A method of measuring the eg and ek parameters of soft soils

Une méthode pour mesurer les paramètres eg et ek des sols mous

T. F. WIDDIS, Lecturer, Dept. of Civil Engineering, University College, Dublin, Ireland

SYNOPSIS The deformation of soils under stress can be determined by using the eg and ek parameters. A method of measuring these parameters is given along with a discription of the apparatus and its use. The results of these tests carried out on four typical soft soils are given along with their conventional properties.

INTRODUCTION

A major geotechnical problem for the civil engineer engaged in the design of earth embankments on soft soils is the prediction of the magnitude and rate of settlement of the soft soils under the applied loads. At present three components of settlement are considered, immediate, primary and secondary consolidation.

Immediate settlement is assumed to take place immediately on application of the load under undrained conditions. If the soil is saturated and of low permeability settlement is due to change of shape caused by shear stresses and there is no change in volume.

Primary consolidation takes place as the hydraulic gradient of the excess porewater induced by the applied stress causes water to flow out of the soil resulting in a change in volume. This is a time dependent process as the rate of flow depends on the magnitude of the excess porewater, the boundary conditions and the coefficients of permeability and compressibility of the soil. The illogical term secondary consolidation is used to describe the settlements which take place after the dissipation of the excess porewater pressure or after the completion of primary consolidation. Oedometer test results indicate soft clays, soft organic silts and clays, and peat to have large components of secondary consolidation.

At present the physical behaviour of such soils under increments of stress is not understood and there is disagreement as to how to distinguish between primary and secondary consolidation (Bogermum, 1967), (Barden 1969), (Mesri 1973), (Mesri, Godlwski 1977).(Hanrahan 1954).

Leonards (1977) proposed that the term secondary compression be used to describe the deformation that takes place at constant effective stress. This is better terminology as the use of the word consolidation in the term secondary consolidation is bad as consolidation is associated with the expulsion of water and changing effective stress.

BASIC THEORY OF eg AND ek PARAMETERS

The basic theory (Hanrahan) subdivides the deformation into two elements of strain where

$$e_1 = eg_1 + ek_1 \qquad (1)$$

(i) The eg strains (Hanrahan,) (Farrell, 1982) are caused by shear stresses and are stress, time and strength of soil dependent. At low stress levels the plot of eg strains against the log of time is linear.

$$eg_1 = \frac{\Delta h}{ho} \qquad (2)$$

where Δh is the change in vertical height of a soil sample under a particular shear stress and at a particular time. ho is the original height of the sample.

The eg strain is measured by applying an increment of shear stress under undrained conditions to a soil sample and measuring change in vertical height with time. The resulting eg's are calculated and plotted against the log of time.

A number of tests are carried out at increasing increments of shear stress and a family of curves obtained for a particular soil. A linear regression analysis is applied to the normalised results (Hanrahan,) yielding a relationship between eg_1, $(\sigma_1-\sigma 3)/\sigma c'$ and the log of time. $\sigma c'$ is the effective consolidation stress to which the samples are subjected.

(ii) The ek strains are caused by volumetric stress and are stress, stress level, size of specimen, and time dependent. The rate at which ek strains develop is dependent on drainage and boundary conditions and on the size of specimen tested.

For isotropic stress conditons

$$ek_1 = \frac{\Delta V}{3Vo} \qquad (3)$$

where ek_1 is the strain in the vertical direction, V is the change in volume of a soil specimen at a particular time and Vo is the original volume of the specimen.

ek is measured by applying an equal all round stress under drained conditions to a soil sample and measuring the resulting change in volume with time. The resulting ek's are plotted against the log of time. If a multistage test is carried out by applying increments of increasing isotropic stress and measuring the resulting change in volumes over twenty four hour periods a family of curves is obtained.

Alternatively the ek values at the end of each stage can be plotted against the corresponding consolidation stress to obtain a non-linear relationship between ek_1 and σc^1.

