A new oedometer with splitted ring for the measurement of lateral stress

Un nouvel oedomètre avec un anneau en deux parties pour la mesure des contraintes latérales

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SYNOPSIS: A new oedometer with a splitted ring has been used to investigate the relation between horizontal stress and applied vertical stress. The three parts of the splitted ring may be adjusted to clamp an undisturbed soil sample with a controlled contact pressure. In each part of the ring a sensitive LVDT records the horizontal stresses developed during the oedometer test. The new oedometer allows for tests with a controlled lateral deformation. The corresponding influence on K_0'-values and deformation parameters may be found. The paper presents the new equipment and some results from tests on a norwegian clay to demonstrate its performance.

1 INTRODUCTION

The measurement of in situ stress relations, horizontal versus vertical stress, has been a topic of research and development for many years. Several field instruments as well as laboratory techniques have been presented in order to measure and evaluate the in situ coefficient of lateral earth pressure at rest. The installation of an instrument into the soil in situ is causing soil displacement and disturbance. Hence the horizontal stress may be difficult to evaluate from the test results.

For clayey soils we may apply sampling techniques giving close to undisturbed samples. In the laboratory we then find representative values of strength and deformation parameters. It has been developed instruments and techniques aiming at the determination of the very important coefficient of lateral earth pressure at rest (examples, Dyvik 1985, Janbu 1973).

This paper presents a new oedometer where the supporting ring is splitted in three parts. By this, several advantages are obtained. The mounting of an undisturbed sample is simple as the ring is "clamped" around the sample. In each part of the ring the contact pressure between sample and ring might be measured. This allows the application of an actual initial horizontal stress situation, and also the measurement of the horizontal stress occurring during a consolidation test. It is also possible to introduce an initial "gap" between sample and ring to find the influence of lateral displacements to deformation parameters and to the measured horizontal stress.

Only test results for one norwegian marine clay are presented in this paper. Incremental and continuous loading oedometer procedures are applied.

2 THE SPLIT RING OEDOMETER

The split ring oedometer is developed and designed at the Geotechnical Division, The Norwegian Institute of Technology. The idea of a split ring oedometer has been discussed for a long time, and the first mechanical solution was worked out in 1982, in connection with a project on soil disturbances. (Senneset 1982). Since then, the ring is re-designed and the measuring system changed and improved.

Fig.1 presents a simplified cross-section of the split ring oedometer, and Fig.2 and Fig.3 show photos of the oedometer without and with sample mounted. The three parts of the ring is moved by a precision lathe chuck.

The three ring parts may be moved with great precision to clamp a sample of given dimension. The lateral stress is recorded by three precision LVDT's. The parts of the ring are very stiff, except for a membrane in each where the LVDT is measuring the small deformations caused by pressure exerted by the specimen.

The membrane is formed by an inner steel stratum, which also provides an overlapping of the necessary slit between ring parts. The final machining of the ring inside is performed in a precision lathe where the oedometer chuck with ring is mounted. The inside diameter of the ring is perfectly circular at a diameter of D = 54.3 mm (23.15 cm² specimen area). The height of a trimmed specimen H = 20 mm (specimen H/D = 0,37).

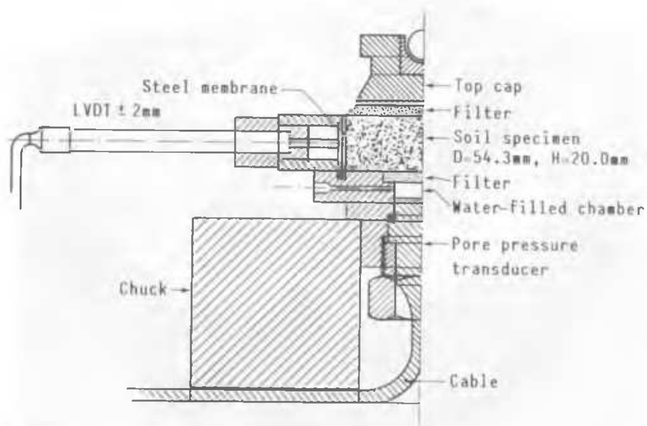

Figure 1. Simplified cross-section of the oedometer.

