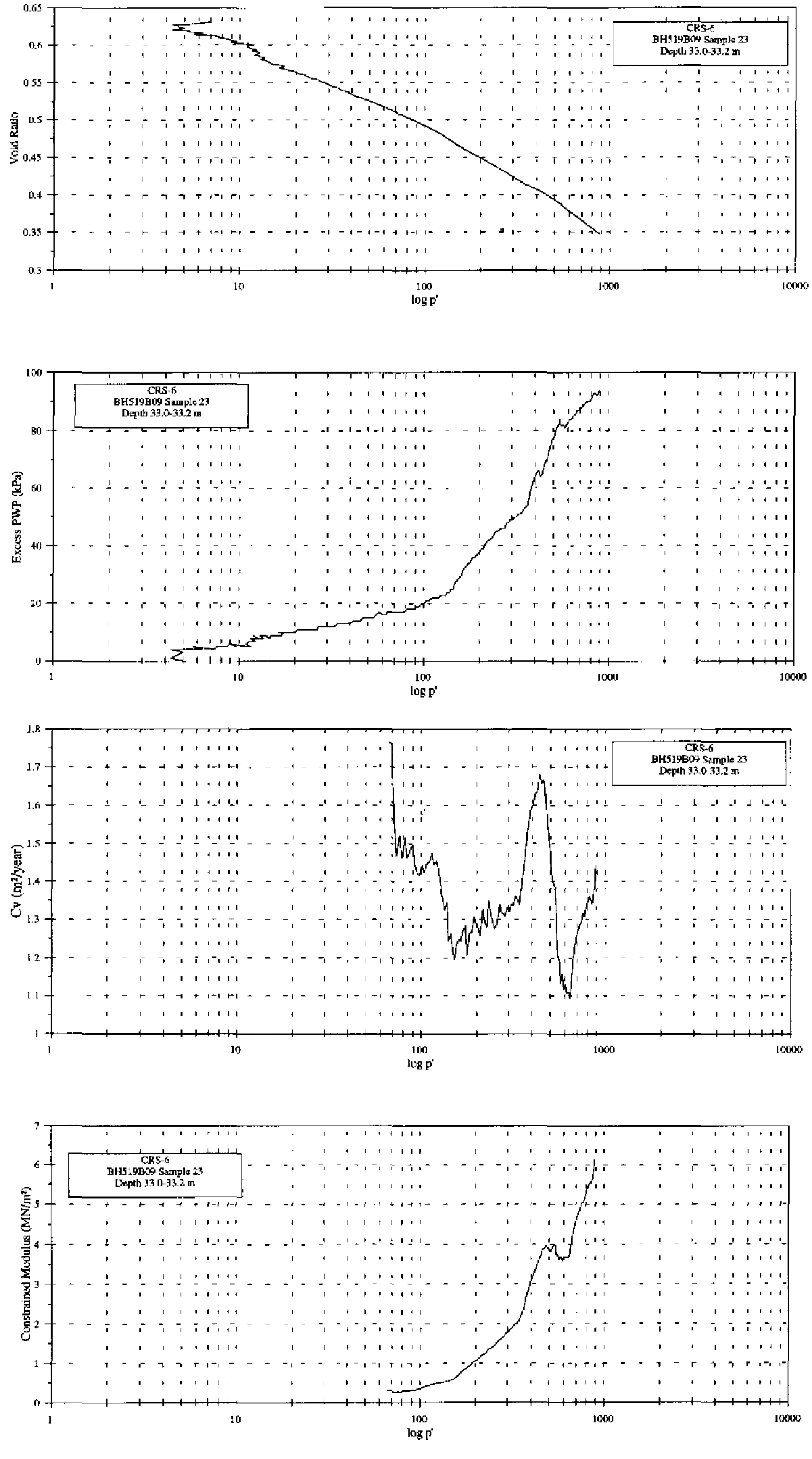

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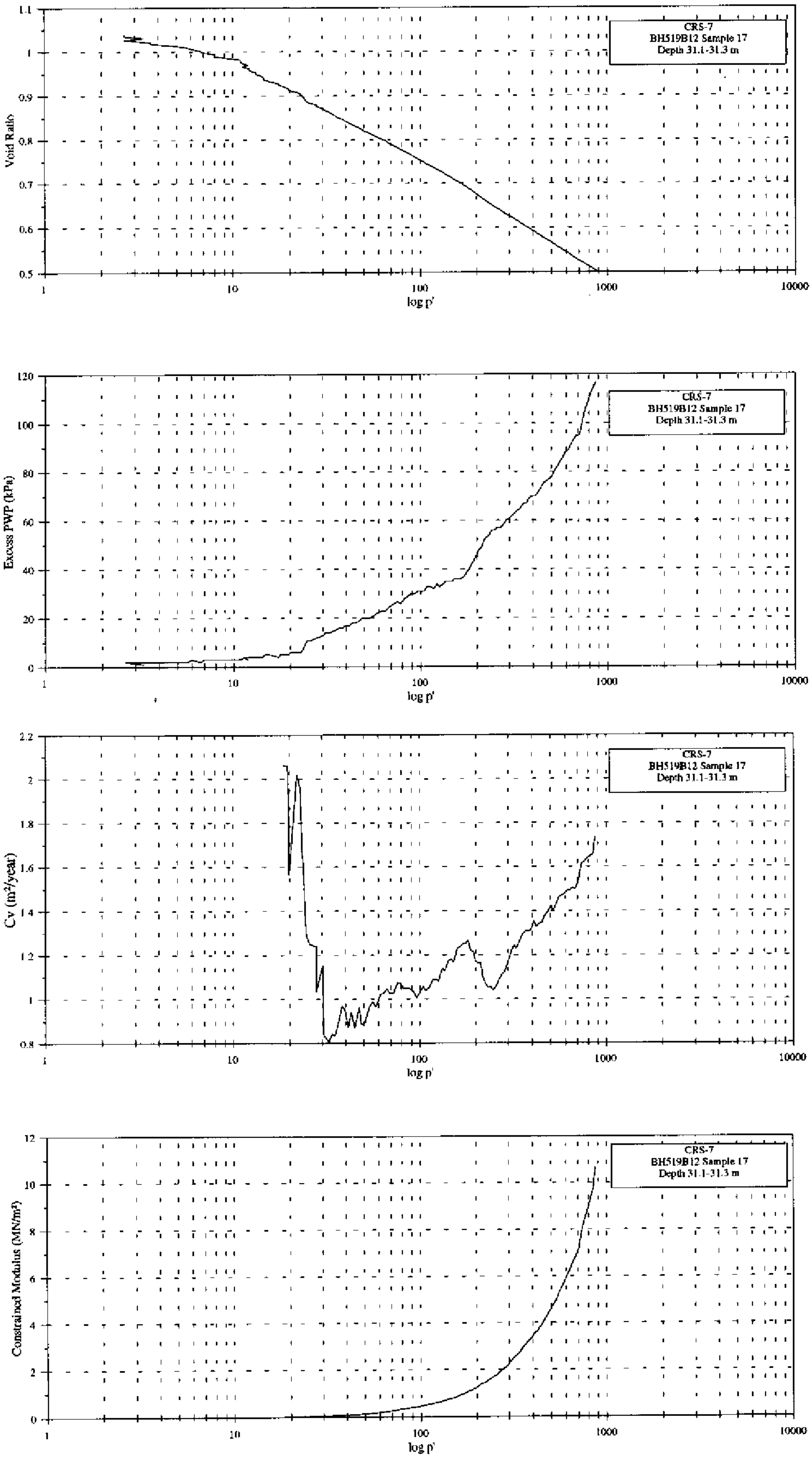