In reality where non isotropic stress condition exist ek_1 as measured in isotropic stress conditions in the laboratory has a factor applied to it to obtain the pertinent field value.

For example.

$$ek_1 = \frac{\Delta V}{3V_o} \cdot \frac{\sigma_1}{\sigma oct} \qquad (4)$$

where σ_1 is the vertical principal stress and

$\sigma oct = (\sigma_1 + \sigma_2 + \sigma_3) | 3$.

In order to determine the deformation during the secondary phase the method used for determining that during the primary stage (Hanrahan,) is modified to taking into account the increment of excess pore-water pressure due to changes in lateral stress.

MEASUREMENT OF eg AND ek PARAMETERS

(i) In order to calculate the deformation of soils under load it is necessary to determine the eg and ek parameters. This can be done using the apparatus shown in Fig. 1 and Fig. 2.

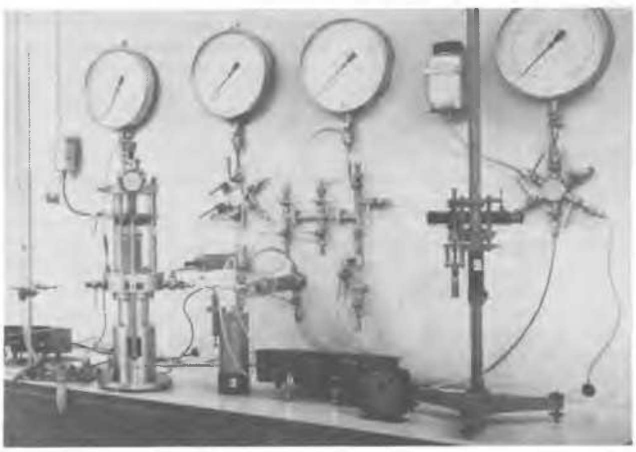


Fig. 1. Layout of complete apparatus

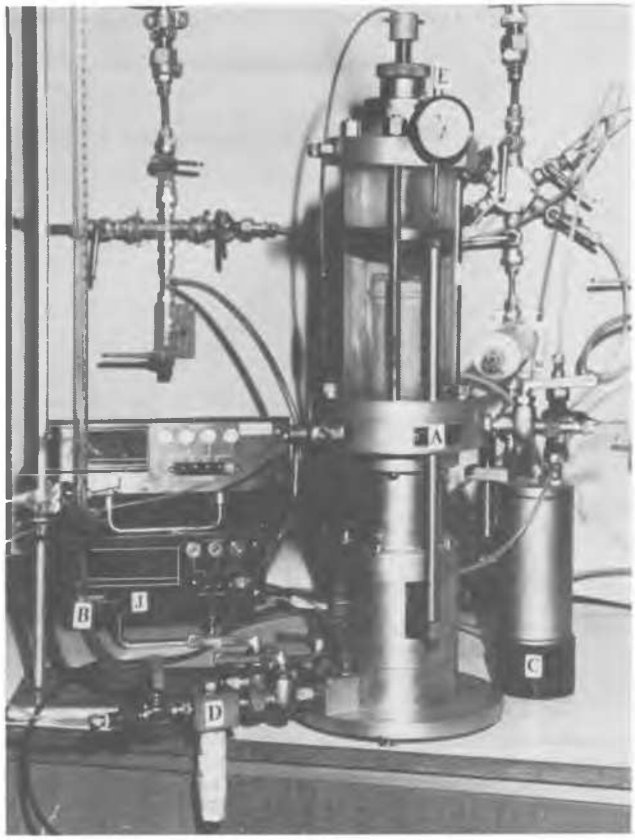


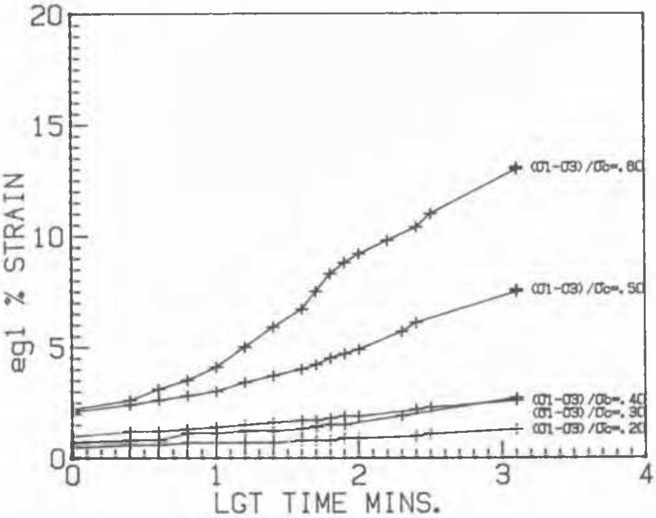
Fig. 2 Close up of Bishop Wesley cell with cell, porewater pressure transducer, vertical strain gauge, atmospheric burette, pressure volume change and digital indicators.

