Statens vegvesen

FOU-prosjekt
Parameterbestemmelser for siltige materialer.
Delrapport B) Laboratorieundersøkelser

RAPPORT

Teknologiavdelingen

Nr: 2382

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Tittel

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Utarbeidet av

Dato:	Saksbehandler	Prosjektnr:
20050205	DR. Mike Long, Gisle T. Gudjonsson	
	Kontrollert av	Antall sider og vedlegg:
		15/4

Sammendrag

Rapporten presenterer en kortversjon av teorien og prosedyrene bak de utførte laboratorieanalysene for dette prosjekte. Videre så presenteres resultatene fra laboratorieanalysene.
Resultatene fra de utførte laboratorieanalysene er ikke diskutert i rapporten. Samlerapport hvor resultatene fra utført laboratorieanalysene er sammenstilte og diskutert vil bli presentert ved et senere tidspunkt i Intern rapport 2383. teorien og prosedyrene brukt i prosjekte er beskrevet med engelsk bokmål.
Prøvefeltet, den geologiske historien til prøvefeltet, tidligere utført feltundersøkelser, utførte feltundersøkelser og de erfaringer som er gjort i forbindelse med feltarbeidet er presentert i Intern rapport 2381.

Summary

This report presents the results from the laboratory work and a briefly version of the theory and the procedures behind the laboratory work preformed in this project. Analysis regarding the behaviour of the soft silty soil and comparison of the results from the field investigation and from the results from the laboratory will be presented in a final report 2383 for the project.

The geologist history of the site and the field work preformed at site can be found in The Norwegian Public Road internal report 2381 (2005)

Emneord:

Moisture content, Organic content, Bulk density, Specific Gravity, Salt content, Particle size, Atterberg limits, Falling cine, Oedometer tests,
Triaxial test and Bender elements.

TABLE OF CONTEST.

LIST OF FIGURES.

LIST OF TABLES.

1. INTRODUCTION.

The Norwegian Public Road Administration, Technological Department Region West, have preformed geotechnical site investigations (in situ measurements and sampling) and geotechnical recommendations for a period of 30 years. In resent years soft silty soils have been discovered in some areas of the region while sampling on new roads project. For examples were soft silty soils found at E39 Stigedalen in Nordfjordeid, Stedje in Sogn and Fjordane and several of areas in Os county.

Only a limited amount of research papers and knowledge on which site investigations methods and sampling procedures gives the "best" reliable parameters to use in a geotechnical engineering recommendations is available in Norway. This is due to the fact that most geotechnical research in Norway for the last decades have been concentrated on clay and quick clay. The Technological Department experiences with performing sampling in a soft silty soils is that it is difficult to get undisturbed samples to use in a geotechnical engineering recommendation which involves evaluation of the material strength- and deformations- parameters. This is due to the fact that the soft silty soil found in the region is often very sensitive and wet, which leads to loss of sample material and sample disturbances.

To increase the knowledge about the material behaviour of the Technological Department has preformed in situ measurements, sampling and laboratory tests with material from Skeisleira in Os county. The project is financed with FoU- foundings from Research Department at the Norwegian Public Road Administration and the project is done in a co-operation with University Collage Dublin (UCD), The Norwegian University of Science and Technology (NTNU) in Trondheim and Vegdirektoratet.

This report presents the results from the laboratory work and a brief summary of the theory and the procedures behind the laboratory work preformed in this project. The site investigation preformed in this project involves total sounding method, field vane, cone penetration with pore pressure measurements, T-bar measurements and several of different sample tubes.

The laboratory work described in this project was carried out mostly at the University College Dublin and at The Norwegian Public Road Administration, Technological Department Region vest (Bergen) in the period October 2004 to July 2005.

2. THEORY AND PROCEDURES

The objective of this chapter is to summarize briefly the procedures and theory used in this project. The procedures, theory and interpretation methods which will be described in this chapter are as follow:

- Routine laboratory tests.
- Maintained load (ML) oedometer tests.
- Constant rate of strain (CRS) oedometer tests.
- Anisotropically consolidated undrained (CAUC) triaxial tests.
- Shear wave velocity measurement by bender elements.

A large number of classification tests were carried out as part of the study of the site. Procedures used in this project are mostly based on *Håndbok 014 (1997)* and *BS1377(1990)*.

Table A summarizes all the classification tests carried out as part of this study. The table states the number of tests carried out, the test specification (i.e. generally the relevant part of *Håndbok 014 (1997) and BS1377(1990)*.

Type of tests.	NO. of tests.	Specification
Moisture content.	*97*	*14.426 (HB 014)*
Organic content.	*12*	*14.445 (HB 014)*
Bulk density.	*90*	*14.425 (HB 014)*
Specific gravity.	*6*	*Part 2 (BS 1377)*
Salt content.	*2*	*14.643 (HB 014)*
Particle size (Distrib by sieve / hdrom).	*19*	*14.421 (HB 014)*
Atterberg limits.	*3*	*14.441 and 14.442 (HB 014)*
Falling cone	*21*	*14.471 (HB 014)*
Oedometer tests.	*34*	*Part 5 (BS 1377) with some modification*
Triaxial tests.	*11*	*Part 8 (BS 1377) with some modification*
Bender elements	*9*	*Dyvik and Madshus (1985) and Dyvik and Olsen (1989)*
Total tests preformed.	***304***	

Table A. Summary of type of tests preformed and numbers of tests.

2. 1. ROUTINE LABORATORY TESTS.

All tests were carried out according to *Håndbok 014 (1997) and BS1377(1990)*. The theory, procedures, and the equipment behind the routine laboratory testing are assumed to be well know and therefore will they not be described.

2. 2. OEDOMETER TESTS.

Oedometer tests in general.

The main purpose of the oedometer tests is to record the soil behavior when it is exposed to changes in stresses in one dimension such as experienced under a road embankment. In an oedometer test the deformation of the soil, when different stresses are applied, is recorded and from those data the deformation-, consolidation-, and time resistance-parameters for the soil can be determinate.

Maintained load (ML) oedometer tests.

The procedures adopted generally followed those used at the Norwegian Geotechnical Institute (NGI) as detailed by Sandbækken et al. (1987). Reference is also made to the appropriate British Standard BS1377 (1990), Part 5.

The oedometer cells had an internal diameter of 50 mm and a height of 19 mm.

Building in specimen:

1. The oedometer ring is lightly coated with silicon oil to minimise friction.
2. A sub-sample approximately 50 mm long is cut from the parent sample (which was either 54 mm or 76 mm in diameter) using a piano wire and then trimmed to a diameter slightly greater than that required.
3. The oedometer ring is then carefully pushed into the sample, while trimming away residual material at approximately 2 mm intervals of penetration.

Setting up in oedometer:

1. The filter stones are mounted dry to prevent absorption of water by the soil.
2. Filter paper is not used because the time dependent nature of their compression makes it impossible to separate their compliance from the compression of the sample.
3. The sample is inserted in the oedometer apparatus. Set the beam of the apparatus to an upward inclination approximately equal to the likely final downward inclination. If necessary the beam can be adjusted during the test by raising the beam and adjusting the loading stem, as shown on Figure A.

Figure A. ML oedometer testing at UCD

Loading cycles:

The following sequence of loading should be carried out as detailed on Table B. (broadly follows that of Sandbækken et. al. 1987).

Cycle No.	Load Increment	Duration
	kN/m^2	Hours
1	0.25 σ'_{v0}*	2.5**
2	0.50 σ'_{v0}	2.5
3	σ'_{v0}	2.5
4	1.5 σ'_{v0}	2.5
5	2.0 σ'_{v0}	2.5
6	1.0 σ'_{v0}	2.5#
7	1.5 σ'_{v0}	2.5
8	2.0 σ'_{v0}	2.5
9	4.0 σ'_{v0}	2.5
10	8.0 σ'_{v0}	2.5
11	16.0 σ'_{v0}	2.5

Table B. Loading cycles in oedometer tests.

* σ'_{v0} = in situ vertical effective stress

** Typically 3 increments can be carried out in a working day. Any increments left overnight are corrected to the 2.5 hour reading

The porous stones are saturated during increment 6.

The samples should be unloaded slowly to prevent high suctions during dismantling and therefore incorrect determination of the final void ratio.

Correcting for false deformation:

1. Increment 1 normally needs to be corrected for take up in system slack etc. This is done by back projection of the of the time settlement curve.
2. False deformation (system compliance) for the remainder of the increments needs to be corrected for using the data from a set of loading on a dummy specimen as shown on Figure B.
3. A correction is also carried out for secondary compression if a load increment had been imposed overnight or over a weekend, as discussed above.

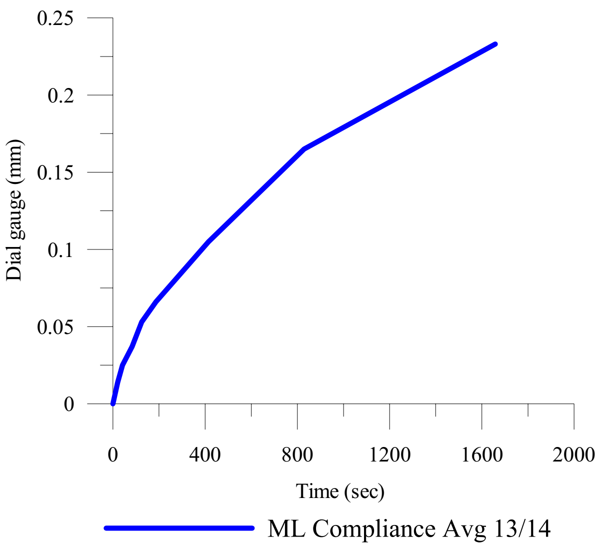


Figure B. Compliance correction for UCD ML oedometers 13 and 14.

Calculations:

Full details of the calculation method can be found elsewhere (e.g. Head, 1982, Vol. 2, BS1377, 1990) but the following points should be noted:

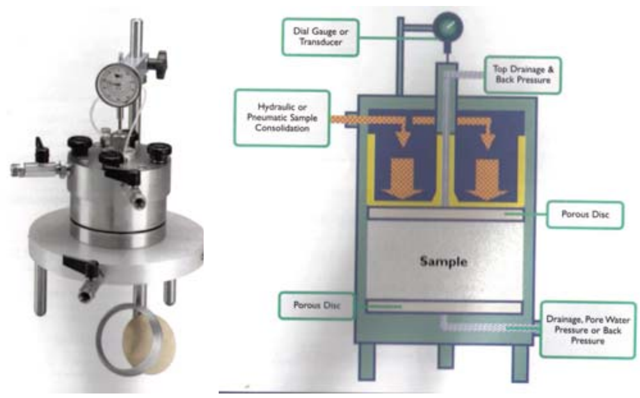
1. Before analysis examine shape of square root of time versus settlement curve and check if the curve is similar to that of clay or silt etc. Analysis will differ depending on the material type. (see Head, Vol. 2).
2. Should try √time and log time construction for at least one cycle to see which is most appropriate and to act as a cross check.
3. Should determine G_s for particular material.

Transducer resolution and accuracy:

The LVDT's used to record the specimen compression have a resolution of 0.01 mm (Oedometers 13 and 14). This information was recorded electronically and output produced graphically continuously to ensure the test was proceeding well. In each case output from the transducer was cross-checked using a conventional plunger type dial gauge which had a resolution of 0.002 mm. (In the calculations for e - log p, the LVDT data was used). Differences between the LVDT and dial gauge readings were generally less than 1%. Load was applied to the specimens using dead weights. The weight of each was checked on an externally calibrated scales.

Constant rate of strain (CRS) oedometer tests.

In these tests the total vertical stress was applied by fluid pressure acting across a flexible platen. Fluid pressure is applied through a diaphragm with convoluted sides to allow for the necessary vertical expansion and contraction of the sample. For this project tests were carried out using the Wykeham Farrance Ltd. "Hydrocon" system, see Figure C(a). The best known version of this type of apparatus is the Rowe cell (Rowe and Barden, 1966). Strictly speaking these tests were actually constant rate of loading tests rather than constant rate of strain tests. A detailed description of these family of tests can be found in Davison and Atkinson (1990) or in Janbu et al. (1981)



a) *b)*

Figure C. UCD "CRS" system

Some details of the system are as follows:

- Specimens are 50 mm in diameter by 19 mm high.
- Drainage is one way via a porous stone at the top of the samples, see Figure C(b).
- Pore pressure is measured via a transducer mounted at the base of the specimen.
- With this system it is possible to apply a back pressure to ensure the sample is saturated and that the subsequent pore pressure generation system is "rigid".

The test procedure is as follows:

1. The specimen is prepared in the same manner as described for the ML oedometer tests above except that in this case, by necessity, the porous stones are wet.
2. A small static load (typically) 10 kPa was applied to ensure that the initial system slack etc. was removed.
3. A back pressure of 200 kPa was applied.

4. The specimen was loaded at a constant rate up to the system capacity of 750 kPa.
5. It was initially necessary to alter the rate of loading so as to achieve an equivalent constant rate of strain of about 1% per hour, which is typical of that used in Norway (Janbu et al., 1981, Sandbækken et al., 1987). This was achieved using a loading rate of between 30 kPa/hour and 60 kPa/hour.

The calculation procedure involves:

1. Carrying out a machine compliance correction similar to that for the ML tests, using the graph shown on Figure D.
2. Determining the vertical effective stress and the constrained modulus and plotting these against strain in the normal manner.
3. Average pore pressure in the specimen was assumed to be 2/3 of that measured at the base.
4. It is possible to determine the coefficients of consolidation (c_v) and permeability (k) from the pore pressure data but this has not been done to date in this case.

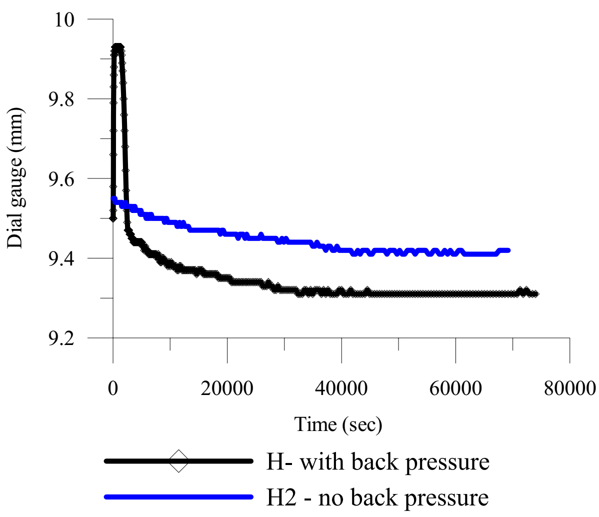


Figure D. Compliance correction for UCD 50 mm Hydrocon.

2. 3. TRIAXIAL TESTS.

Triaxial tests are performed to study the behaviour of the soil in more detail when it is exposed to changes in stresses. In a triaxial test the deformation of the soil and the pore pressure, when an increase or degrees in stresses is applied, is recorded and from those data the strength parameters for the soil can be determinate. Figure E illustrates the triaxial equipment used in this project.

Figuer E. Triaxial equipment.

For this project the triaxial tests were anisotropically consolidated undrained tests. These test are commonly called CAUC tests or sometimes CK_0U tests. They are used frequently to give reliable estimates of the undrained shear strength (s_u) and are often the standard reference test used in sample disturbance assessment programs.

The procedures used are generally in accordance with BS1377, Part 8 (1990) with some modifications as listed below. The modifications are drawn largely from experience at the Norwegian Geotechnical Institute (Berre, 1981), Imperial College London (Hight et. al. 1992) as well as experience at UCD. Some of the recommendations of Head (1986) are also used.

Specimen size:

Specimens were usually trimmed to 50 mm in diameter. Occasionally untrimmed 76 mm specimens were used. Where possible a length of specimen equal to twice its diameter was used to minimise end effects caused by the top and bottom caps. At a minimum the specimen length should be 1.5 times its diameter.

Sample preparation:

The samples were trimmed to size using a thin piano wire and a soil lathe. The sample was then place in a split ring mould and the ends were trimmed. The trimmings were used for moisture content determination. The sample weight, length and diameter were measured. When the sample was ready it is wrapped in cling film while the base pedestal is prepared.

One of the porous stones is placed on a film of water on the base pedestal. Filter paper is used in the form of spiral drains if experience suggests that consolidation without the use of drains would take an unacceptable length of time. In this case filter drains were omitted.

The sample was unwrapped and put in place. The other porous stone was placed on top of the sample. The membrane was now stretched, placed over the soil sample and released ensuring that no air is trapped between the sample and the membrane. If necessary suction, not exceeding 50kPa, can be applied to suck out the air. Two O-rings, previously mounted on the base pedestal, were used to seal the bottom of the membrane and a further two rings, previously mounted on the membrane stretcher, were used to seal the top of the specimen. Care is needed to ensure all air is expelled from the system.

The cell was then filled with deaired water.

Specimen "settling in" stage:

In order to allow the sample settle down and bed into the system, a cell pressure (p_i) equal to one half of the total vertical overburden stress (i.e. 1/2 σ_{v0}) was applied. This was usually left overnight. Pore pressure is monitored and the final value u_i is recorded.

This stage also allows the initial (or residual) effective stress or sample suction (u_r) to be measured (Hight et. al, 1992). u_r can be used to assess sample quality.

$$u_r = p_i - u_i \qquad (1)$$

Saturation stage:

For soft materials such as under consideration here the saturation stage must be carried out very carefully. Sudden rapid increases in cell pressure ($\Delta\sigma_3$) can easily lead to local failure around air voids. An increase in cell pressure of 25 kPa was first applied. The pore pressure parameter ($B = \Delta u/\Delta\sigma_3$) was then determined. If $B \geq 0.95$ then the sample is adjudged to be sufficiently saturated and the cell pressure can be raised in fairly rapid steps to that required for the consolidation stage. If $B < 0.95$ then a back pressure was applied to reinstate the initial effective stress and the system is allowed to equalise. A further increment of cell pressure was then applied and B is measured. This cycle of cell pressure and back pressure application is continued until a satisfactory value of B was achieved. This stepwise application should be carried out slowly in such a manner that the axial strain does not exceed 0.1%. A final back pressure of 200 kPa is considered appropriate for soft soils and was used in all tests here.

It has been suggested (Berre, 1981) that a B value of 0.9 is adequate for static tests on soft clays.

Consolidation stage:

Stresses to be applied

The vertical effective stress (σ'_a) to be applied is taken to be equal to the in-situ vertical effective stress (σ'_{v0}) determined from the soil and groundwater profile and the soil strata unit weights. The horizontal effective stress, σ'_r (or σ'_{h0}), is given by:

$$\sigma`_r = \sigma`_{h0} = K_0 \sigma`_{V0} \qquad (2)$$

where K_0 is the co-efficient of earth pressure at rest. This is determined from the relationship between K_0, plasticity index (I_p), and overconsolidation ratio, OCR, developed by Brooker and Ireland (1965). OCR is determined from the preconsolidation pressure, (p'_c) in the oedometer test. In this project a K_0 of 0.5 was adopted.

Stress path

The stress path used for application of the consolidation stresses is as described in Figure F (Hight et. al. 1992).

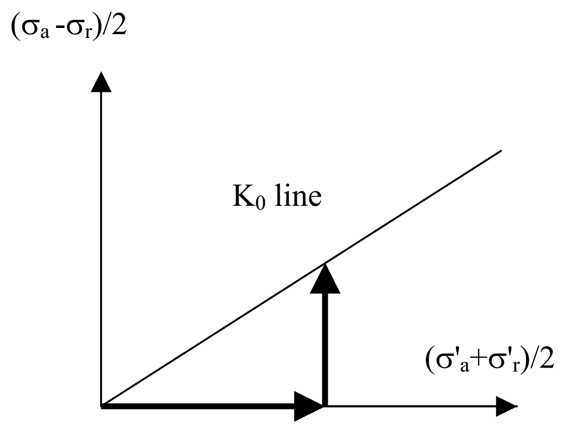


Figure F. Stress path for consolidation stresses

It can be seen that the consolidation stresses are applied in two stages as follows:

- an initial isotropic pressure application (equal to 50% to 60% of the final σ'_{h0}) which is then left to stabilise overnight,
- and an anisotropic pressure application, which should be applied in a number of steps. This is again left to stabilise overnight.

The last increment of consolidation stress should be maintained for a period of 24 hours and until the volume change is less than 0.0001% per minute.

Shearing stage:

Shearing rate

The rate of shearing should be slow enough to allow full pore water pressure equalisation occurs. The standard Norwegian rate of 18% axial strain / day proposed by Berre et al. (1981) was used here.

Corrections to results of shearing stage:

The following corrections should be made to the results of the shearing stage:

- correct heights and volumes at start of shearing,
- membrane stiffness correction (Berre et al., 1981),
- system compliance correction (for external displacement measurement),
- Bottom chamber friction correction
- transducer drift.

Correct heights and volumes at start of shearing

During isotropic consolidation, it is assume that the specimen deforms as a right cylinder and that the new area (A) and length (L) parameters can be determined as follows:

$$A_{new} = A_{old}\left[1 - \frac{2}{3}\left(\frac{\Delta V}{V_0}\right)\right] \qquad (3)$$

where:

V_0 = initial volume,

ΔV = volume change during isotropic consolidation.

Following the anisotropic consolidation stage L_{new} is determined from the length change given by the displacement transducer and A_{new} is calculated using L_{new} and the measured volume change.

Membrane stiffness correction

The assumption here is that pure slip plane failures are rare for soft soils. Therefore correction theory can be reliably based on bulging (or necking) type failure. According to Berre et al. (1981), for undrained tests i.e. no volume change, the correction to be subtracted from the axial stress is given by:

$$\frac{2tE_m\varepsilon_a}{r} \qquad (4)$$

where:

E_m = Young's modulus of membrane = 1,400 kPa typically

t = initial membrane thickness

r = initial membrane radius

ε_a = axial strain

System compliance correction (for external displacement measurement)

Bottom chamber friction correction

Transducer drift.

These corrections were found to be negligible and were ignored.

Transducer resolution and accuracy:

The transducers output a continuous ("analogue") voltage to the digital measuring systems which break this down using a 16 bit analogue / digital (A/D) converter. This means that the A/D converter breaks down the full range output (FRO) to 2^{16} = 65,536 parts. Transducer resolution is thus given by this system limitation.

Transducer accuracy, on the other hand, is the difference between the true value and the value being outputted by the transducer. It will depend on many factors, including age and service history of the transducer, environmental factors, quality of system set up etc. It can be measured in a series of tests or it can be determined from experience. A summary of the transducer resolution and accuracy (expressed in engineering units and as a percentage of full range output) is summarised on Table B.

Trans-ducer	**Resolution**	**Accuracy**	**Accuracy**
	Engineering units	**Engineering units**	**% FRO**
Pore pressure transducer	0.5 kPa	2 - 3 kPa	0.07
Load cell	1 N	3 N	0.1
Displace-ment transducer	1 μm	200 μm	0.5
Volume change transducer	10 mm^3	10 mm^3	0.25

Table C. Summary of transducer resolution and accuracy

Transducer error can then be calculated from error = resolution + accuracy.

Tests were carried out during the work to establish electrical stability of the transducer output. No noticeable variations were observed.

2. 4. BENDER ELEMENTS.

Shear wave velocity measurement by bender elements

Background information on the use of bender elements to measure shear wave velocity in soils can be found in various publications including Dyvik and Madshus (1985) and Dyvik and Olsen (1989). In this study bender elements were mounted in the top and bottom caps of the UCD triaxial system, see Figure G.

Figure G. Bender elements in UCD triaxial system

The bender element at one end of the specimen is used to generate a shear wave pulse, which propagates along the length of the specimen, and the other element is used to derive the arrival time of the shear wave at the other end. The travel time along the known specimen length produces a direct measurement of the shear wave velocity (v_s) and in turn G_{max} from the following expression:

$$G_{\max} = \rho v_s^2 \qquad (5)$$

where ρ is the soil density.

The UCD system has previously been used by Donohue (2005) for the purposes of estimating sample quality and the reader is referred to this thesis for details on the different types of shear wave that can be used, methods for determining travel time etc. In summary the following parameters were used for the test results presented here:

- Sine wave pulse.
- First arrival time used to determine wave travel time.
- Ratio d (distance) /λ (wave length) > 4 so as to minimise near field effects.
- Input frequency typically > 4 Hz.

Measurements were made immediately after specimen trimming and placement in the triaxial cell (i.e. "in air"), after the isotropic consolidation phase and after the final anisotropic consolidation phase just before shearing.

4. RESULTS.

All the laboratory results are presented back in this report.

Figure 1 to 11 illustrates the results from the routine laboratory tests and the shear wave velocity tests preformed.

Table 1 to 2 summarises the results from the maintained- and the CRS oedometer tests preformed. Individual tests preformed can been seen in figure 12 to 45.

A summary of the triaxial tests preformed can be seen in Table 3 and each individual test preformed can been seen in 46 to 56.

Photographs of the samples after extrusion, and salt/remoulded test can been seen in photograph 1 to 4.

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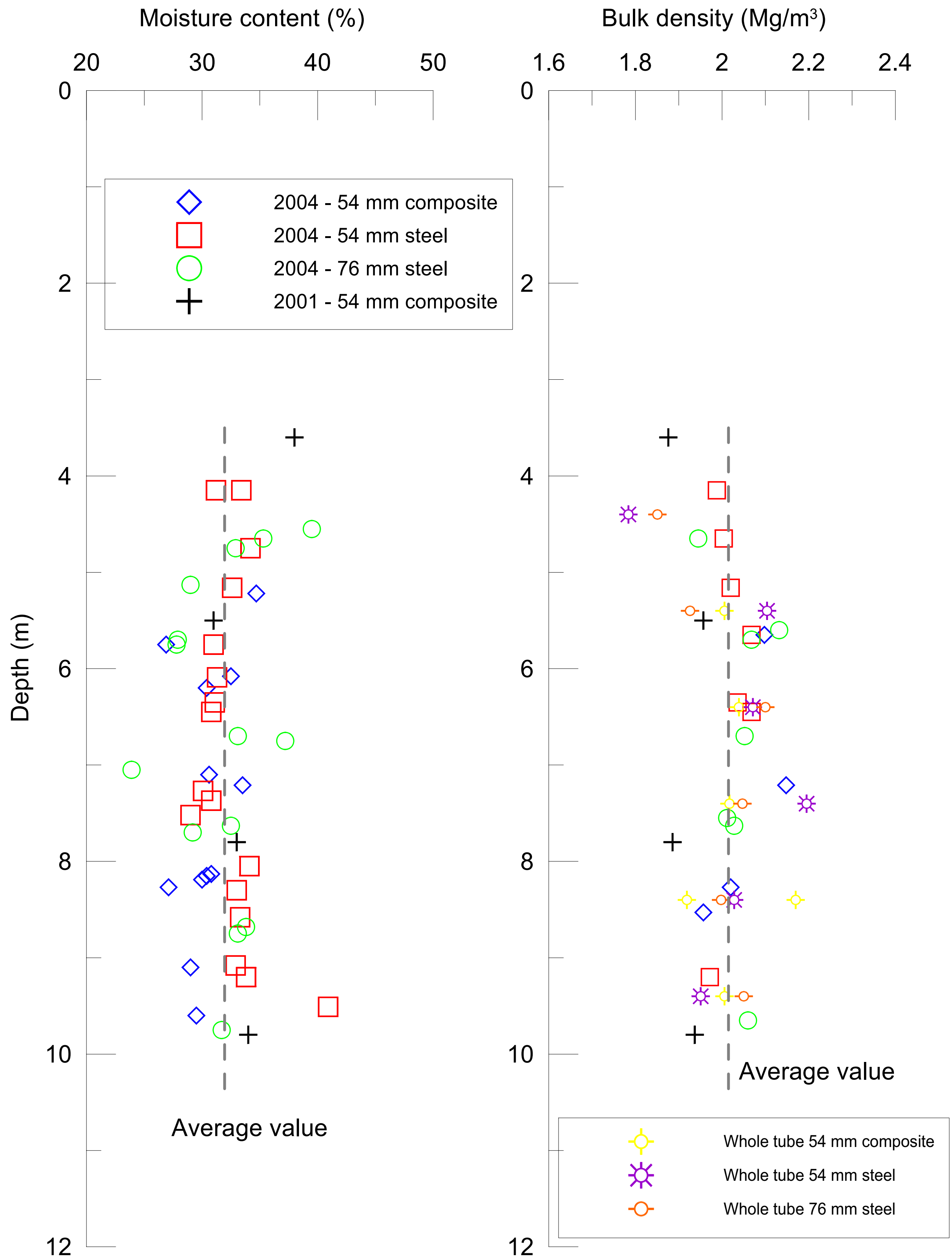
SUMMARY OF RESULTS FROM THE LAB.



Fou project - Quality of silt samples - Os site	Report No. 2005-G1	Figure No. 1
Bulk density and moisture content vs. depth Data from small element tests and whole sample tubes (Do not include data from CAUC, MSL, CRS etc.)	Drawn by ML	Date 2005-07-07
	Checked	
	Approved	

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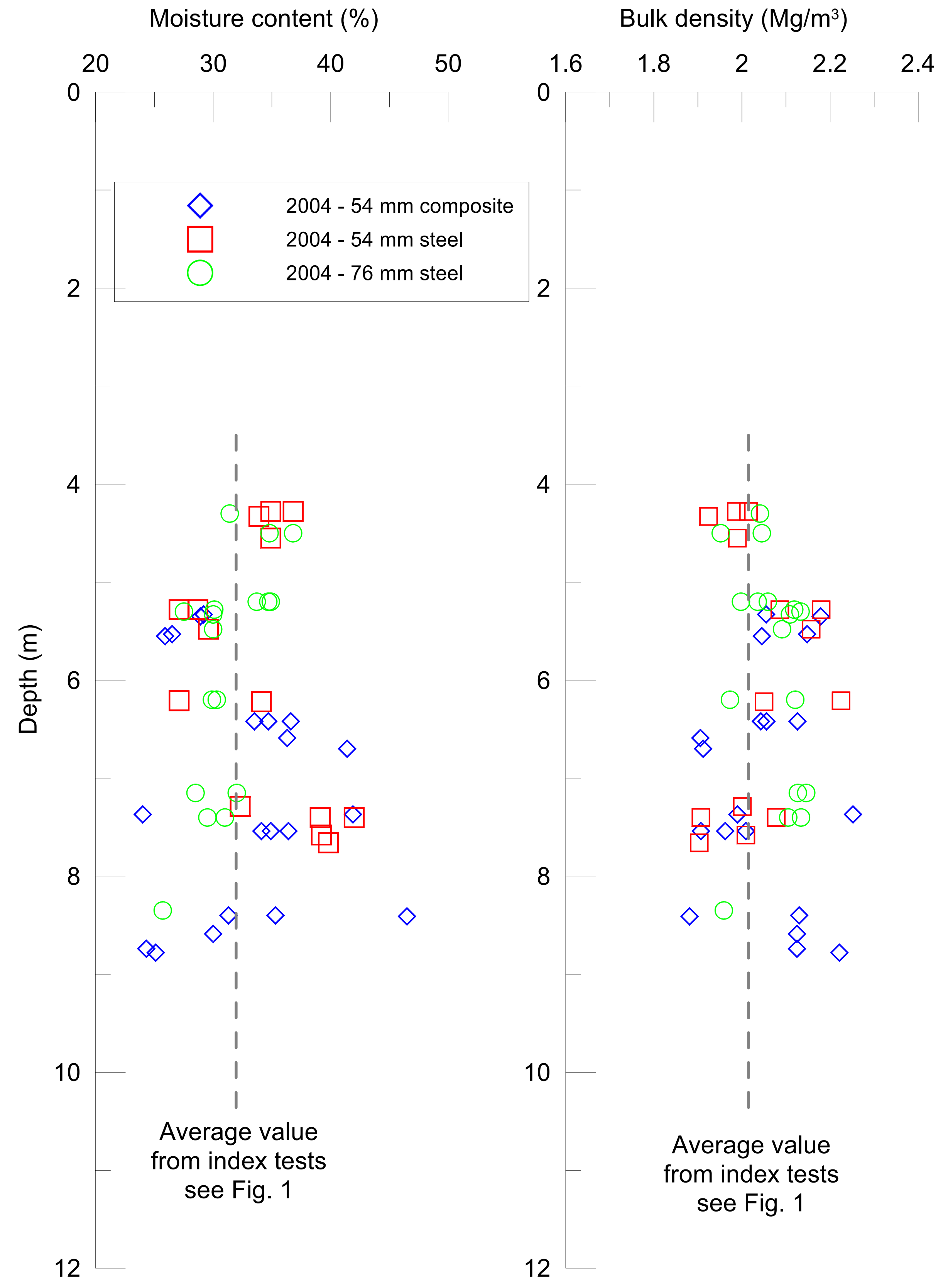
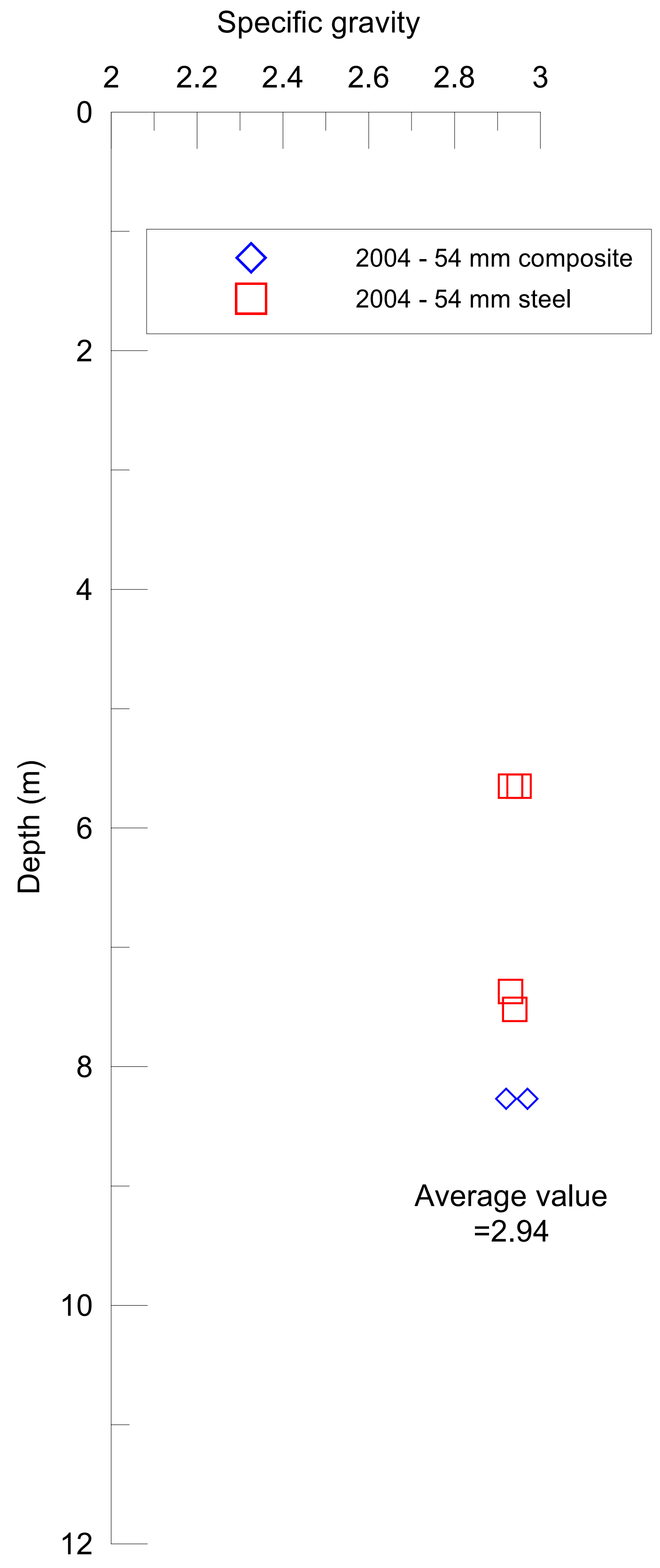


Fou project - Quality of silt samples - Os site	Report No. 2005-G1	Figure No. 2
Bulk density and moisture content vs. depth Data from CAUC, MSL and CRS tests	Drawn by ML	Date 2005-07-07
	Checked	
	Approved	