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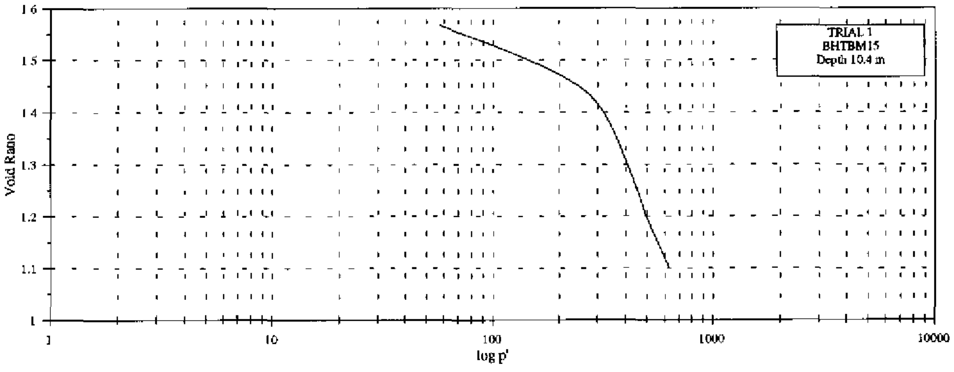

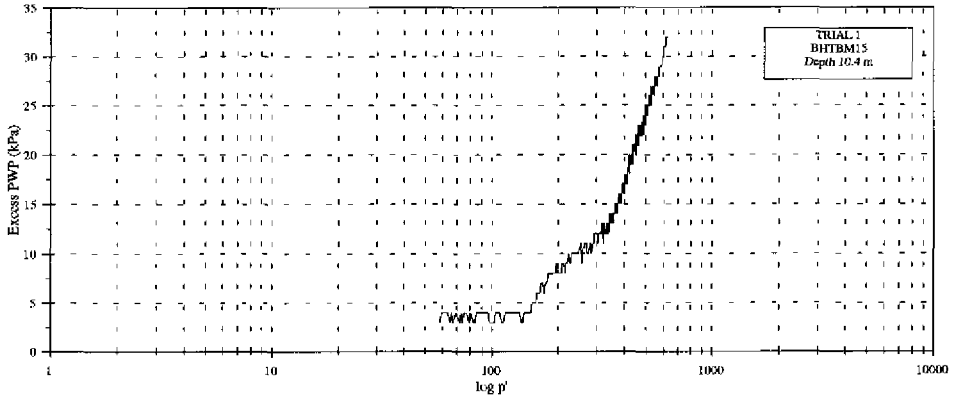

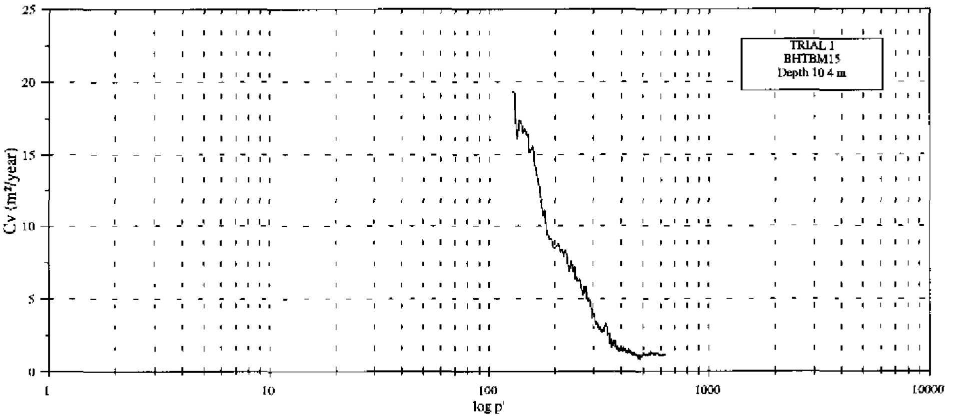

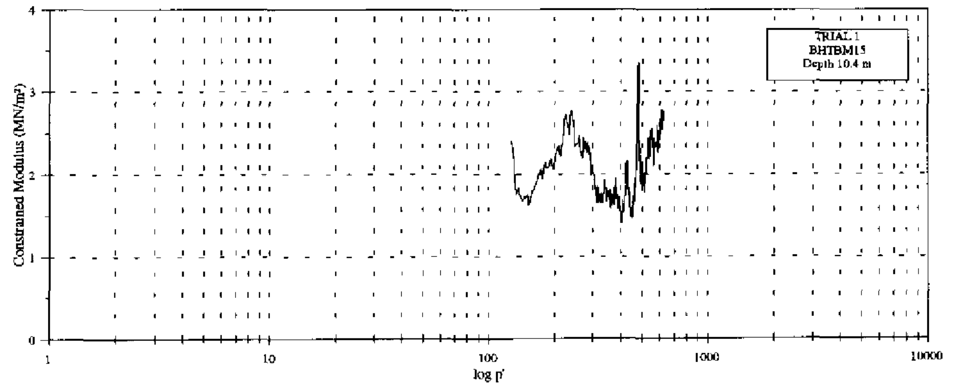

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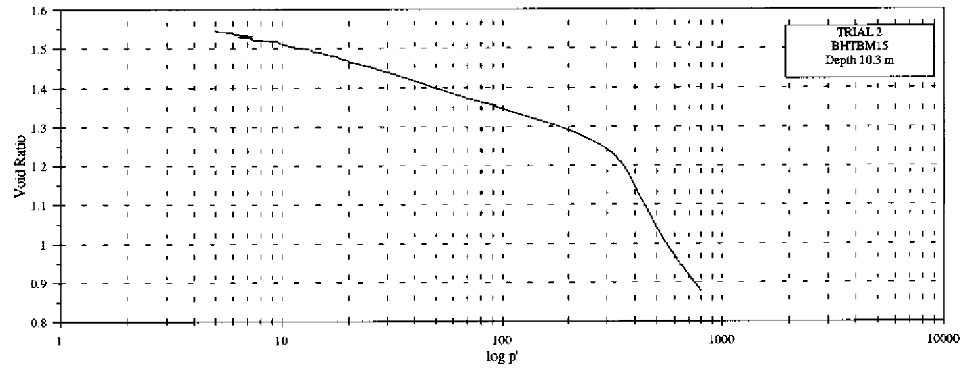