The Bishop Wesley cell is used to determine the change in volume of a saturated soil sample under an isotropic consolidation stress either by measuring the volume of water flowing out into the atmospheric burette or by measuring the volume of water flowing into the cell to replace the outflowing water by a pressure volume change apparatus.

The ek parameters can be calculated as the test is in progress and after consolidation is complete usually taken at twenty four hours. To facilitate the calculations the data is filed on magnetic discs and processed by a micro-

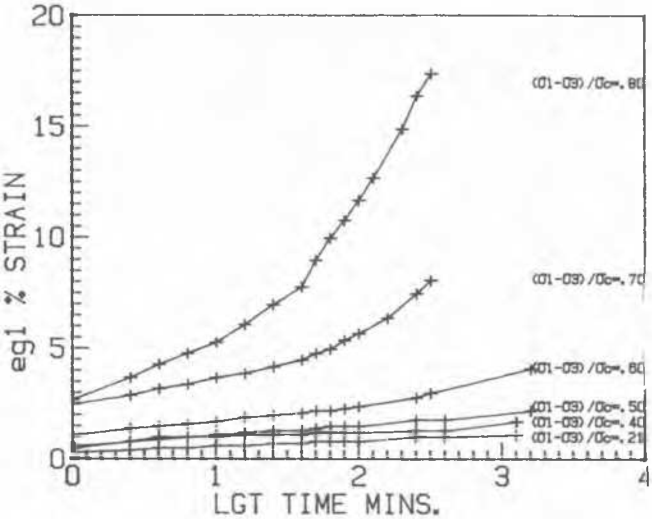
	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	UNIT WEIGHT	UNDRAINED SHEAR STRENGTH
Soil Description	%	%	%	kN/m^3	kPa
Soft Back Peat	400	-	-	100	16.0
Soft Yellow Silt	130	45	99	120	11.0
Soft Grey Organic Clay	80	20	60	170	9.0
Soft Brown Laminated Clay	30	18	33	180	7.0

FIG. 3. Conventional Test Results for Soft Soils.



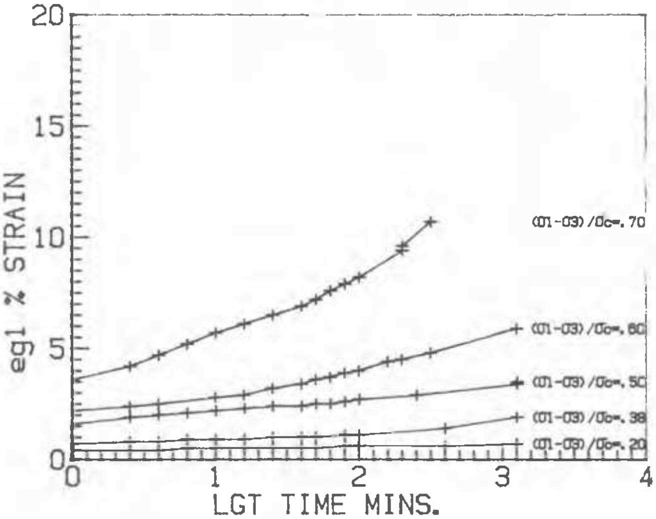
eg1=2.41((σ1-σ3)/σc)^.99+2.06((σ1-σ3)/σc)^1.38*LGT TIME

Fig. 4. eg test results with regression equation for peat.