D(AF)\FoU\Bdenmcmainlab.grf

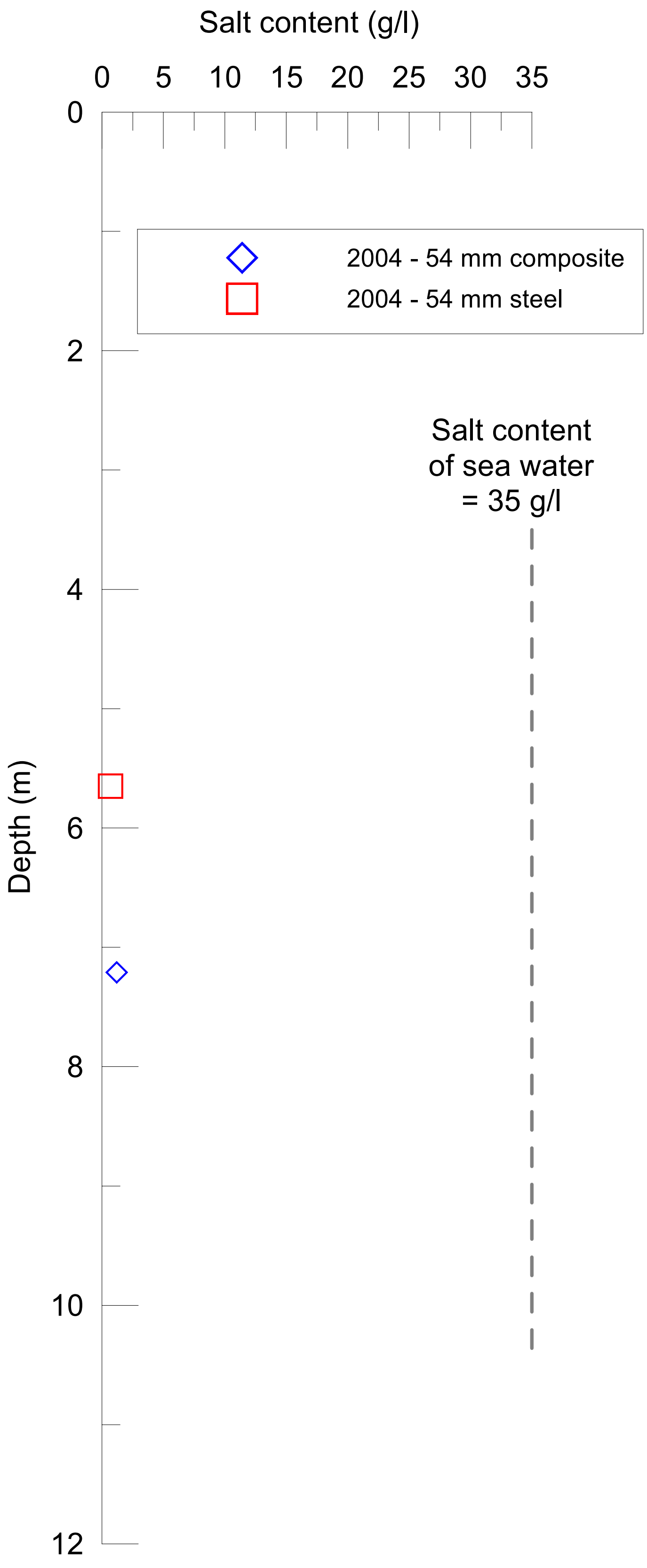


FoU project - Quality of silt samples - Os site

Specific gravity (or particle density) vs. depth

Report No.	Figure No.
2005-G1	3
Drawn by ML	Date 2005-07-07
Checked	
Approved	

D(AF)\FoU\Specificgravity.grf

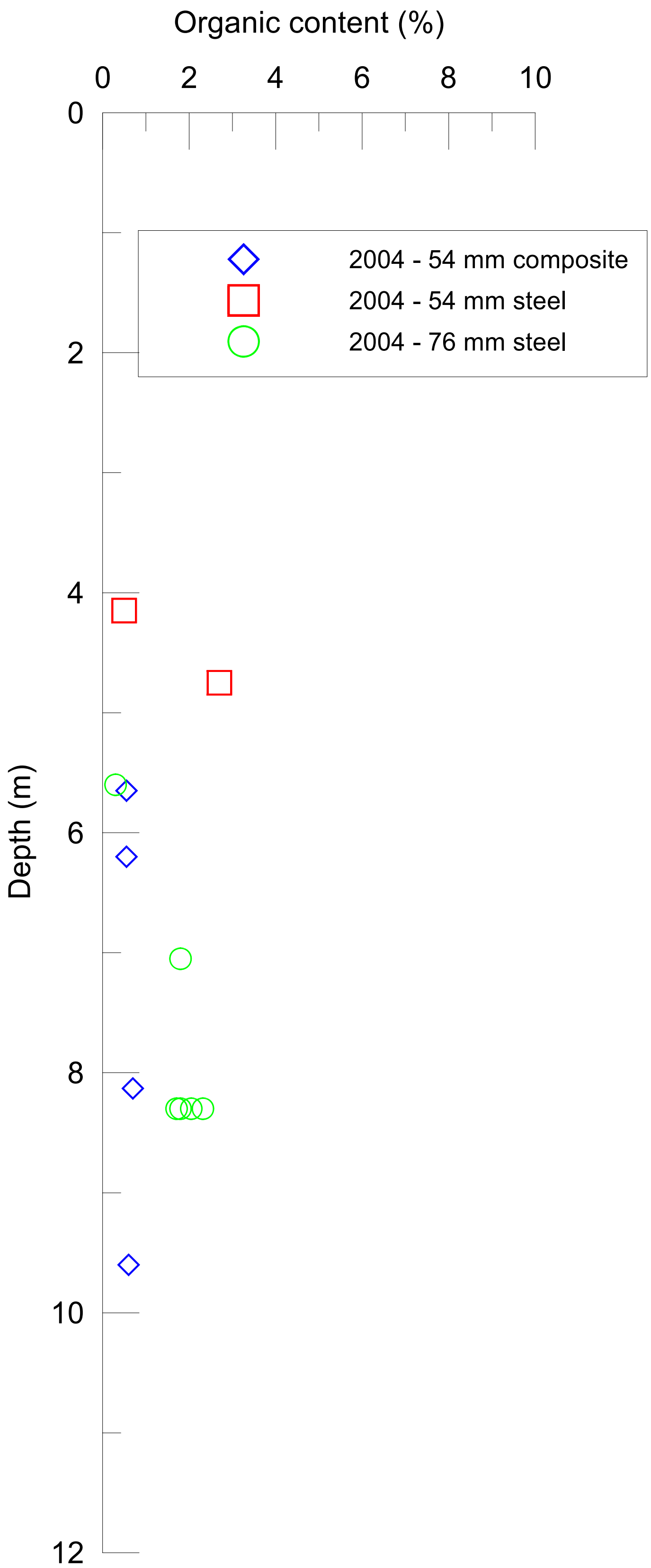


FoU project - Quality of silt samples - Os site

Salt content vs. depth

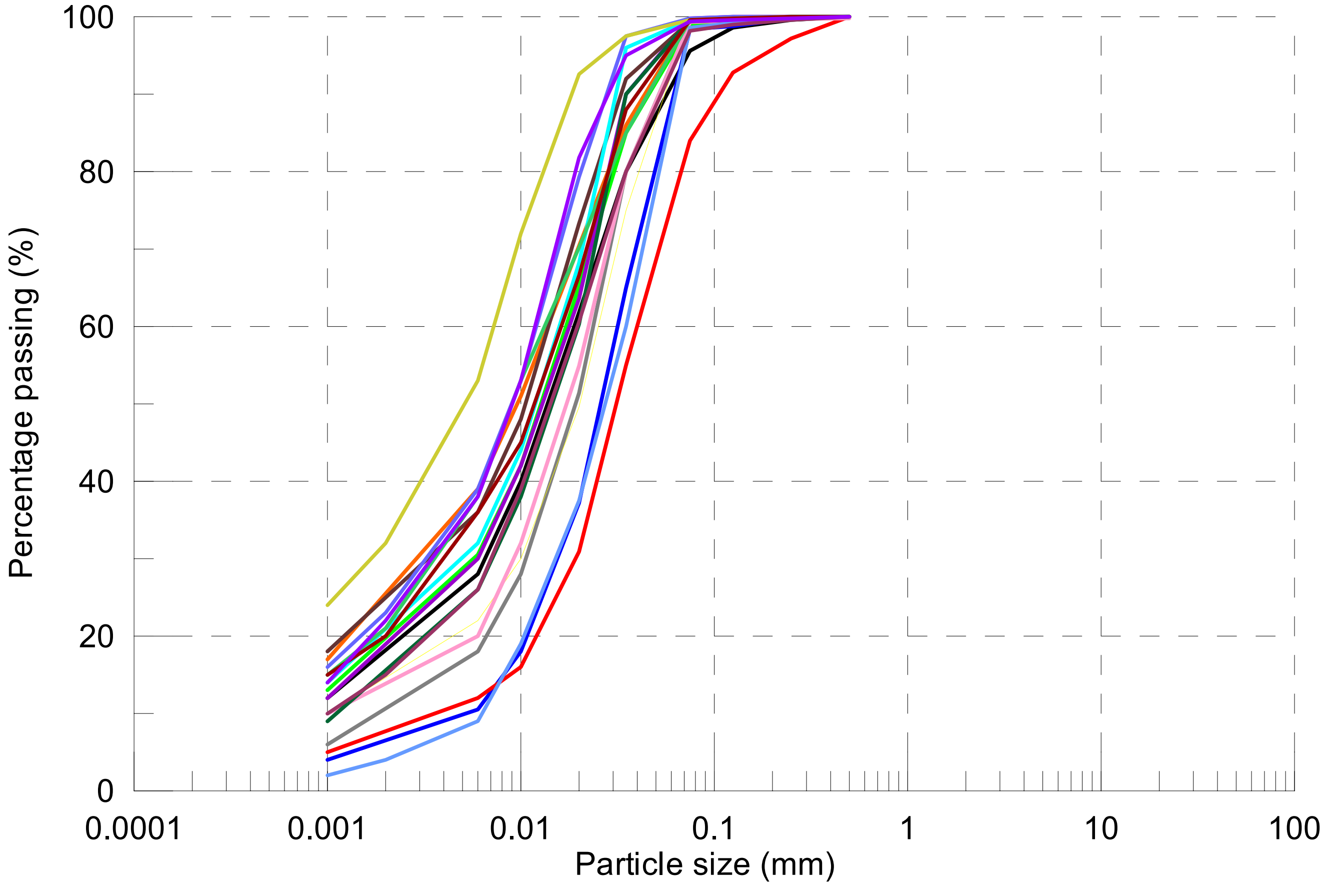
Report No. 2005-G1	Figure No. 4
Drawn by ML	Date 2005-07-07
Checked	
Approved	

Dell\Labtests\FoU\Salinity.grf



FoU project - Quality of silt samples - Os site	Report No. 2005-G1	Figure No. 5
Organic content from loss on ignition (LOI) at 440 deg. C vs. depth	Drawn by ML	Date 2005-07-07
	Checked	
	Approved	

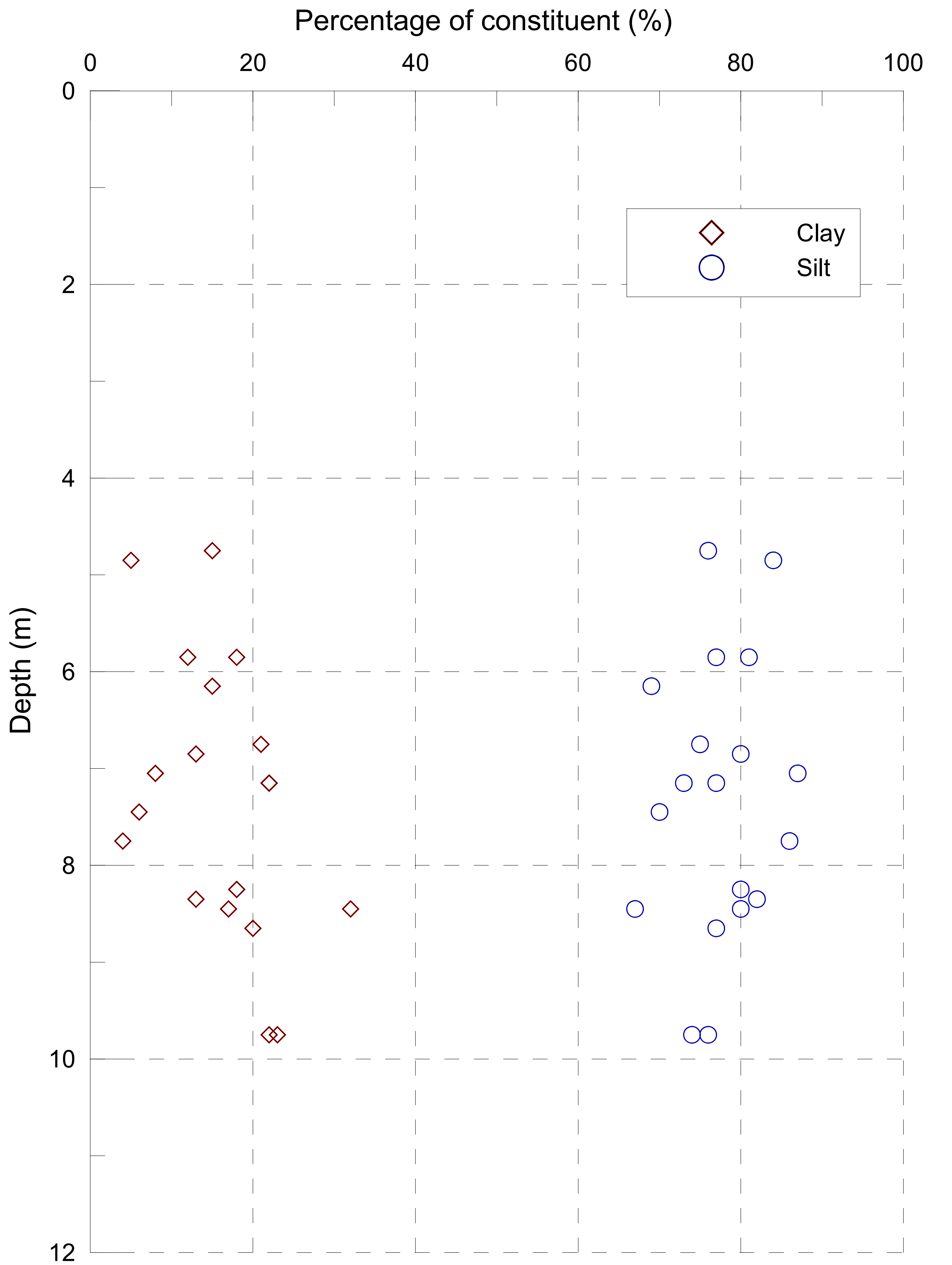
Dell\Labtests\FoU\Organic.grf



Clay	Silt			Sand			Gravel		
	Fine	Med.	Coarse	Fine	Med.	Coarse	Fine	Med.	Coarse

FoU Project - Os Site	Report No. 2005 - G1	Figure No. 6
Particle Size Distribution	Drawn by GC/GG	Date 2005-07-07
	Checked ML	
	Approved	

Dell+D(AE)\Labtests\FoU\psd.grf

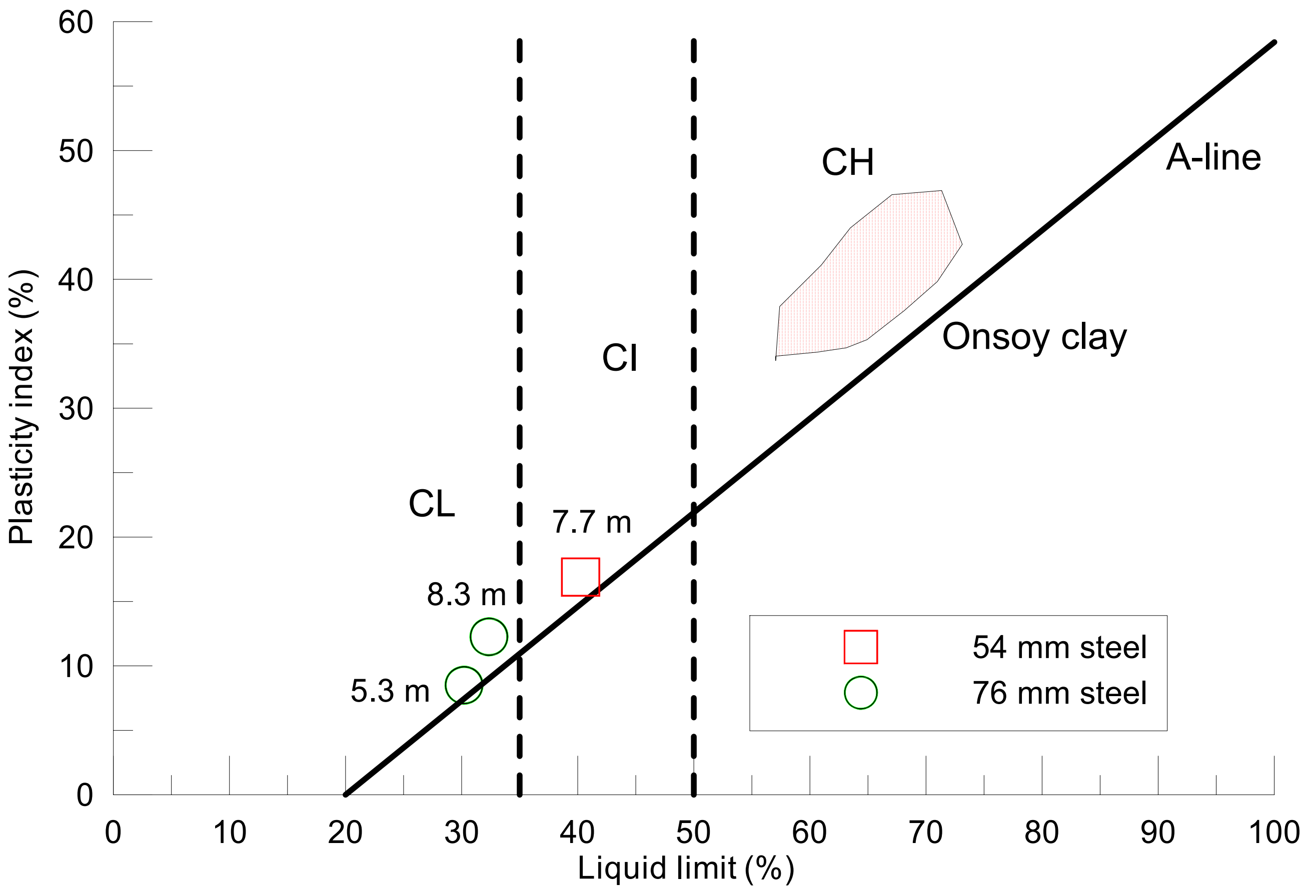


Average clay content = 16%

Average silt content = 77%

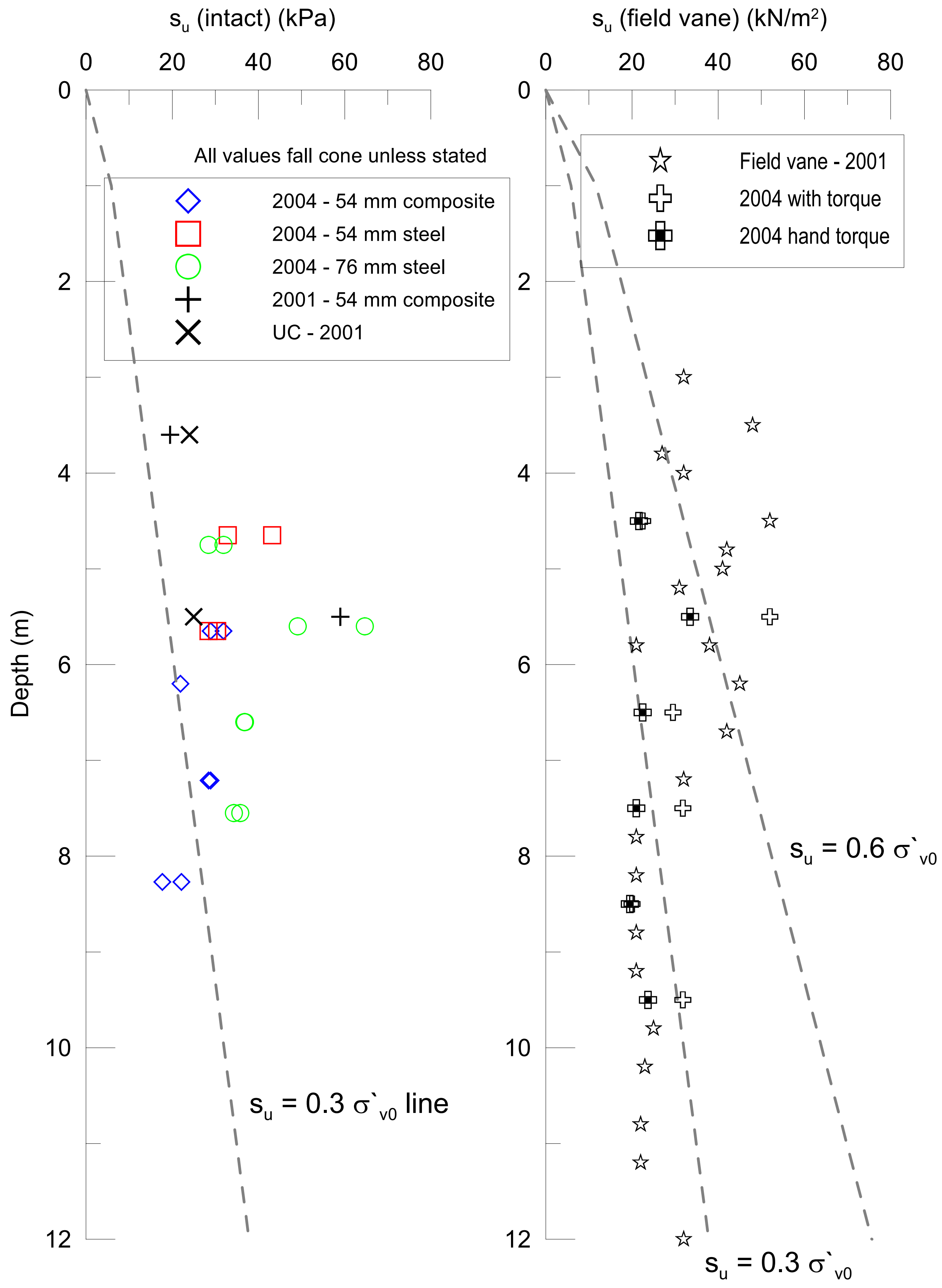
FoU Project - Os Site	Report No. 2005 - G1	Figure No. 7
Particle size distribution with depth	Drawn by GC/GG	Date 2005-07-07
	Checked ML	
	Approved	

Dell+D(AE)\Labtests\FoU\psdwithdepth.grf



FoU project - Quality of silt samples - Os site	Report No. 2005-G1	Figure No. 8
Plasticity chart	Drawn by ML	Date 2005-07-14
	Checked	
	Approved	

Dell\Labtests\FoU\Atterberg.grf

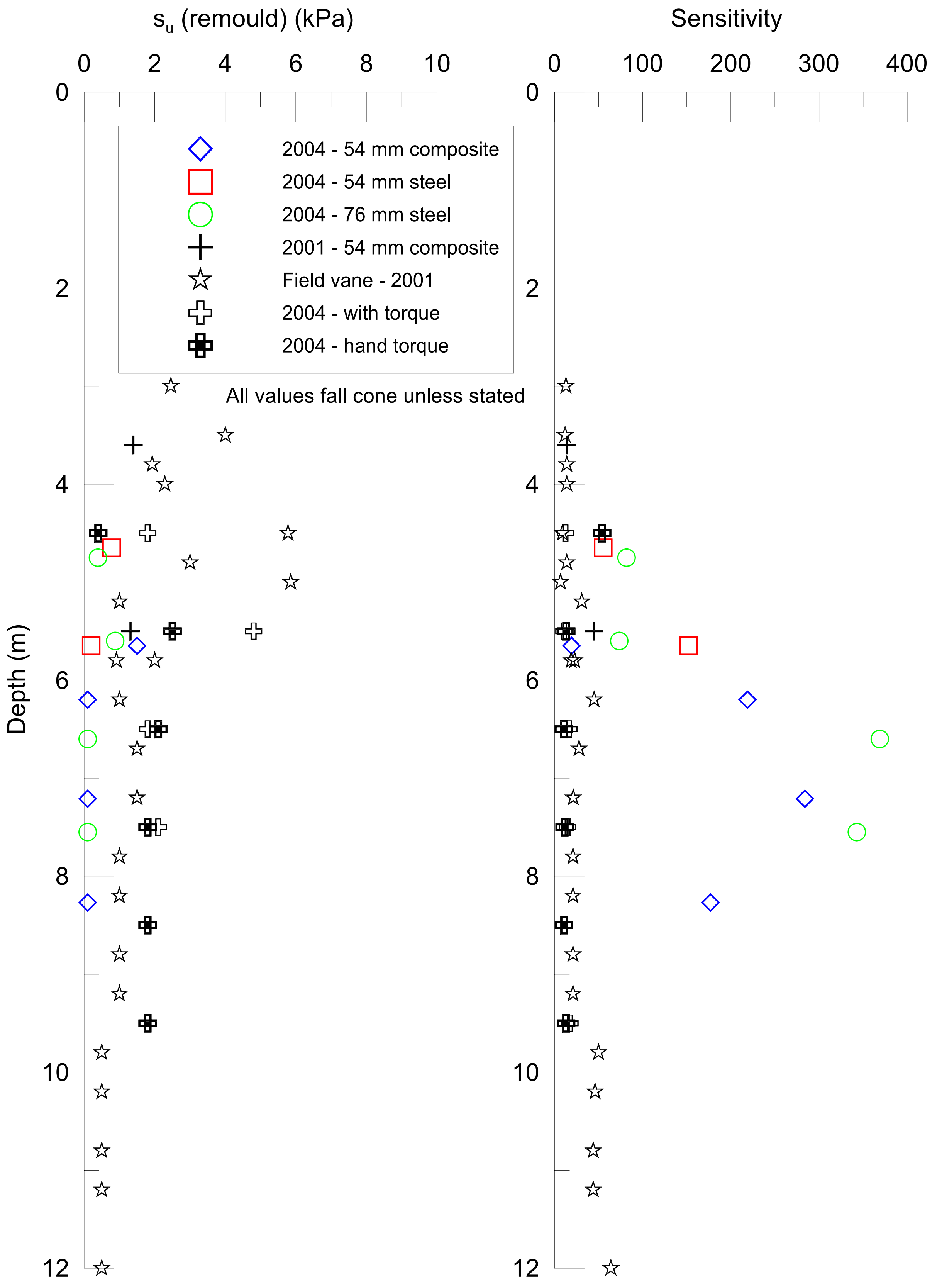


FoU project - Quality of silt samples - Os site

Undrained shear strength from index type tests and f ield vane testing

Report No.	Figure No.
2005 - G1	9
Drawn by ML	Date 2005-07-19
Checked	
Approved	

D(AF)\FoU\su.grf

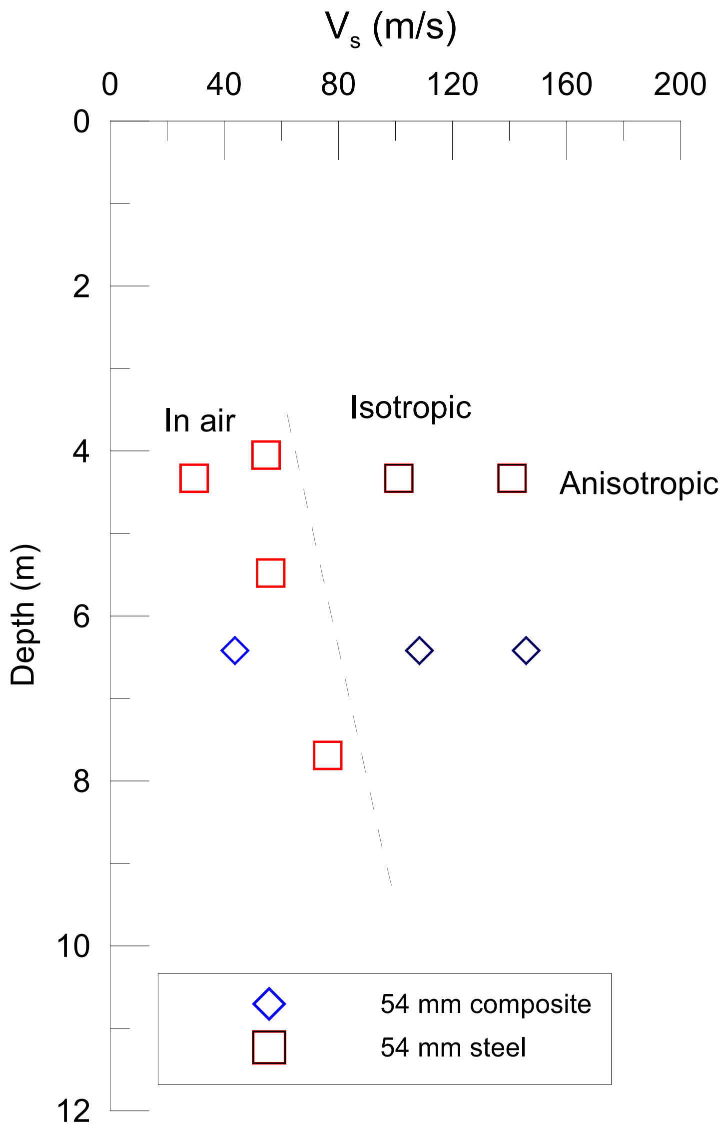


FoU project - Quality of silt samples - Os site

Remoulded undrained shear strength and sensitivity

Report No.	Figure No.
2005 - G1	10
Drawn by ML	Date 2005-07-08
Checked	
Approved	

D(AF)\FoU\Sensitivity.grf



FoU project - Quality of silt samples - Os site	Report No. 2005 - G1	Figure No. 11
Shear wave velocity from bender elements vs. depth	Drawn by ML	Date 2005-07-19
	Checked	
	Approved	

Dell\Labtests\FoU\Vs.grf

FoU Os Oedometer tests

Gs = 2.94 measured

Oedometer Test	Sample (m)	Sample Depth (m)	σ_{v0} (kPa)	w_i (%)	ρ_i (Mg/m³)	ρ_{di} (Mg/m³)	e_0	Sr (%)	M_0 (at $\sigma`_{v0}$) (MPa)	m	Casagrande Method $p`_c$ (kPa)	Casagrande Method OCR	Janbu Method $p`_c$ (kPa)	Janbu Method OCR
ML54(P)-1	5 - 5.8	5.53	59.8	26.5	2.148	1.698	0.731	96.7	2.59	21.5				
ML54(P)-2	6 - 6.8	6.7	70.3	41.4	1.912	1.352	1.174	94.1	1.7	14.2				
ML54(P)-3	7 - 7.8	7.54	77.9	34.9	1.962	1.454	1.021	91.2	4.37	9.7	175	2.25		
ML54(P)-4	8 - 8.8	8.74	88.7	24.3	2.125	1.710	0.720	90.1	5.32	20.9				
ML54(P)-5	8 - 8.8	8.41	85.7	46.5	1.881	1.284	1.290	96.3	1.27	11.7				
ML54(P)-6	8 - 8.8	8.59	87.3	30	2.125	1.635	0.799	100.3	3.31	24.9				
ML54(S)-1	5 - 5.8	5.28	57.5	28.7	2.086	1.621	0.814	94.2	2.99	17.2				
ML54(S)-2	7 - 7.8	7.4	76.6	42	1.907	1.343	1.189	94.3	2.23	10.1	113	1.48		
ML54(S)-3	6 - 6.8	6.22	66.0	34.1	2.05	1.529	0.923	98.6	1.81	14.5				
ML54(S)-4	7 - 7.8	7.29	75.6	32.3	2.001	1.512	0.944	91.4	2.15	6.8				
ML54(S)-5	4 - 4.8	4.28	48.5	34.9	2.015	1.494	0.968	96.2	2.53	11.2				
ML76-1	5 - 5.8	5.48	59.3	30	2.091	1.608	0.828	96.8	3.53	19.6				
ML76-2	6 - 6.8	6.2	65.8	30.3	2.121	1.628	0.806	100.4	1.95	16.4				
ML76-3	7 - 7.8	7.15	74.4	28.5	2.146	1.670	0.760	100.1	2.75	25.6				
ML76-4	7 - 7.8	7.4	76.6	31	2.134	1.629	0.805	102.8	4.01	35.5				

All of these values are considered to be dubious

Oedometer Test	Depth (m)	Quality Criterion 1 $\varepsilon_{\sigma'v0}$ (%)	Quality	Quality Criterion 2 Δe	Δe / e_0	Quality	Overall Quality	Comment
ML54(P)-1	5.53	4.37	Poor	0.076	0.104	Poor	3	
ML54(P)-2	6.7	8.24	Poor	0.179	0.152	Very poor	4	
ML54(P)-3	7.54	3.76	Good to fair	0.076	0.074	Poor	2	
ML54(P)-4	8.74	2.59	Good to fair	0.044	0.061	Good to fair	2	
ML54(P)-5	8.41	19.8	Very poor	0.453	0.351	Very poor	4	Unusually high water content
ML54(P)-6	8.59	9.59	Poor	0.173	0.217	Very poor	4	
ML54(S)-1	5.28	2.47	Good to fair	0.044	0.054	Good to fair	2	
ML54(S)-2	7.4	3.61	Good to fair	0.079	0.066	Good to fair	2	Visible organic fleks - may not be representative
ML54(S)-3	6.22	11.92	Very poor	0.229	0.248	Very poor	4	
ML54(S)-4	7.29	4.08	Poor	0.079	0.084	Poor	2	
ML54(S)-5	4.28	1.26	Very g to excel	0.025	0.026	Very g to excel	1	
ML76-1	5.48	4.42	Poor	0.081	0.098	Poor	3	
ML76-2	6.2	7.45	Poor	0.134	0.166	Very poor	4	
ML76-3	7.15	5.5	Poor	0.097	0.128	Very poor	3	
ML76-4	7.4	10.18	Very poor	0.184	0.229	Very poor	4	Visibly disturbed - top layer spongy / charged

* After Andresen and Kolstad (1979) > 1-2% = very good to excellent, 2-4% = good to fair, > 4-10% = poor, >10% = very poor

** After Lunne et al. (1997) for OCR 1 - 2: < 0.04 = very good to excellent, 0.04-0.07 = good to fair, 0.07-0.14 = poor, > 0.14 = very poor

Dell/Labtests/Os/Osoedsum.xls

FoU - Os - Summary of ML oedometer tests **Table 1**

FoU Os CRS Oedometer tests

Gs = 2.94 measured

Oedometer Test	Sample type	Sample (m)	Sample Depth (m)	Test rate (kPa/hour)	Initial static load (kPa)	Static settlement (mm)	σ'_{v0} (kPa)	w_i (%)	ρ_i (Mg/m^3)	ρ_{di} (Mg/m^3)	e_0	Sr (%)	M_0 (at σ'_{v0}) (MPa)	m	Casagrande Method		Janbu Method	
															p'_c (kPa)	OCR	p'_c (kPa)	OCR
CRS1	54 mm plastic	5 - 5.8	5.35	30	15	dubious	58.2	28.9	2.179	1.690	0.739	104.4	3	49.6				
CRS2	76 mm steel	5 - 5.8	5.33	30	10	0.07	58.0	30	2.109	1.622	0.812	98.6	2.1	41.7				
CRS3	76 mm steel	5 - 5.8	5.28	60	10	0.12	57.5	30.1	2.119	1.629	0.805	99.8	1.9	39.1				
CRS4	54 mm steel	5 - 5.8	5.48	120	10	0.08	59.3	29.6	2.157	1.664	0.766	103.1	?	?				
CRS5	76 mm steel	7 - 7.8	7.15	60	10	0	74.4	32	2.127	1.611	0.825	103.6	1.8	35.9				
CRS6	76 mm steel	4 - 4.8	4.5	60	10	0	50.5	36.8	1.952	1.427	1.060	92.7	1.35	16				
CRS7	76 mm steel	5 - 5.8	5.2	60	15	0.02	56.8	33.7	2.036	1.523	0.931	96.7	2.35	25.3				
CRS8	76 mm steel	5 - 5.8	5.2	60	15	0.17	56.8	34.7	1.998	1.483	0.982	94.3	1.8	24.9				
CRS9	76 mm steel	5 - 5.8	5.2	60	Various	1.33	56.8	34.9	2.059	1.526	0.926	100.6	?	22.1				
CRS10	54 mm plastic	6 - 6.8	6.42	60	10	0	67.8	34.7	2.043	1.517	0.938	98.7	2.15	29.1				
CRS11	54 mm plastic	6 - 6.8	6.59	60	10	0	69.3	36.3	1.906	1.398	1.102	87.9	0.9	26.7				
CRS12	54 mm plastic	6 - 6.8	6.42	30	0	0	67.8	33.5	2.056	1.540	0.909	98.4	1.2	36				
CRS13	54 mm plastic	7 - 7.8	7.37	30	0	0	76.3	41.9	1.99	1.402	1.096	102.0	2.8	?				
CRS14	54 mm plastic	7 - 7.8	7.54	30	0	0	77.9	34.1	2.009	1.498	0.962	94.6	?	?				
CRS15	54 mm steel	4 - 4.8	4.28	30	0	0	48.5	36.8	1.987	1.452	1.024	95.9	2.1	28.5				
CRS16	54 mm plastic	8 - 8.8	8.78	30	0	0	89.0	25.1	2.221	1.775	0.656	102.2	6.3	46.4				
CRS17	54 mm plastic	8 - 8.8	8.4	30	0	0	85.6	31.3	2.13	1.622	0.812	102.9	4.1	42.2				
CRS18	54 mm steel	7 - 7.8	7.66	30	0	0	78.9	39.8	1.903	1.361	1.160	91.6	2.8	12				
CRS19	54 mm steel	4 - 4.8	4.55	30	0	0	51.0	34.9	1.99	1.475	0.993	93.8	0.300	25.2				

Oedometer Test	Depth (m)	Quality Criterion 1		Quality Criterion 2		Overall Quality	Comment
		$\varepsilon_{\sigma'v0}$ (%)	Quality	$\Delta e / e_0$	Quality		
CRS1	5.35	4.7	Poor	0.111	Poor	3	
CRS2	5.33	5.6	Poor	0.125	Poor	3	
CRS3	5.28	4.3	Poor	0.096	Poor	3	
CRS4	5.48	?		?			Very poor test
CRS5	7.15	5.7	Poor	0.126	Poor	3	
CRS6	4.5	3.45	Good to fair	0.067	Good to fair	2	
CRS7	5.2	2.55	Good to fair	0.053	Good to fair	2	
CRS8	5.2	3.8	Good to fair	0.077	Poor	3	
CRS9	5.2	?		?			60 kPa static component - were checking hydrocon
CRS10	6.42	3.8	Good to fair	0.078	Poor	3	Transducer "held" during static
CRS11	6.59	9.2	Poor	0.175	Very poor	4	Incomplete loading
CRS12	6.42	9.9	Poor	0.208	Very poor	4	Incomplete loading
CRS13	7.37	3.4	Good to fair	0.065	Good to fair	2	Incomplete loading
CRS14	7.54	?		?			Incomplete loading
CRS15	4.28	3	Good to fair	0.059	Good to fair	2	
CRS16	8.78	5.1	Poor	0.129	Poor	3	
CRS17	8.4	9.2	Poor	0.205	Very poor	4	
CRS18	7.66	8.9	Poor	0.166	Very poor	4	
CRS19	4.55	8.9	Poor	0.179	Very poor	4	

* After Andresen and Kolstad (1979) > 1-2% = very good to excellent, 2-4% = good to fair, > 4-10% = poor, >10% = very poor
** After Lunne et al. (1997) for OCR 1 - 2: < 0.04 = very good to excellent, 0.04-0.07 = good to fair, 0.07-0.14 = poor, > 0.14 = very poor

Dell/Labtests/Os/CRSSummary.xls

FoU - Os - Summary of CRS (Hydrocon) oedometer tests

Basic and consolidation

Assumptions: G_s = 2.94 γ = 19 kN/m³

Triaxial Test	Test type	Borehole	Sample Depth (m)	Specimen Depth (m)	Sample Type	ρ_t Mg/m³	w_i %	e_0	σ'_{v0} kPa	B	u_r kPa	Final Consol stress (kPa) σ_1	σ_3	Volumetric strain (%)	Criterion 1* Quality	$\Delta e / e_0$	Criterion 2** Quality	Overall Quality
54P-1	CAUC	BH2	5-5.8	5.33	54 mm composite	2.055	29.2	0.848	58.0	1	0	60	30	4.93	Likely disturbed	0.107	Poor	3
54P-2	CAUC	BH2	5-5.8	5.55	54 mm composite	2.045	25.9	0.810	60.0	0.98	2	60	30	2.35	Acceptable	0.053	Good to fair	2
54P-3***	CAUC	BH2	6-6.8	6.42	54 mm composite	2.126	36.6	0.889	67.8	1	4	68	34	11.9	Likely disturbed	0.253	Very poor	4
54P-?	Slump	BH2	7-7.8	7.37	54 mm composite	2.252	24	0.619	76.3									
54P-?	Slump	BH2	7-7.8	7.54	54 mm composite	1.907	36.4	1.103	77.9									
54P-?	Slump	BH2	8-8.8	8.4	54 mm composite		35.3		85.6									
54S-1	CAUC	BH10	5-5.8	5.28	54 mm steel	2.18	27.1	0.714	57.5	1	5.5	58	29	3.11	Acceptable	0.075	Poor	2
54S-2	CAUC	BH10	7-7.8	7.4	54 mm steel	2.078	39.1	0.968	76.6	0.98	4.5	76	38	3.25	Acceptable	0.066	Good to fair	2
54S-?	Slump	BH10	6-6.8	6.21	54 mm steel	2.225	27.1	0.679	65.9									
54S-3***	CAUC	BH10	4-4.8	4.33	54 mm steel	1.924	33.9	1.046	49.0	0.97	4	49	24	1.94	Very good	0.038	Very good	1
54S-4	CAUC	BH10	7-7.8	7.58	54 mm steel	2.009	39.2	1.037	78.2	1	6	78	40	2.39	Acceptable	0.047	Good to fair	2
76-1	CAUC	BH2	5-5.8	5.3	76 mm steel	2.133	27.5	0.757	57.7	1	7	58	29	3.02	Acceptable	0.070	Poor	2
76-2	CAUC	BH2	6-6.8	6.2	76 mm steel	1.973	29.9	0.936	65.8	1	2			6.5	Likely disturbed	0.134	Poor	3
76-?	Slump	BH2	7-7.8	7.15	76 mm steel				74.4									
76-3	CAUC	BH2	4-4.8	4.3	76 mm steel	2.041	31.4	0.893	48.7	1	4.5	50	25	3.31	Acceptable	0.070	Poor	2
76-4	CAUC	BH2	4-4.8	4.5	76 mm steel	2.045	34.8	0.938	50.5	1	4.5	50	25	1.86	Very good	0.038	Very good	1
76-5	CAUC	BH2	7-7.8	7.4	76 mm steel	2.105	29.5	0.809	76.6	1	2	76	38	7.26	Likely disturbed	0.162	Very poor	4
76-?	Slump	BH2	8-8.8	8.35	76 mm steel	1.959	25.7	0.886	85.2									

* After Kleven et al. (1986) for OCR 1.2 to 1.5: <2% = very good, 2-4% = acceptable, > 4% = likely disturbed
** After Lunne et al. (1997) for OCR 1 - 2: < 0.04 = very good to excellent, 0.04-0.07 = good to fair, 0.07-0.14 = poor, > 0.14 = very poor
*** Bender element test carried out.

Shearing Stage

Triaxial Test	s_u kPa	s_u / σ'_{v0}	$\varepsilon_{failure}$ %	$A_{failure}$	$E_{0.01}$ MPa	$E_{0.1}$ MPa	ϕ' deg.	c' kPa	Comments
54P-1	49	0.817	16.6	-0.1	30	10	35	2	Specimen disturbed during trimming?
54P-2	51.2	0.853	6.5	-0.15	20	6.5	36	0	Better specimen than above but high pwp at start of shearing
54P-3	31.7	0.466	10.8	0.42	100	15	36	0	
54P-?									Sample "slumped" during specimen preparation.
54P-?									Sample "slumped" during specimen preparation.
54P-?									Sample "slumped" during specimen preparation.
54S-1	87.2	1.503	15.9	-0.25	48	10	36	0	
54S-2	38.6	0.508	9.8	0.25	60	15	36	0	Relatively high water content - representative?
54S-?									Sample "slumped" during specimen preparation.
54S-3	35.8	0.731	15.7	-0.02	70	12	36	0	
54S-4	32.2	0.413	2.2	0.28	150	25	36	0	
76-1	64.4	1.110	13.4	-0.2	35	7.5	36	0	Trimmed to 50 mm
76-2	n/a								Test abandoned after iso consol. Specimen damaged during trimming
76-?									Test abandoned during specimen preparation. Damaged during trimming.
76-3	39.9	0.798	7.1	-0.05	32	9.5	36	0	Trimmed to 50 mm
76-4	34.3	0.686	12.8	0.09	30	8	36	0	First 76 mm specimen untrimmed - tested at 76 mm
76-5	32.6	0.429	4.1	0.51	190	28	36	0	Untrimmed - tested at 76 mm - Specimen contracts
76-?									Test abandoned during specimen preparation. Damaged during trimming.

Dell/Labtests/FoU/Triaxsu1.xls

FoU - Os - Summary of CAUC triaxial tests **Table 3**

PHOTOGRAPHS FROM THE LABORATORY.

a) *Cylinder L-16, depth 5,0 – 5,8 m.*

b) Cylinder L-26, depth 6,0 – 6,8 m.

c) Cylinder L-19, depth 7,0 – 7,8 m.

d) Cylinder L-9, depth 8,0 – 8,8 m.

e) Cylinder R-27, depth 9,0 – 9,8 m.

f) Cylinder L-6, depth 8,0 – 8,8 m.