The pore pressure developed at the base of the sample is recorded by a pressure transducer. The chamber and filter above is saturated with water.

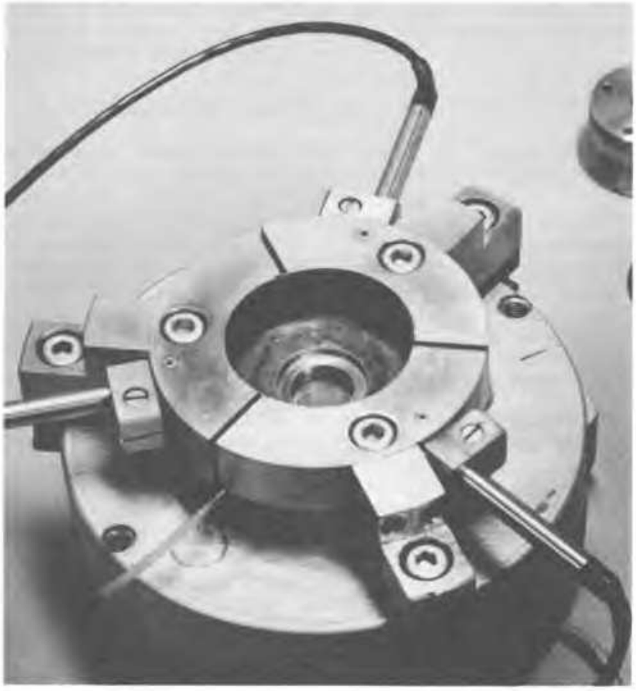

Figure 2. The splitted oedometer ring.

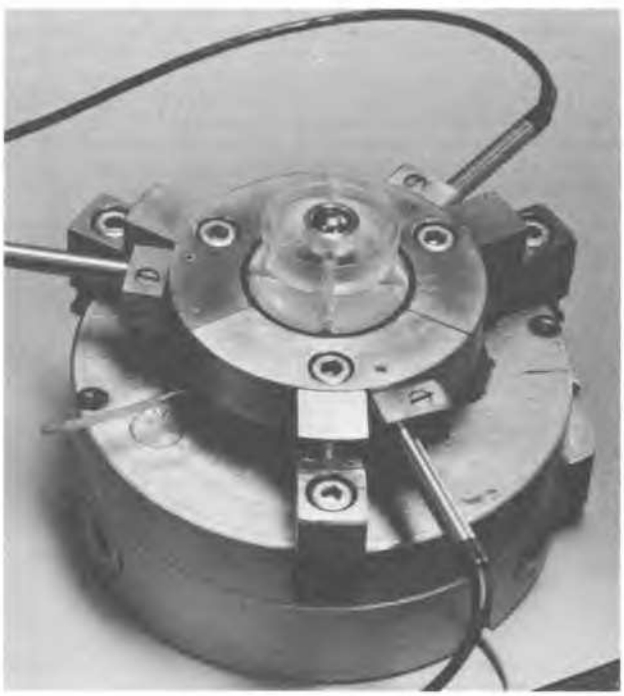

Figure 3. Oedometer with sample.