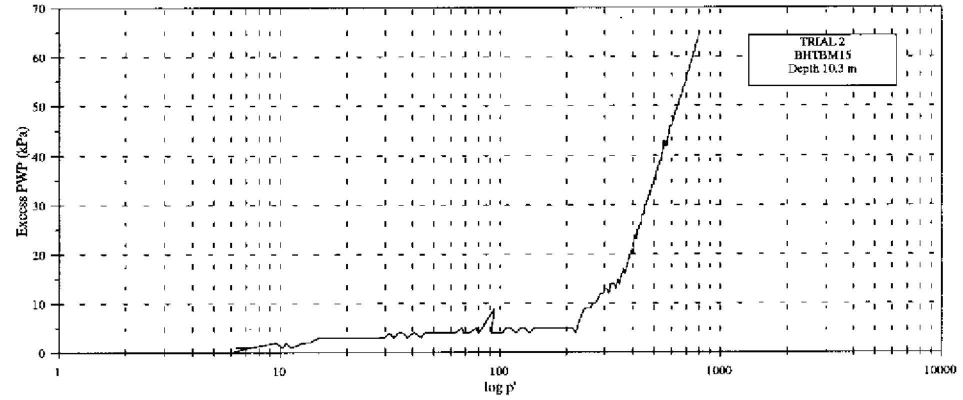

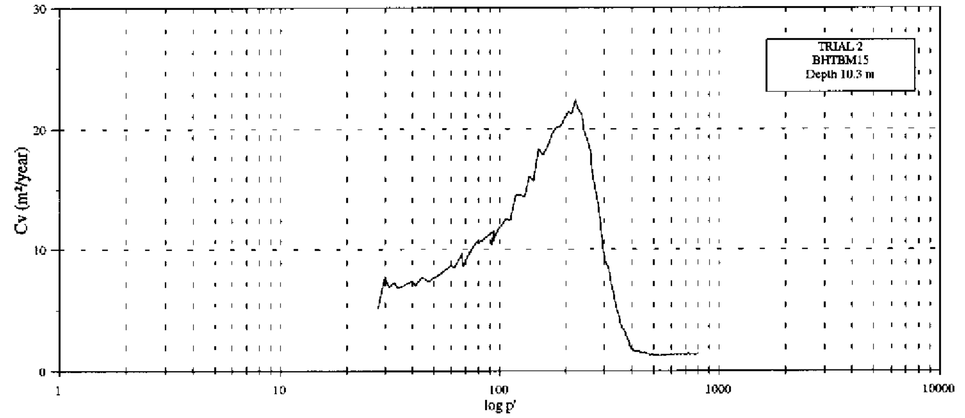

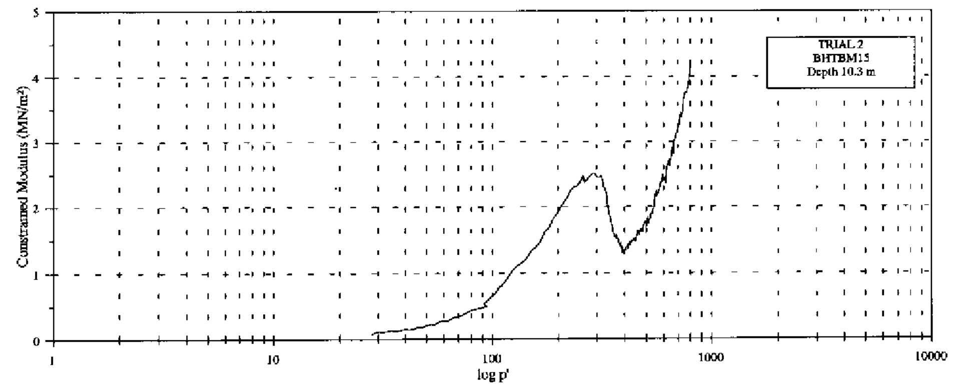

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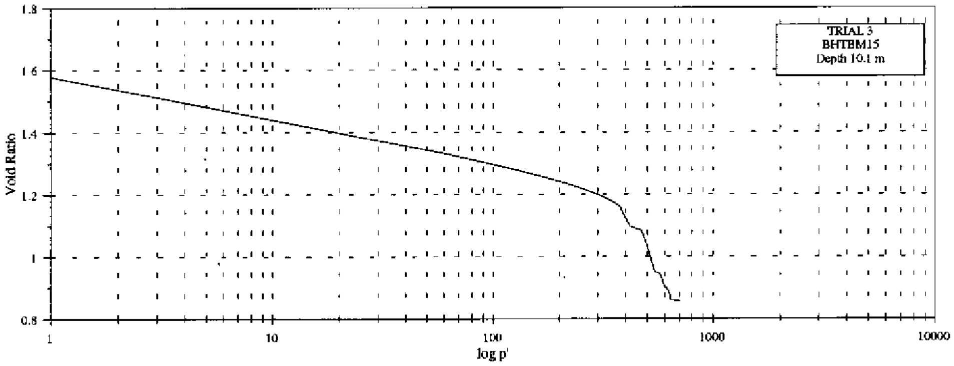
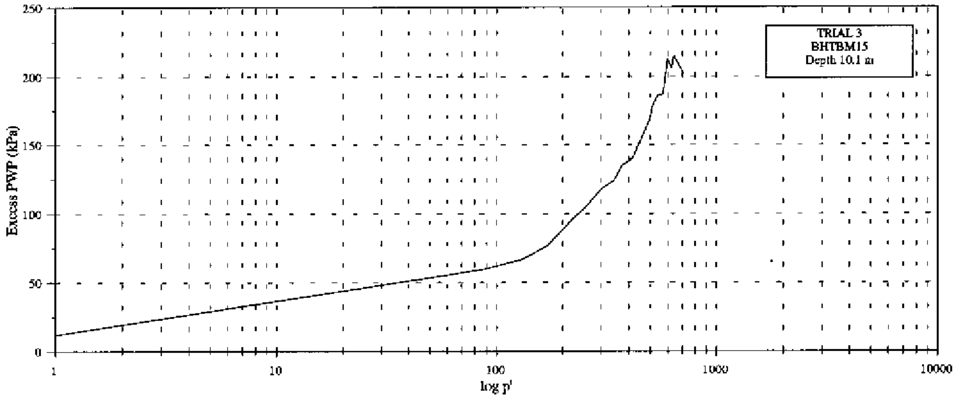
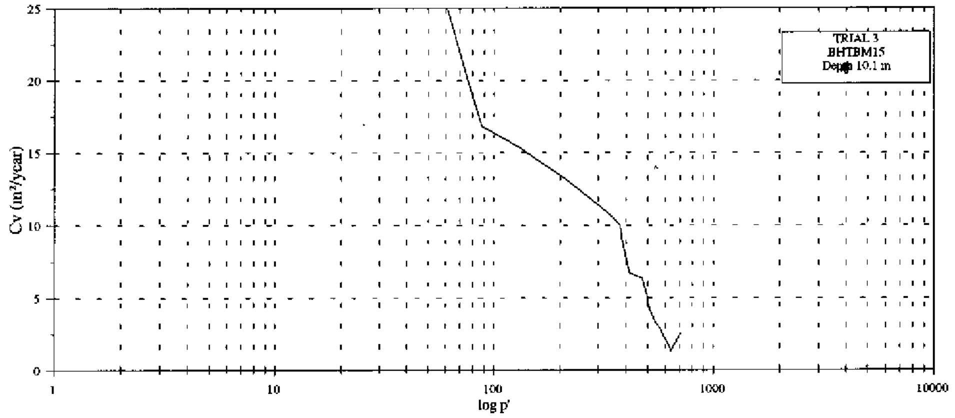
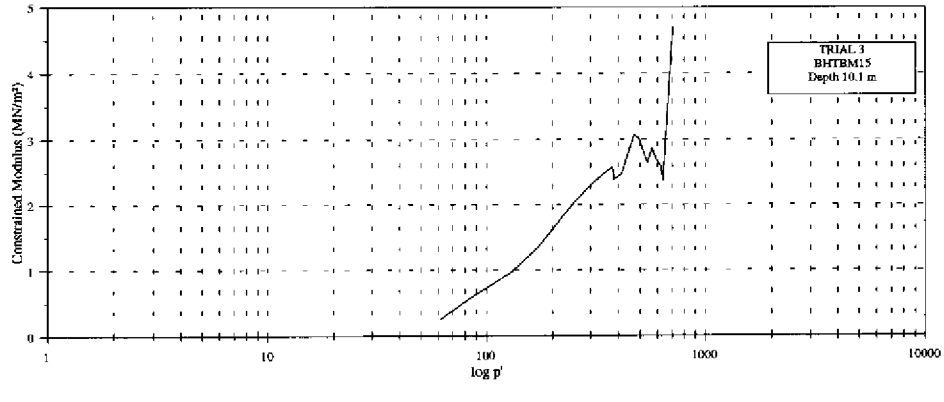