Photograph 1. Samples after extrusion, 54 mm plastic cylinder.

a) *Cylinder L-17, depth 4,0 – 4,8 m.*

b) Cylinder L-18, depth 6,0 – 6,8 m.

c) Cylinder L-20, depth 7,0 – 7,8 m.

d) Cylinder R-49, depth 8,0 – 8,8 m.

e) Cylinder R-73, depth 9,0 – 9,8 m.

Photograph 2. Samples after extrusion, 54 mm steel cylinder.

a) *Cylinder NO. 2, depth 6,0 – 6,8 m.*

b) Cylinder NO. 3, depth 7,0 – 7,8 m.

c) CylinderNo 4, depth 8,0 – 8,8 m.

d) Cylinder NO 5, depth 9,0 –98,8 m.

Photograph 3. Samples after extrusion, 76 mm steel cylinder.

a) Original sample in container.

b) Disturbed sample after half a minute mix up.

c) Salt mixed into the sample.

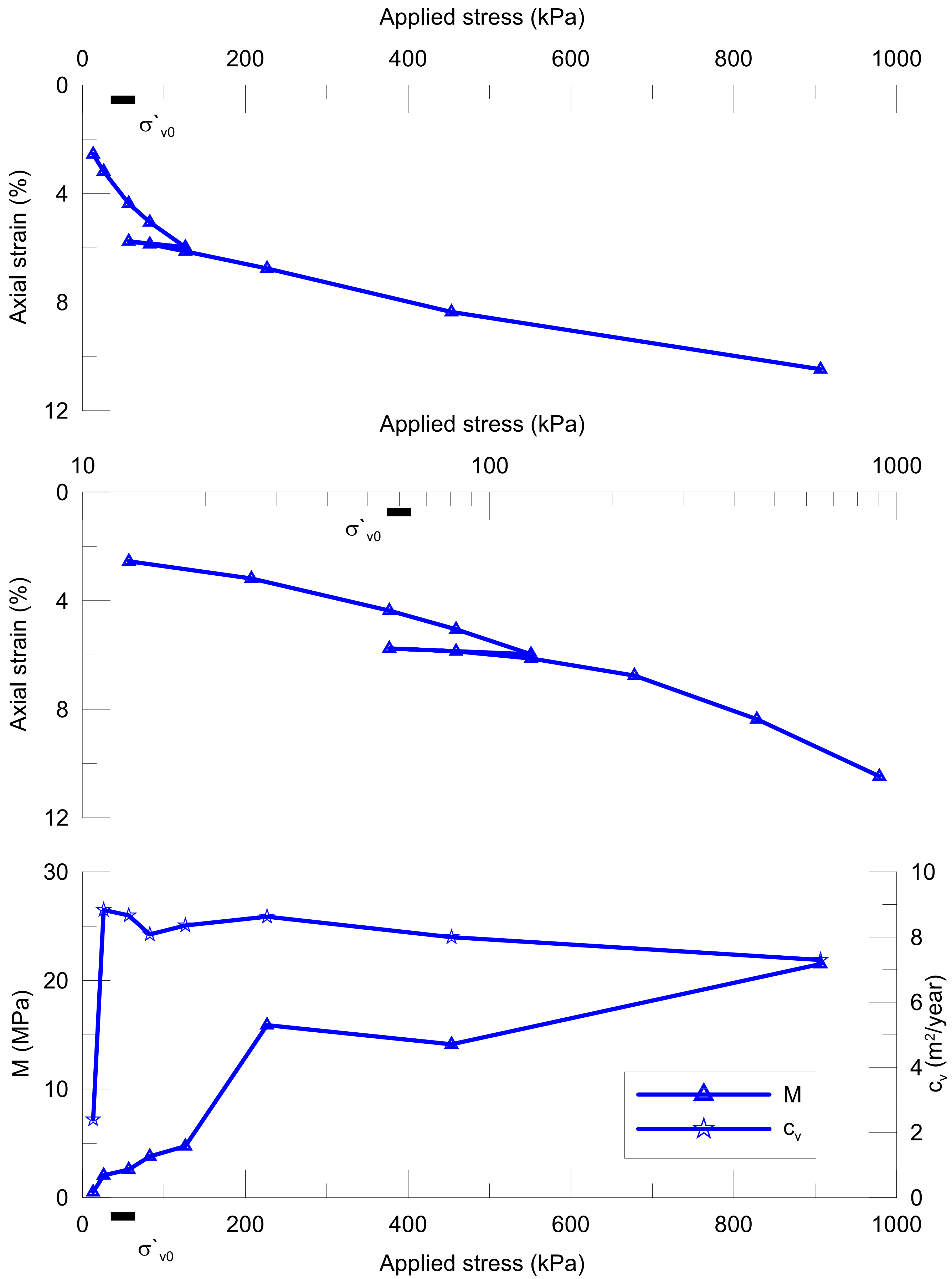
d) Sample after half a minute mix up.

e) Sample after one minute mix up.

f) Sample after two minute mix up.

Photograph 4. Salt / remould test, cylinder R-49 at depth 8,4 – 8,45 m.

OEDOMETER TESTS RESULTS.



FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 - G1

Figure No. 12

ML Oedometer Test 54(P)-1

BH: 2

Tube: L16, 5-5.8 m

Depth: 5.53 m

$\sigma`_{v0}$ = 59.8 kPa

ρ = 2.148 Mg/m3

w = 26.5 %

ε_{v0} / $\Delta e/e_0$ = 4.4 % /0.104

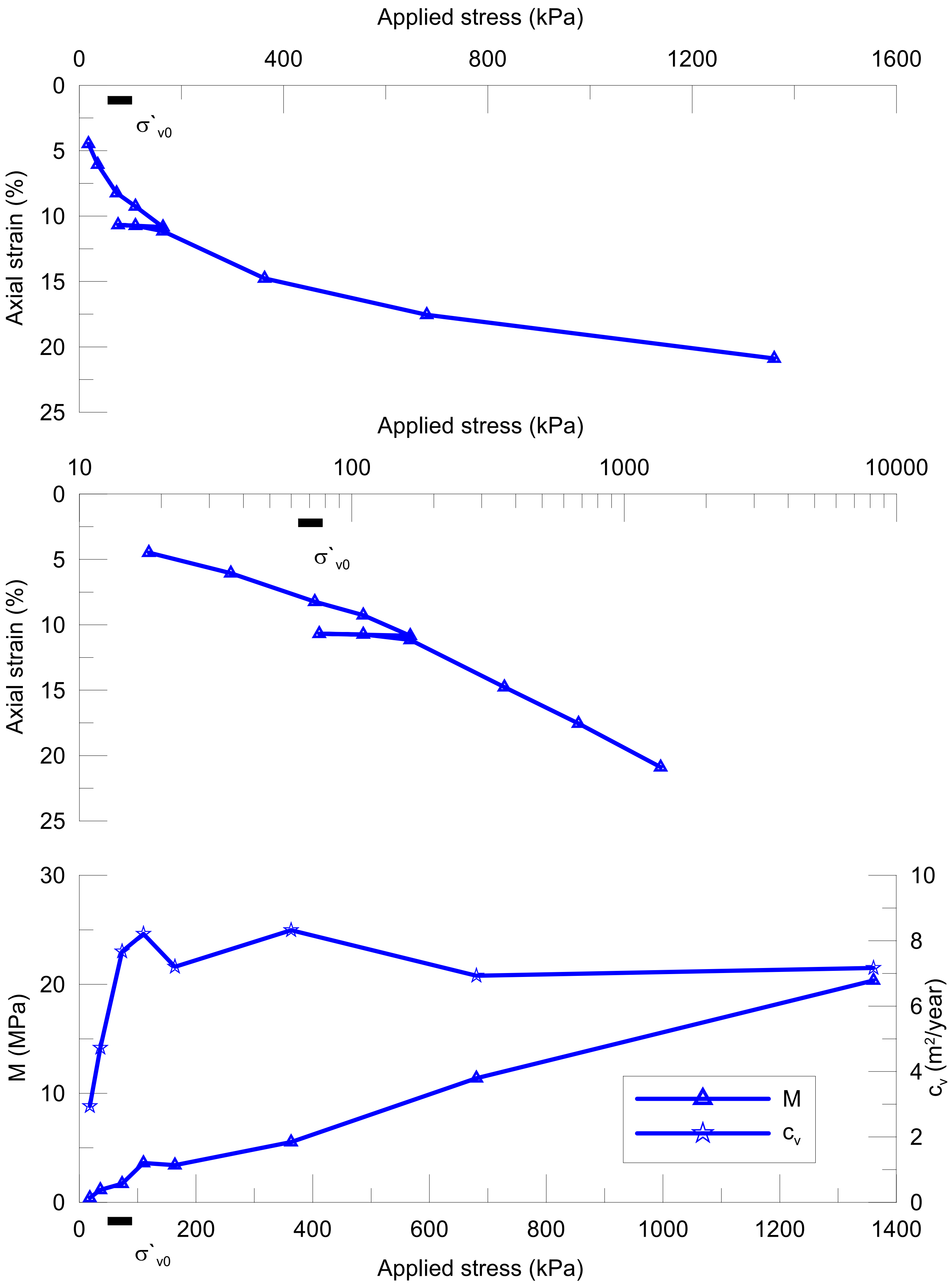
Drawn by GC

Date 2005-07-19

Checked ML

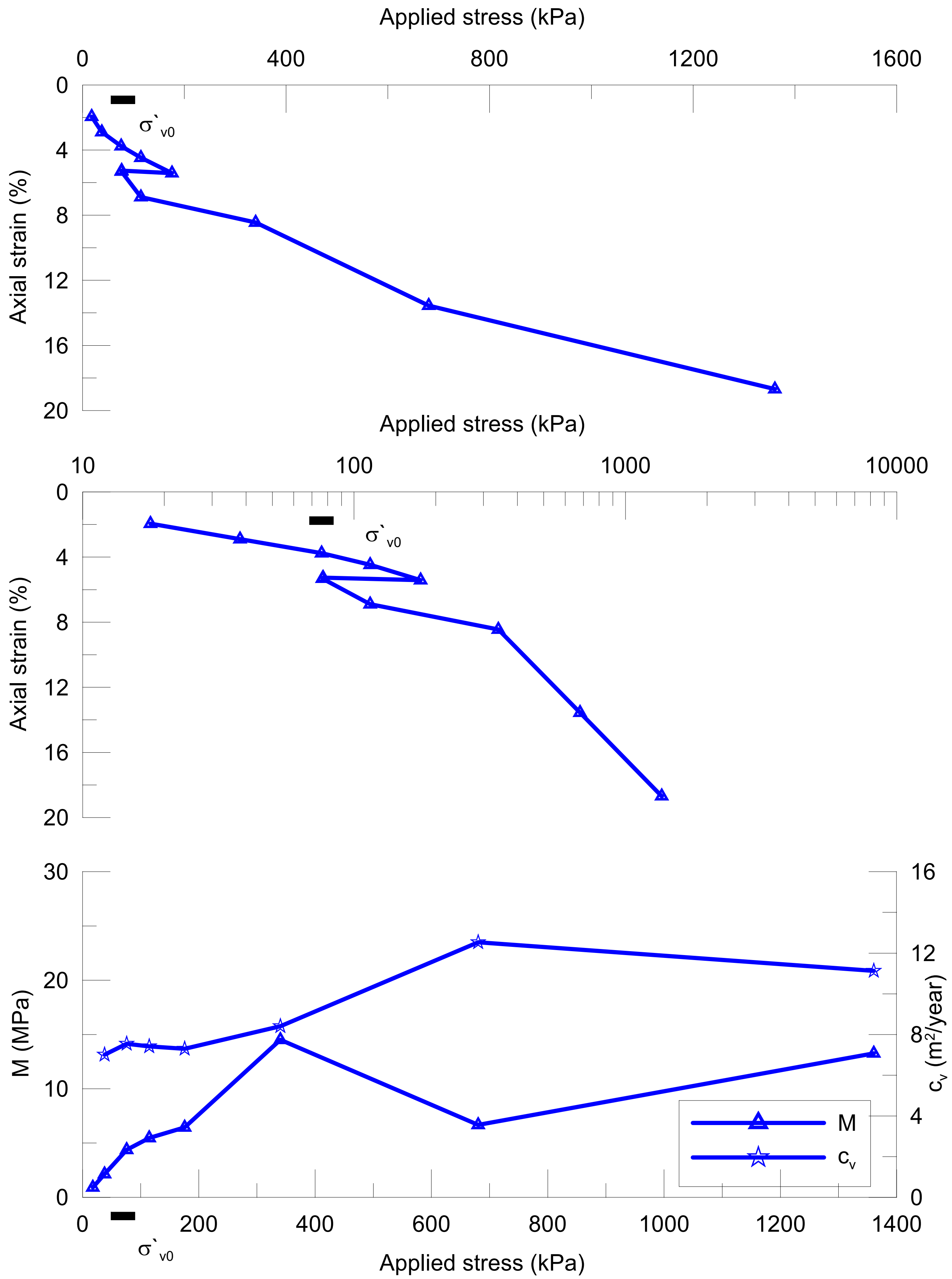
Approved

Dell/labtests/FoU/ML54(P)-1.grf



FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 - G1	Figure No. 13
ML Oedometer Test 54(P)-2 BH: 2 Tube: L26, 6-6.8 m Depth: 6.7 m	Drawn by GC	Date 2005-07-19
σ'_{v0} = 70.3 kPa ρ = 1.912 Mg/m3 w = 41.4 % ε_{v0} / $\Delta e/e_0$ = 8.2% /0.152	Checked ML	
	Approved	

Dell/labtests/FoU\ML54(P)-2.grf



FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 - G1	Figure No. 14	
Drawn by GC	Date 2005-07-19	
Checked ML		
Approved		

ML Oedometer Test 54(P)-3

BH: 2

Tube: L19, 7-7.8 m

Depth: 7.54 m

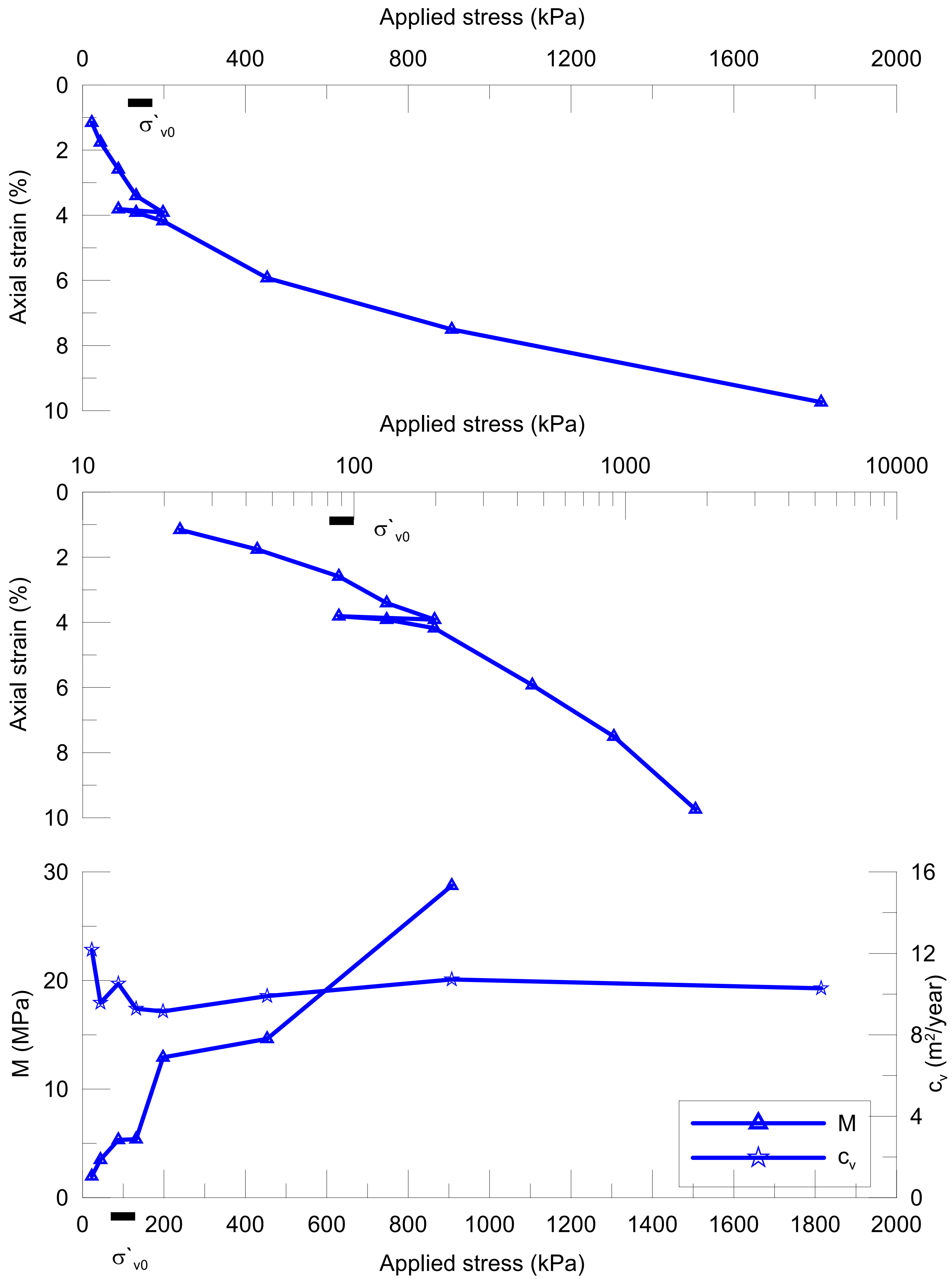
σ'_{v0} = 77.9 kPa

ρ = 1.962 Mg/m3

w = 34.9 %

ε_{v0} / $\Delta e/e_0$ = 3.8% /0.074

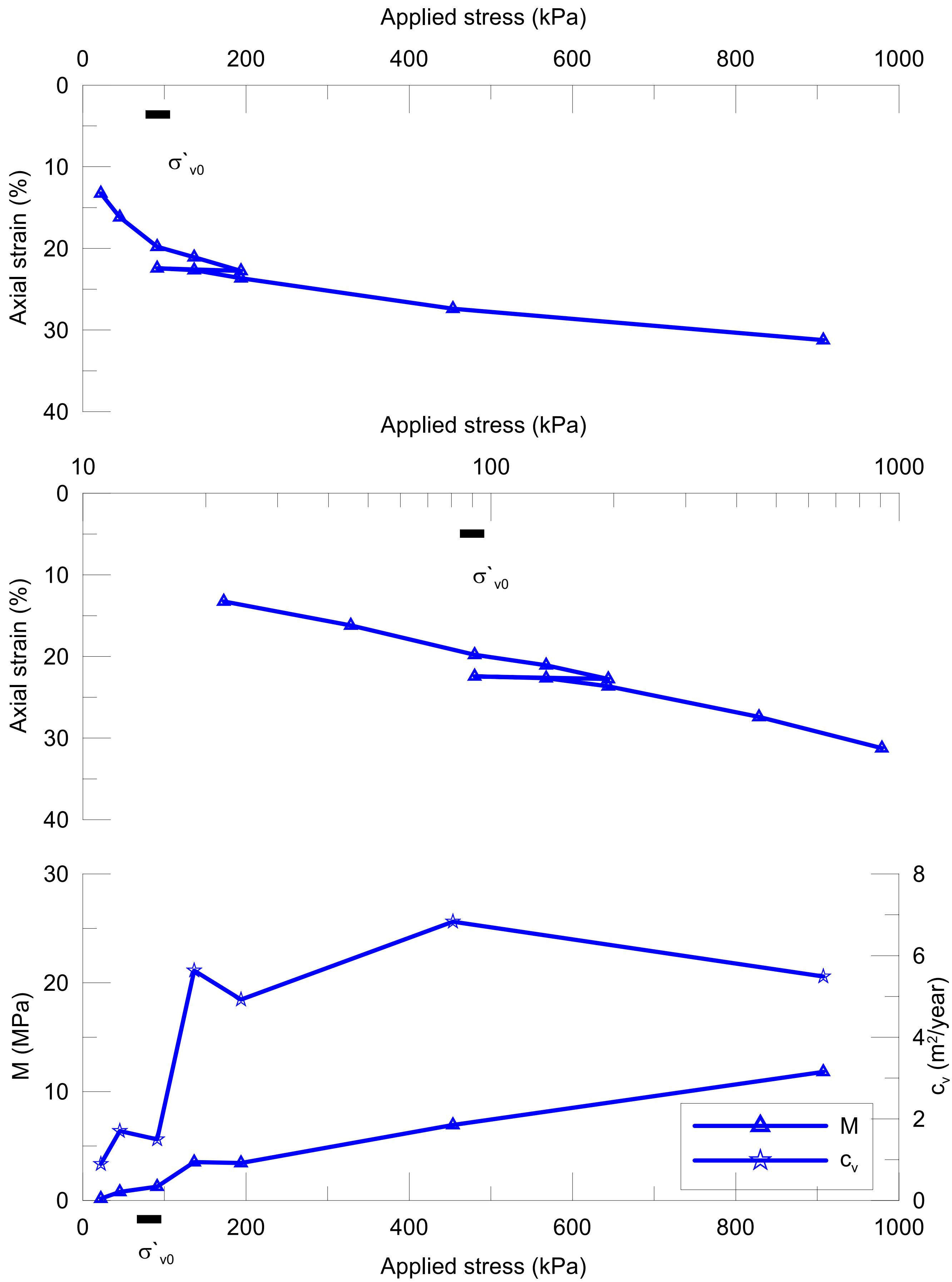
Dell/labtests/FoU/ML54(P)-3.grf



FoU Project - Os Site - 2004 Site Investigation

ML Oedometer Test 54(P)-4	σ'_{v0} = 88.7 kPa	Report No. 2005 - G1	Figure No. 15
BH: 2	ρ = 2.125 Mg/m3	Drawn by GC	Date 2005-07-19
Tube: L6, 8-8.8 m	w = 24.3 %	Checked ML	
Depth: 8.74 m	ε_{v0} / $\Delta e/e_0$ = 2.6% /0.061	Approved	

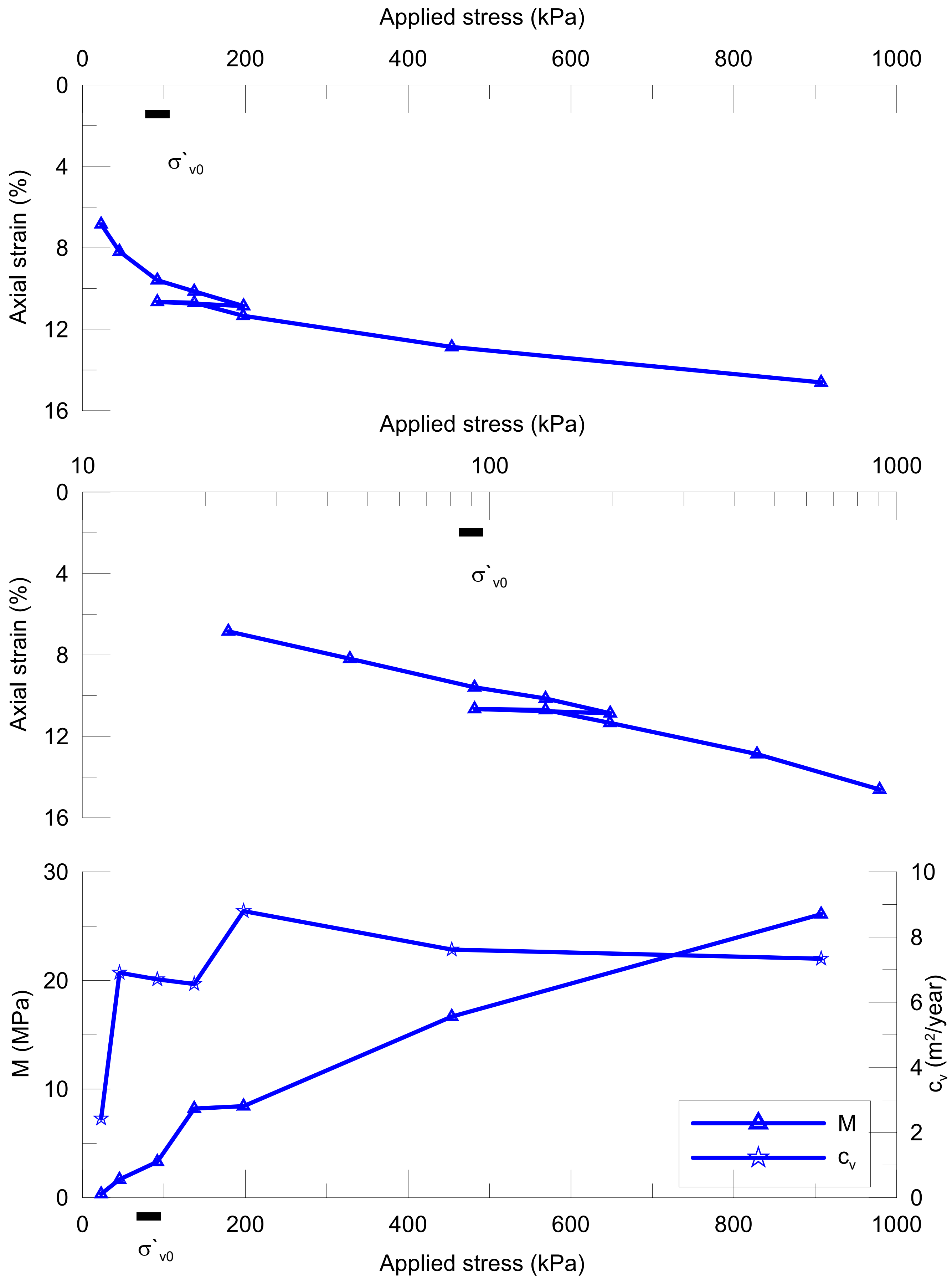
Dell/labtests/FoU\ML54(P)-4.grf



FoU Project - Os Site - 2004 Site Investigation

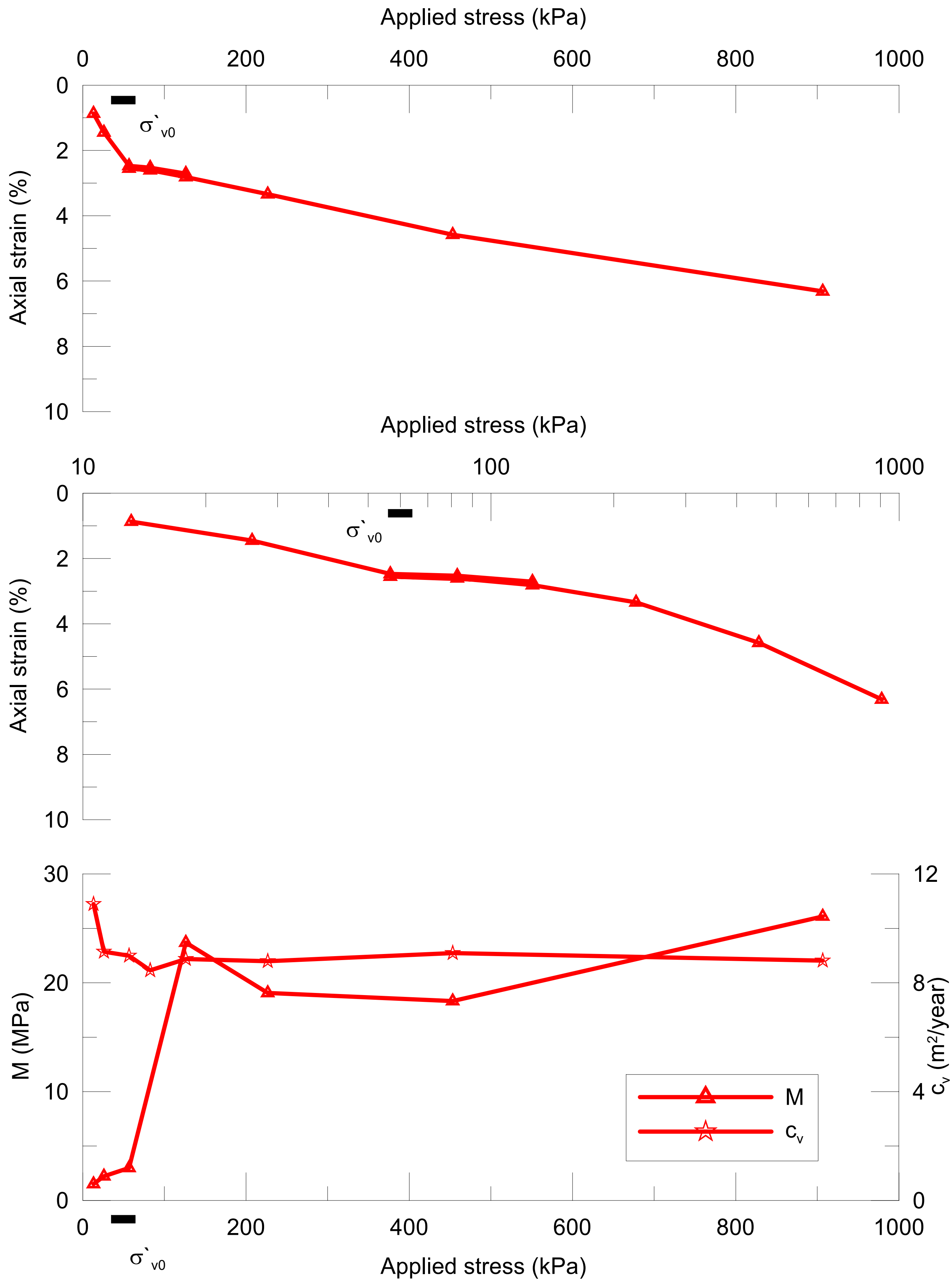
		Report No. 2005 - G1	Figure No. 16
ML Oedometer Test 54(P)-5	σ'_{v0} = 85.7 kPa	Drawn by GC	Date 2005-07-19
BH: 2	ρ = 1.881 Mg/m3	Checked ML	
Tube: L6, 8-8.8 m	w = 46.5 %		
Depth: 8.41 m	ε_{v0} / $\Delta e/e_0$ = 19.8% /0.351	Approved	

Dell/labtests/FoU\ML54(P)-5.grf



FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 - G1	Figure No. 17
ML Oedometer Test 54(P)-6 BH: 2 Tube: L6, 8-8.8 m Depth: 8.59 m σ'_{v0} = 87.3 kPa ρ = 2.125 Mg/m3 w = 30 % ε_{v0} / $\Delta e/e_0$ = 9.6% /0.217	Drawn by GC Checked ML Approved	Date 2005-07-19

Dell/labtests/FoU\ML54(P)-6.grf



FoU Project - Os Site - 2004 Site Investigation

Report No.	2005 -G1	
Figure No.	18	
Drawn by	GC	
Date	2005-07-19	
Checked	ML	
Approved		

ML Oedometer Test 54(S)-1

BH: 10

Tube: L23, 5-5.8 m

Depth: 5.28 m

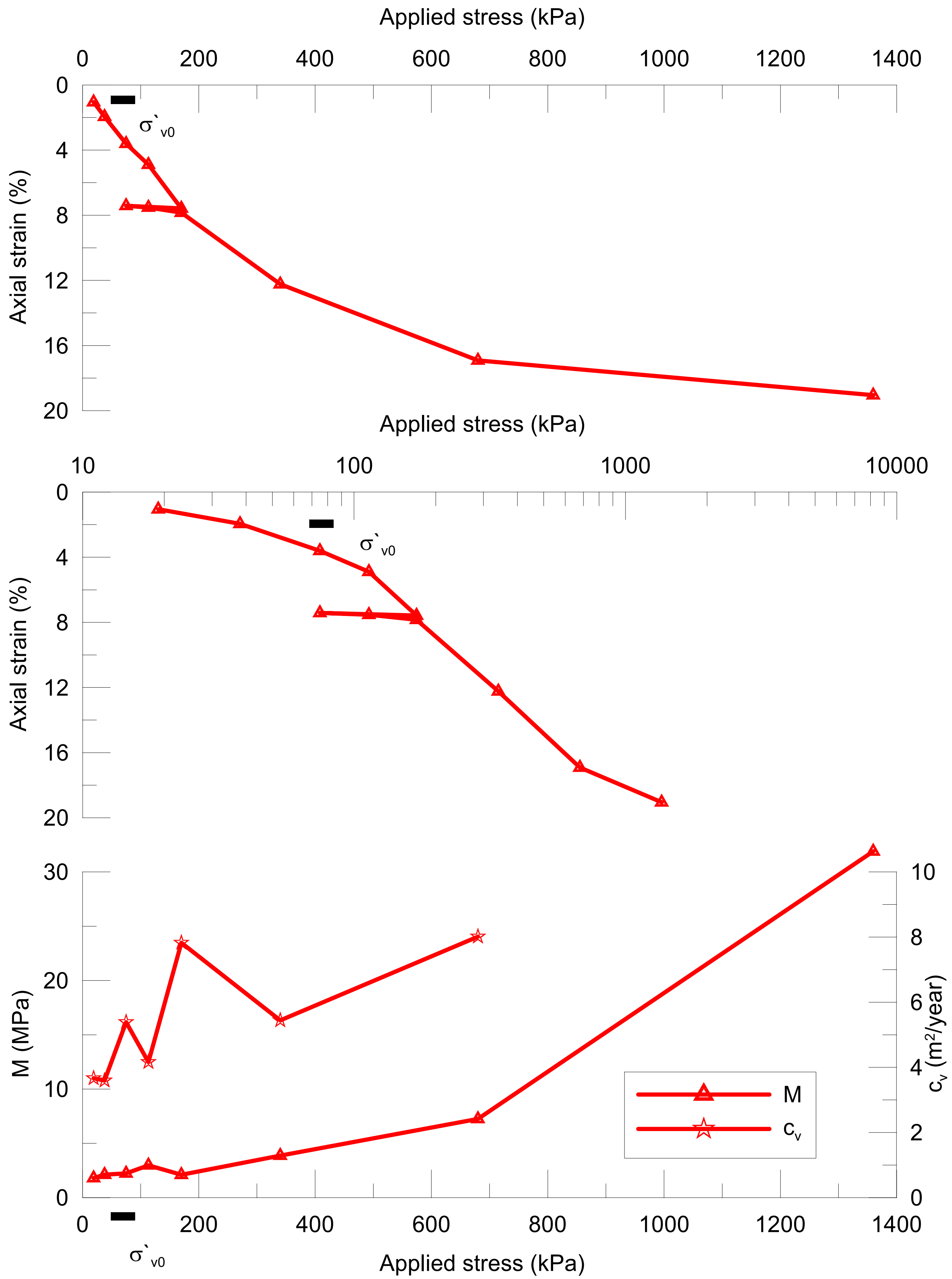
$\sigma`_{v0}$ = 57.5 kPa

ρ = 2.086 Mg/m3

w = 28.7 %

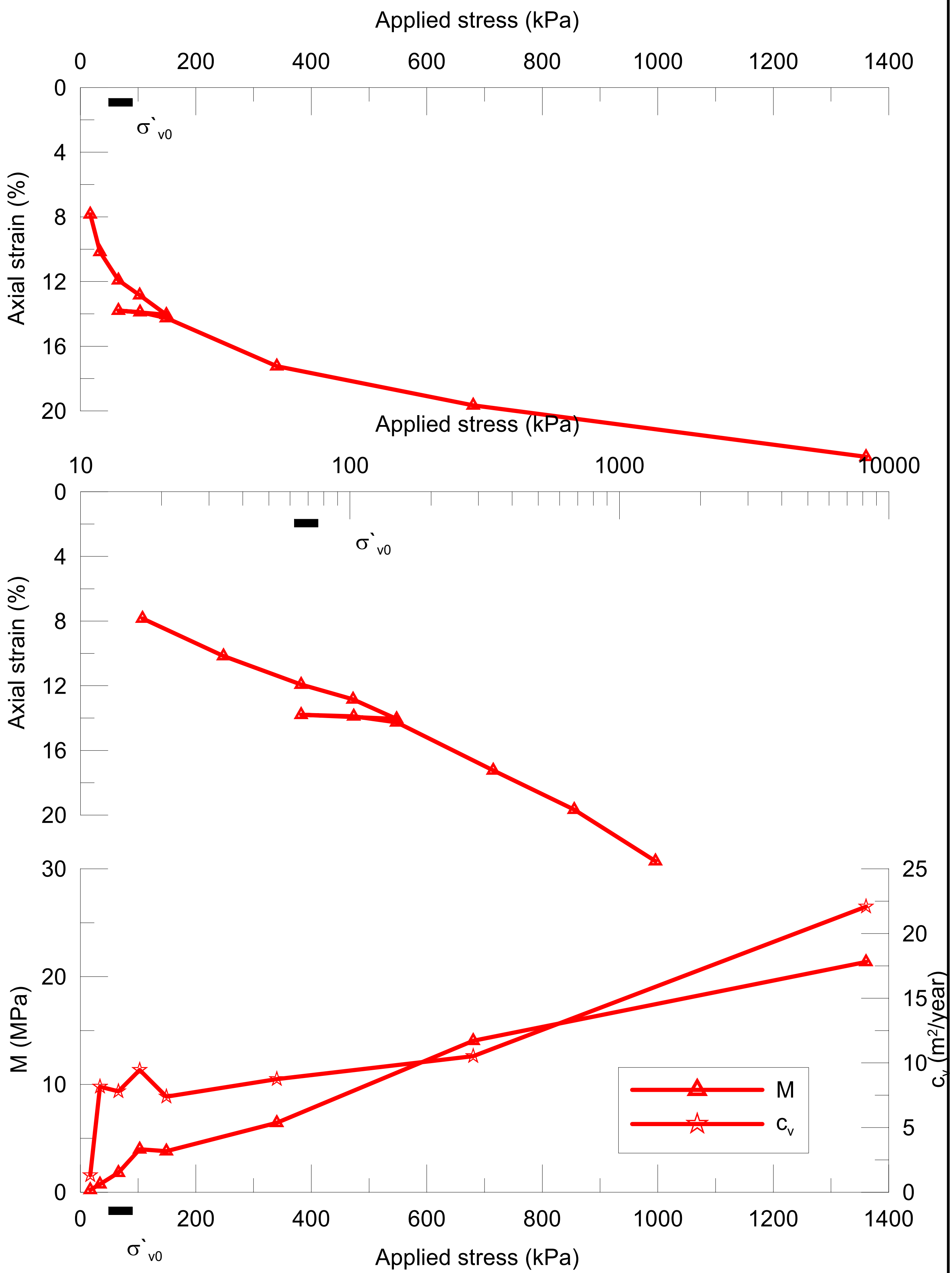
ε_{v0} / $\Delta e/e_0$ = 2.5 % /0.054

Dell/labtests/FoU\ML54(S)-1.grf

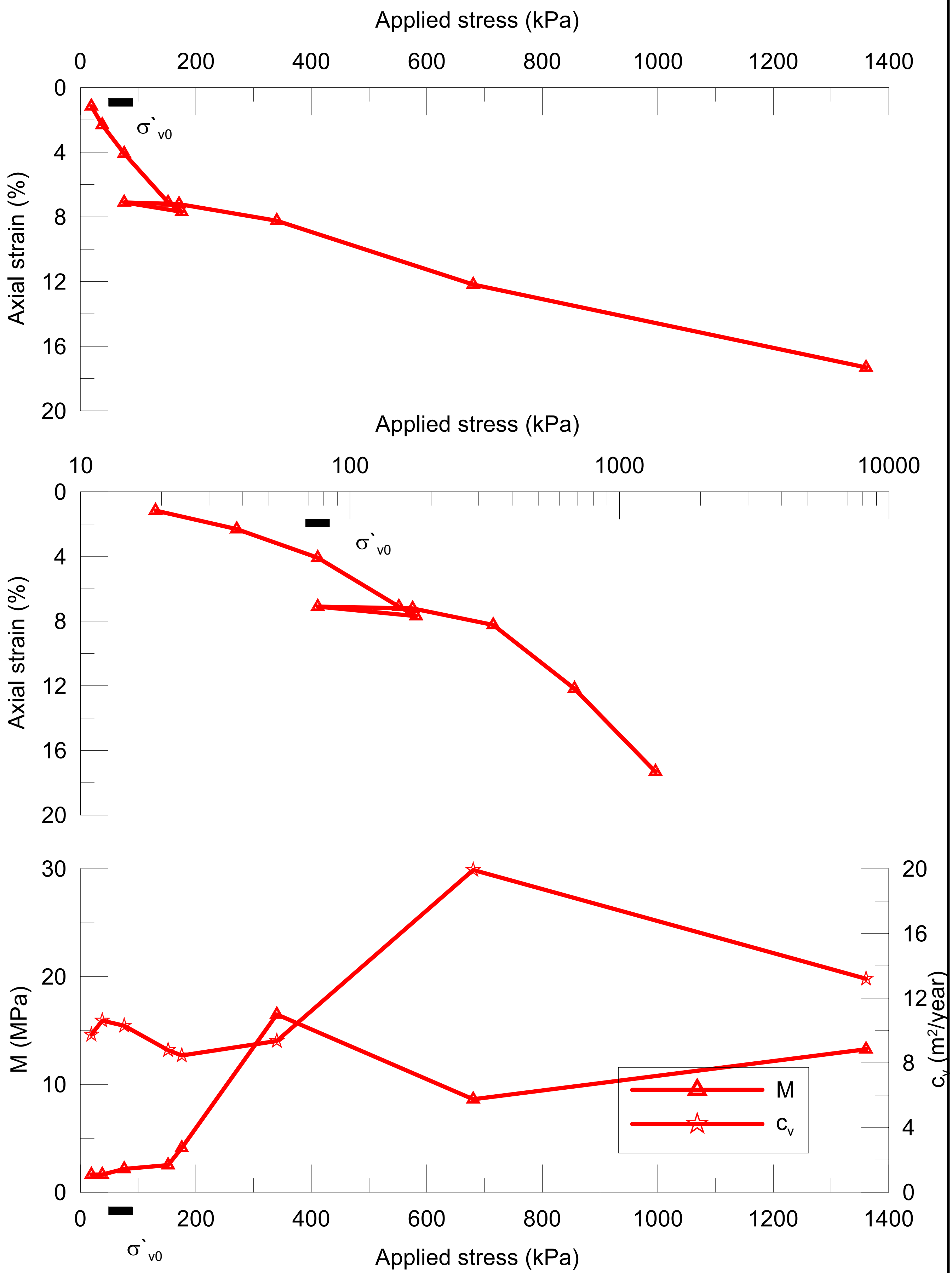


FoU Project - Os Site - 2004 Site Investigation		Report No. 2005 -G1	Figure No. 19
ML Oedometer Test 54(S)-2 BH: 10 Tube: L20, 7-7.8 m Depth: 7.4 m	σ'_{v0} = 76.6 kPa ρ = 1.907 Mg/m3 w = 42 % ε_{v0} / $\Delta e/e_0$ = 3.6 % /0.066	Drawn by GC Checked ML Approved	Date 2005-07-19