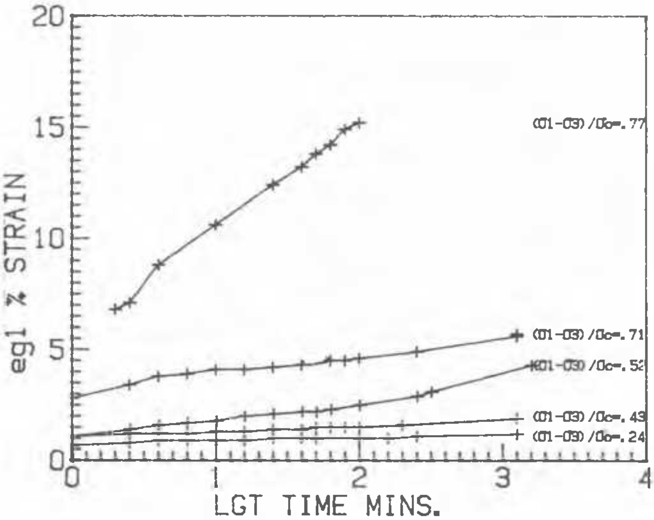
eg1=1.47((σ1-σ3)/σc)^.99+0.79((σ1-σ3)/σc)^0.77*LGT TIME

Fig. 6. eg test results with regression equation for grey clay.



eg1=3.52((σ1-σ3)/σc)^1.4+1.28((σ1-σ3)/σc)^1.60*LGT TIME

Fig. 5. eg test results with regression equation for silt.



eg1=1.65((σ1-σ3)/σc)^.55+2.07((σ1-σ3)/σc)^2.20*LGT TIME

Fig. 7. eg test results with regression equation for brown clay.

computer, the data and final results being printed or plotted out.

After a soil sample has been consolidated to the required stress, an increment of shear stress is applied to the sample by increasing the vertical principal stress and keeping the upper cell pressure constant. The resulting change with time of the height of sample is recorded on the strain dial gauge or linear transducer. Adjustments are made to the constant pressure mercury pots in order to maintain the required principal stress difference as the sample deforms under undrained conditions.

(ii) Tests have been carried out on samples of four soft soils taken at the location of the proposed Athlone byepass in Co. Westmeath. Typical geotechnical properties of these soils are given in Fig.3.

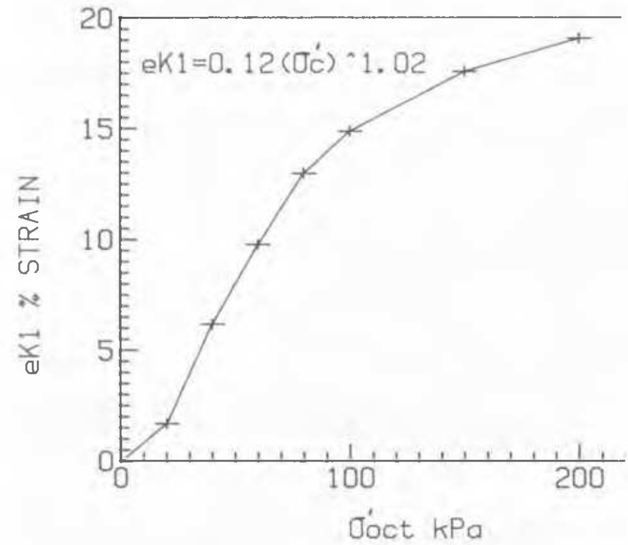


Fig. 8. ek test results with regression equation for peat.