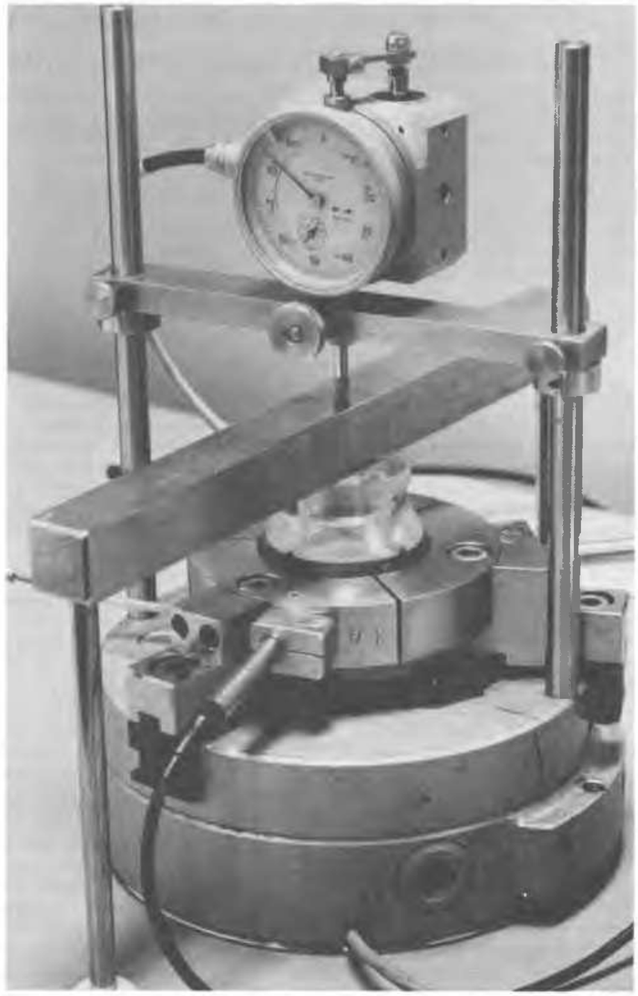

Figure 4. Oedometer and rig for incremental loading tests.

Figure 5. Oedometer and rig for continuous loading tests.

3 SPESIFICATIONS AND CALIBRATION

The LVDT measurements are made by a Tesa System. The system provides a measuring range of ±200 μm (gain error 0,3% at 20°C, zero drift 0,01% per °C). Maximum measuring range is ±2000μm. Repeatibility and hysteresis error is 0,01 μm. The calibration of the horizontal stress measuring system was accomplished by applying water pressure to the membranes with a dead weight pressure calibrator. The calibration load applied was 800 kPa and showed excellent linearity and insignificant hysteresis between increasing and decreasing pressure.

The maximum local membrane deformation was 40μm at a horizontal pressure of 800 kPa. The average of the three membrane readings are used for calibration.

The radial deformations measured outside the stiff ring, as the overall system deformation, were approximately 8 μm for a horizontal pressure of 800 kPa. (i.e. increase of diameter 16μm). The pore pressure transducer used is a Model AB from Data Instruments, measuring range 1400 kPa absolute pressure. Accuracy 1% of full scale including non-linearity, repeatibility and hysteresis, and the transducer is temperature compensated.

4 TEST PROCEDURE

The undisturbed soil sample with a trimmed base is placed at the oedometer base, while the three ring parts are sufficiently separated. The ring parts moves with minor clearance at the base on a O-ring seal. In addition, and to prevent any pore pressure dissipation, the slit is given a layer of cock grease. The slit between the three ring parts are for the same reason sealed off with Loctite Silicone Sealant.

The ring is then adjusted to the sample, introducing a given horizontal contact pressure. This may correspond to a vertical load in order to establish an approximate in situ stress situation (with an estimated K_0-value and for a given sample depth).

For ordinary tests (to be compared with standard oedometer tests) a lesser contact pressure of 4-20 kPa is applied. If a gap between ring and sample is to be established (to investigate effect of lateral deformations) the ring is moved back a given distance measured by a dial gauge.

The oedometer test is performed either by incremental loading (max. vertical stress 1200 kPa), or as a constant rate of strain test. No loading-reloading cycles are applied.

The deformations and pressures are recorded, processed and plotted by our laboratory computer (HP-1000).

The picture in Fig.4 shows the oedometer assembled in a rig for incremental loading and Fig.5 the arrangement for continuous loading (Janbu 1981).

5 SOIL DATA

The oedometer specimens are all from sample tubes from the same borehole, depths respectively 8,0-8,8 meters, 9,0-9,8 meters and 10,0-10,8 meters. Table 1 summarizes the geotechnical data for the three sample tubes. The Glava clay is overconsolidated.

Table 1. Geotechnical data for Glava Clay.