Dell/labtests/FoU\ML54(S)-1.grf

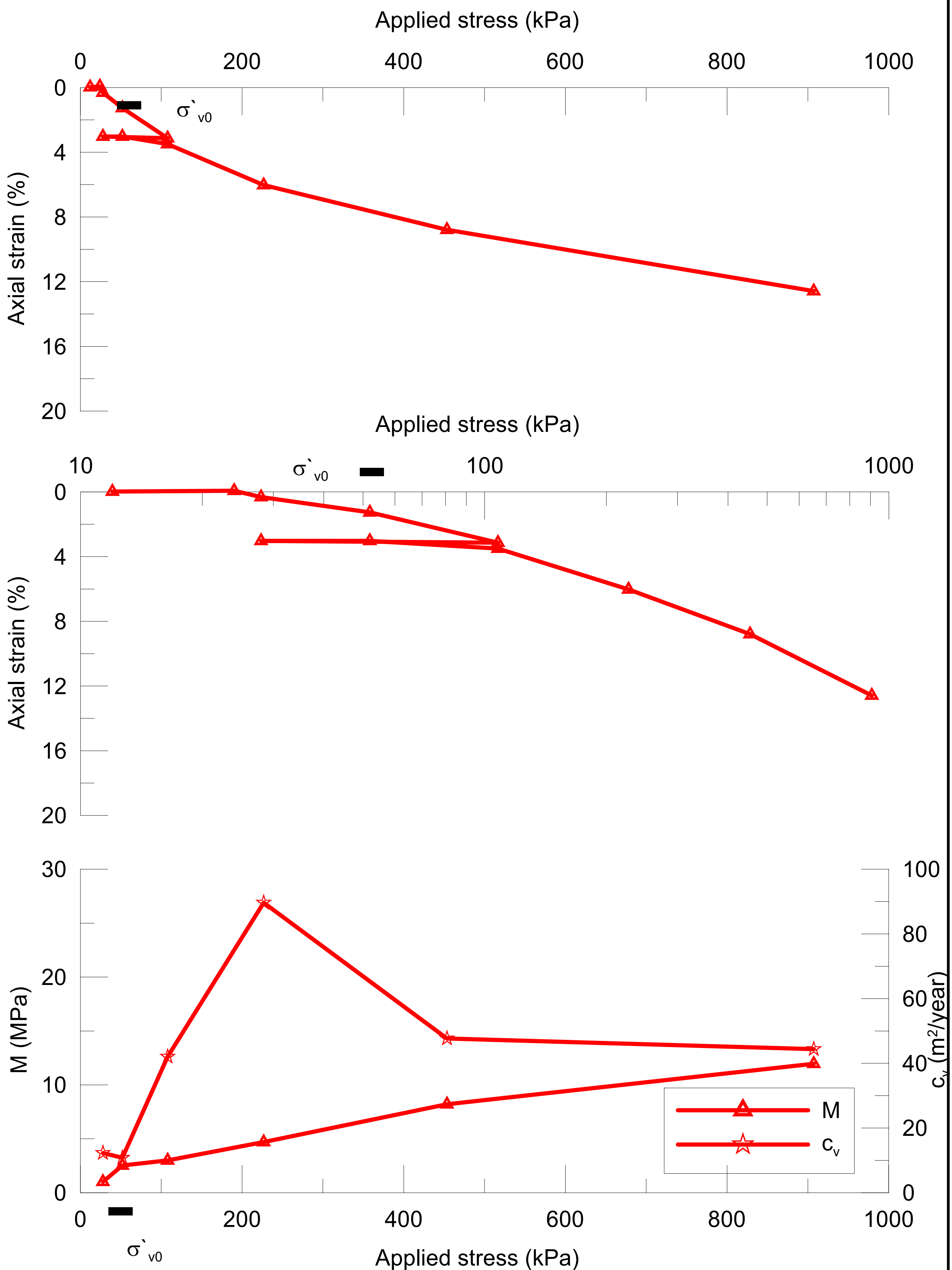


FoU Project - Os Site - 2004 Site Investigation		Report No. 2005 -G1	Figure No. 20
ML Oedometer Test 54(S)-3 BH: 10 Tube: L18, 6-6.8 m Depth: 6.22 m	σ'_{v0} = 66 kPa ρ = 2.05 Mg/m3 w = 34.1 % ε_{v0} / $\Delta e/e_0$ = 11.9 % /0.248	Drawn by GC	Date 2005-07-19
		Checked ML	
		Approved	



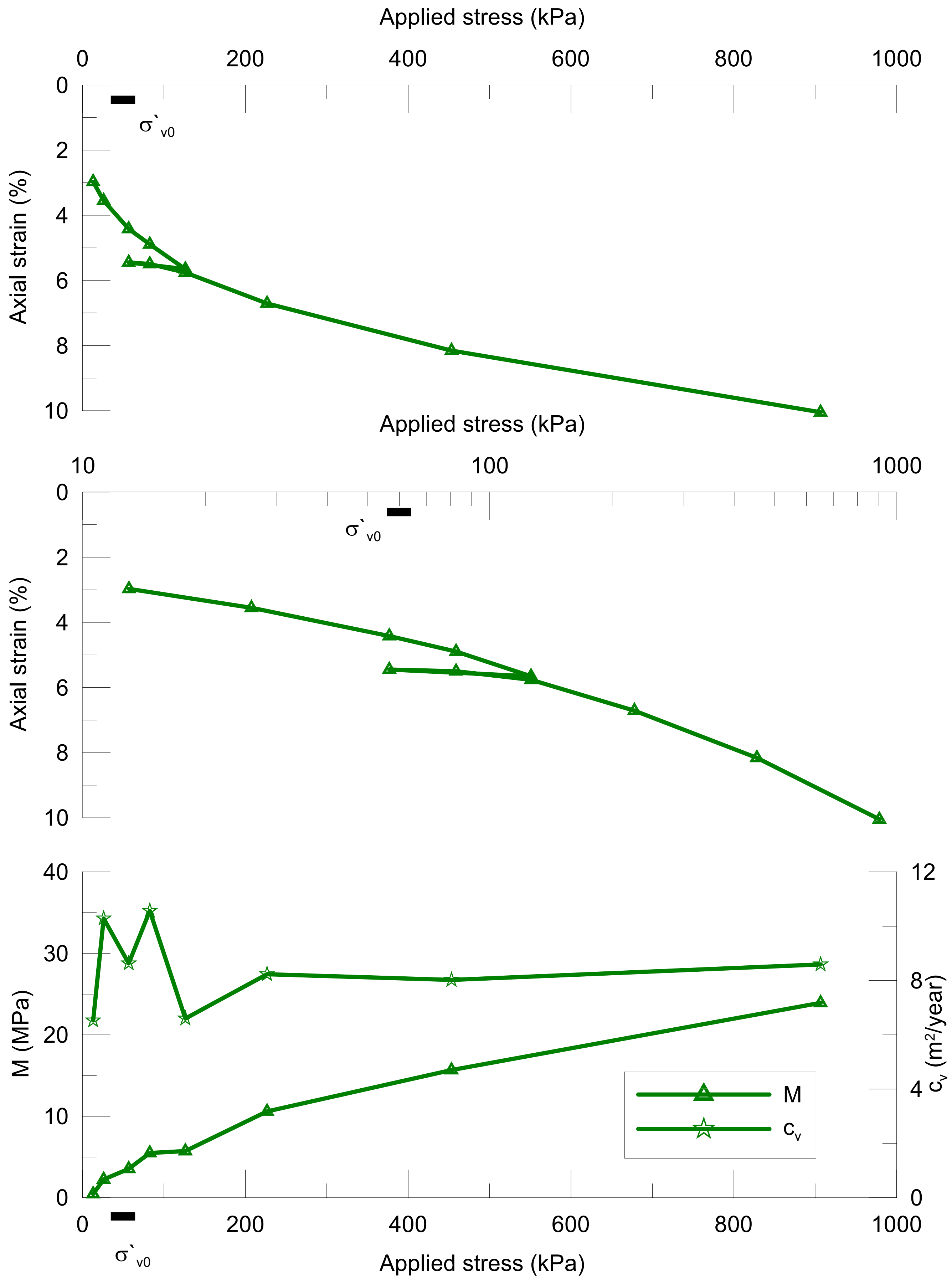
FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 -G1	Figure No. 21
ML Oedometer Test 54(S)-4 BH: 10 Tube: L20, 7-7.8 m Depth: 7.29 m $\sigma`_{v0}$ = 75.6 kPa ρ = 2.001 Mg/m3 w = 32.3 % ε_{v0} / $\Delta e/e_0$ = 4.1 % /0.084	Drawn by GC Checked ML Approved	Date 2005-07-19

Dell/labtests/FoU\ML54(S)-4.grf



FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 -G1	Figure No. 22
ML Oedometer Test 54(S)-5 BH: 10 Tube: L17, 4-4.8 m Depth: 4.28 m σ'_{v0} = 48.5 kPa ρ = 2.015 Mg/m3 w = 34.9 % ε_{v0} / $\Delta e/e_0$ = 1.3 % /0.026	Drawn by GC Checked ML Approved	Date 2005-07-19

Dell/labtests/FoU\ML54(S)-5.grf



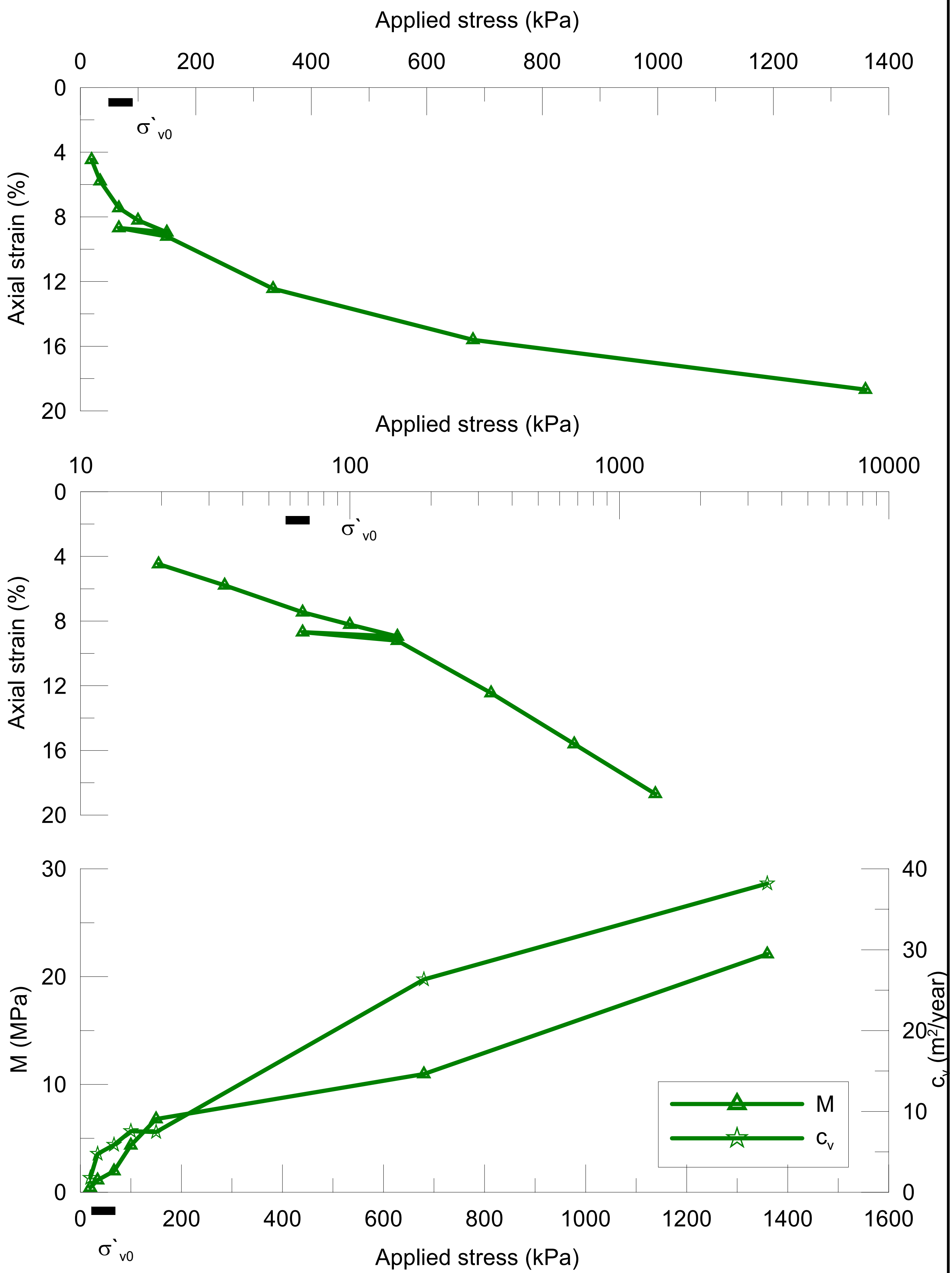
FoU Project - Os Site - 2004 Site Investigation

Report No.	Figure No.
2005 - G1	23
Drawn by GC	Date 2005-07-19
Checked ML	
Approved	

ML Oedometer Test 76-1
BH: 2
Tube: No.6, 5-5.8 m
Depth: 5.48 m

σ'_{v0} = 59.3 kPa
ρ = 2.091 Mg/m3
w = 30.0 %
ε_{v0} / $\Delta e/e_0$ = 4.4 % /0.098

Dell/labtests/FoU/ML76-1.grf



FoU Project - Os Site - 2004 Site Investigation

Report No.	Figure No.
2005 - G1	24
Drawn by	Date
GC	2005-07-19
Checked	
ML	
Approved	

ML Oedometer Test 76-2

BH: 2

Tube: No. 10, 6-6.8 m

Depth: 6.2 m

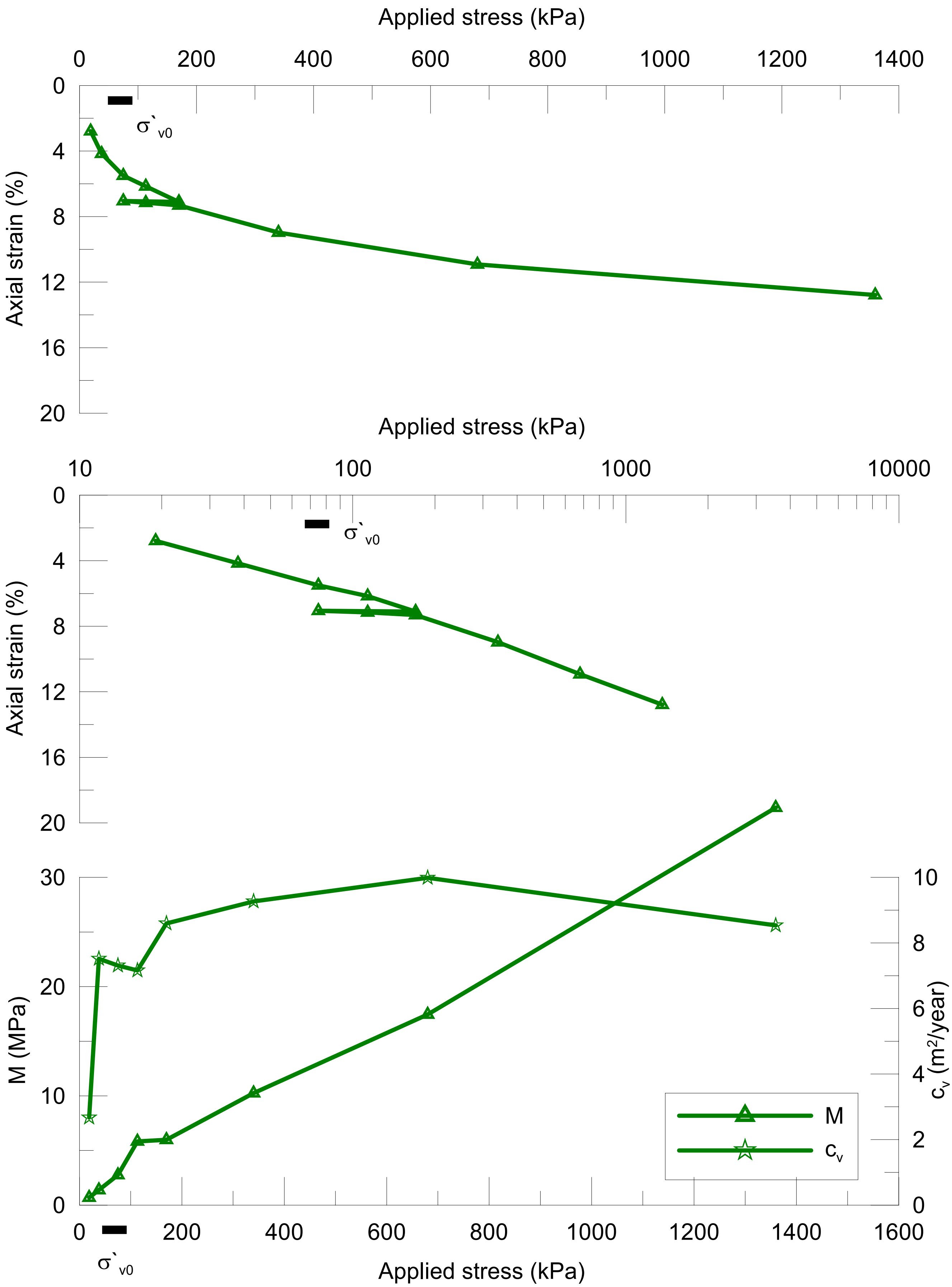
σ'_{v0} = 65.8 kPa

ρ = 2.121 Mg/m3

w = 30.3 %

$\varepsilon_{v0} / \Delta e/e_0$ = 7.5 % / 0.166

Dell/labtests/FoU\ML76-2.grf



FoU Project - Os Site - 2004 Site Investigation

Report No.	Figure No.
2005 - G1	25
Drawn by: GC	Date: 2005-07-19
Checked: ML	
Approved	

ML Oedometer Test 76-3

BH: 2

Tube: No. 3, 7-7.8 m

Depth: 7.15 m

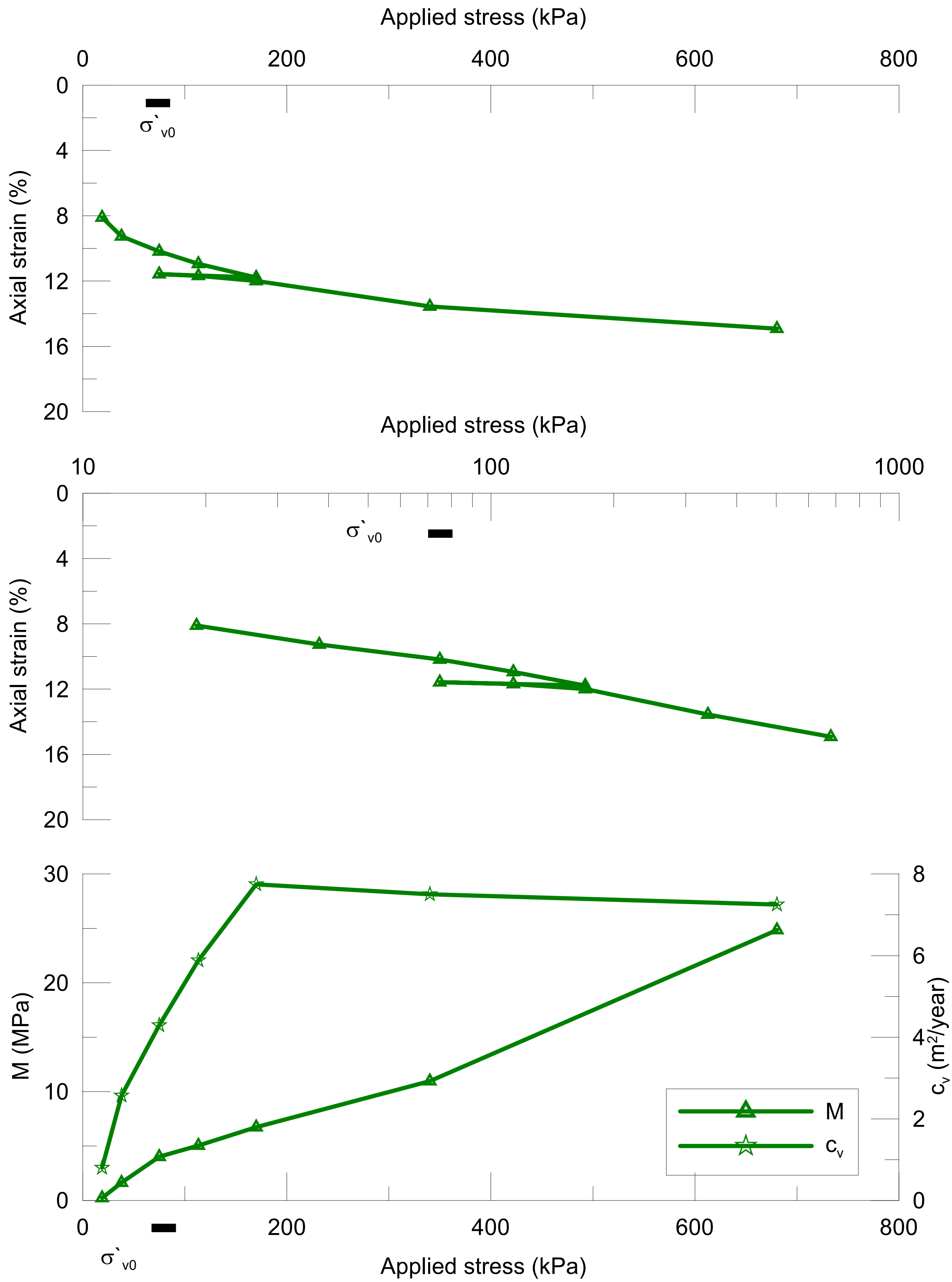
σ'_{v0} = 74.4 kPa

ρ = 2.146 Mg/m3

w = 28.5 %

ε_{v0} / $\Delta e/e_0$ = 5.5 % / 0.128

Dell/labtests/FoUML76-3.grf



FoU Project - Os Site - 2004 Site Investigation

Report No.	2005 - G1
Figure No.	26
Drawn by	GC
Date	2005-07-19
Checked	ML
Approved	

ML Oedometer Test 76-4

BH: 2

Tube: No. 3, 7-7.8 m

Depth: 7.4 m

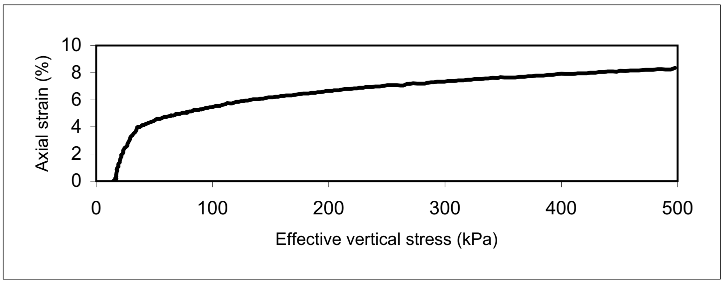
σ'_{v0} = 76.6 kPa

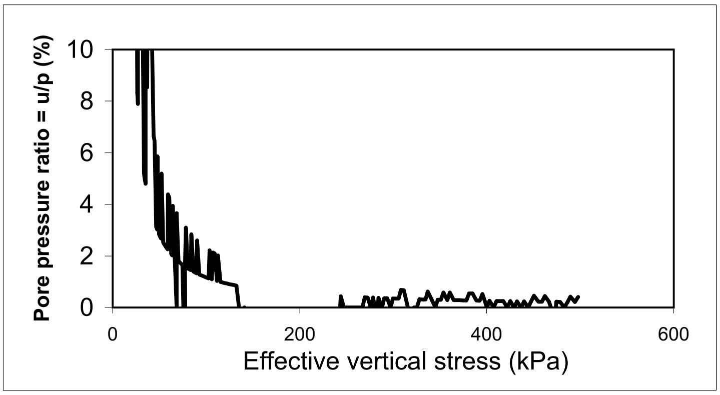
ρ = 2.134 Mg/m3

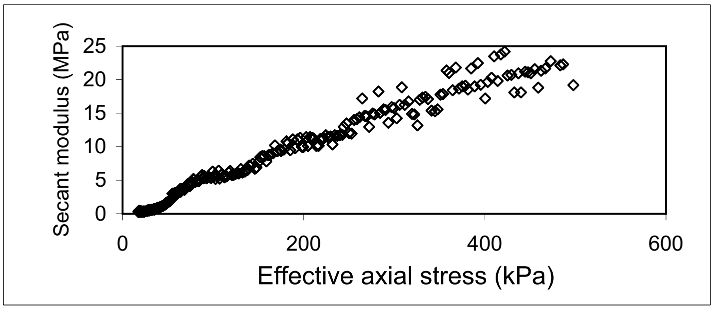
w = 31 %

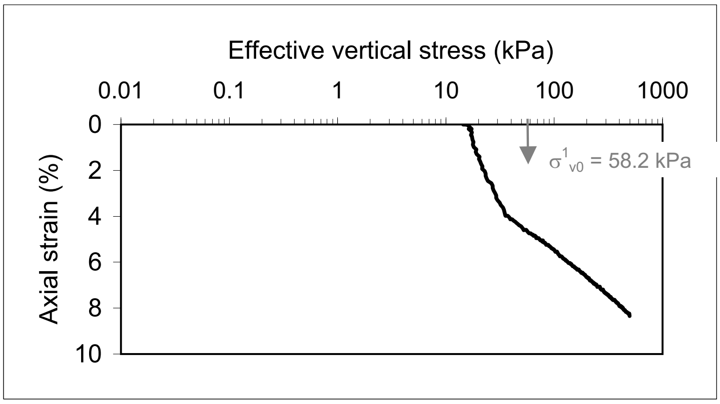
$\varepsilon_{v0} / \Delta e/e_0$ = 10.2 % / 0.229

Dell/labtests/FoU/ML76-4.grf









Site: FoU - Os
BH: 2, Sample L16 - 54 mm plastic
Specimen depth: 5.35 m
w_i = 28.9 %
ρ_i = 2.179 Mg/m^3
Test rate = 30 kPa / hour

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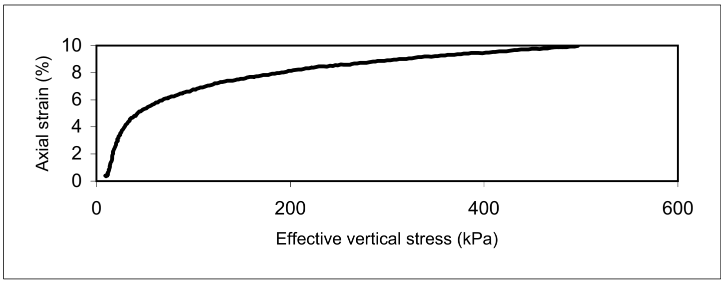
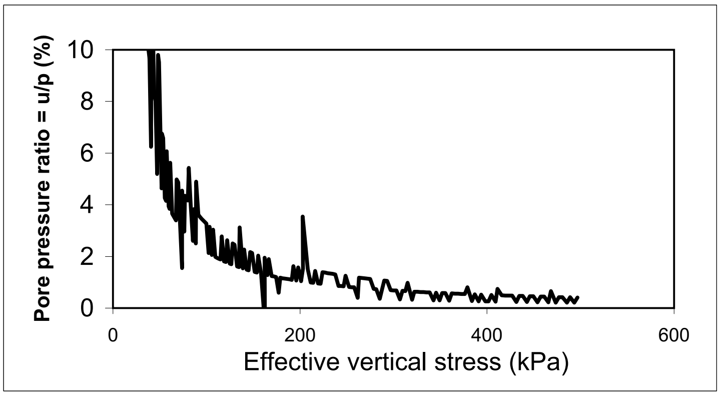
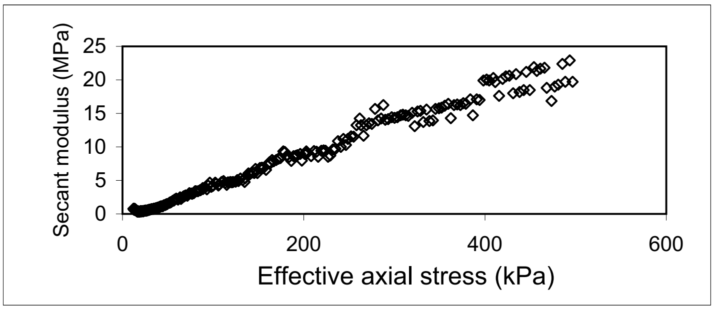
File: Dell/labtests/FoU/crs1.xls

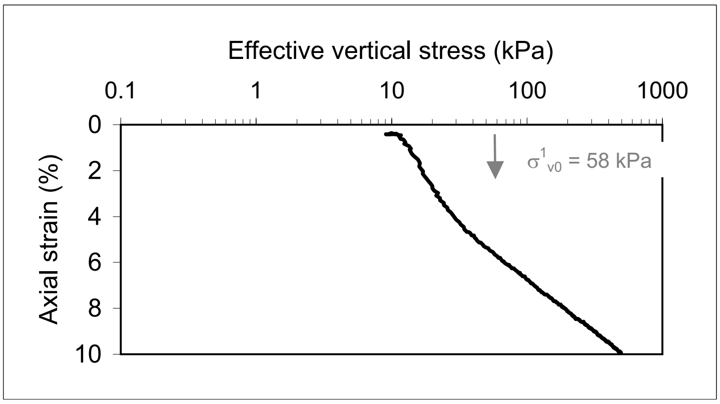
Os - CRS1

Fig 27









Site: FoU - Os

BH: 2, Sample No. 2 - 76 mm steel

Specimen depth: 5.33 m

w_i = 30.0 %

ρ_i = 2.109 Mg/m^3

Test rate = 30 kPa / hour

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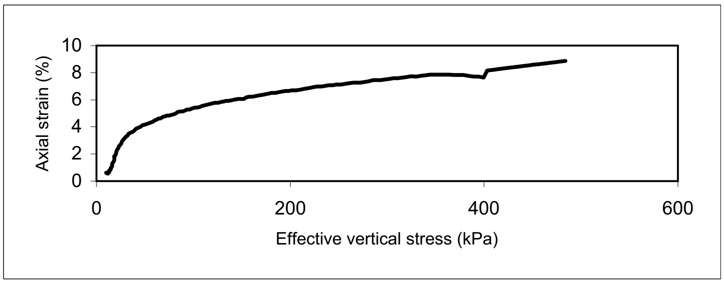
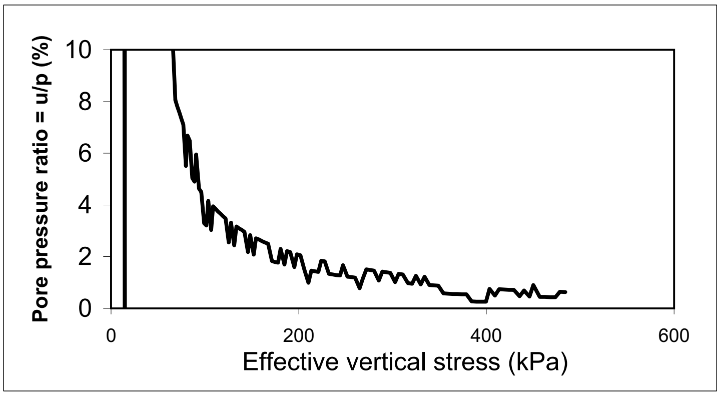
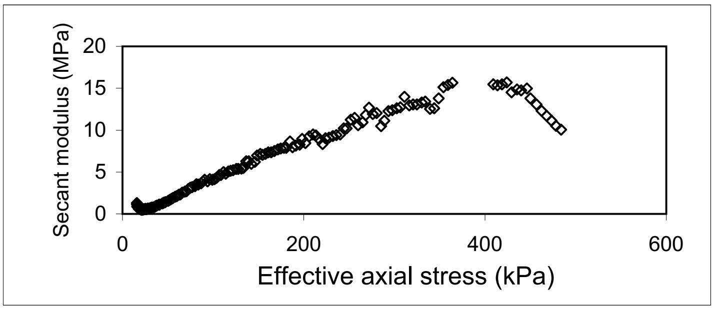
File: Dell/labtests/FoU/crs2.xls

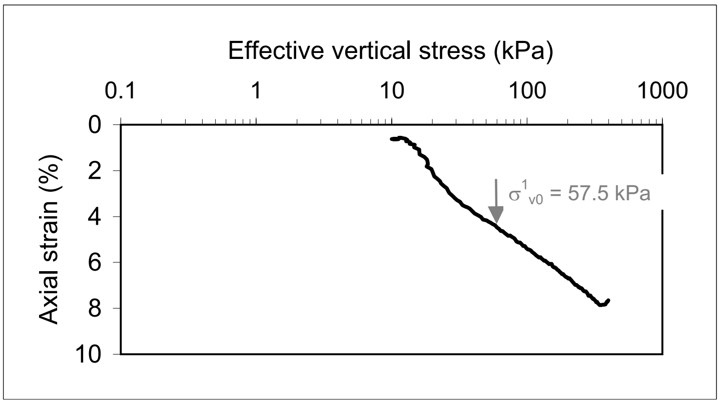
Os - CRS 2

Fig 28









Site: FoU - Os
BH: 2, Sample No. 2 - 76 mm steel
Specimen depth: 5.48 m
w_i = 30.1 %
ρ_i = 2.119 Mg/m^3
Test rate = 60 kPa / hour

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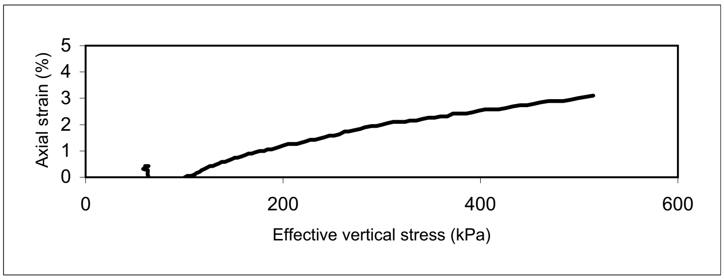
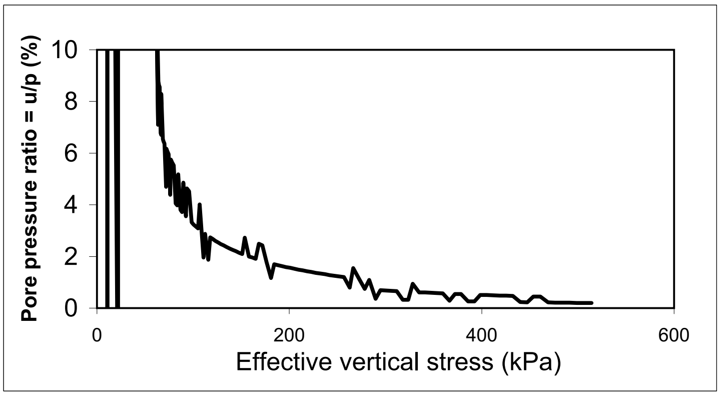
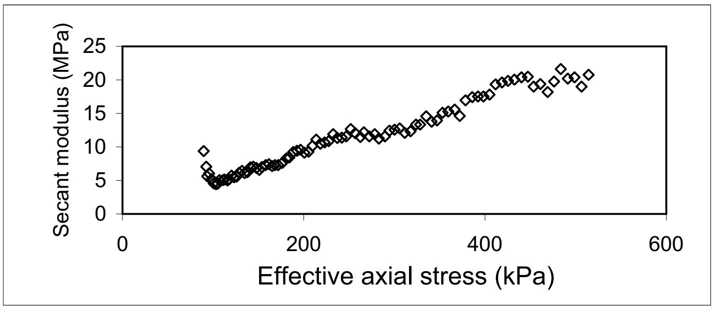
File: Dell/labtests/FoU/crs3.xls

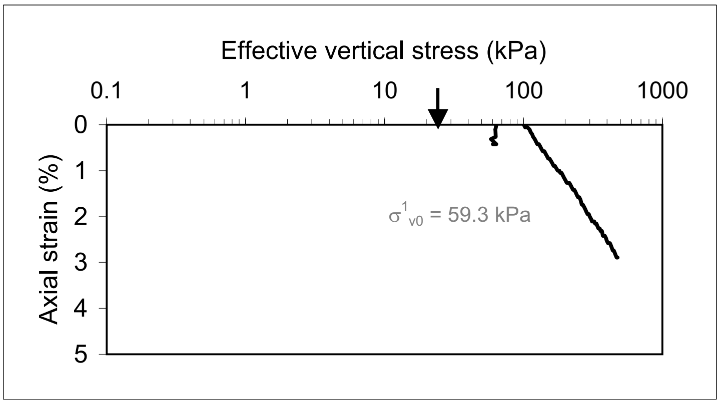
Os - CRS 3

Fig 29









Site: FoU - Os
BH: 10, Sample No. L23 - 54 mm steel
Specimen depth: 5.48 m
w_i = 29.6 %
ρ_i = 2.157 Mg/m^3
Test rate = 120 kPa / hour

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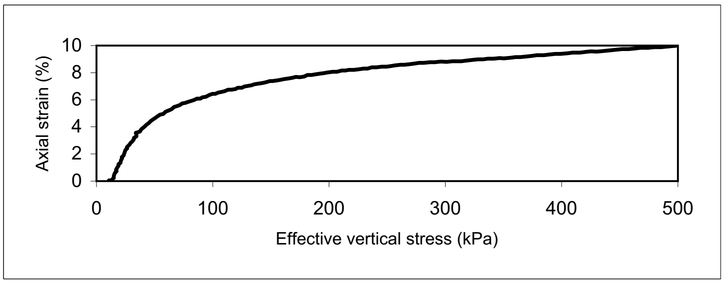
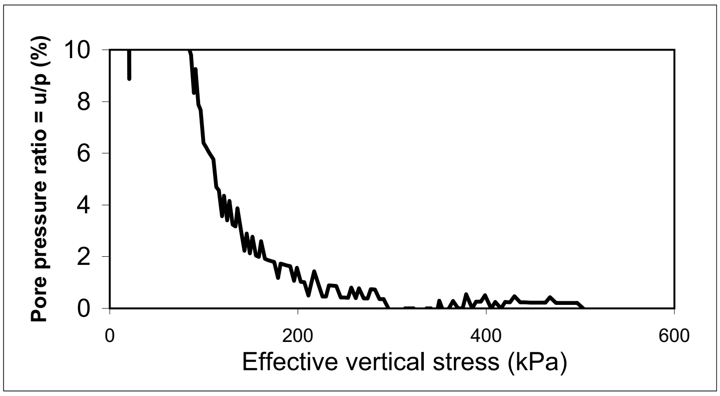
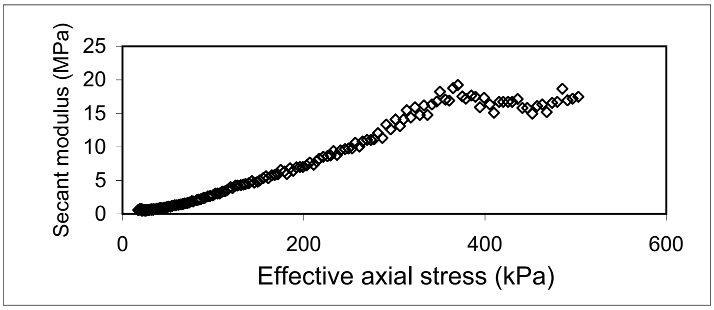
File: Dell/labtests/FoU/crs4.xls