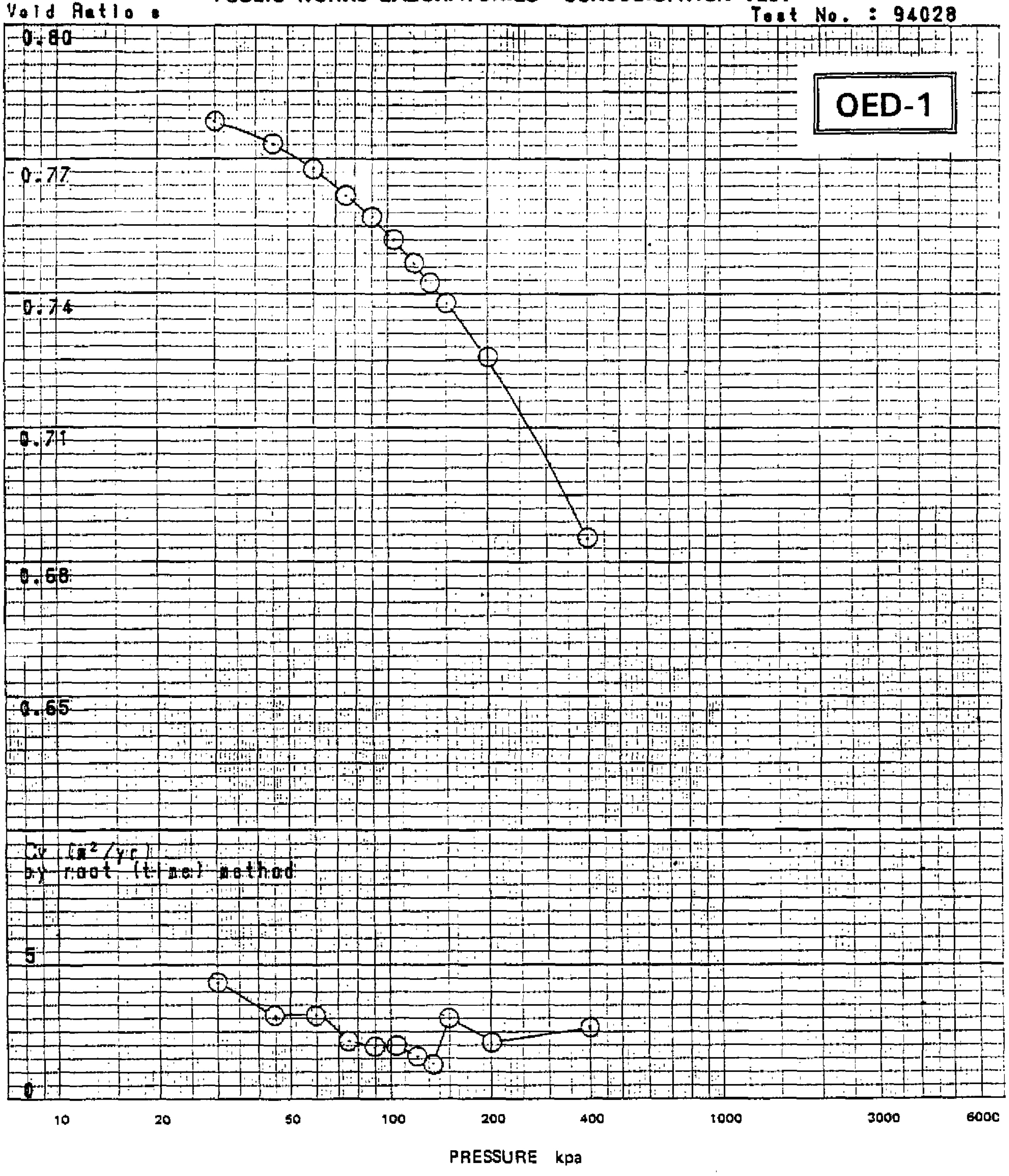


APPENDIX E

CONSOLIDATION CURVES FROM SMALL STEP LOADING TESTS

PUBLIC WORKS LABORATORIES – CONSOLIDATION TEST

Test No. : 94028



Description

Initial bulk density 1.99 Mg/m^3

Initial moisture content 28.4 %

Initial saturation 100.0 %

Initial dry density 1.55 Mg/m^3

Initial void ratio 0.783

Specific gravity 2.76 [✓ measured] assumed

Compression index Cc

Job Small Incremental Loading Oedometer Testing

Ref. No. 49/94/33

Location — —

Borehole No. 519808

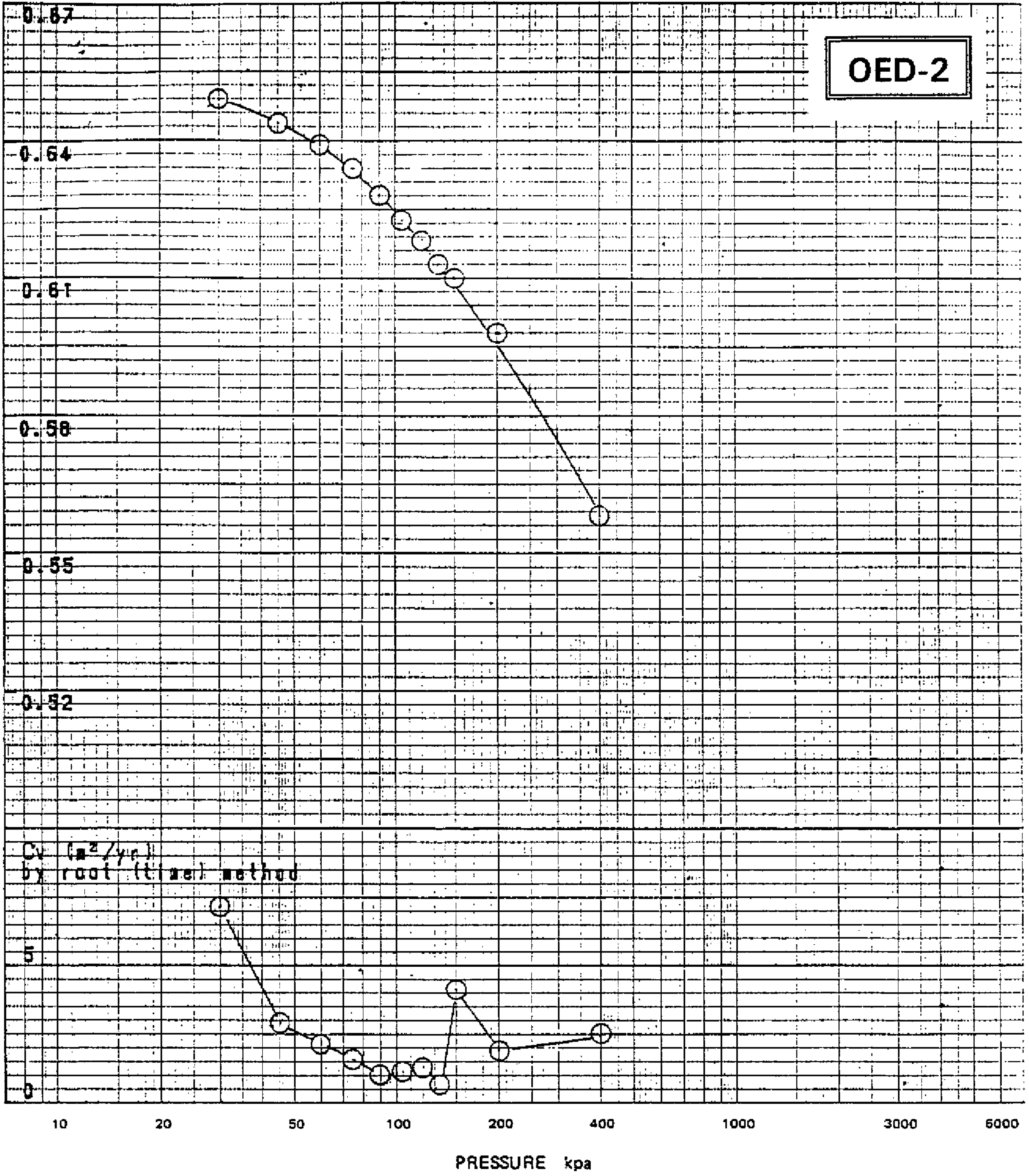
~~Sample No.~~ Depth (m) : 31.37 - 31.47