Data	Depth, m	8,0-8,8	9,0-9,8	10,0-10,8
Water content	(%)	32-34	32-33	29-36
Liquid limit	(%)	33,1	31	32
Plasticity index	(%)	9,4	9	12
% < 2μ		39-47	41-47	39-40
Undrained shear strength	(kPa)	36-39	36-41	29-37
Overburden pressure	(kPa)	~85	~95	~100
Preconsolidation pressure	(kPa)	~350	~350	~350
Modulus number		16	16	16
Friction	(tanφ)	0,51	0,55	0,56
Attraction	(kPa)	30	20	20

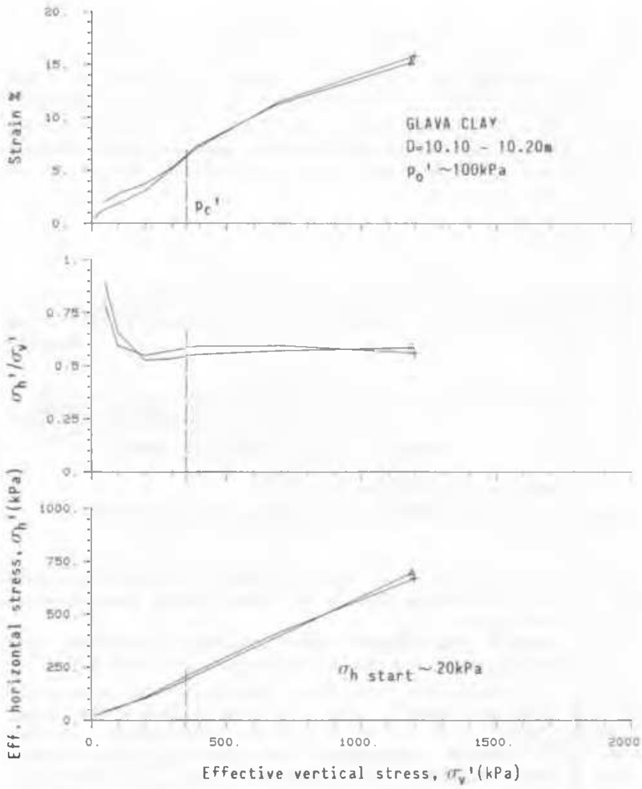

Figure 6. Test results, incremental loading.

6 TEST RESULTS

The intention of this paper is to describe the ability and performance of the new oedometer ring. This is demonstrated by only a few test results from one clay deposit.

Fig.6 gives the test results for two incremental load tests. The stress-strain curves and the principal stress curves are presented.

The relationship between applied vertical stress and the measured lateral stress during the consolidation test is shown.

The coefficient of lateral earth pressure at rest is defined as (Janbu 1973, 1985).

$$K_0' = \frac{\sigma_h' + a}{\sigma_v' + a}$$

where a = attraction (cohesion = a·tanφ). In the

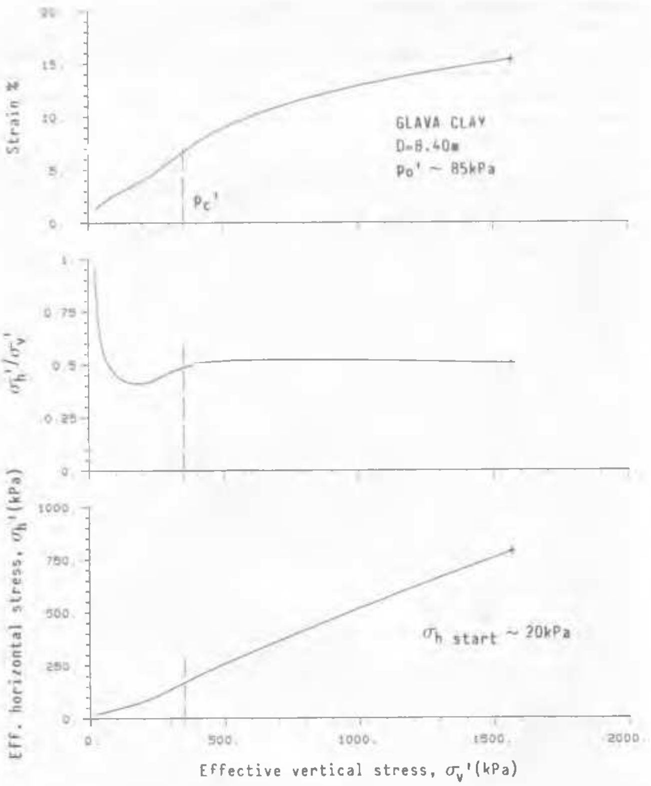

Figure 7. Test results, continuous loading.