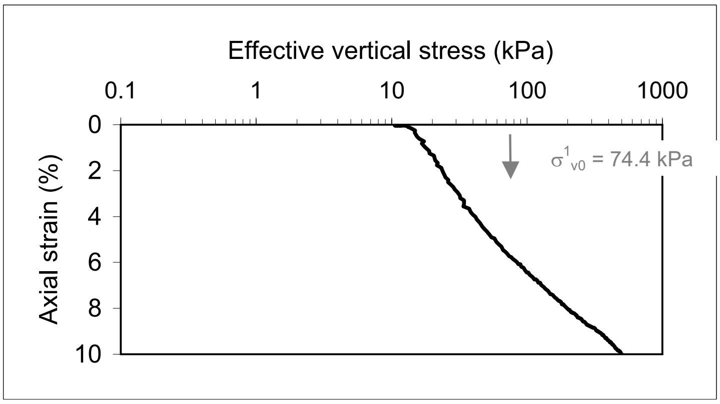
Os - CRS 4

Fig. 30









Site: FoU - Os
BH: 2, Sample No. 3 - 76 mm steel
Specimen depth: 7.15 m
w_i = 32.0 %
ρ_i = 2.127 Mg/m^3
Test rate = 60 kPa / hour

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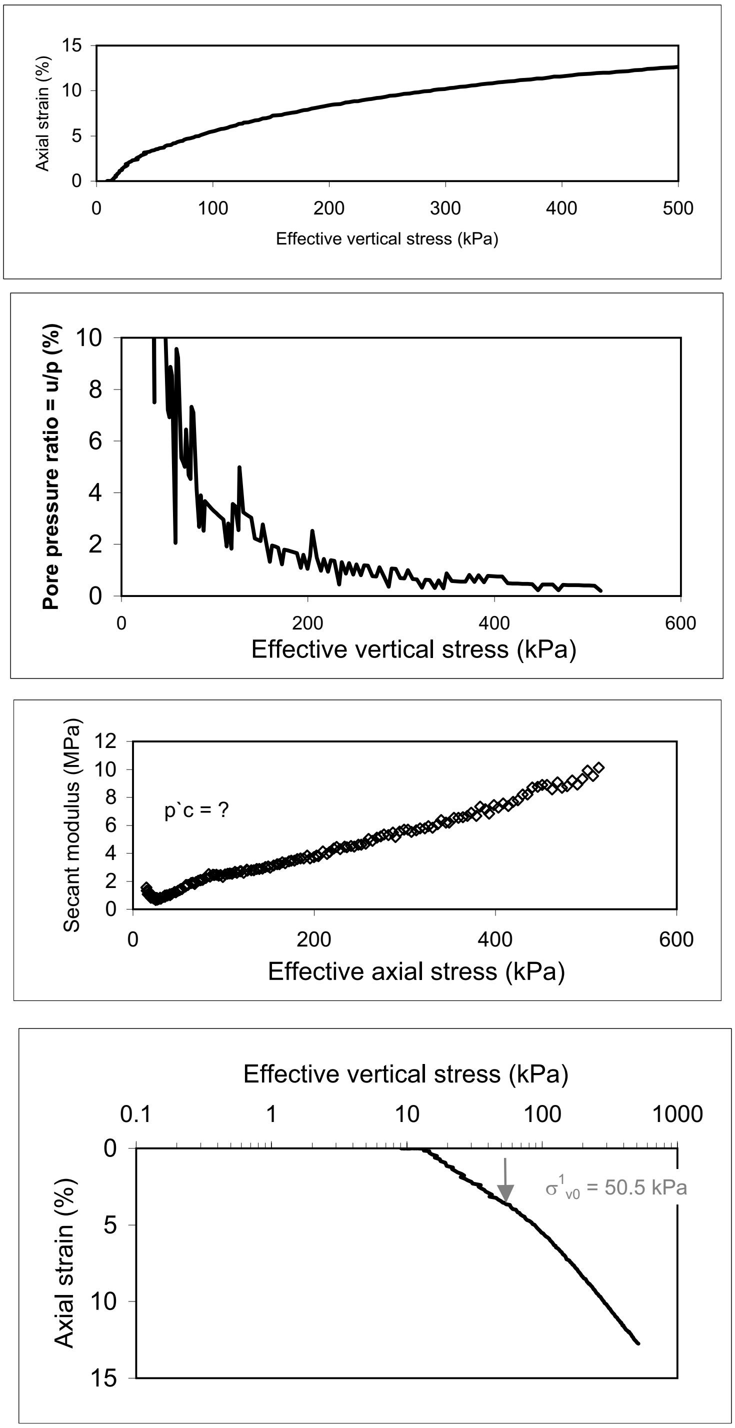
File: Dell/labtests/FoU/crs5.xls

Os - CRS 5

Fig 31



Site: FoU - Os
BH: 2, Sample No. 1 - 76 mm steel
Specimen depth: 4.5 m
w_i = 36.8 %
ρ_i = 1.952 Mg/m^3
Test rate = 60 kPa / hour

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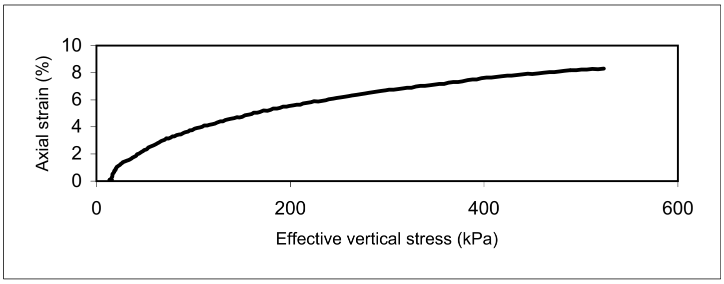
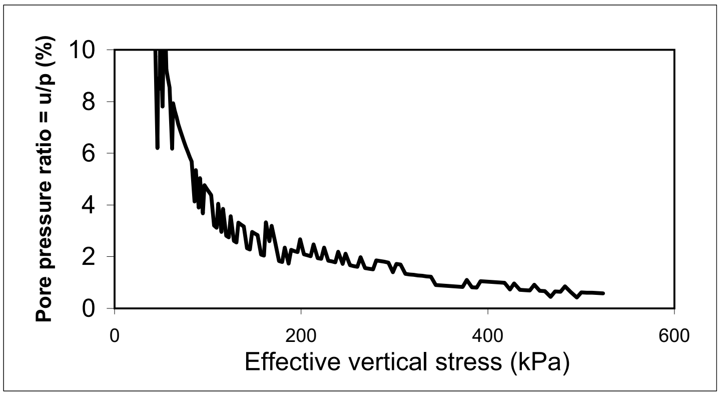
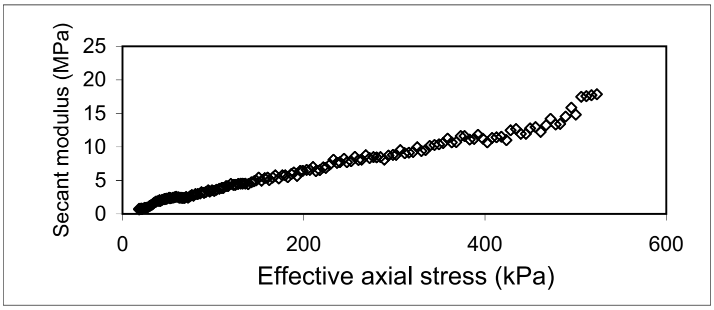
File: Dell/labtests/FoU/crs6.xls

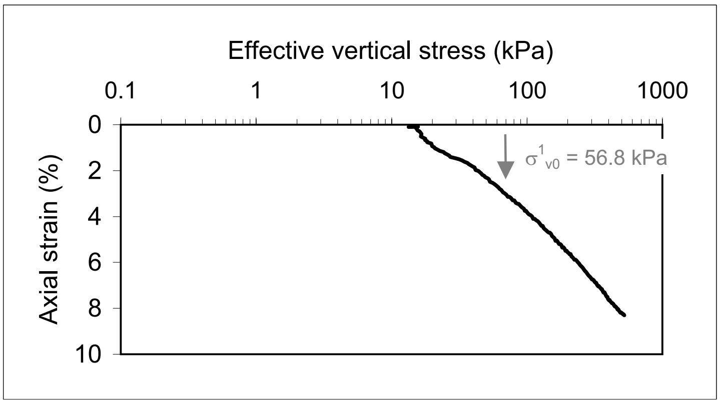
Os - CRS 6

Fig 32









Site: FoU - Os
BH: 2, Sample No. 6 - 76 mm steel
Specimen depth: 5.20 m
w_i = 33.7%
ρ_i = 2.036 Mg/m^3
Test rate = 60 kPa / hour

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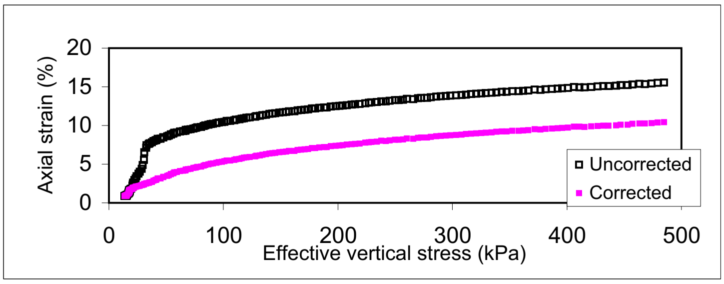
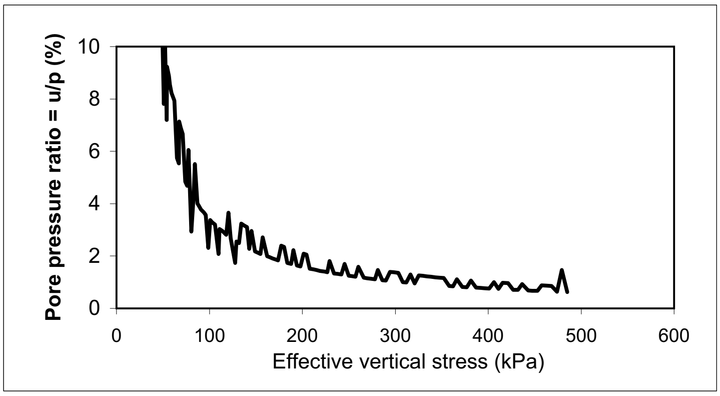
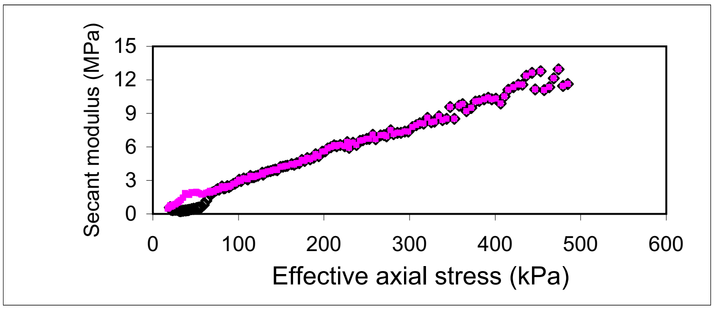
File: Dell/labtests/FoU/crs7.xls

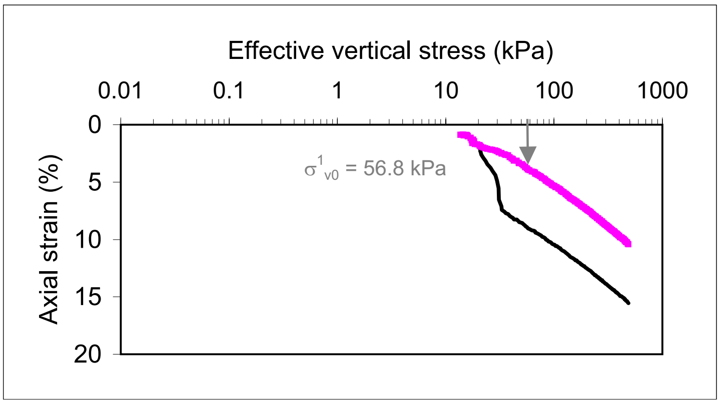
Os - CRS 7

Fig. 33









Site: FoU - Os

BH: 2, Sample No. 6 - 76 mm steel

Specimen depth: 5.20 m

w_i = 34.7 %

ρ_i = 1.998 Mg/m^3

Test rate = 60 kPa / hour

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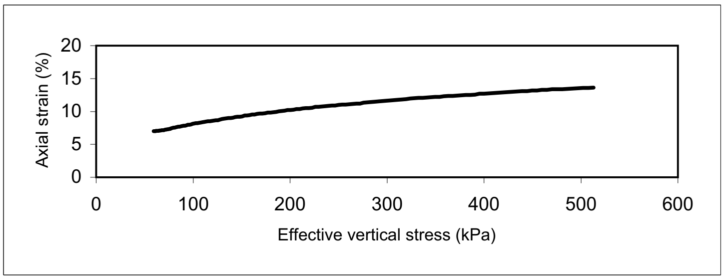
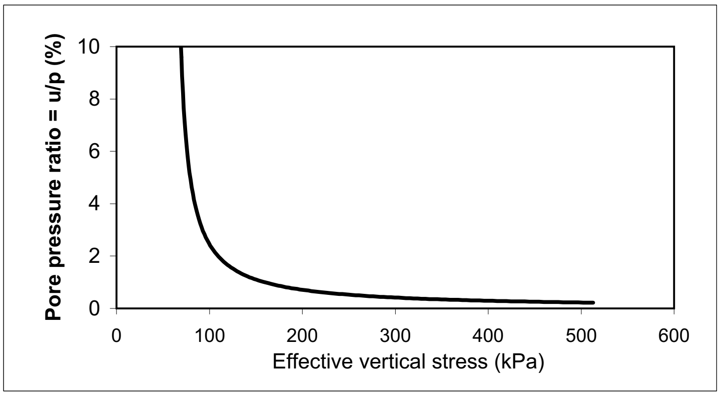
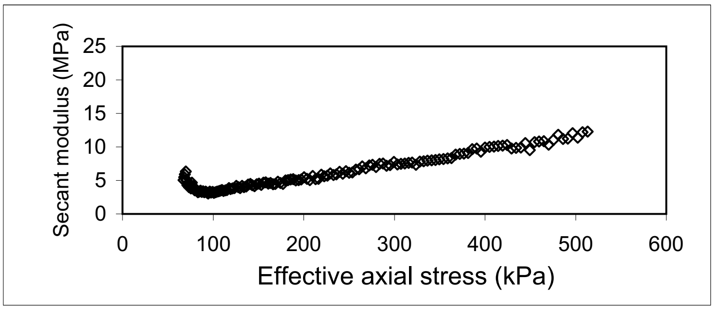
File: Dell/labtests/FoU/crs8.xls

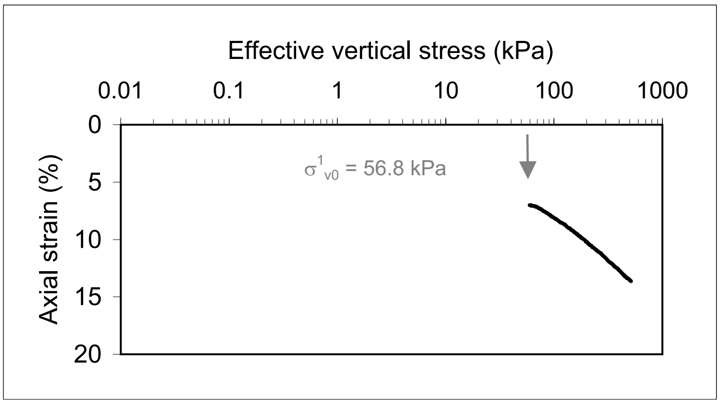
Os - CRS 8

Fig. 34









Site: FoU - Os
BH: 2, Sample No. 6 - 76 mm steel
Specimen depth: 5.20 m
w_i = 34.9 %
ρ_i = 2.059 Mg/m^3
Test rate = 60 kPa / hour

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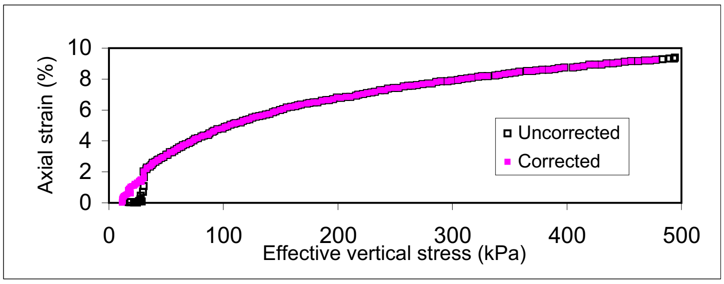
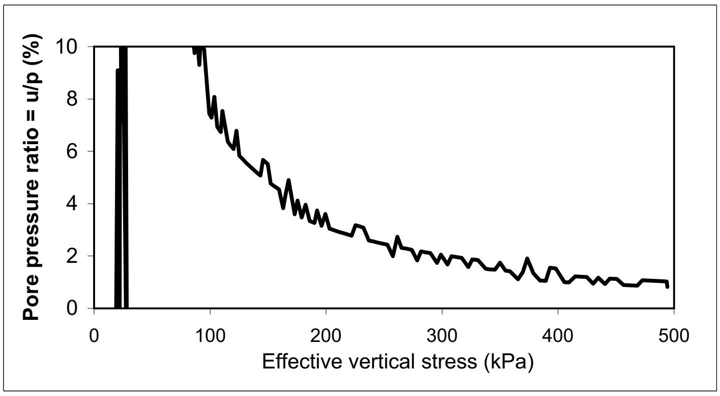
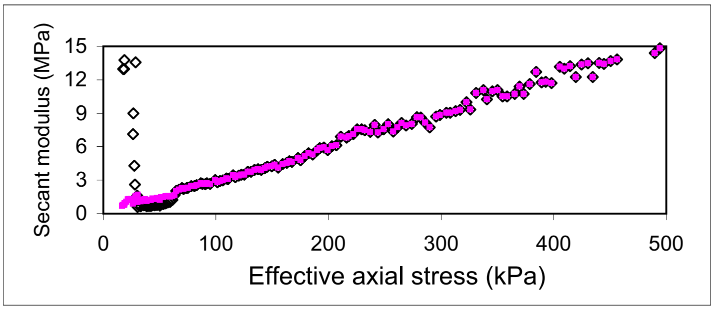
File: Dell/labtests/FoU/crs9.xls

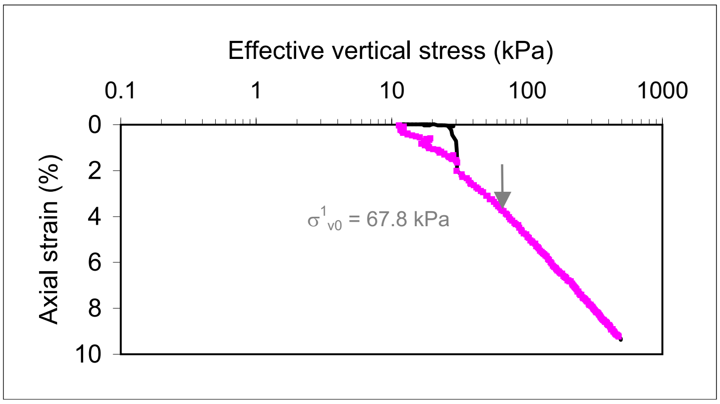
Os - CRS 9

Fig. 35









Site: FoU - Os
BH: 2, Sample L26 - 54 mm composite
Specimen depth: 6.42 m
w_i = 34.7 %
ρ_i = 2.043 Mg/m^3
Test rate = 60 kPa / hour

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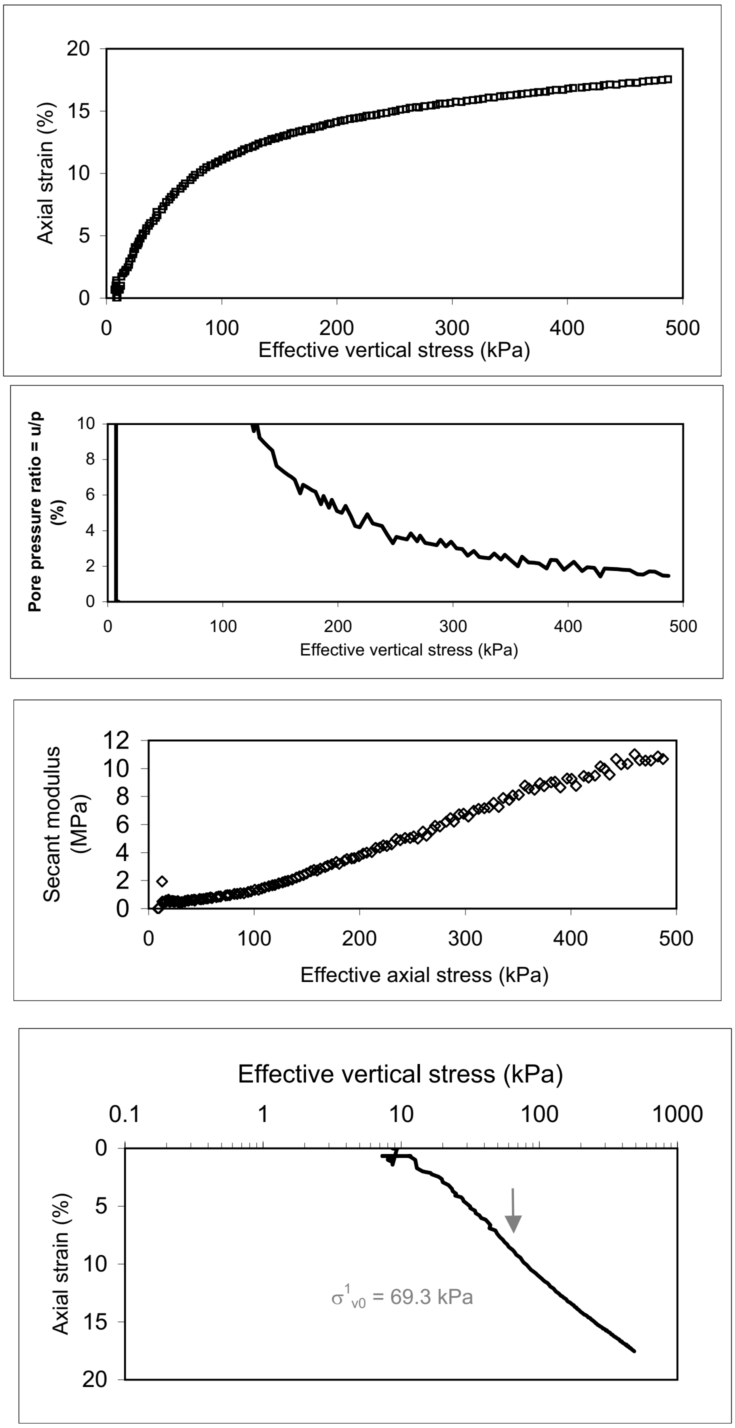
File: Dell/labtests/FoU/crs10.xls

Os - CRS 10

Fig. 36



Site: FoU - Os
BH: 2, Sample L26 - 54 mm composite
Specimen depth: 6.59 m
w_i = 36.3 %
ρ_i = 1.906 Mg/m^3
Test rate = 60 kPa / hour

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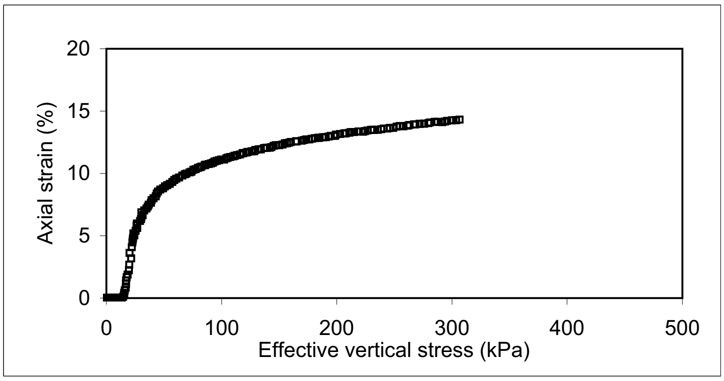
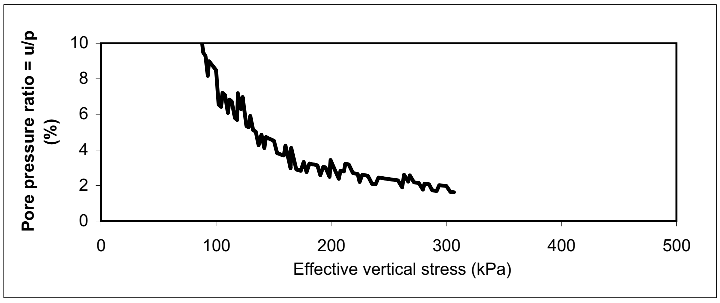
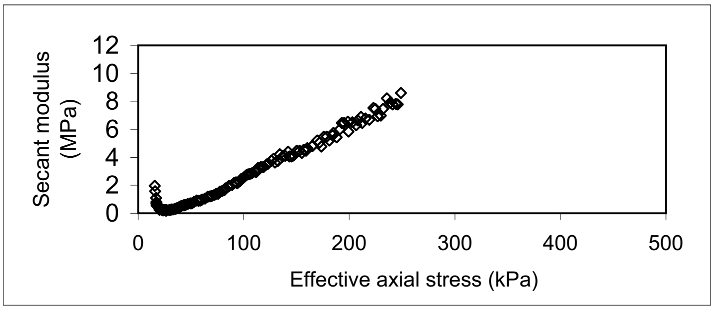
File: Dell/labtests/FoU/crs11.xls

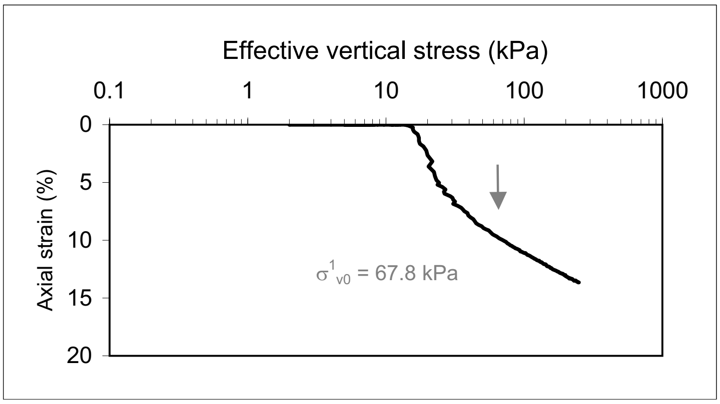
Os - CRS 11

Fig. 37









Site: FoU - Os
BH: 2, Sample L26 - 54 mm composite
Specimen depth: 6.42 m
w_i = 33.5%
ρ_i = 2.056 Mg/m^3
Test rate = 30 kPa / hour

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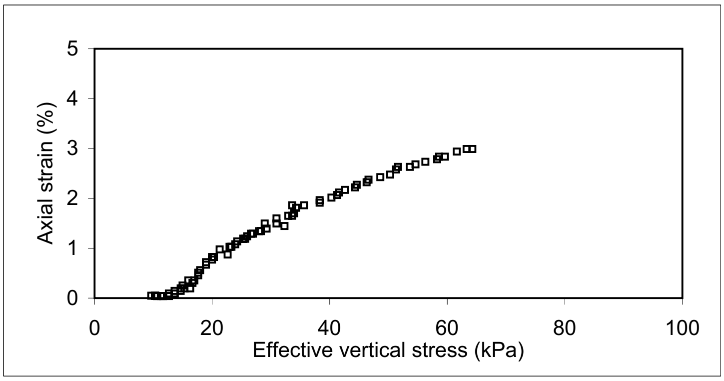
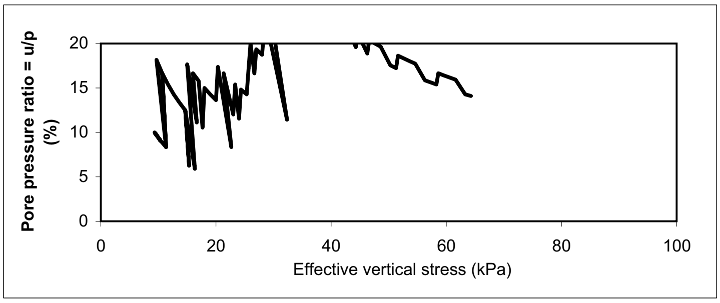
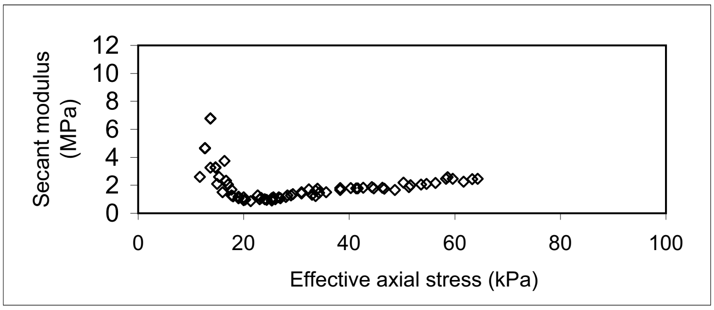
File: Dell/labtests/FoU/crs12.xls

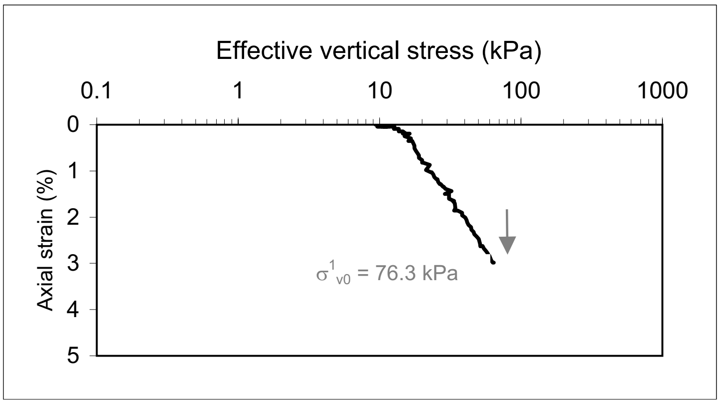
Os - CRS 12

Fig. 38









Site: FoU - Os
BH: 2, Sample L19 - 54 mm composite
Specimen depth: 7.37 m
w_i = 41.9%
ρ_i = 1.990 Mg/m^3
Test rate = 30 kPa / hour

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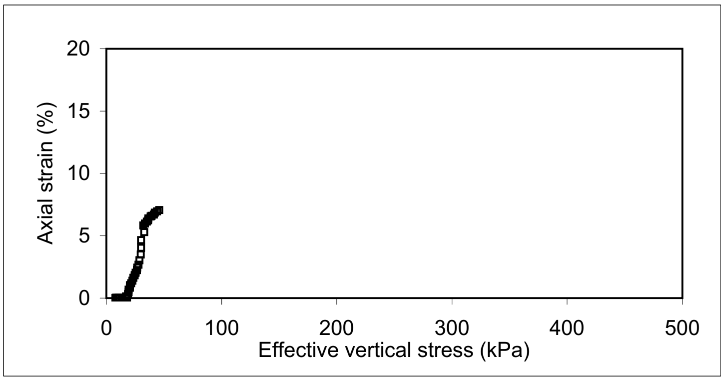
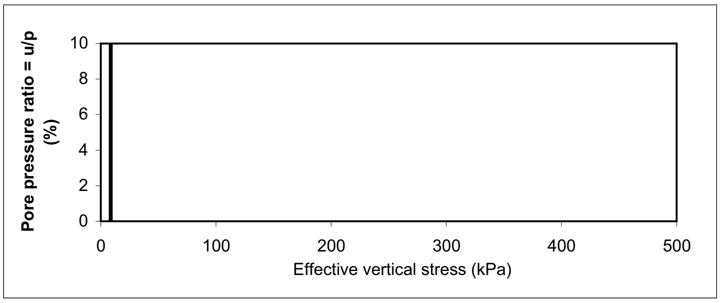
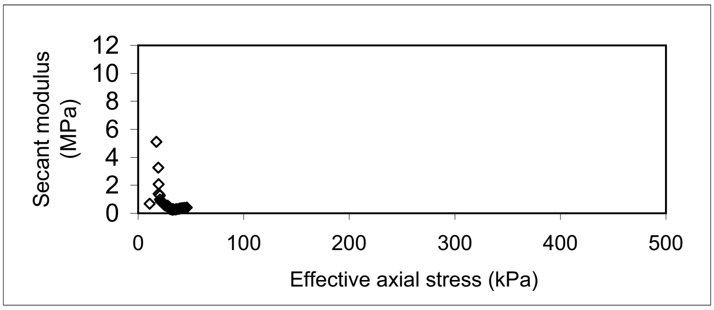
File: Dell/labtests/FoU/crs13.xls

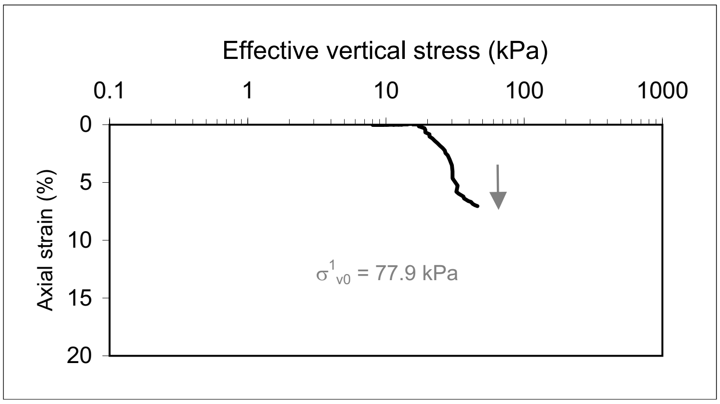
Os - CRS 13

Fig. 39









Site: FoU - Os
BH: 2, Sample L19 - 54 mm composite
Specimen depth: 7.54 m
w_i = 34.1 %
ρ_i = 2.009 Mg/m^3
Test rate = 30 kPa / hour

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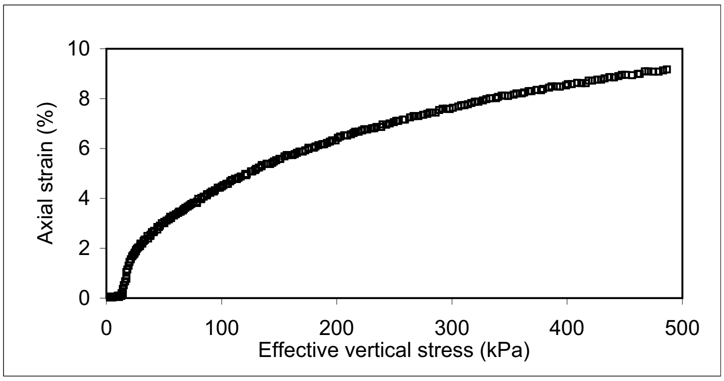
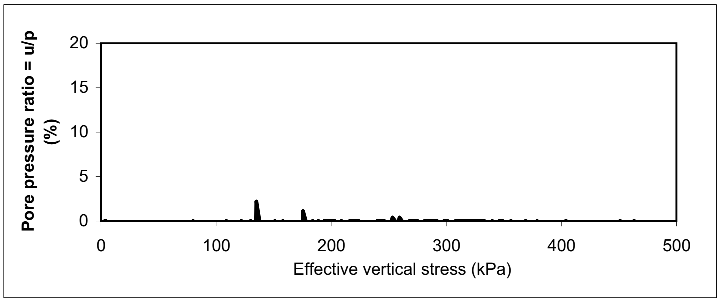
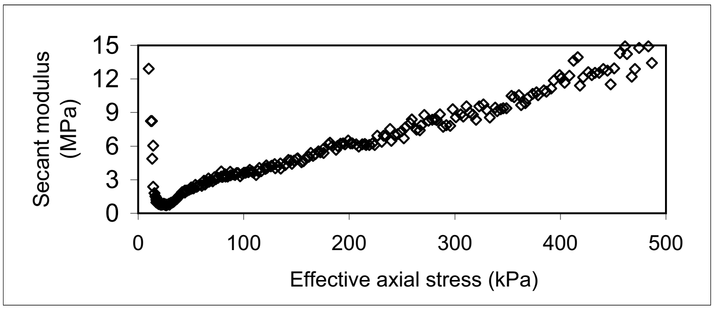
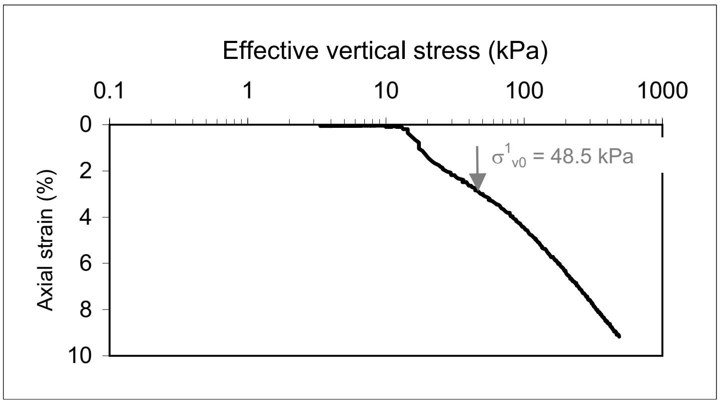
File: Dell/labtests/FoU/crs14.xls









Site: FoU - Os
BH: 10, Sample L17 - 54 mm steel
Specimen depth: 4.25 m
w_i = 36.8%
ρ_i = 1.987 Mg/m^3
Test rate = 30 kPa / hour

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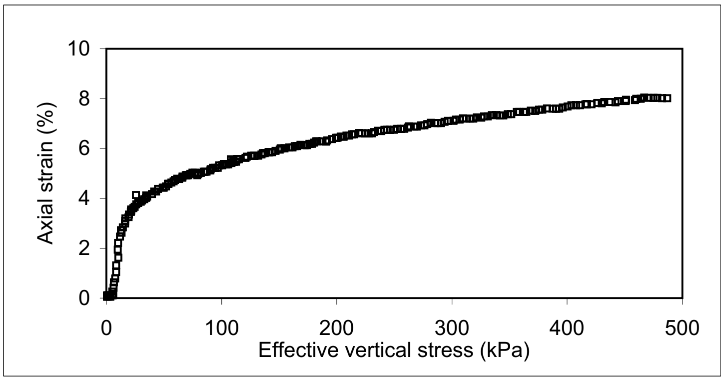
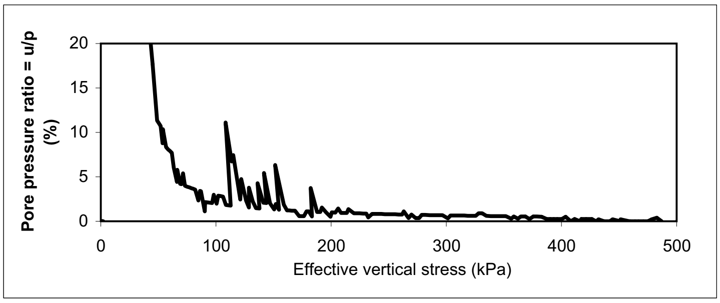
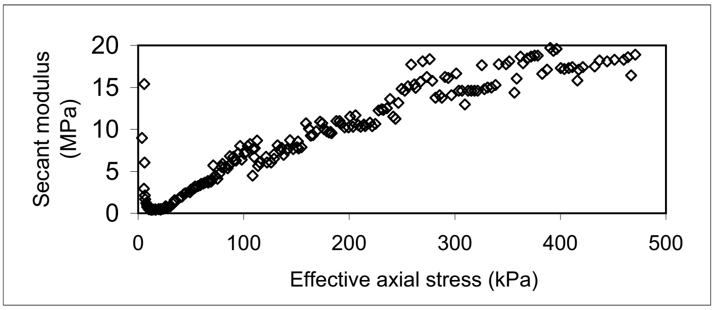
File: Dell/labtests/FoU/crs15.xls

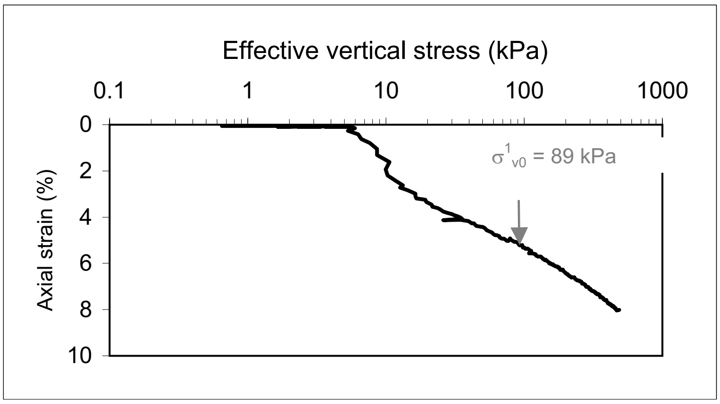
Os - CRS 15

Fig. 41









Site: FoU - Os
BH: 2, Sample L6 - 54 mm composite
Specimen depth: 8.78 m
w_i = 25.1%
ρ_i = 2.221 Mg/m^3
Test rate = 30 kPa / hour