G.C.O. 46

PUBLIC WORKS LABORATORIES – CONSOLIDATION TEST

Void Ratio e

Test No. : 94026



Description ______________________________

Initial bulk density 2.02 Mg/m³

Initial moisture content 24.5 %

Initial saturation 99.3 %

Initial dry density 1.62 Mg/m³

Initial void ratio 0.667

Specific gravity 2.70 measured / assumed

Compression index Cc ______________

Job Small Incremental Loading Oedometer Testing

Ref. No. 49/94/33

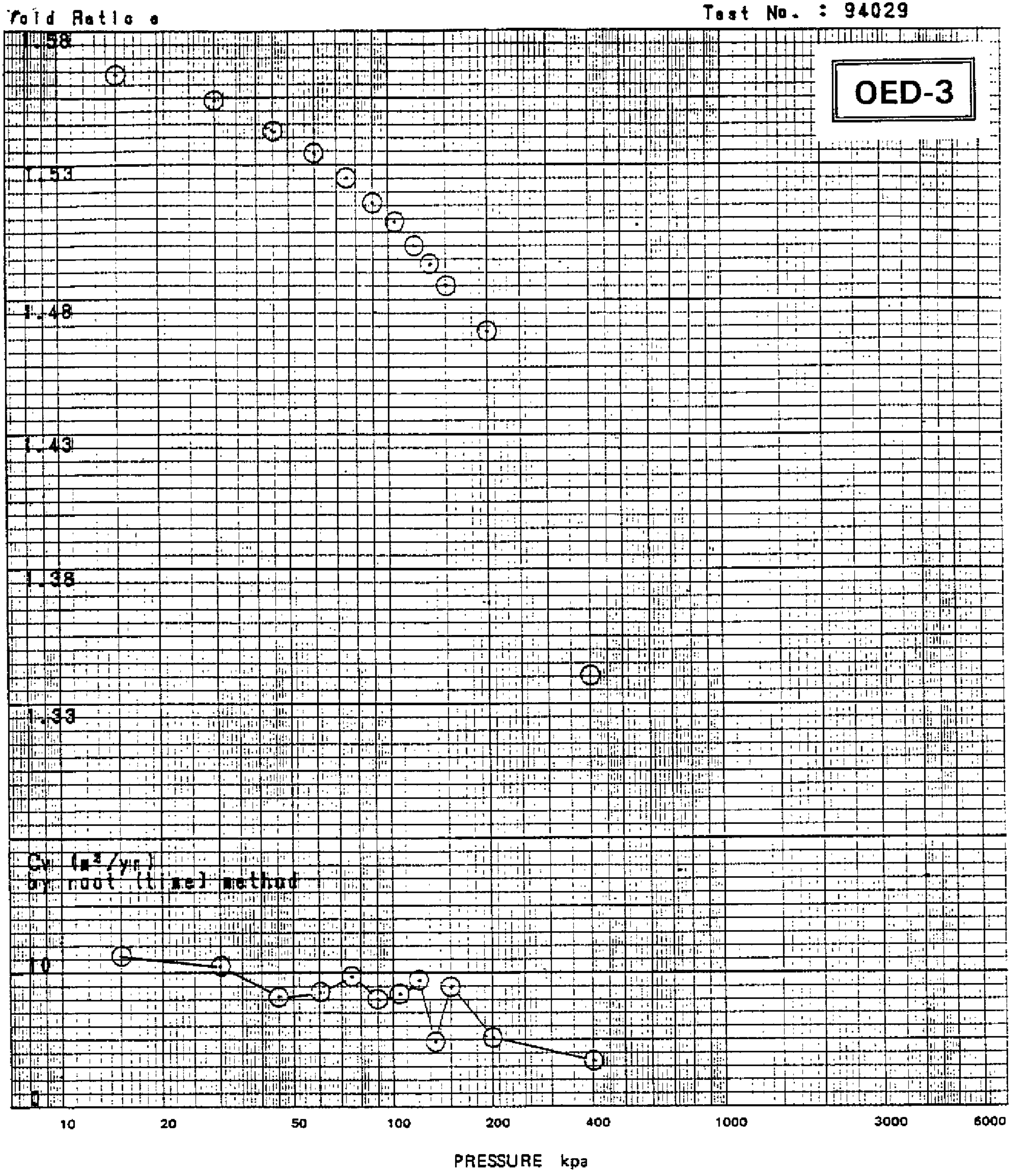
Location — —

Borehole No. 519808

~~Sample No.~~ Depth (m) : 34.12 - 34.2

P.W.D. MATERIALS LABORATORY-CONSOLIDATION TEST

Test No. : 94029



Description

Initial bulk density 1.68 Mg/m^3

Initial moisture content 56.8 %

Initial saturation 99.6 %