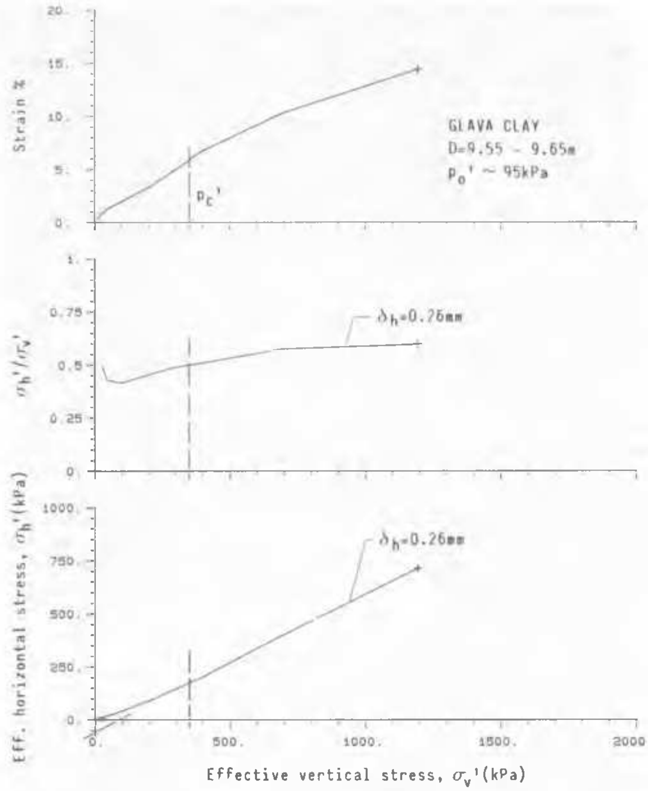

Figure 8. Test with lateral displacement δ_h= 0,26mm, incremental loading.

figures given is only shown the relation between principal stresses σ_h'/σ_v' without this correction (measured data).

All tests performed are one-way drained and with measurement of pore pressure at the base.

Fig. 7 presents the test results for a continuous loading test. Figs. 6 and 7 indicate that the ratio of the lateral stress increment to the vertical stress increment is near constant above the preconsolidation pressure, p_c'. (a constant K_0'-value). The corresponding straight lines intercept the vertical stress axis close to origo.

To demonstrate the influence of lateral deformations (as may be the case for poorly built in samples in ordinary oedometers), Fig.8 shows a test with an introduced gap between sample and ring of 0,26 mm (diameter increase of ring). The essential difference is that the σ_h'/σ_v'-ratio increases after the preconsolidation pressure, and that the σ_h'- σ_v' line intercept the negative horizontal stress axis. Such a negative interception is discussed by Dyvik et al. 1985, and one of their suggestions is that it is caused by radial deformations. The test presented in Figs. 6-8 confirm that explanation. Further tests on different clays, normally and overconsolidated, are in progress. The major goal of this research is to find if a reliable value of the in situ K_0' may be obtained by this new oedometer technique.

7 CONCLUSIONS

A new oedometer with a splitted ring has been used to investigate the relations between horizontal and vertical stresses by incremental and continuously loaded oedometer tests.

The splitted ring allows for a controlled and secure initial contact between sample and ring. Tests performed indicate that lateral deformations influence the K_0'-values, (as well as the settlement parameters to some degree).

The splitted oedometer ring may be considered as rigid, when comparing tests where significant lateral deformations are introduced and tests with only minor ring deformations. The splitted ring oedometer presents a promising possibility to find representative K_0'-values for an undisturbed soil, together with the deformation parameters.

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