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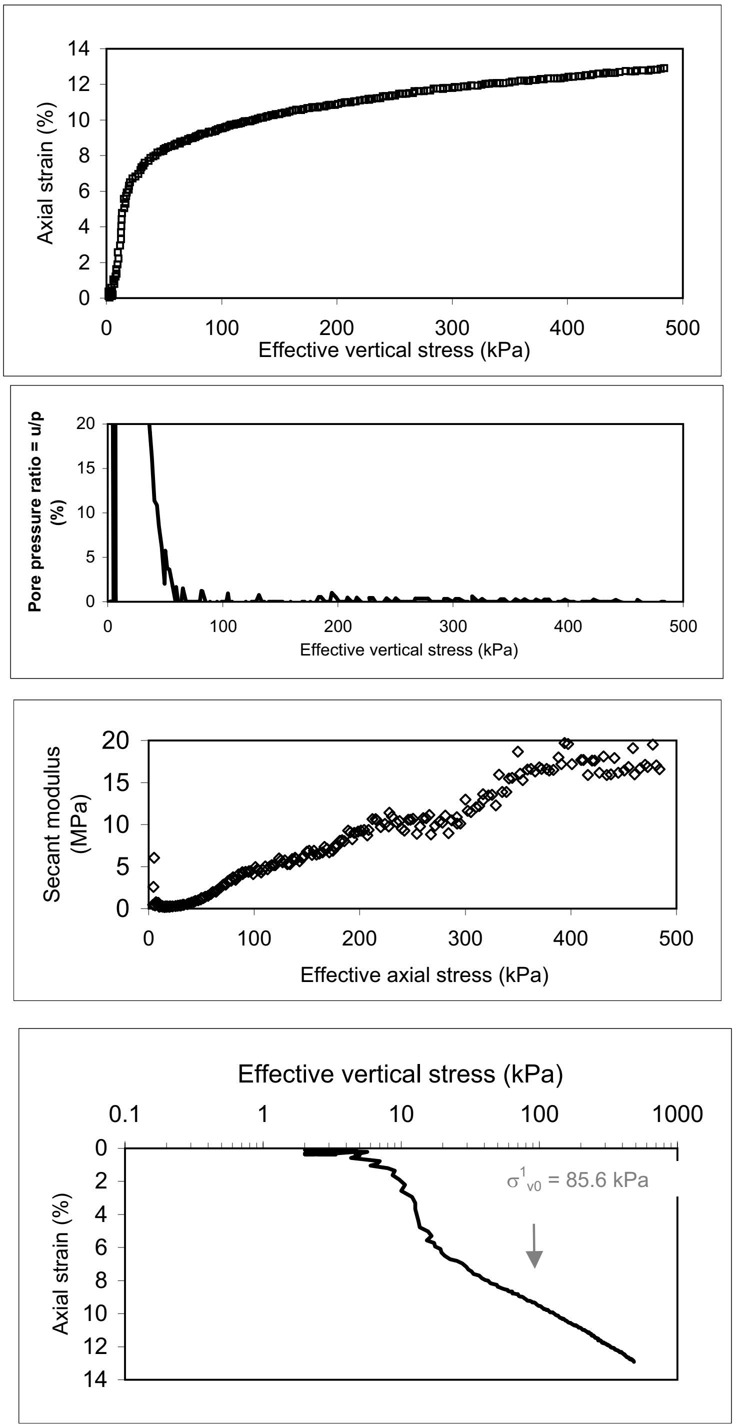
File: Dell/labtests/FoU/crs16.xls

Os - CRS 16

Fig. 42



Site: FoU - Os
BH: 2, Sample L6 - 54 mm composite
Specimen depth: 8.4 m
w_i = 31.3%
ρ_i = 2.130 Mg/m^3
Test rate = 30 kPa / hour

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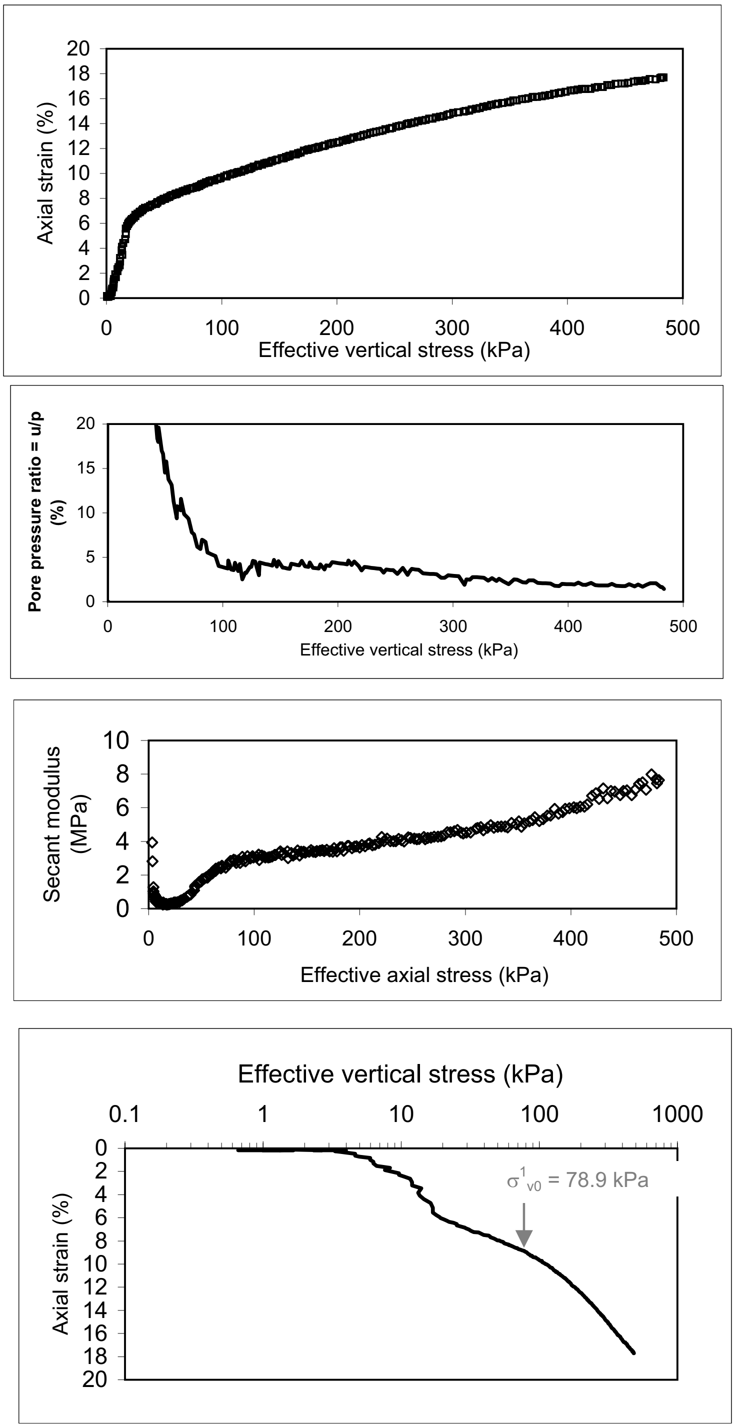
File: Dell/labtests/FoU/crs17.xls

Os - CRS 17 **Fig. 43**



Site: FoU - Os
BH: 2, Sample L20 - 54 mm steel
Specimen depth: 7.66 m
w_i = 39.8%
ρ_i = 1.903 Mg/m^3
Test rate = 30 kPa / hour

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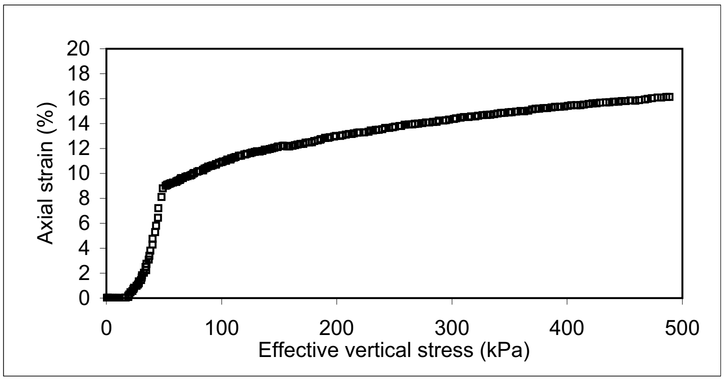
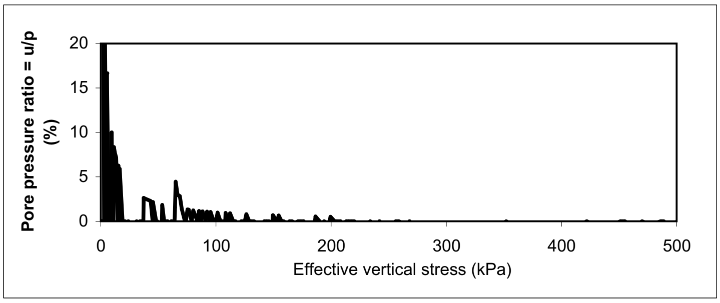
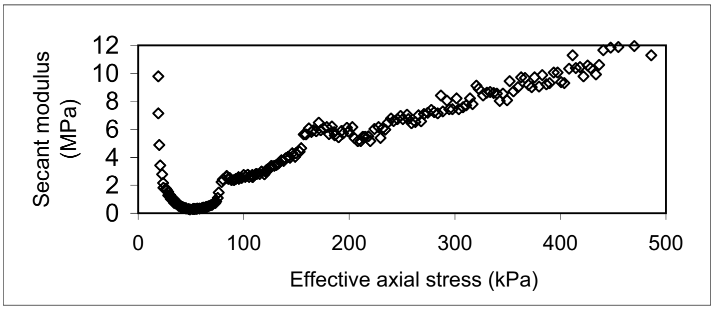
File: Dell/labtests/FoU/crs18.xls

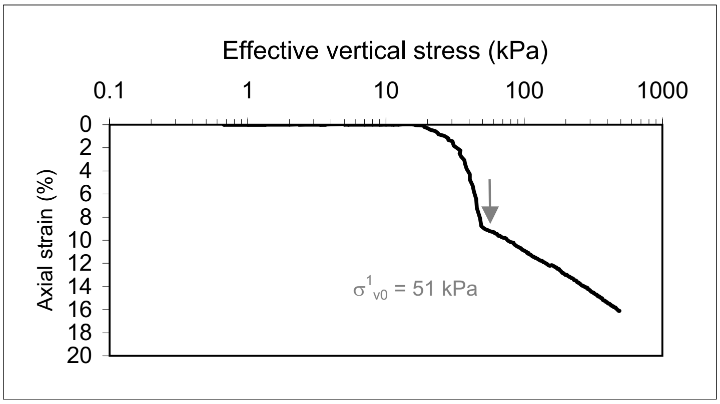
Os - CRS 18

Fig. 44









Site: FoU - Os
BH: 2, Sample L17 - 54 mm steel
Specimen depth: 4.55 m
w_i = 34.9%
ρ_i = 1.990 Mg/m^3
Test rate = 30 kPa / hour

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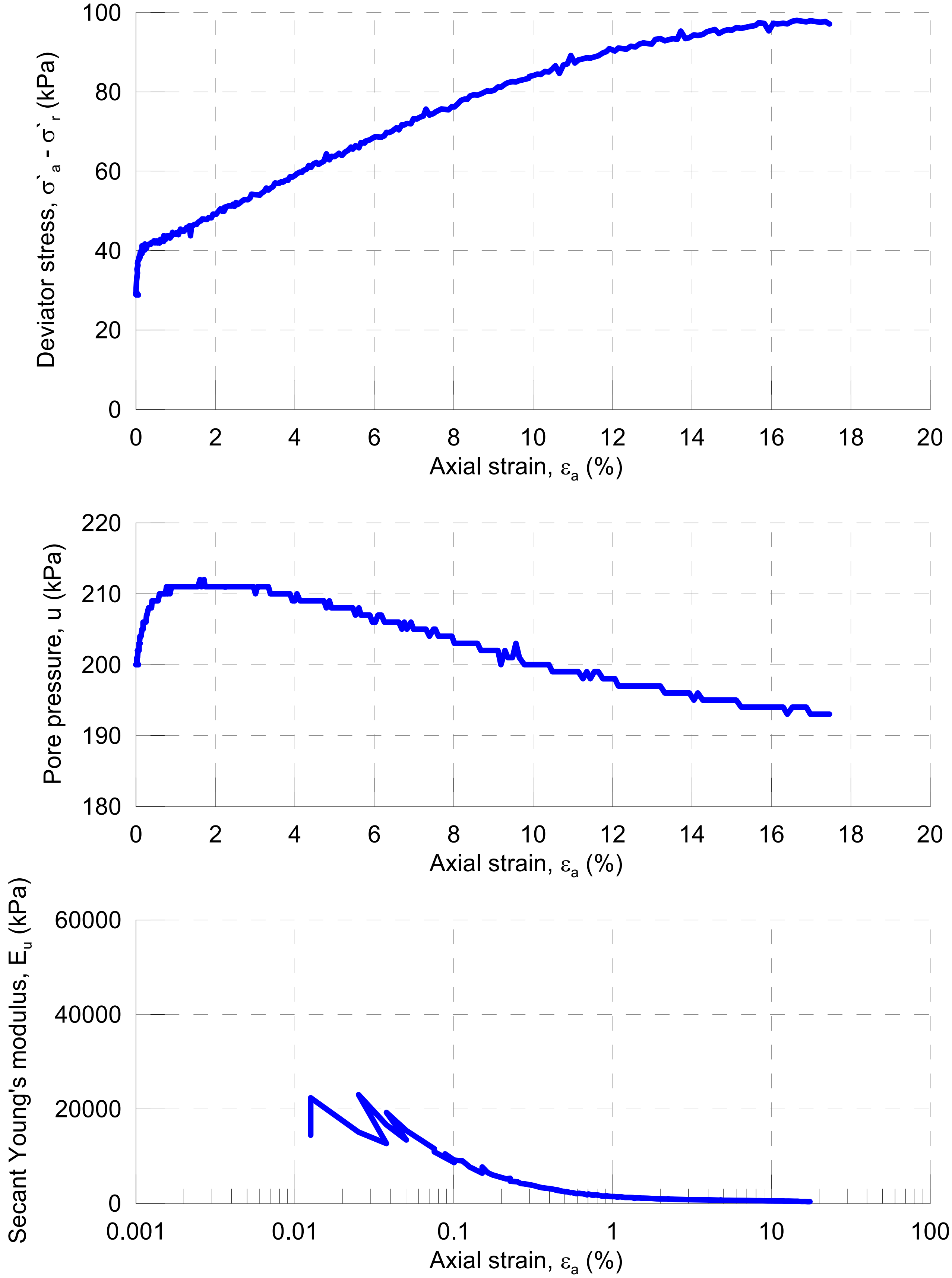
File: Dell/labtests/FoU/crs19.xls

Os - CRS 19

Fig. 45

TRIAXIAL TESTS RESULTS.

** 76-2 had isotropic consol stage only.*



Laptop\Labtests\FoU\54(P)-1.grf

FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 - G1

Figure No. 46(a)

CAUC Test 54(P)-1

BH: 2

Tube: L16, 5-5.8 m

Depth: 5.33 m

$\sigma`_{ac} / \sigma`_{rc}$ = 60 / 30 kPa

ρ = 2.055 Mg/m3

w = 29.2%

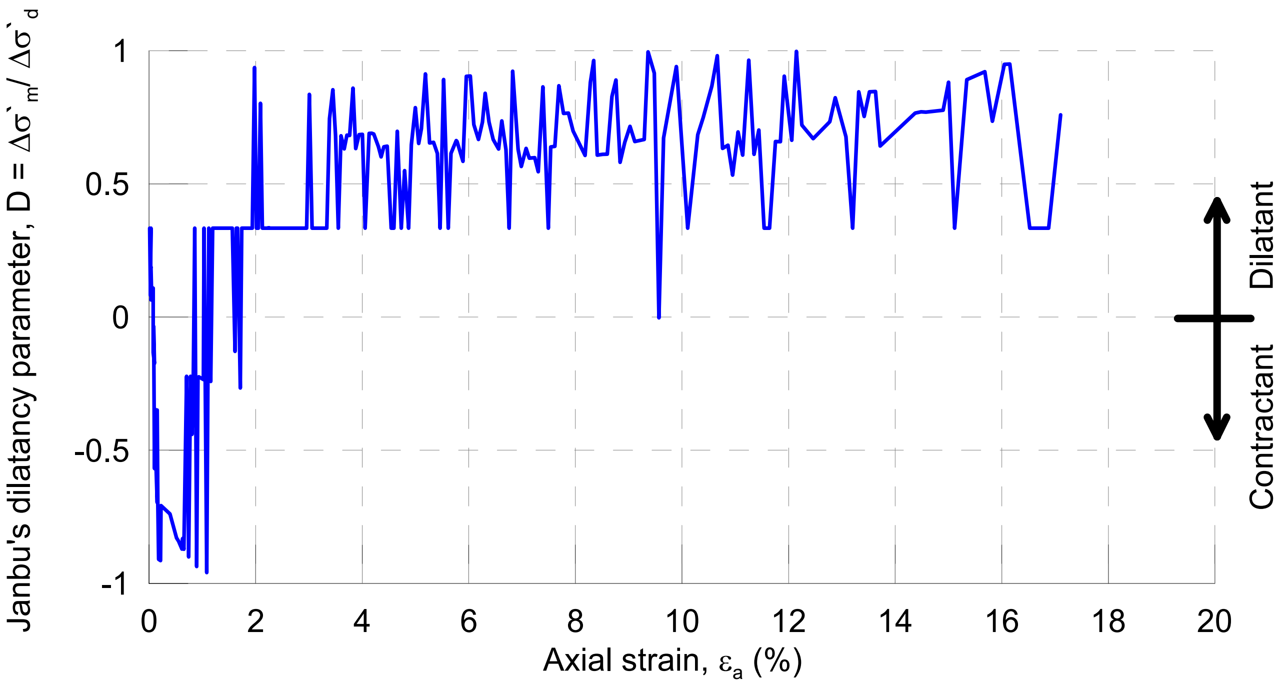
$\varepsilon_{v0} / \Delta e/e_0$ = 4.9% / 0.107

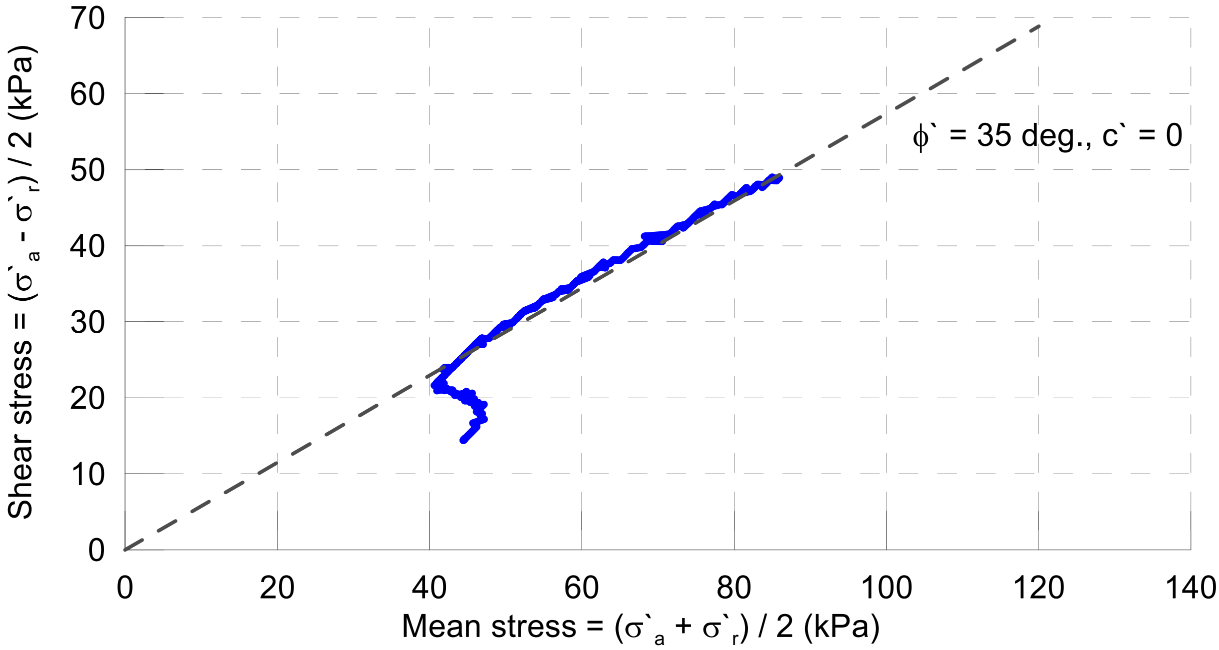
Drawn by GC

Date 2005-07-08

Checked ML

Approved





Laptop\Labtests\FoU\54(P)-1spath.grf

FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 - G1

Figure No. 46(b)

CAUC Test 54(P)-1
BH: 2
Tube: L16, 5-5.8 m
Depth: 5.33 m

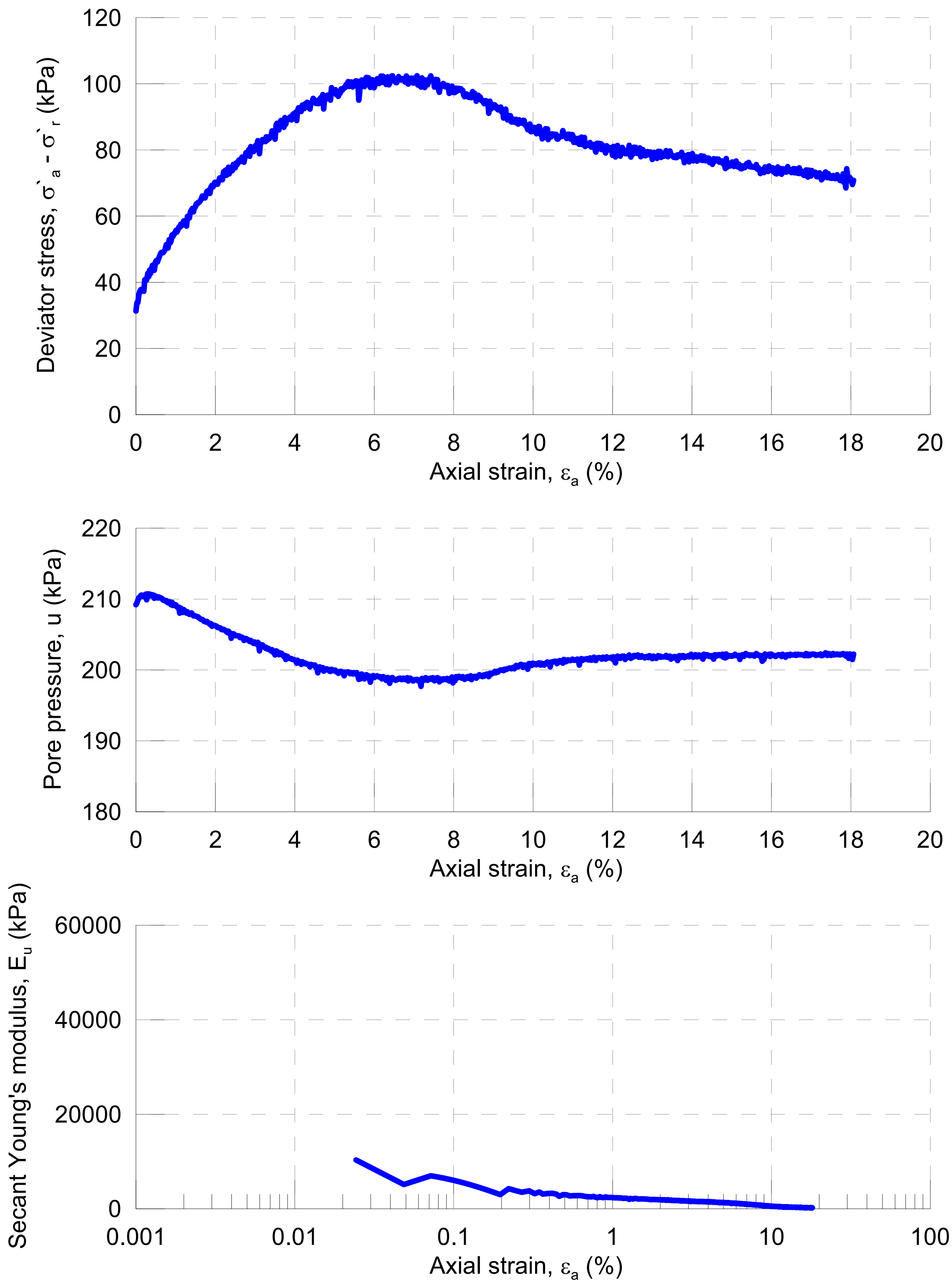
Sheet 2

Drawn by GC

Date 2005-07-08

Checked ML

Approved



Laptop\Labtests\FoU\54(P)-2.grf

FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 - G1

Figure No. 47(a)

Drawn by GC

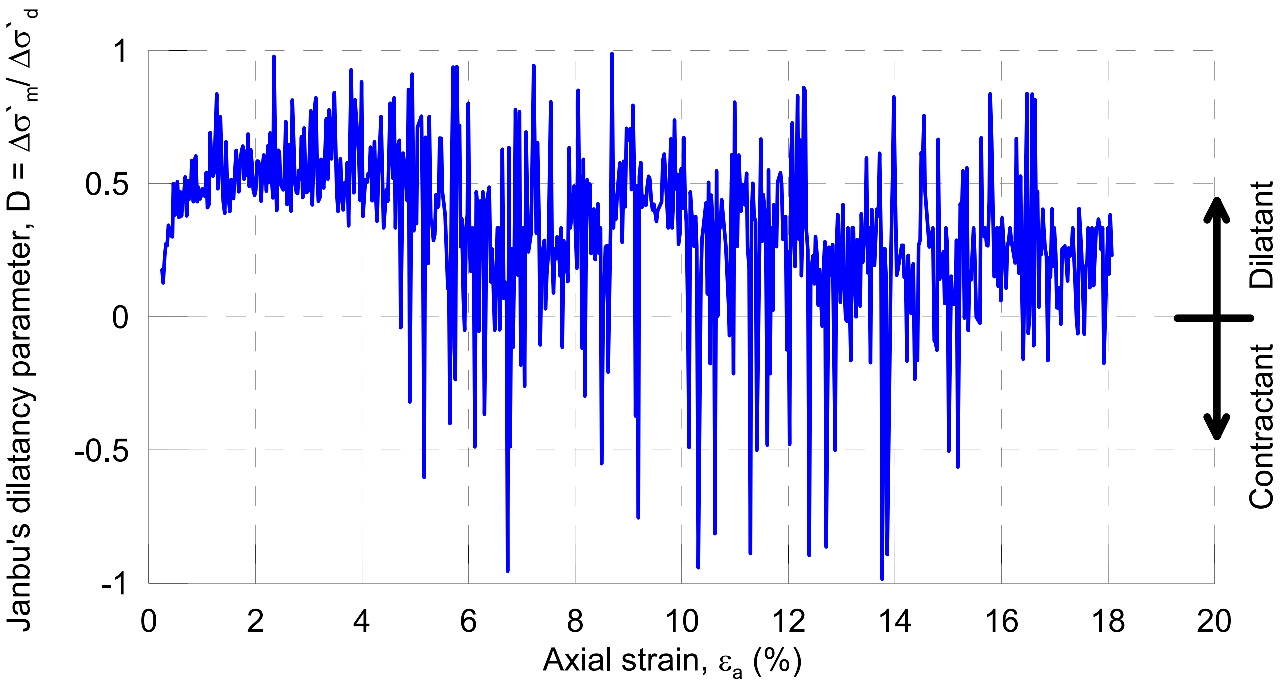
Date 2005-07-08

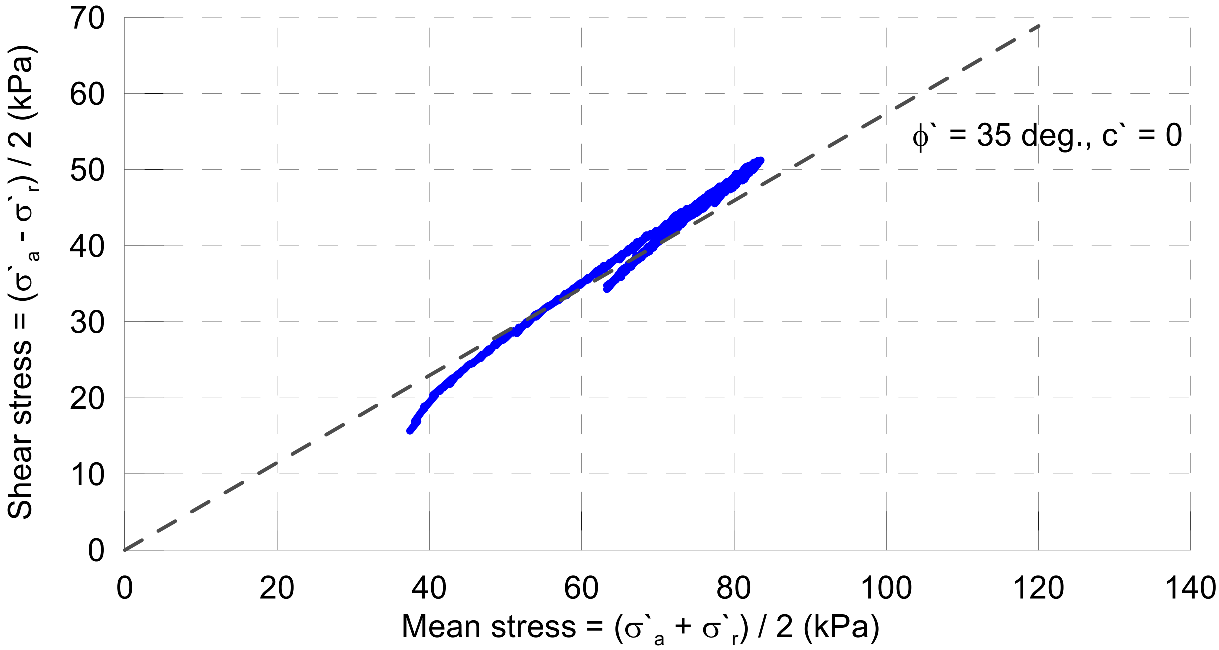
Checked ML

Approved

CAUC Test 54(P)-2
BH: 2
Tube: L16, 5-5.8 m
Depth: 5.55 m

$\sigma'_{ac} / \sigma'_{rc}$ = 60 / 30 kPa
ρ = 2.045 Mg/m3
w = 25.9%
$\varepsilon_{v0} / \Delta e/e_0$ = 2.4% / 0.053

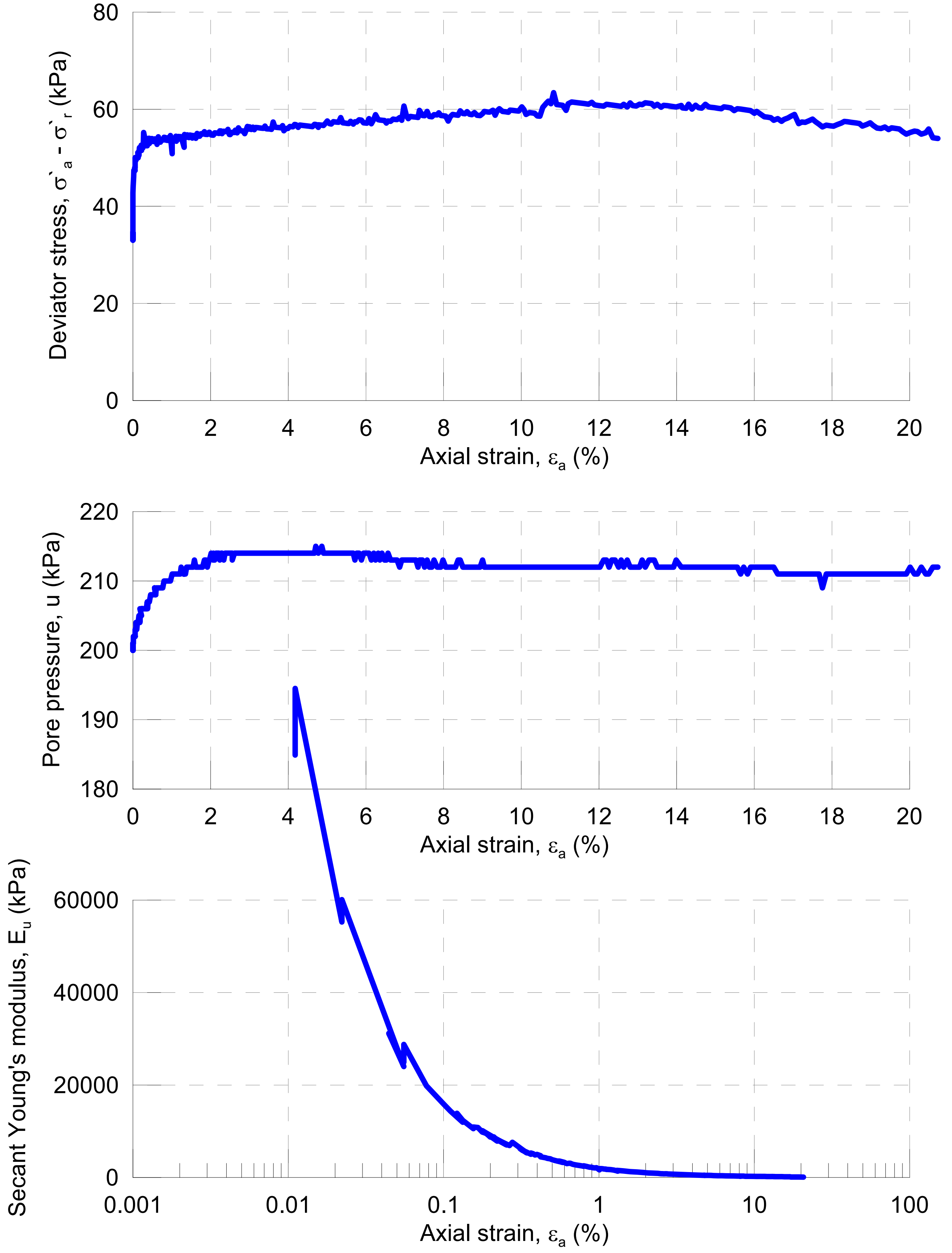




FoU Project - Os Site - 2004 Site Investigation

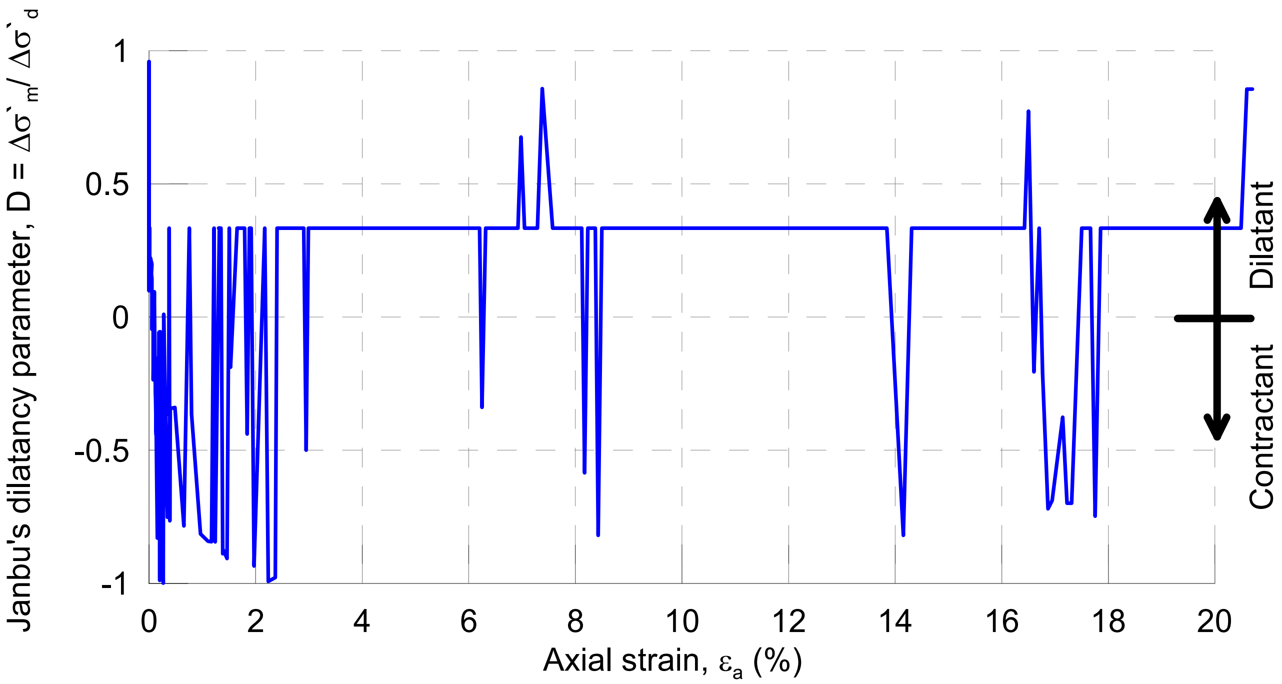
	Report No. 2005 - G1	Figure No. 47(b)
CAUC Test 54(P)-2 BH: 2 Tube: L16, 5-5.8 m Depth: 5.55 m Sheet 2	Drawn by GC	Date 2005-07-08
	Checked ML	
	Approved	

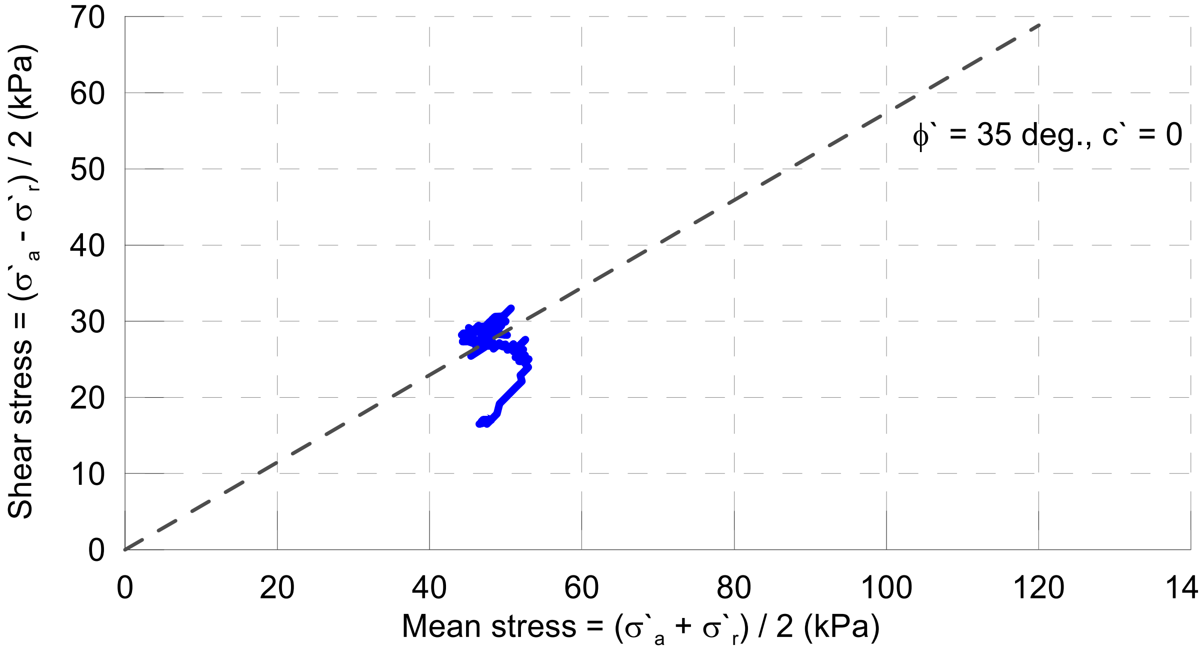
Laptop\Labtests\FoU\54(P)-2spath.grf



FoU Project - Os Site - 2004 Site Investigation		Report No. 2005 - G1	Figure No. 48(a)
CAUC Test 54(P)-3 BH: 2 Tube: L26, 6-6.8 m Depth: 6.42 m	$\sigma'_{ac} / \sigma'_{rc}$ = 68 / 34 kPa ρ = 2.126 Mg/m^3 w = 36.6 % $\varepsilon_{v0} / \Delta e/e_0$ = 11.9% / 0.253	Drawn by GC Checked ML Approved	Date 2005-07-08