Initial dry density 1.07 Mg/m^3

Initial void ratio 1.580

Specific gravity 2.77 [✓ measured] assumed

Compression index Cc

Job Small Incremental Loading Oedometer Testing

Ref. No. 49/94/33

Location — —

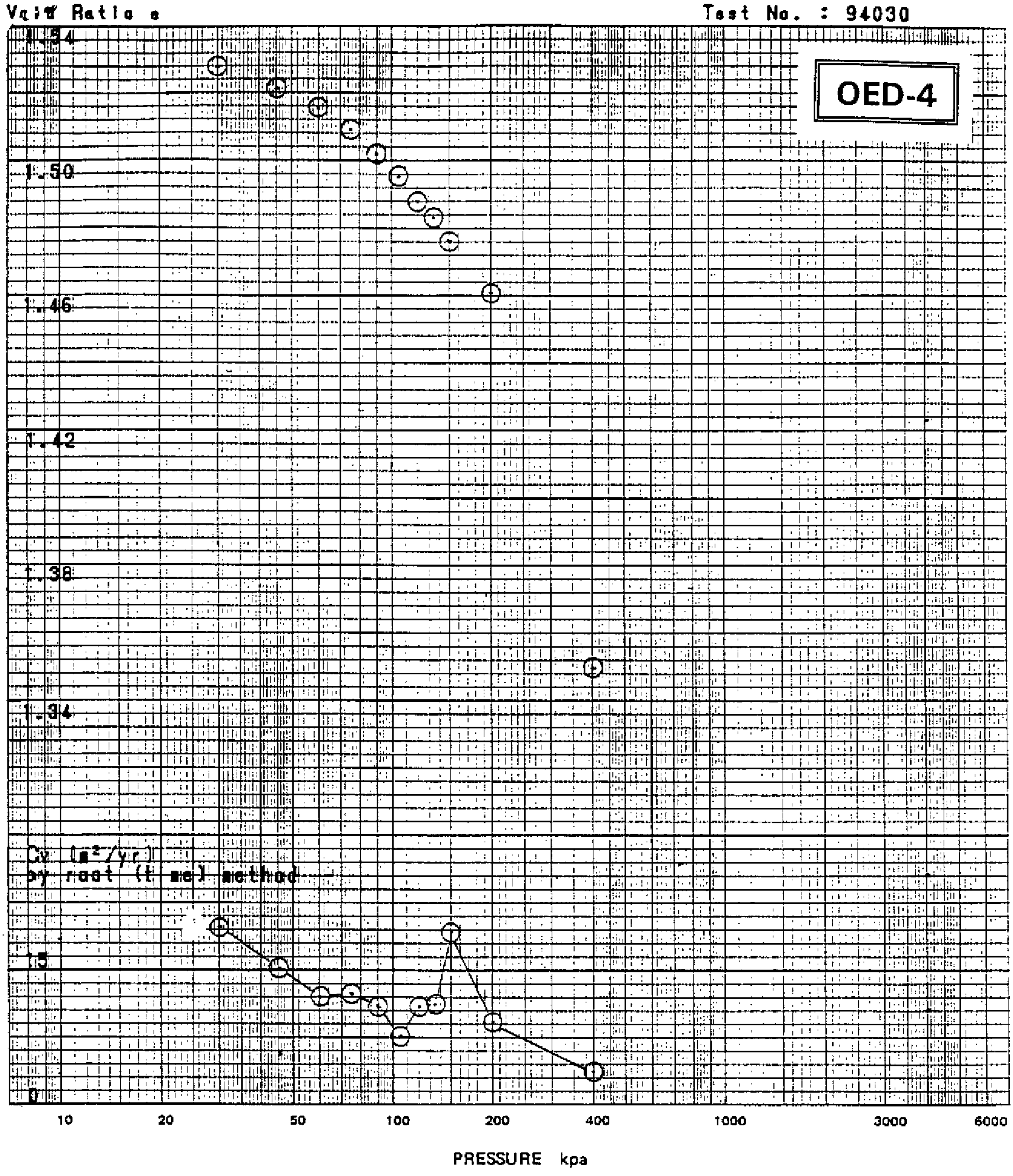
Borehole No. 519809

Depth (m) : 29.87-29.97 ~~Sample No.~~

G.C.O. 46

P.W.D. MATERIALS LABORATORY—CONSOLIDATION TEST

Test No. : 94030



Description

Initial bulk density 1.69 Mg/m³

Initial moisture content 55.2 %

Initial saturation 99.2 %

Initial dry density 1.09 Mg/m³

Initial void ratio 1.543

Specific gravity 2.77 measured / assumed

Compression index Cc

Job Small Incremental Loading Oedometer Testing

Ref. No. 49/94/33

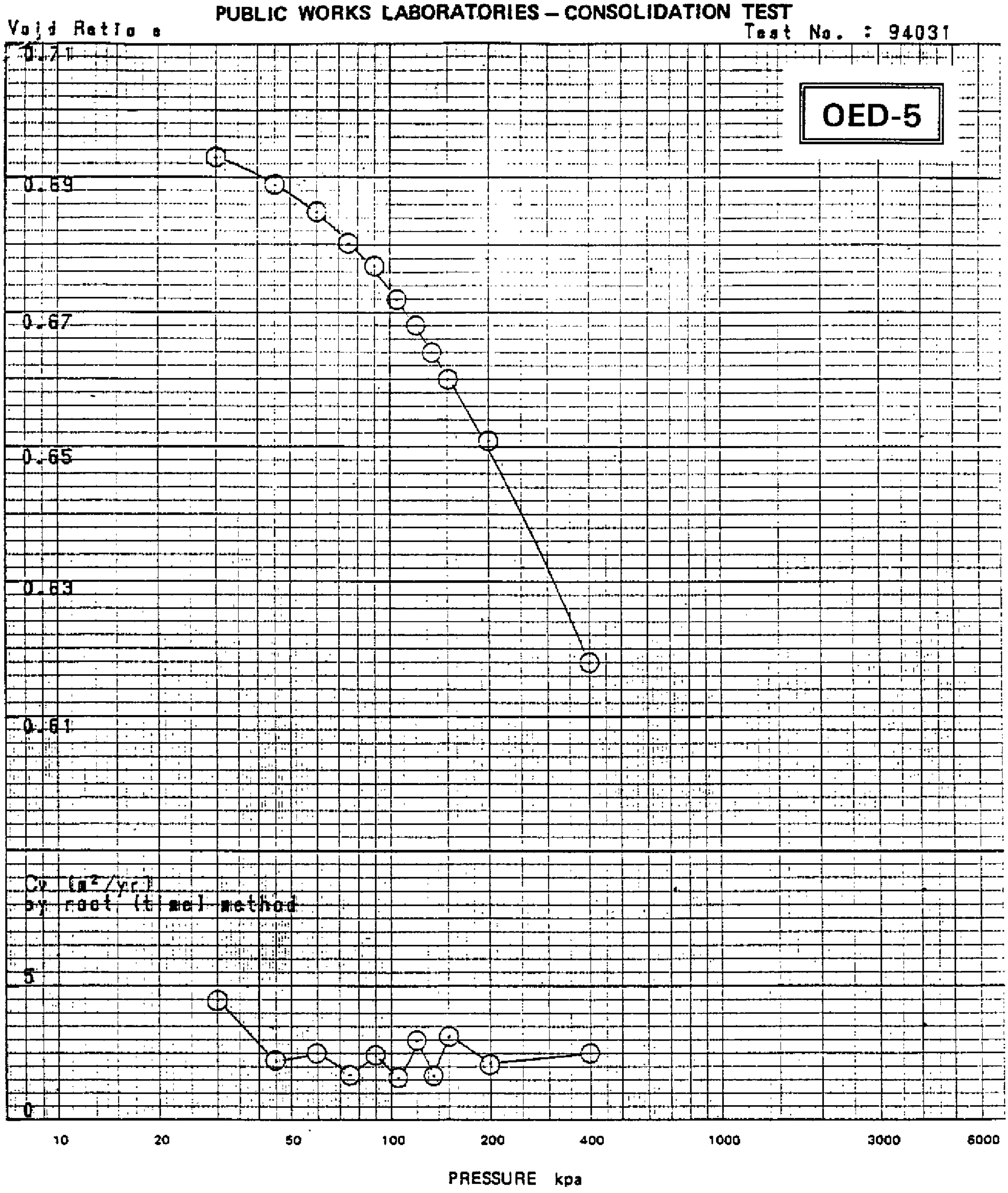
Location - -