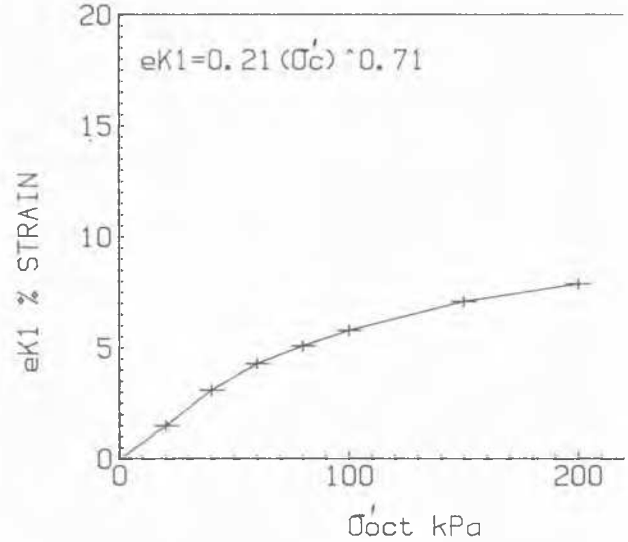


Fig. 10. ek test results with regression equation for grey clay.

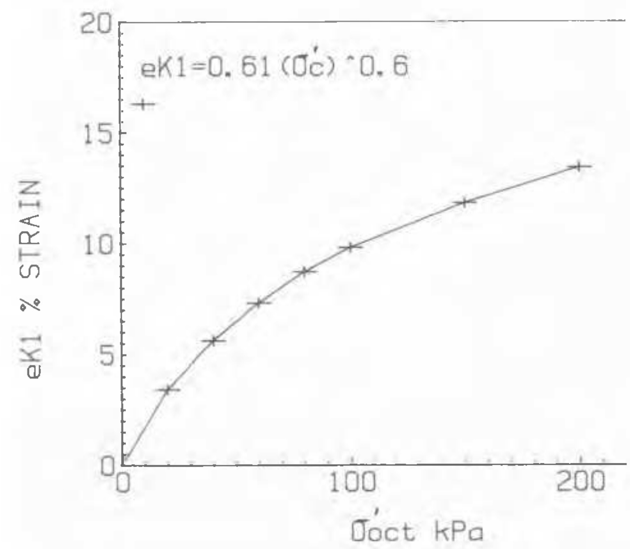


Fig. 9. ek test results with regression equation for silt.

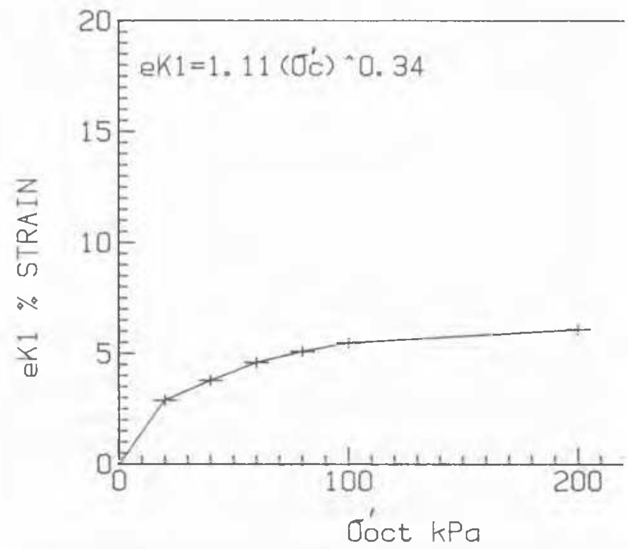


Fig. 11 ek test results with regression equation for brown clay.

The results of the eg tests carried out on soft soils are given in Fig's 4, 5, 6, and 7.

The results of the ek tests carried out on the soft soils are given in Fig's 8, 9, 10 and 11.

CONCLUSION

The method of test and the apparatus required to measure the basic eg and ek parameters have been described.

The results of typical tests carried out on four soft soils along with their conventional geotechnical properties have been given.

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