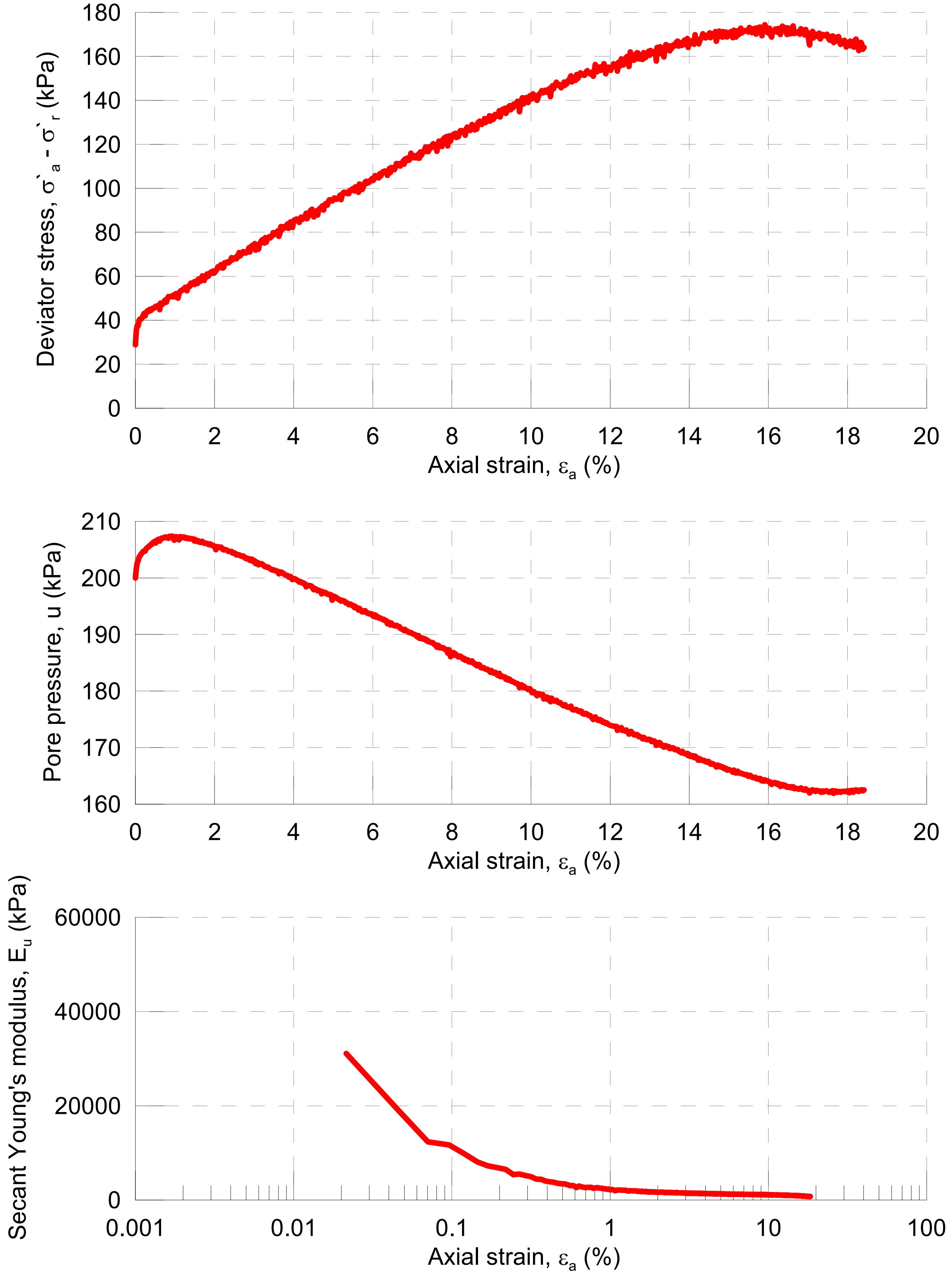
Laptop\Labtests\FoU\54(P)-3.grf





Laptop\Labtests\FoU\54(P)-3spath.grf

FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 - G1	Figure No. 48(b)
CAUC Test 54(P)-3 BH: 2 Tube: L26, 6-6.8 m Depth: 6.42 m Sheet 2	Drawn by GC	Date 2005-07-08
	Checked ML	
	Approved	



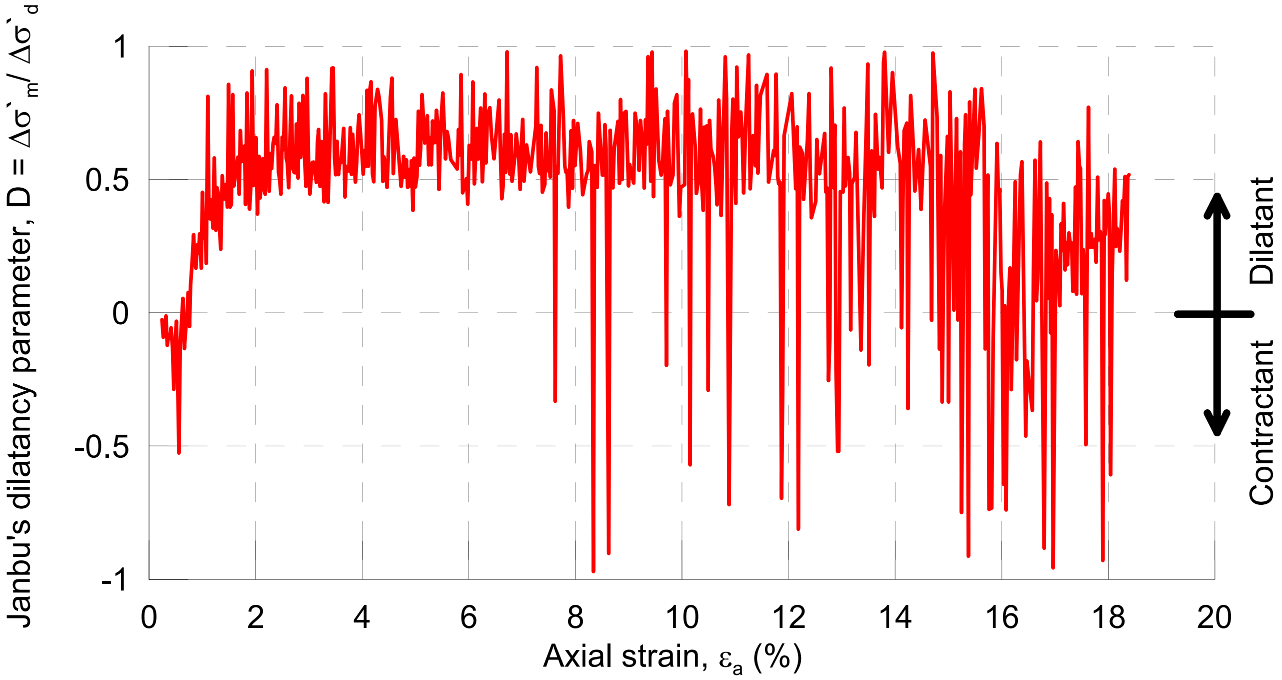
FoU Project - Os Site - 2004 Site Investigation

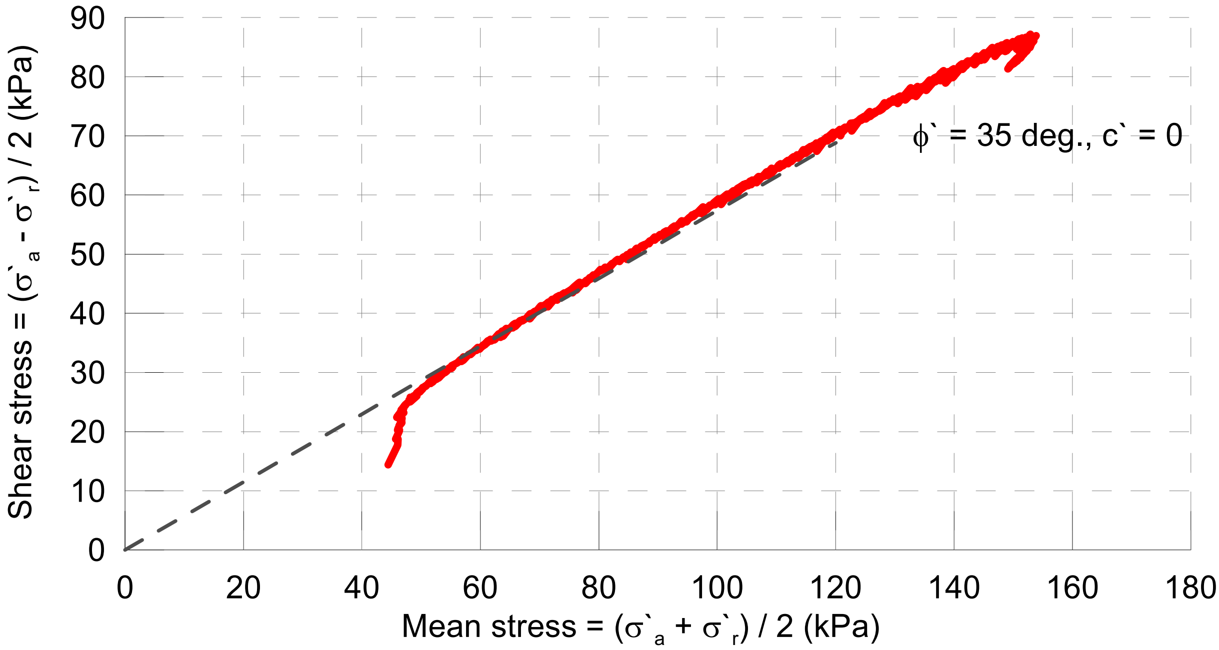
Report No.	Figure No.
2005 - G1	49(a)
Drawn by: GC	Date: 2005-07-08
Checked: ML	
Approved:	

CAUC Test 54(S)-1
BH: 10
Tube: L23, 5-5.8 m
Depth: 5.28 m

$\sigma`_{ac} / \sigma`_{rc}$ = 58 / 29 kPa
ρ = 2.180 Mg/m3
w = 27.1%
$\varepsilon_{v0} / \Delta e/e_0$ = 3.1% / 0.075

Laptop\Labtests\FoU\54(S)-1.grf





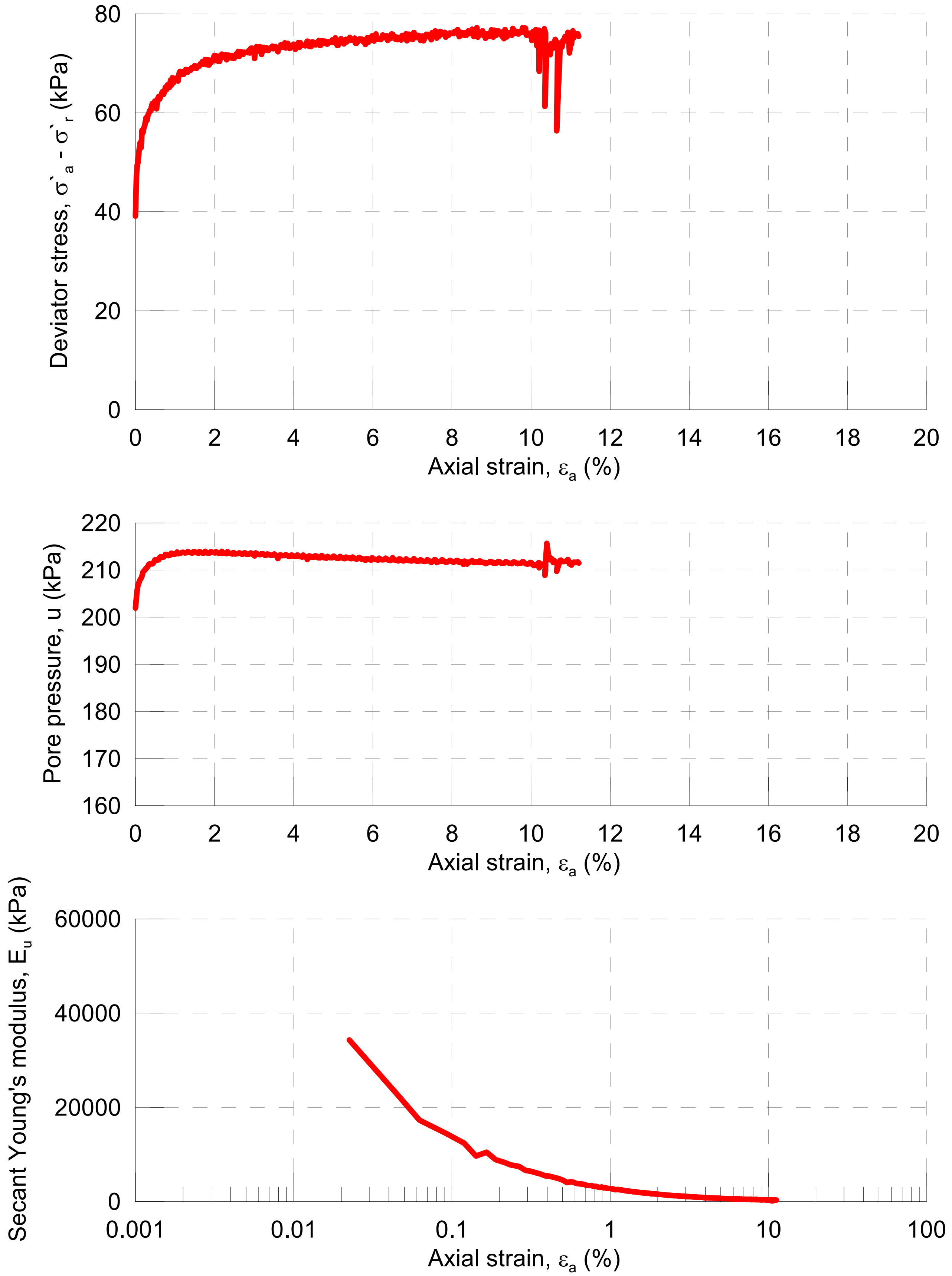
Laptop\Labtests\FoU\54(S)-1spath.grf

FoU Project - Os Site - 2004 Site Investigation

CAUC Test 54(S)-1
BH: 10
Tube: L23, 5-5.8 m
Depth: 5.28 m

Sheet 2

Report No. 2005 - G1	Figure No. 49(b)
Drawn by GC	Date 2005-07-08
Checked ML	
Approved	



FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 - G1

Figure No. 50(a)

CAUC Test 54(S)-2
BH: 10
Tube: L20, 7-7.8 m
Depth: 7.4 m

$\sigma`_{ac} / \sigma`_{rc}$ = 76 / 38 kPa
ρ = 2.078 Mg/m^3
w = 39.1%
$\varepsilon_{v0} / \Delta e/e_0$ = 3.3% / 0.066

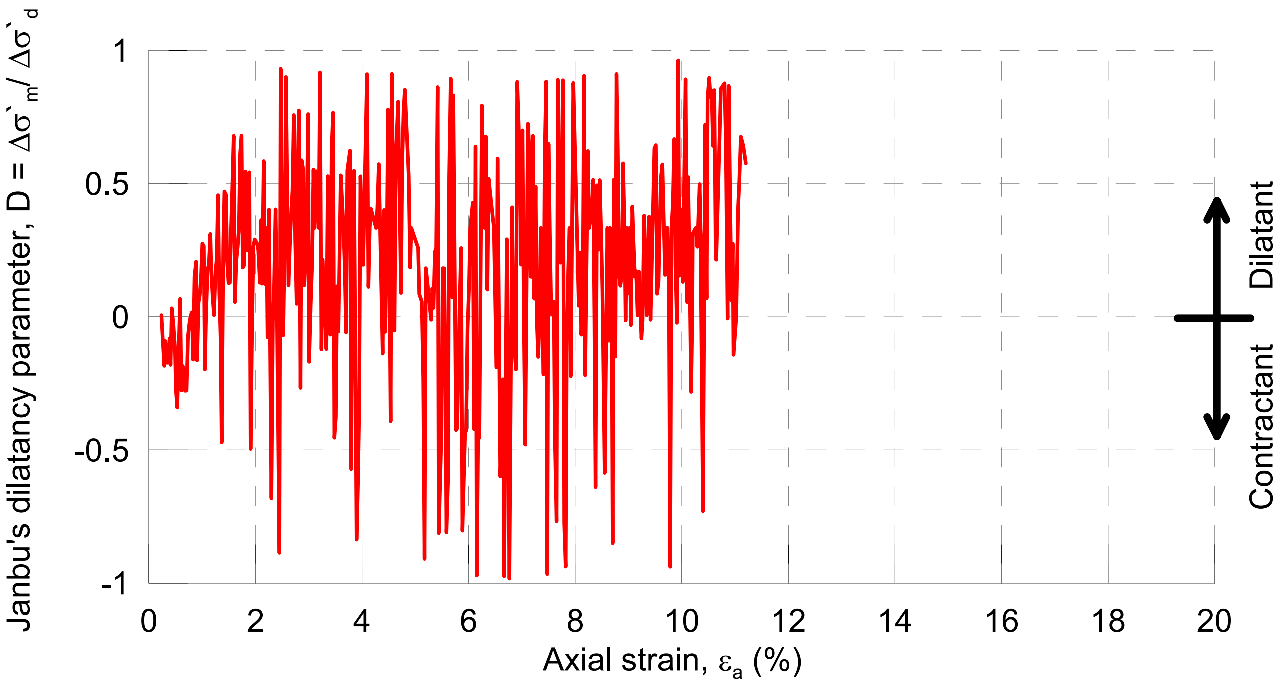
Drawn by: GC

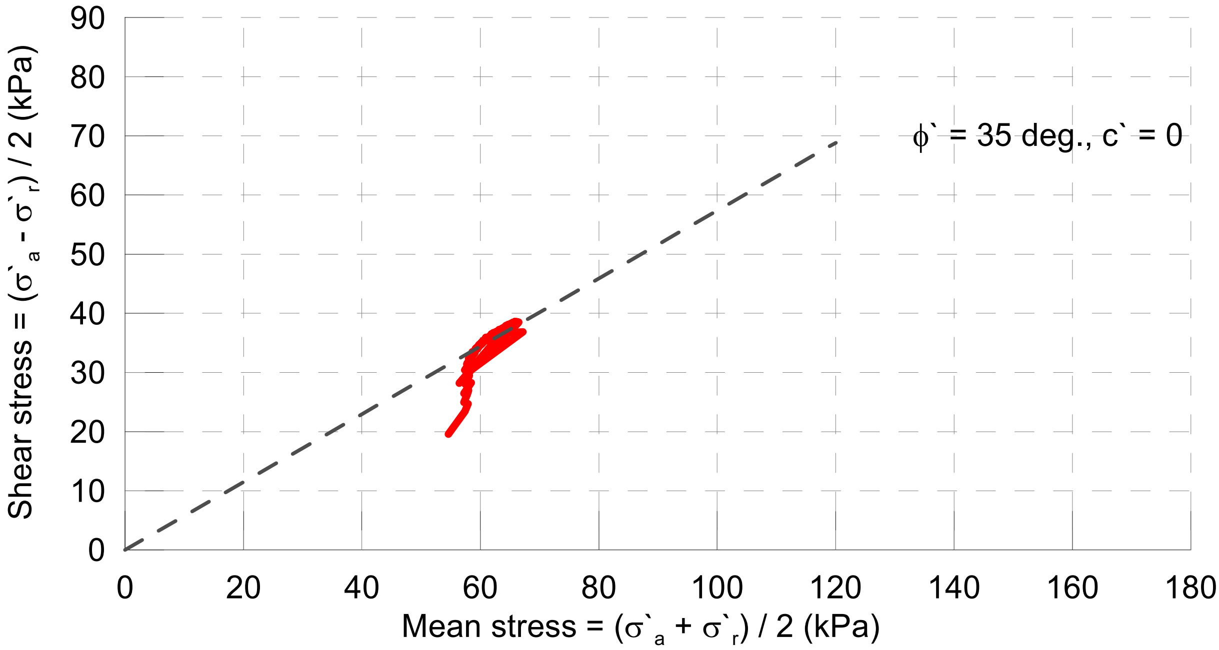
Date: 2005-07-08

Checked: ML

Approved:

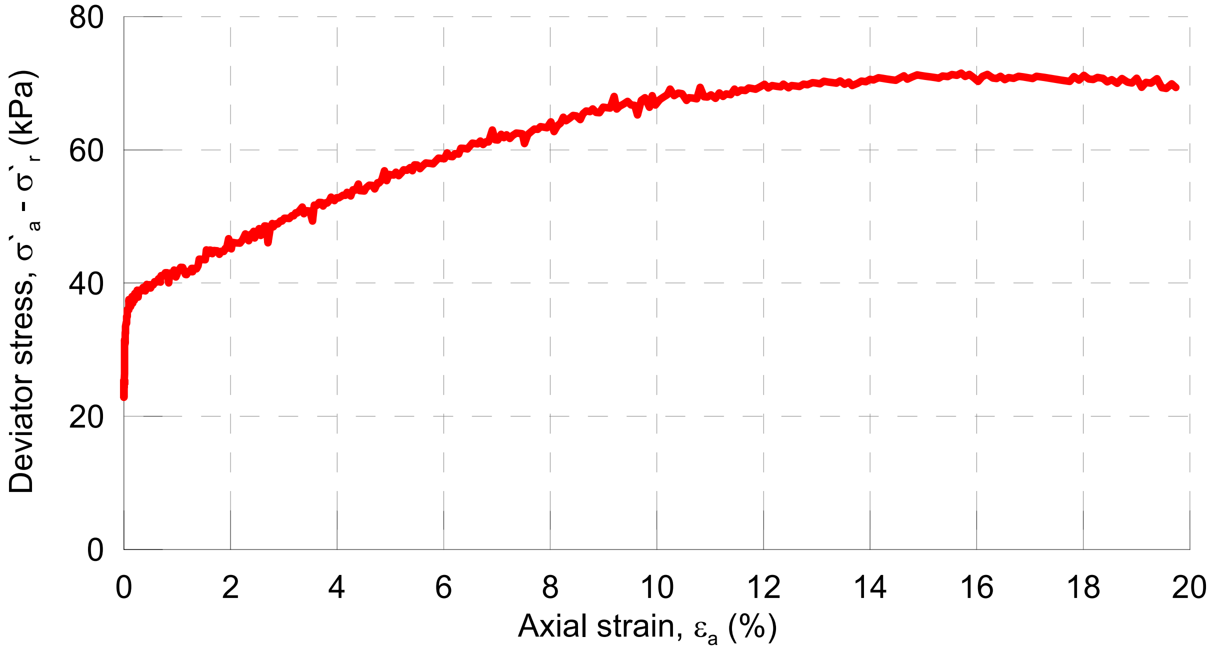
Laptop\Labtests\FoU\54(S)-2.grf

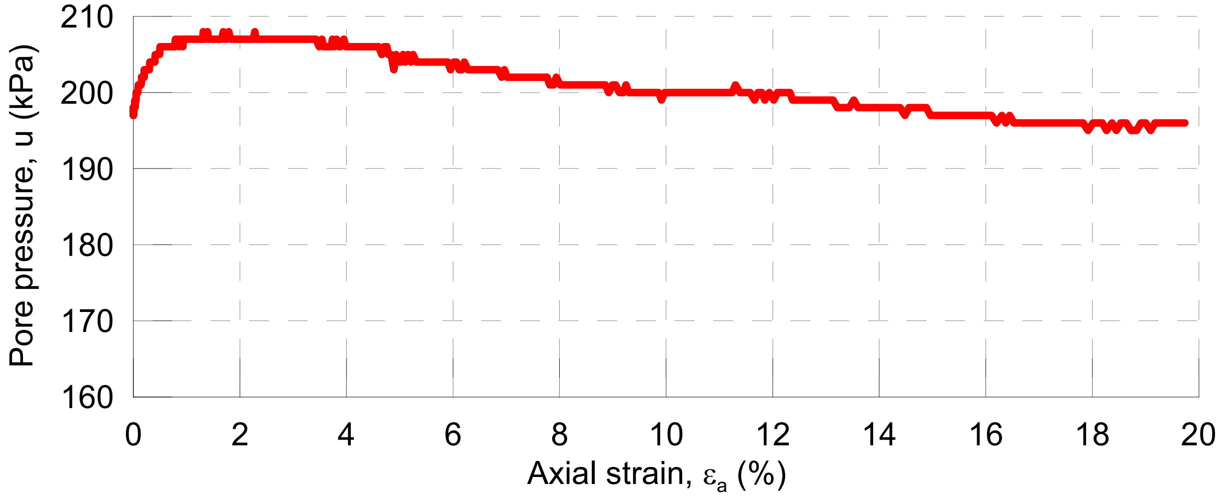


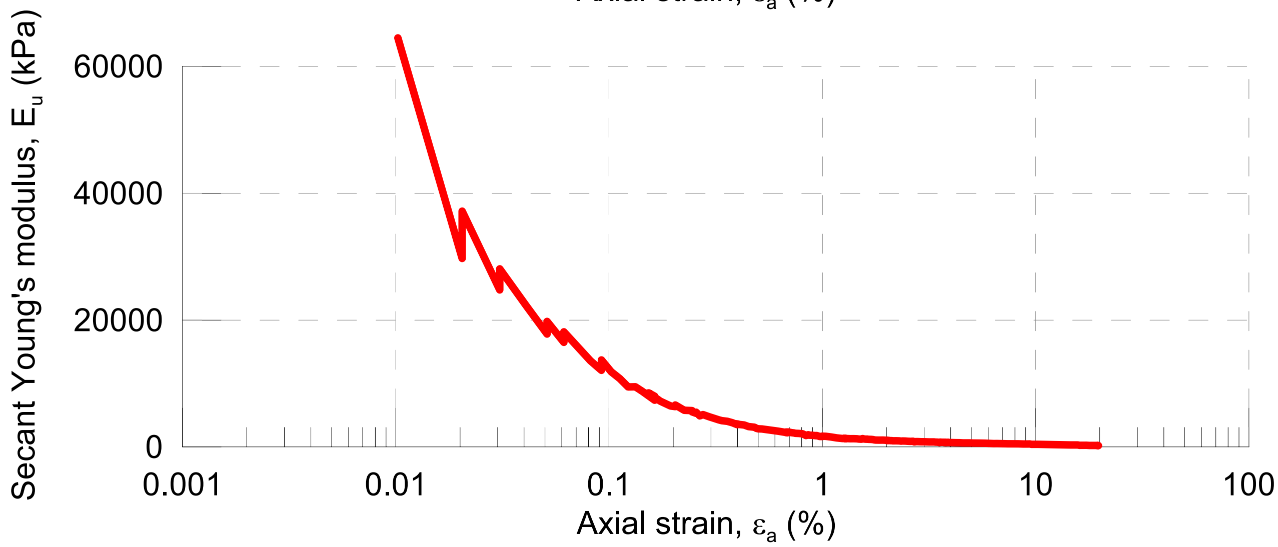


Laptop\Labtests\FoU\54(S)-2spath.grf

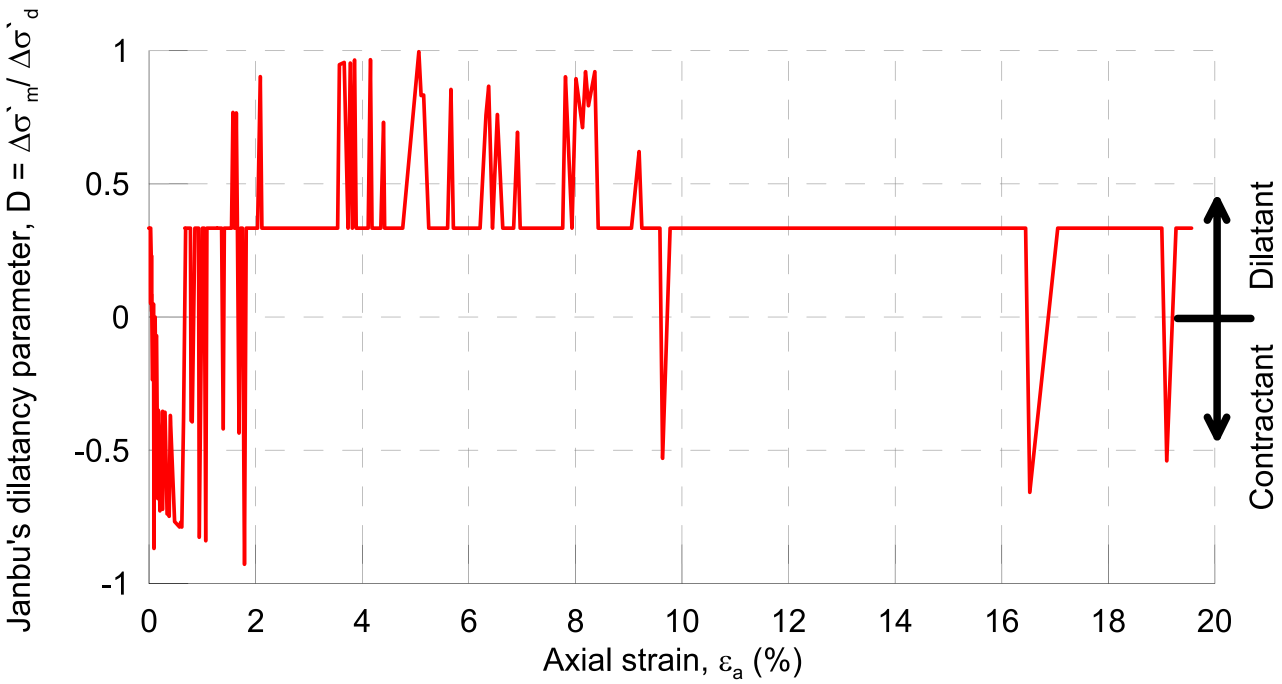
FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 - G1	Figure No. 50(b)
CAUC Test 54(S)-2 BH: 10 Tube: L20, 7-7.8 m Depth: 7.4 m Sheet 2	Drawn by GC	Date 2005-07-08
	Checked ML	
	Approved	

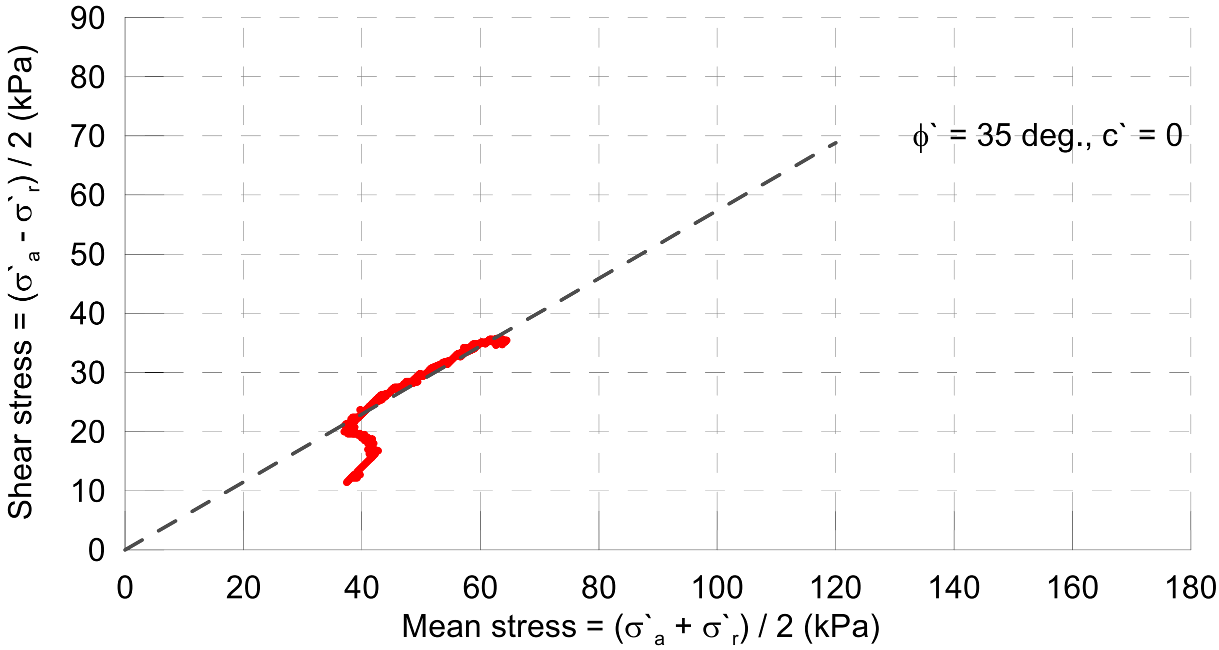






FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 - G1	Figure No. 51(a)
CAUC Test 54(S)-3 BH: 10 Tube: L17, 4-4.8 m Depth: 4.33 m	Drawn by GC	Date 2005-07-08
$\sigma`_{ac} / \sigma`_{rc}$ = 49 / 24 kPa ρ = 1.924 Mg/m^3 w = 33.9% $\varepsilon_{v0} / \Delta e/e_0$ = 1.9% / 0.038	Checked ML	
	Approved	





Laptop\Labtests\FoU\54(S)-3spath.grf

FoU Project - Os Site - 2004 Site Investigation

Report No. 200G - G1

Figure No. 51(b)

CAUC Test 54(S)-3
BH: 10
Tube: L17, 4-4.8 m
Depth: 4.33 m

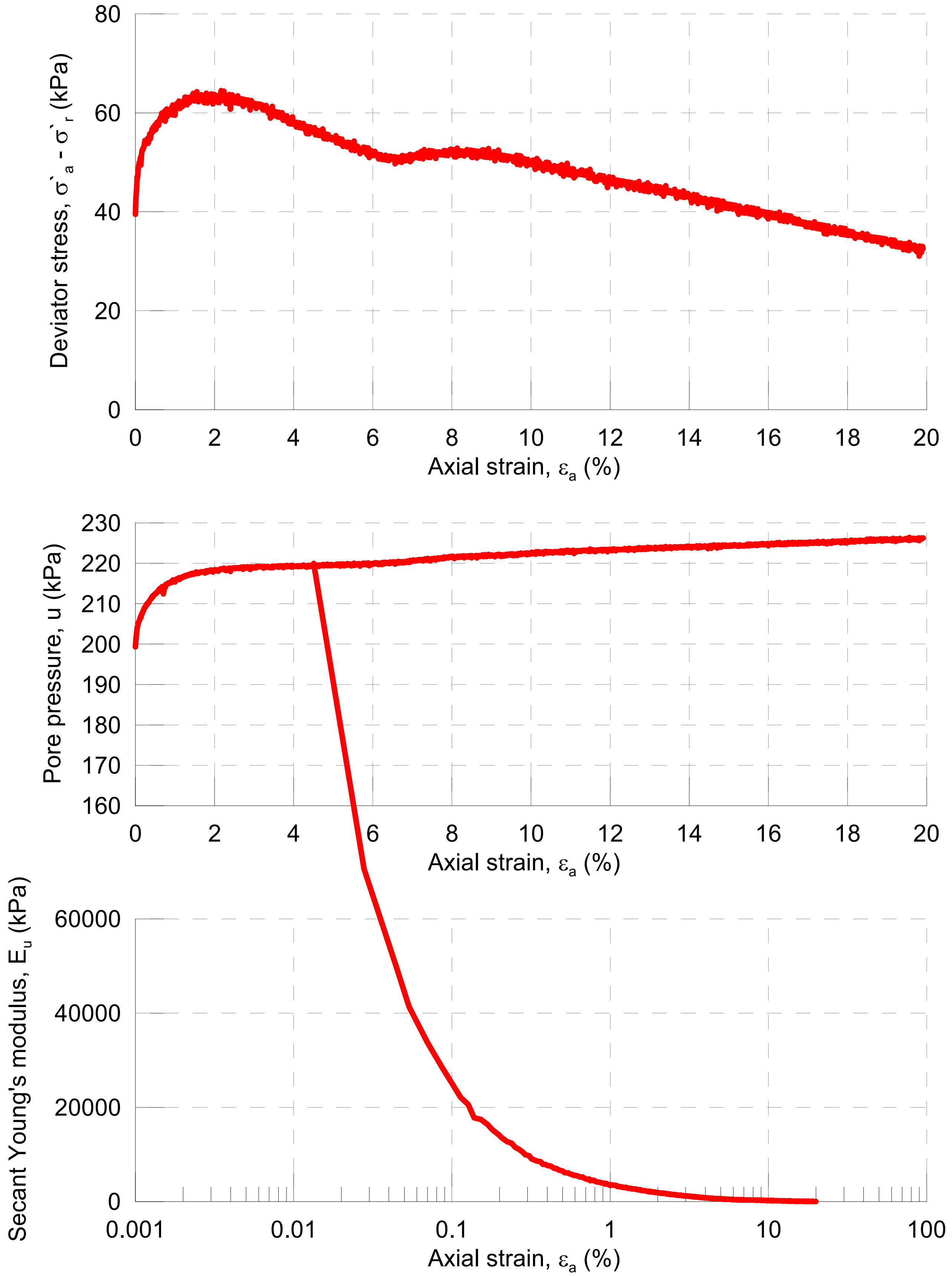
Sheet 2

Drawn by GC

Date 2005-07-08

Checked ML

Approved



FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 -G1

Figure No. 52a

CAUC Test 54(S)-4
BH: 10
Tube: L20, 7-7.8 m
Depth: 7.58 m

$\sigma'_{ac} / \sigma'_{rc}$ = 78 / 40 kPa
ρ = 2.009 Mg/m^3
w = 39.2 %
$\varepsilon_{v0} / \Delta e/e_0$ = 2.4% / 0.047

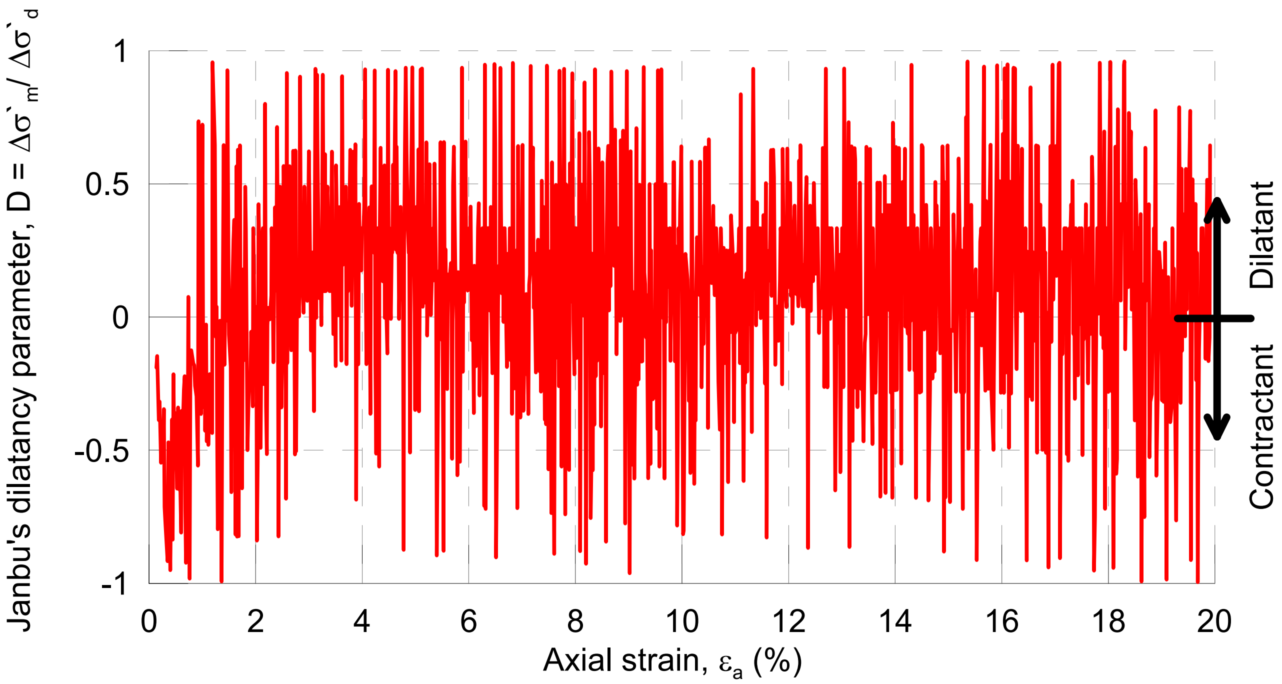
Drawn by GC

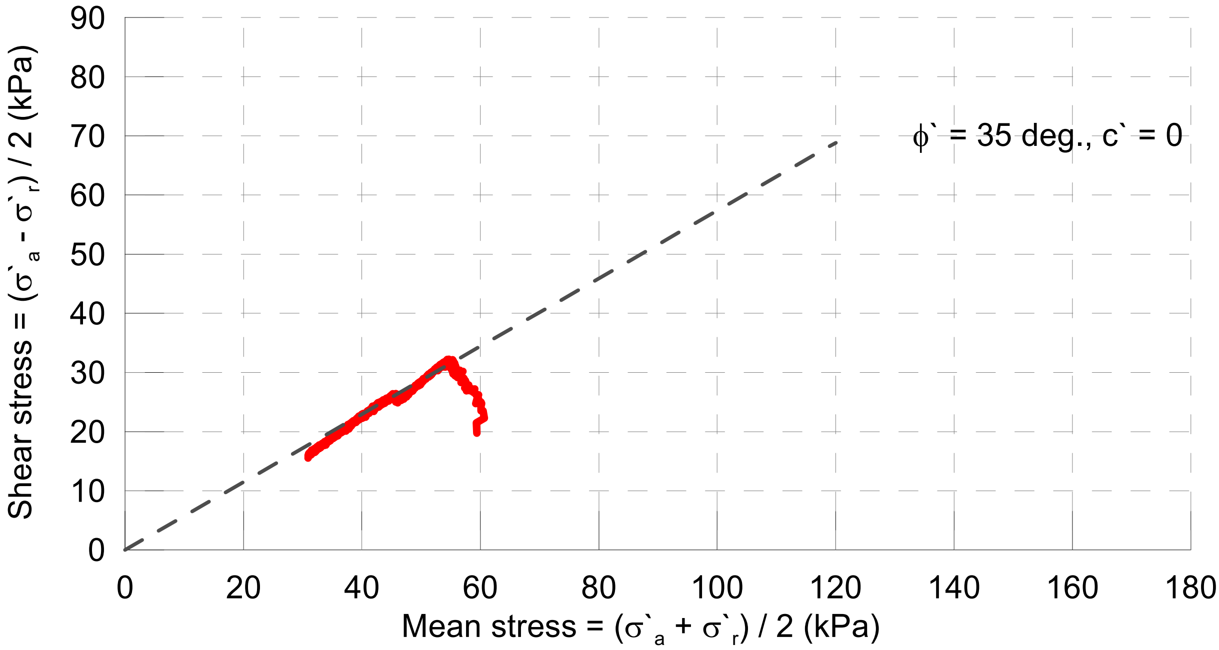
Date 2005-07-08

Checked ML

Approved

Laptop\Labtests\FoU\54(S)-4.grf





FoU Project - Os Site - 2004 Site Investigation

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Figure No. 52(b)