Borehole No. 519809

~~Sample No.~~ Depth (m) : 30.38-30.48

G.C.O. 46

PUBLIC WORKS LABORATORIES – CONSOLIDATION TEST



Description

Initial bulk density 2.03 Mg/m³

Initial moisture content 25.2 %

Initial dry density 1.62 Mg/m³

Specific gravity 2.75 measured / assumed

Initial saturation 99.6 %

Initial void ratio 0.696

Compression index Cc

Job Small Incremental Loading Oedometer Testing

Ref. No. 49/94/33

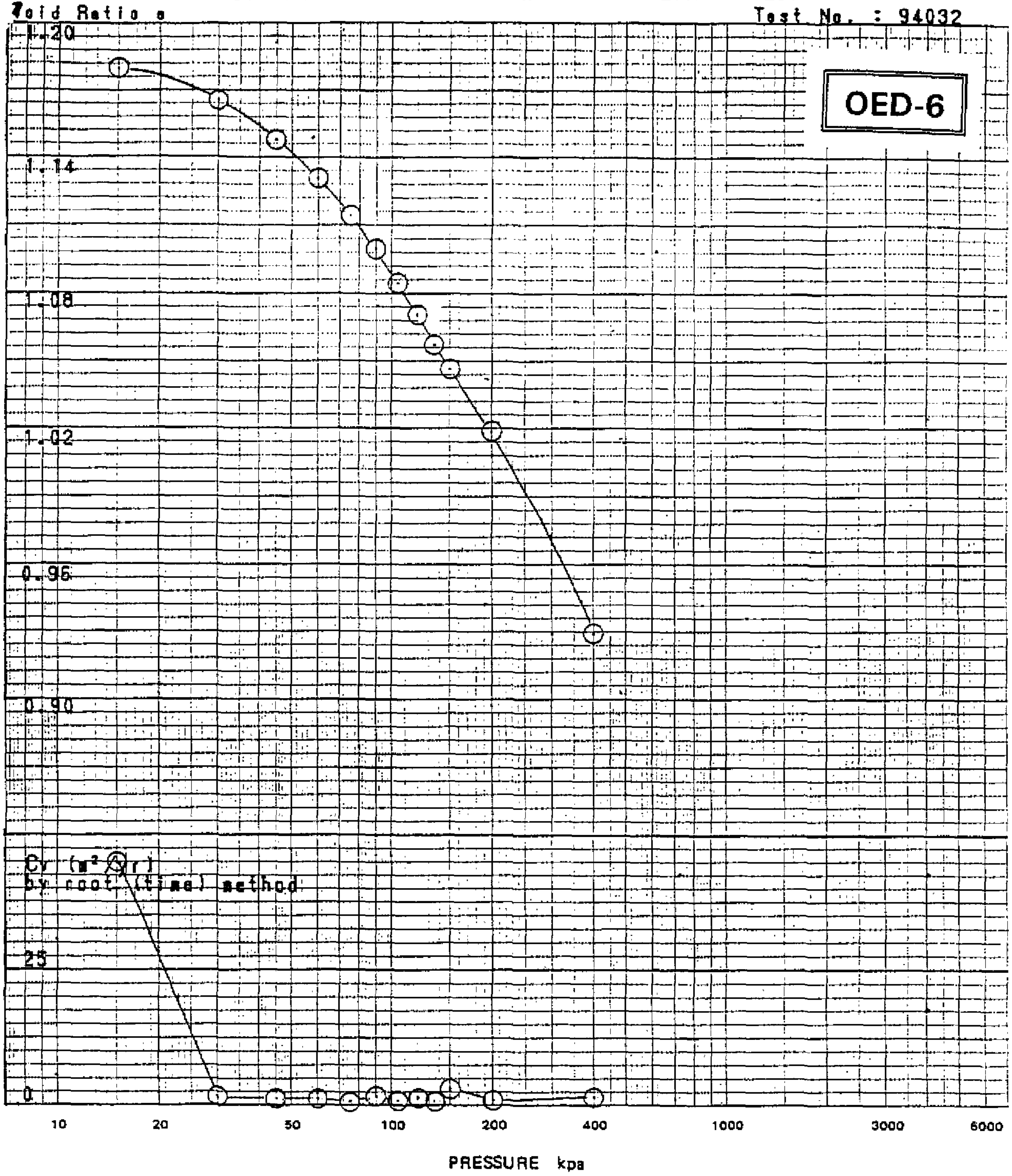
Location --

Borehole No. 519809

Depth (m) : 32.97-33.05 ~~Sample No.~~

G.C.O. 46

PUBLIC WORKS LABORATORIES – CONSOLIDATION TEST



Description

Initial bulk density 1.76 Mg/m³

Initial moisture content 44.2 %

Initial dry density 1.22 Mg/m³