CAUC Test 54(S)-4
BH: 10
Tube: L20, 7-7.8 m
Depth: 7.54 m

Sheet 2

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Date 2005-07-08

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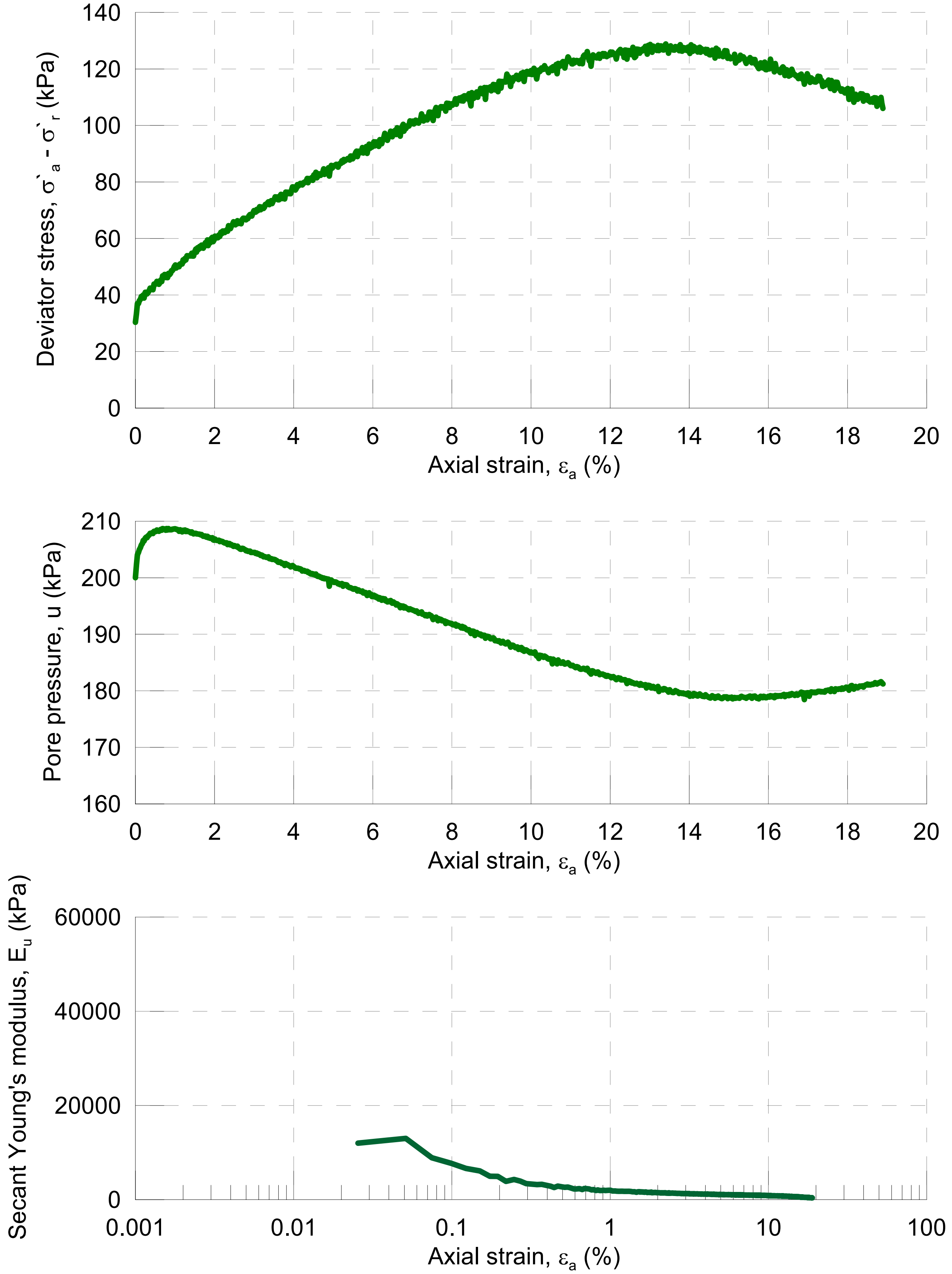

FoU Project - Os Site - 2004 Site Investigation

Report No.	2005 - G1
Figure No.	53(a)
Drawn by	GC
Date	2005-07-08
Checked	ML
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CAUC Test 76-1

BH: 2

Tube: No. 6, 5-5.8 m

Depth: 5.30 m

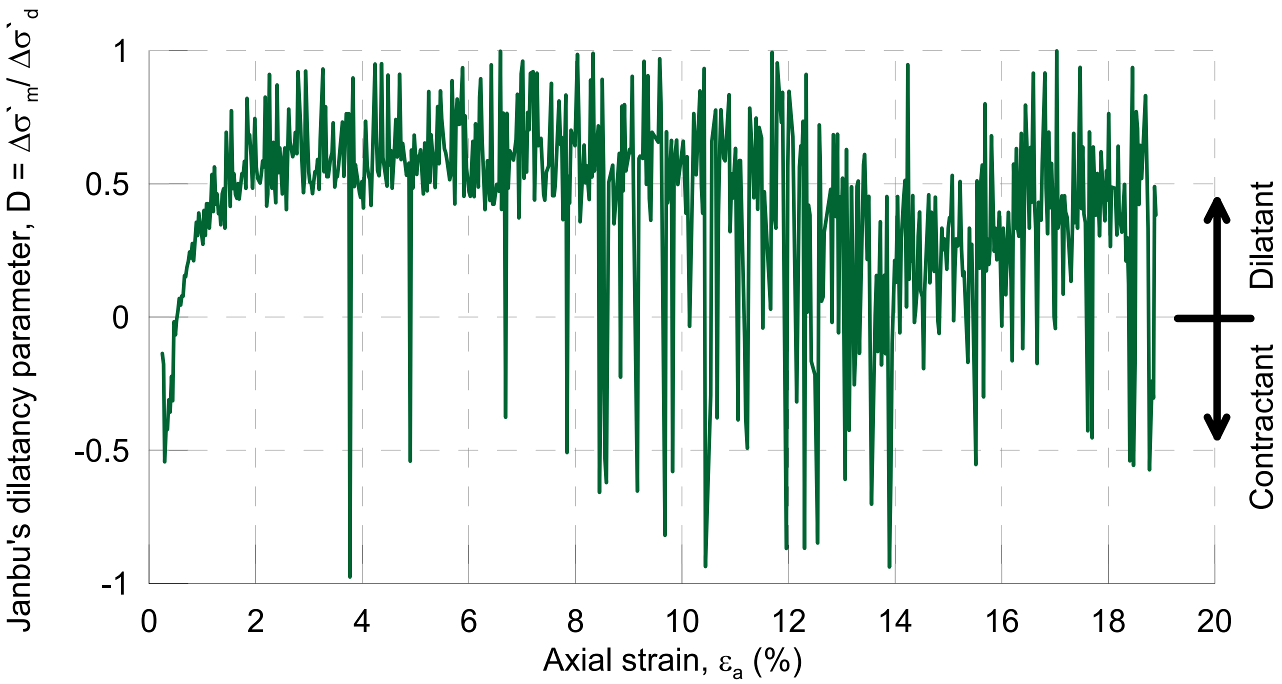
$\sigma`_{ac} / \sigma`_{rc}$ = 58 / 29 kPa

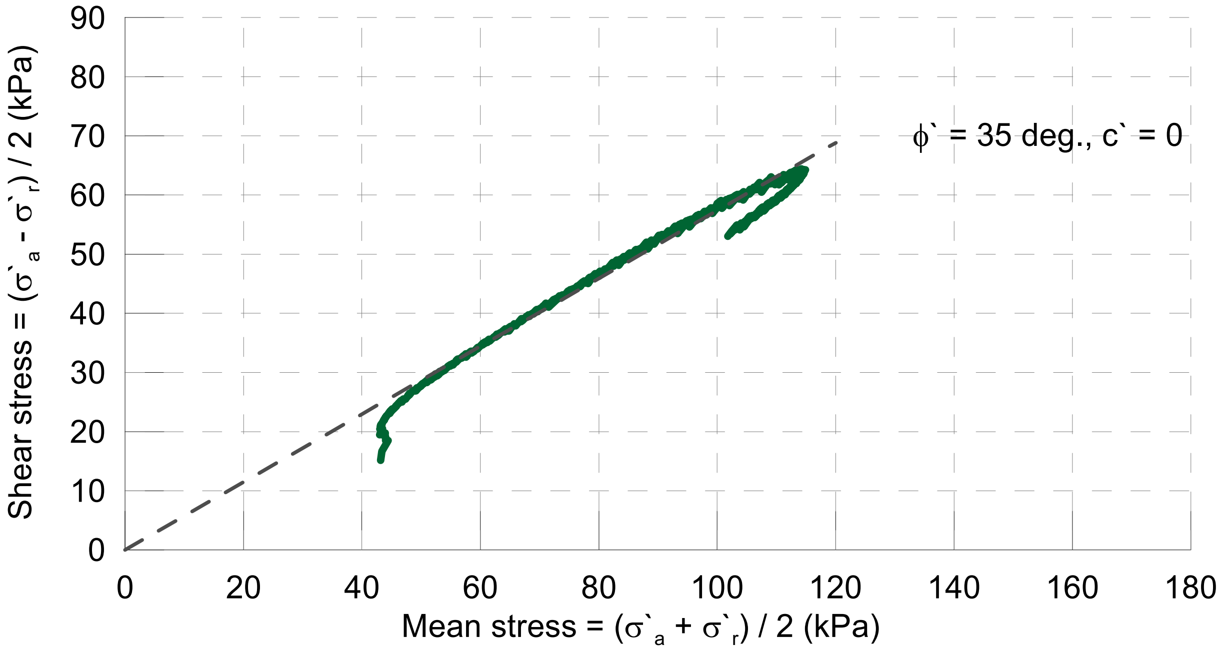
ρ = 2.133 Mg/m^3

w = 27.5%

$\varepsilon_{v0} / \Delta e/e_0$ = 3.0% / 0.070

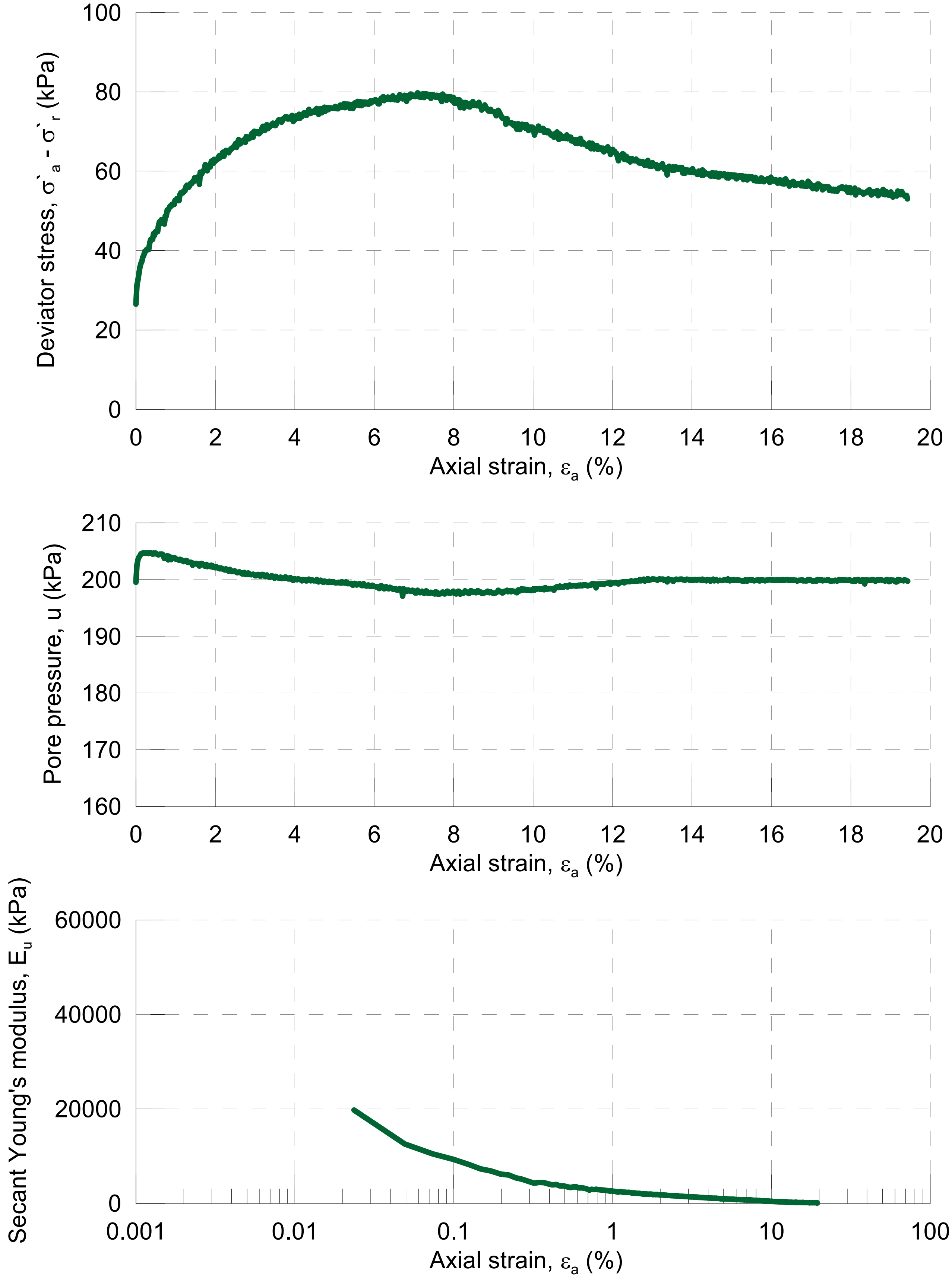
Laptop\Labtests\FoU\76-1.grf





FoU Project - Os Site - 2004 Site Investigation		Report No. 2005 - G1	Figure No. 53(b)
CAUC Test 76-1 BH: 2 Tube: No. 6, 5-5.8 m Depth: 5.30 m	Sheet 2	Drawn by GC	Date 2005-07-08
		Checked ML	
		Approved	

Laptop\Labtests\FoU\76-1spath.grf



FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 - G1

Figure No. 54(a)

CAUC Test 76-3

BH: 2

Tube: No. 1, 4-4.8 m

Depth: 4.30 m

$\sigma`_{ac} / \sigma`_{rc}$ = 50 / 25 kPa

ρ = 2.041 Mg/m^3

w = 31.4%

$\varepsilon_{v0} / \Delta e/e_0$ = 3.3% / 0.070

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Date 2005-07-08

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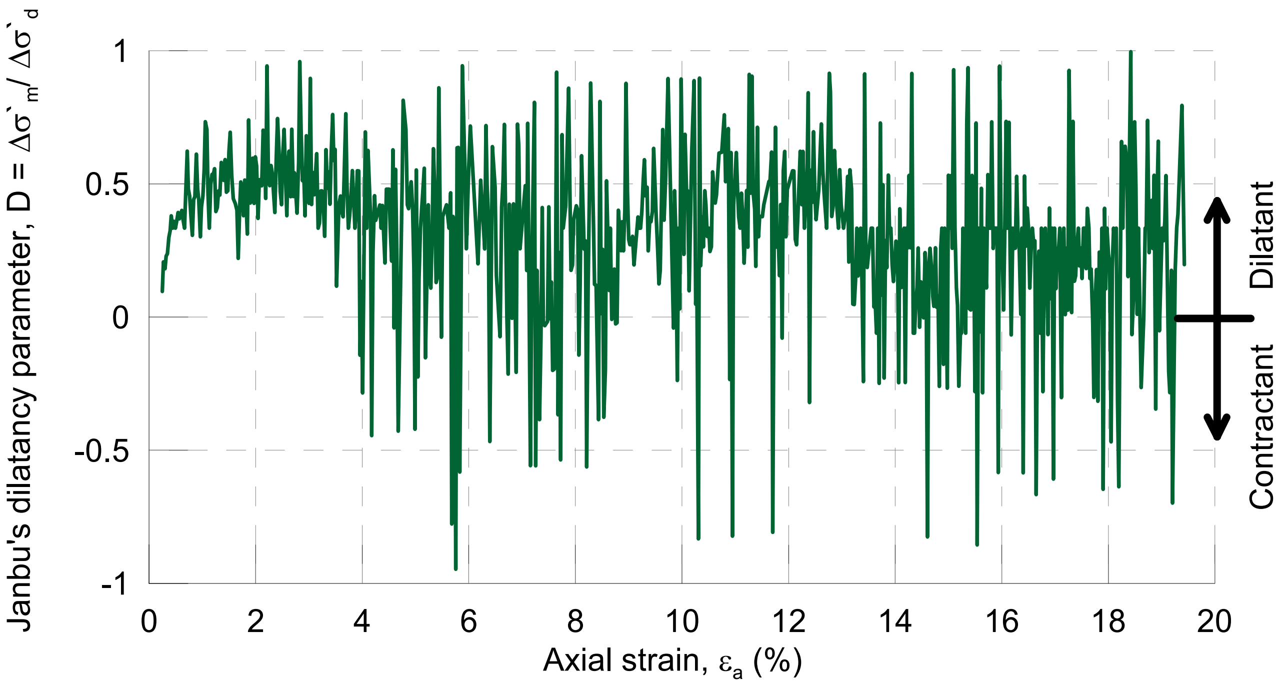
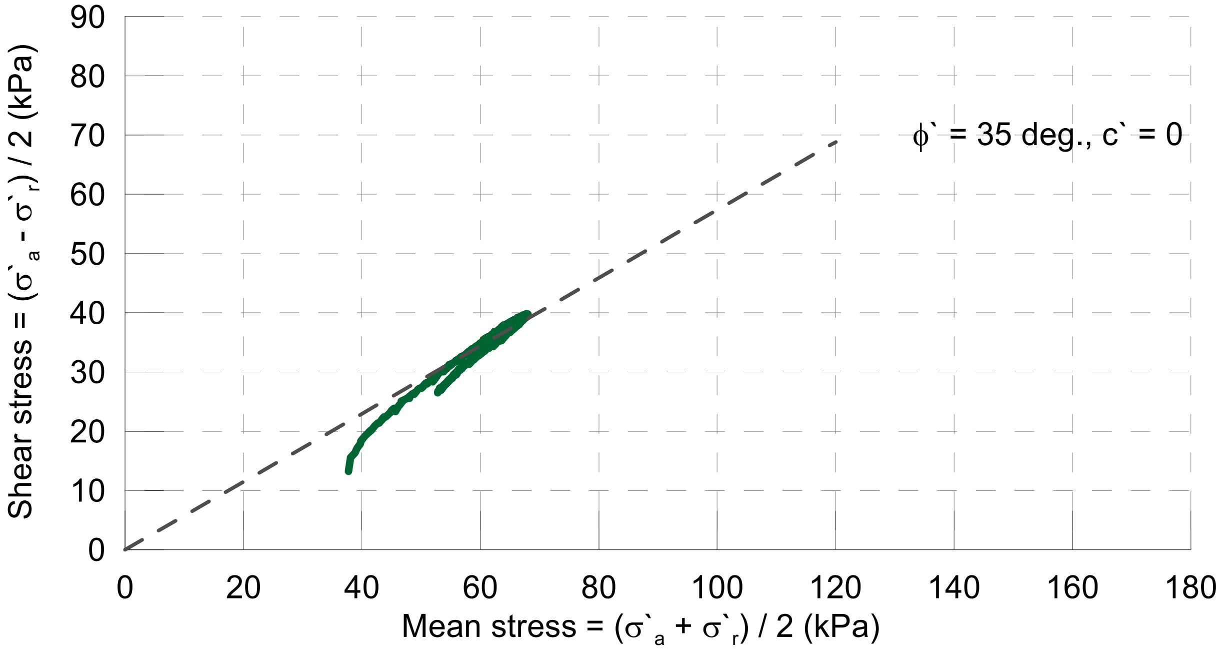
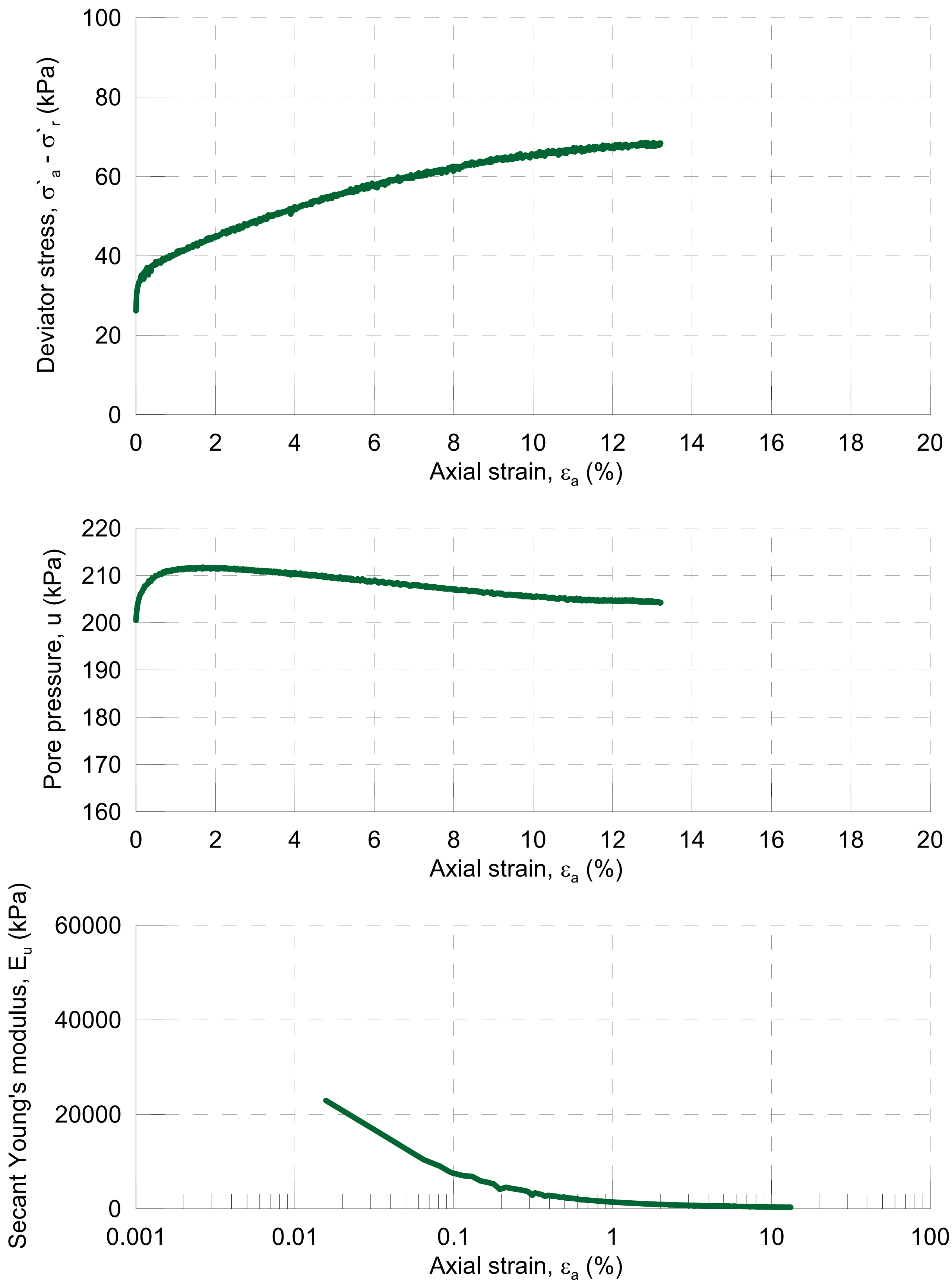




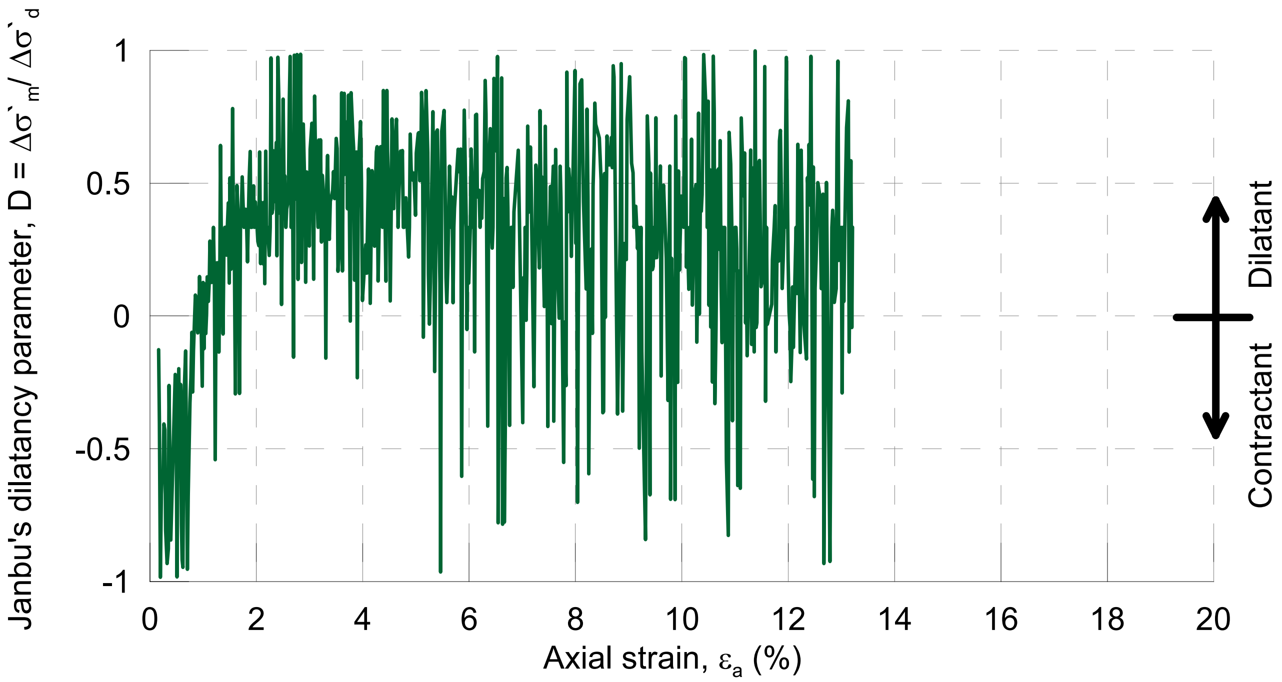
FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 -G1	Figure No. 54(b)
CAUC Test 76-3 Sheet 2 BH: 2 Tube: No. 1, 4-4.8 m Depth: 4.30 m	Drawn by GC	Date 2005-07-08
	Checked ML	
	Approved	

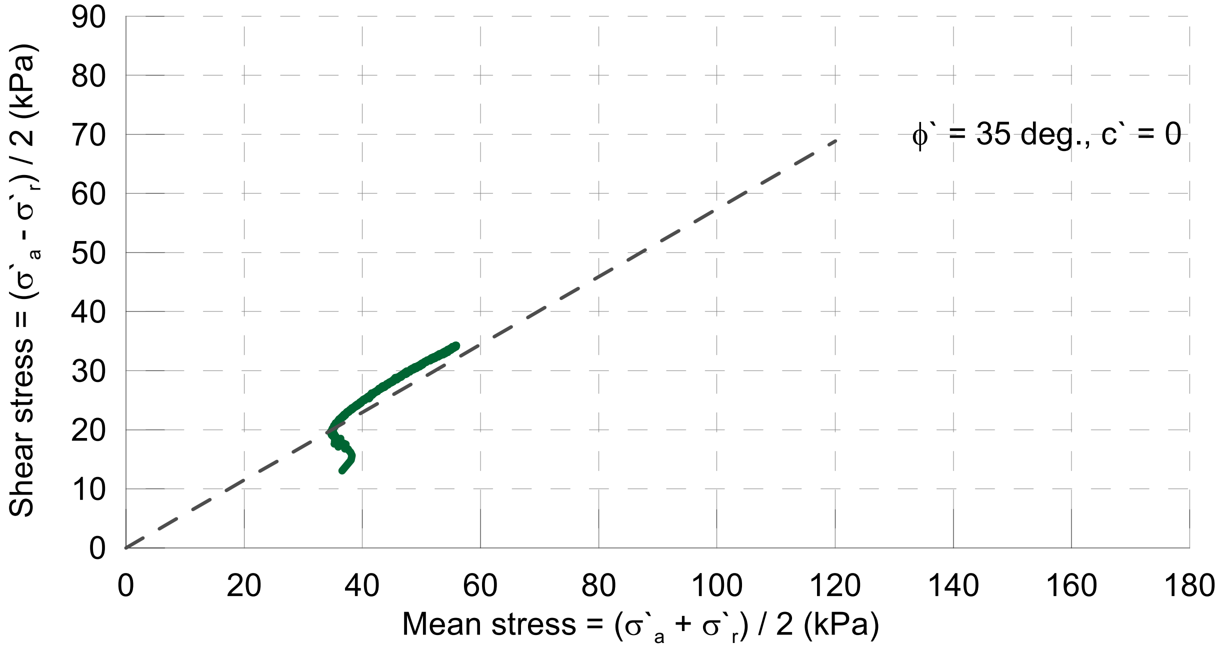
Dell\Labtests\FoU\76-3spath.grf



DellLabtests\FoU\76-4.grf

FoU Project - Os Site - 2004 Site Investigation		Report No. 2005 - G1	Figure No. 55(a)
CAUC Test 76-4 BH: 2 Tube: No. 1, 4-4.8 m Depth: 4.50 m Specimen not trimmed	$\sigma'_{ac} / \sigma'_{rc}$ = 50 / 25 kPa ρ = 2.045 Mg/m^3 w = 34.8% $\varepsilon_{v0} / \Delta e/e_0$ = 1.9% / 0.038	Drawn by GC Checked ML Approved	Date 2005-07-08





FoU Project - Os Site - 2004 Site Investigation	Report No. 2005 - G1	Figure No. 55(b)
CAUC Test 76-4 BH: 2 Tube: No. 1, 4-4.8 m Depth: 4.5 m Specimen not trimmed Sheet 2	Drawn by GC Checked ML Approved	Date 2005-07-08

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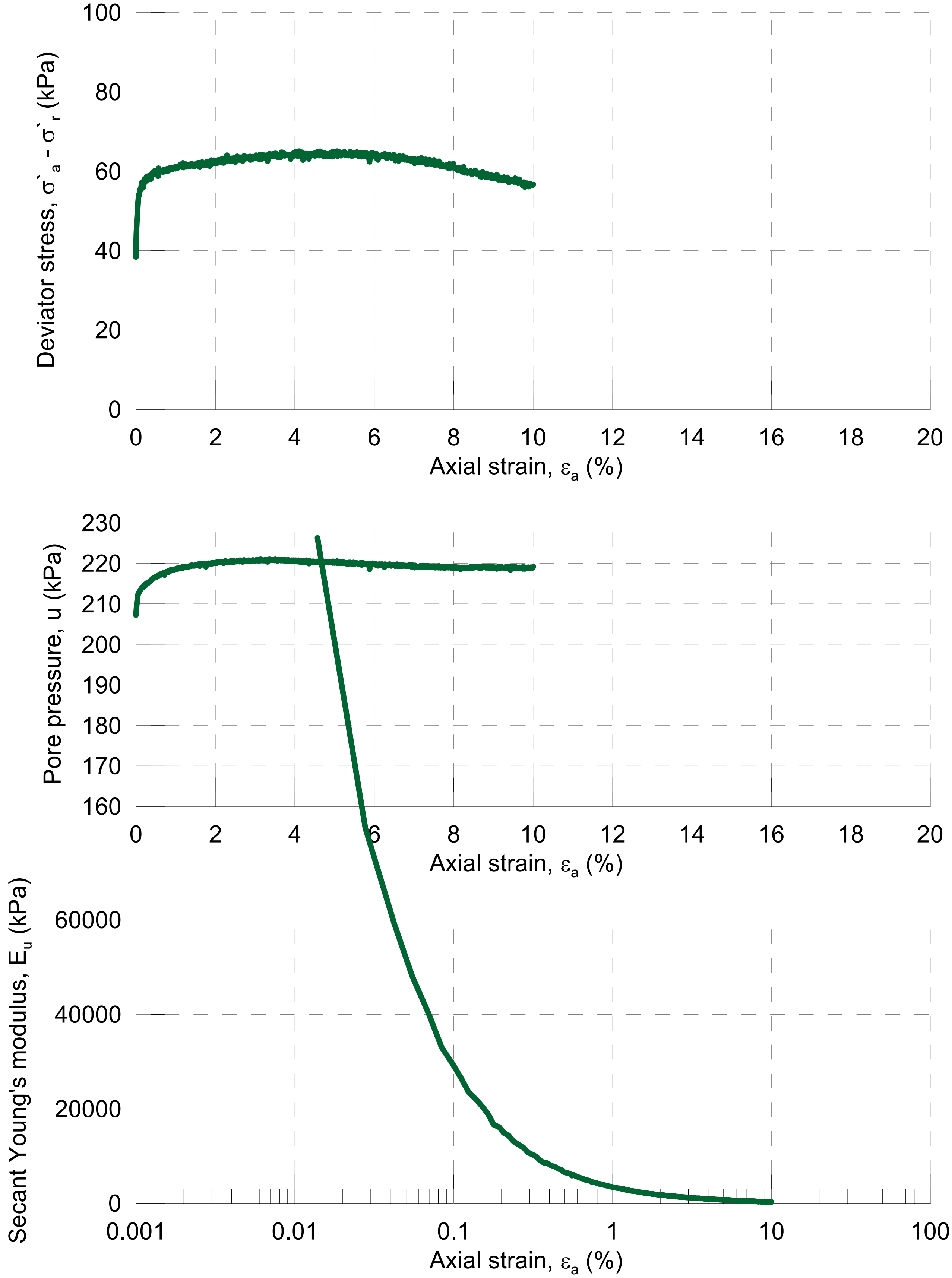

FoU Project - Os Site - 2004 Site Investigation

Report No. 2005 - G1

Figure No. 56(a)

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Date 2005-07-08

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CAUC Test 76-5

BH: 2

Tube: No. 3, 7-7.8 m

Depth: 7.4 m

Specimen not trimmed

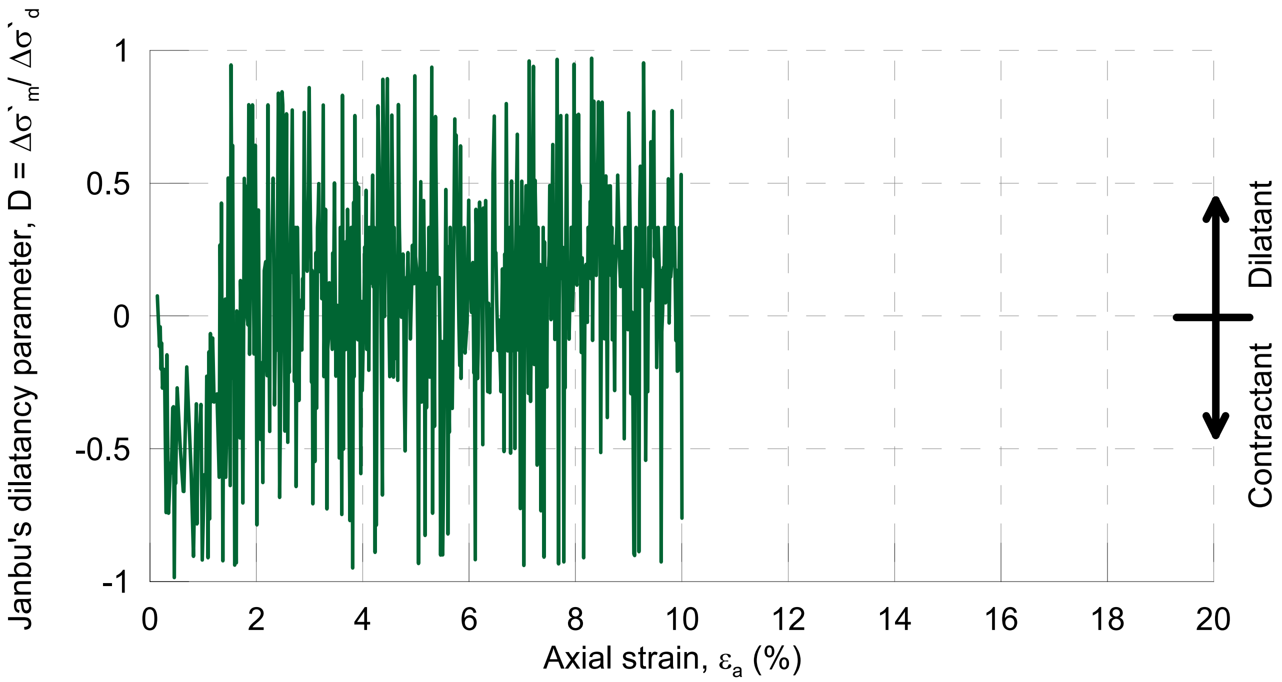
$\sigma`_{ac}$ / $\sigma`_{rc}$ = 76 / 38 kPa

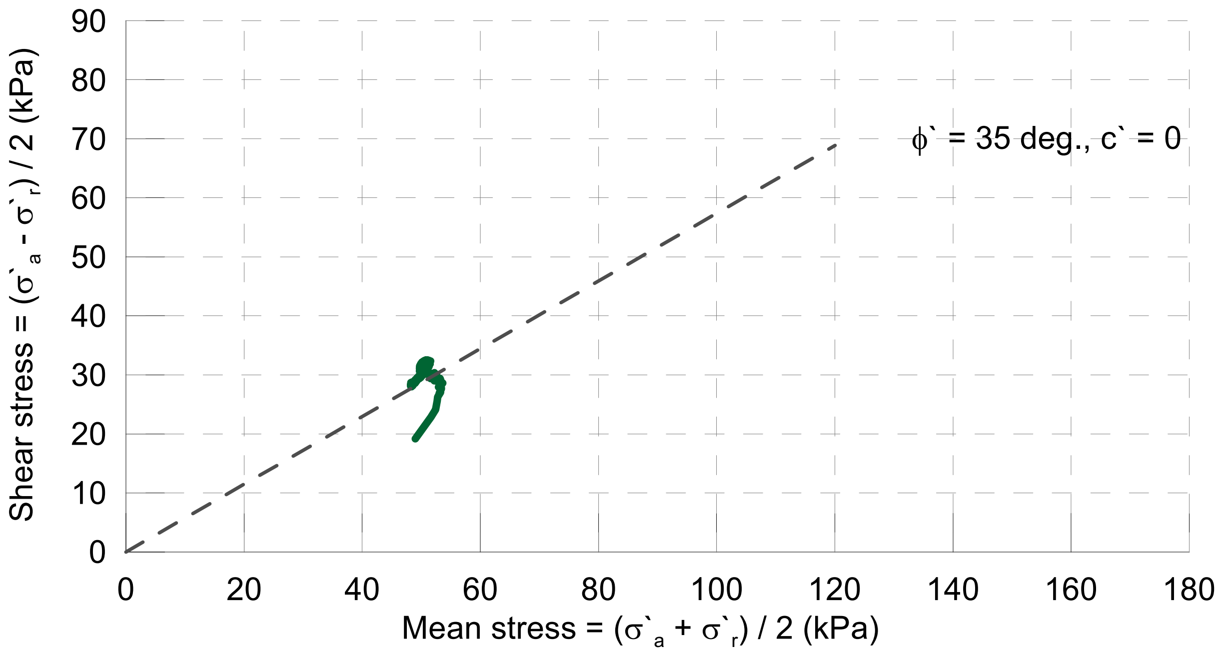
ρ = 2.105 Mg/m^3

w = 29.5 %

ε_{v0} / $\Delta e/e_0$ = 7.3% / 0.162

Dell\Labtests\FoU\76-5.grf





FoU Project - Os Site - 2004 Site Investigation

Report No.	Figure No.
2005 - G1	56(b)
Drawn by GC	Date 2005-07-08
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CAUC Test 76-5

Sheet 2

BH: 2

Tube: No. 3, 7-7.8 m

Depth: 7.40 m

Specimen not trimmed

Dell\Labtests\FoU\76-5spath.grf

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