Specific gravity 2.68 measured / assumed

Initial saturation 99.3 %

Initial void ratio 1.193

Compression index Cc

Job Small Incremental Loading Oedometer Testing

Ref. No. 49/94/33

Location — —

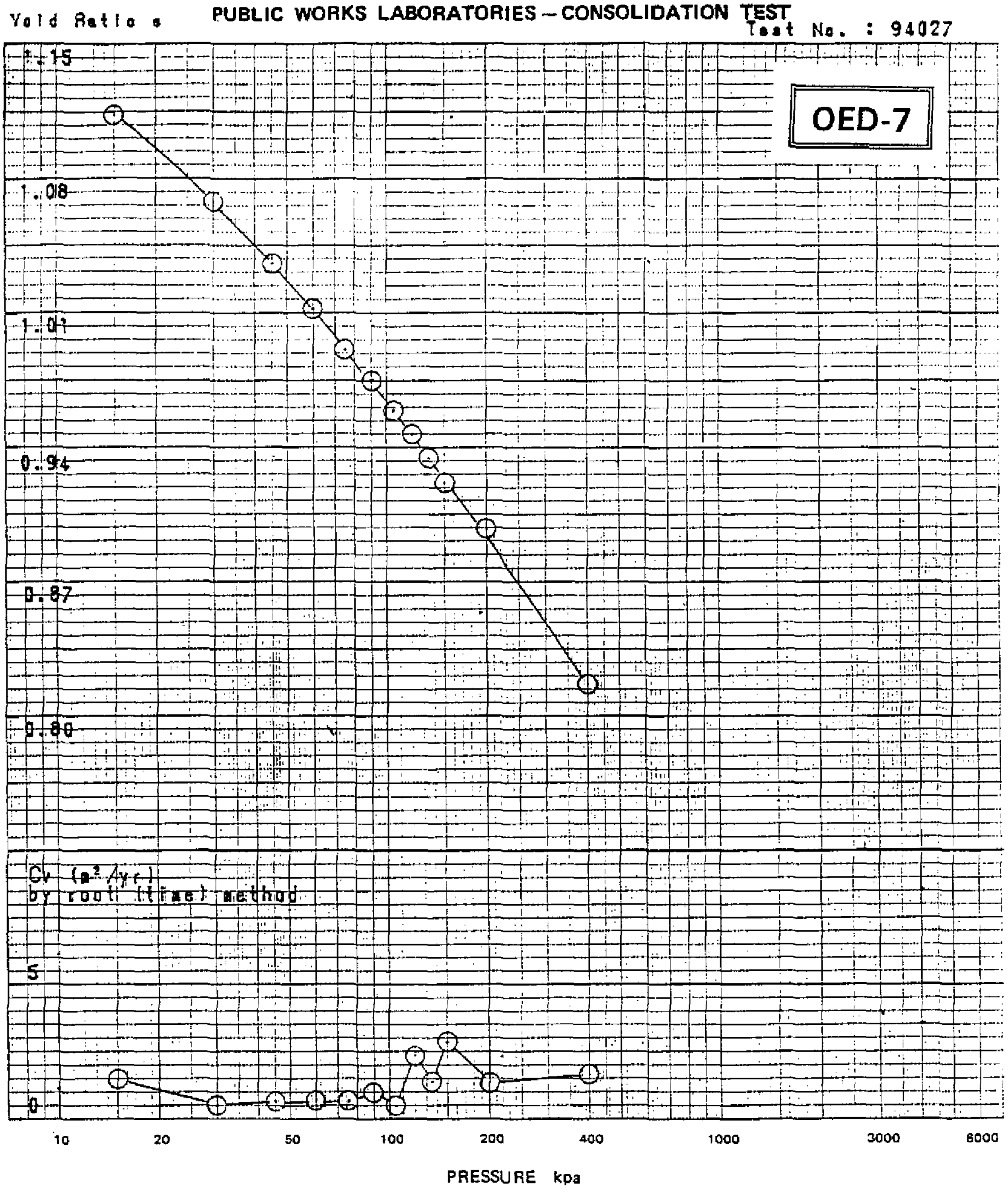
Borehole No. 519812

~~Sample No.~~ Depth (m) : 27.60-27.70

G.C.O. 46

PUBLIC WORKS LABORATORIES – CONSOLIDATION TEST

Test No. : 94027



Description

Initial bulk density 1.79 Mg/m³

Initial moisture content 42.4 %

Initial dry density 1.25 Mg/m³

Specific gravity 2.70 measured / assumed

Initial saturation 99.4 %

Initial void ratio 1.152

Compression index Cc

Job Small Incremental Loading Oedometer Testing

Ref. No. 49/94/33

Location --

Borehole No. 519B12

Depth (m) ~~Sample No.~~ :30.97 - 31.03