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Testing of anisotropic consolidation in organic soils

Essais de consolidation anisotrope des sols organiques

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SYNOPSIS The results of anisotropic consolidation tests of two organic soils, amorphous peat and calciferous gyttja, are presented. The tests have shown a great changeability of effective earth pressure coefficient K_o in the consolidation process. Its value depends on mean and deviatoric effective stresses σ'_m, σ'_q, as well as on overconsolidation ratio OCR. The changeability of anisotropic stresses influences the stress-strain characteristics of organic soils, which should be taken into account in the consolidation analysis.

INTRODUCTION

The explanation of the influence of stress anisotropy on strain characteristics has a great significance in organic soils. The stress state of organic soils changes considerably during the compressibility process. In every point of the subsoil there is a state of overburden caused by the force of gravity. It is described by the components of a stress tensor σ'_1, $\sigma'_2 = \sigma'_3 = K_o \cdot \sigma'_1$, where K_o - coefficient of pressure at rest - determines the value of stress anisotropy. The stress history of subsoil and its structure influence the anisotropy state of stress "in situ". In the soils of a complex structure, mechanical and apparent overconsolidation occurs. Compressibility tests show that the changeability of strain characteristics occurs when the stress exceeds preconsolidation value σ'_p. It can be explained by the influence of the reloading process on the anisotropy stress state. In order to describe the stress-strain relationship in the subsoil, K_o and K_o^{NC} /K_o^{NC} - coefficient of pressure at rest of normally consolidated soils/ values are necessary. These values determine the choice of stress paths in laboratory tests. Investigations carried out in recent years /e.g. Mayne, 1982; Jamiolkowski, 1981; Larsson, 1975/ have proved K_o to be the function of OCR and K_o^{NC}. It should be emphasized that so far K_o has been assumed to be constant for a given type of soil. In organic soils, where a significant anisotropy strain is observed /Lechowicz and Szymanski, 1984/, coefficients K_o and K_o^{NC} cannot characterize stress anisotropy of loaded soils. Therefore, it is essential to introduce a changeable coefficient K' which characterizes a changeable state of stress in the ground.

SOIL CHARACTERISTICS

The consolidation tests on peat and gyttja samples, taken from the depth of 2 and 6 m respectively, were carried out. The properties of soils are presented in Table I. Isotropy consolidation tests, performed in a triaxial cell, have shown overconsolidation of peat and gyttja /cf. Fig. 1/. For peat OCR is 8, for gyttja - 3.

TABLE I

Geotechnical properties of peat and gyttja

Soil properties	Units	Peat	Gyttja
Water content	%	310-340	104-110
Plastic limit	%	185-198	152-54
Liquid limit	%	313-321	101-104
Density of soil	kg/m^3	1070-1120	1410-1430
Density of solid particles	kg/m^3	1400-1450	2200-2300
Organic matter content	%	74-88	32-38
Shear strength	kN/m^2	10	12.5

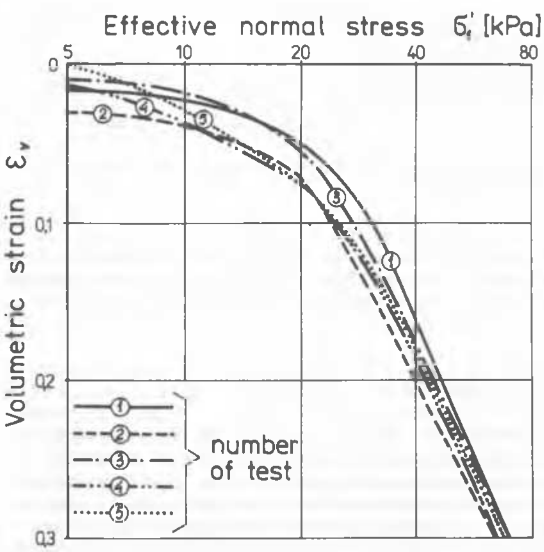

Fig. 1. Stress-strain characteristics of peat.

The coefficient of earth pressure K_o for peat is 0.45, for gyttja - 0.60.

LABORATORY TESTS

Anisotropic consolidation laboratory tests were performed in a triaxial cell equipped with an ultrasonic strain indicator measuring the lateral strain of the sample /Wolski, Barański, 1984/. Two series of tests were carried out:

- determination of K' in consolidation process,
- anisotropic consolidation in the stress state defined by K'.

In the first series of tests the coefficient K' was measured on the basis of stress paths for particular samples /Fig. 2/, in order to determine the changeability of stress state during the consolidation process. The values of coefficient K' were estimated for the stress state occurring after pore pressure dissipation /Fig. 2/. The tests were carried out with a constant value of load for each sample. The following range of loads was applied: 10 - 100 kPa.

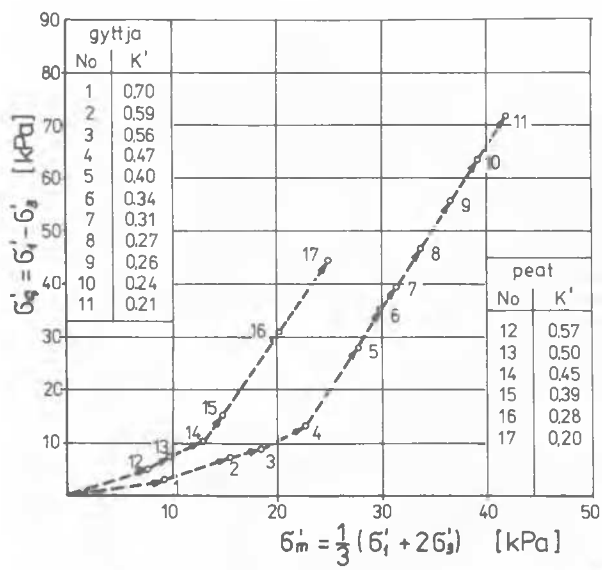

Fig. 2. Stress paths in anisotropic consolidation tests.

In the second series of tests the stress state defined by K' resulting from the first series of tests was accepted.

DISCUSSION OF TEST RESULTS

Results from the first series of tests were presented as a relationship between coefficient K' and mean stress σ_m' /Fig. 3/, as well as between coefficient K' and deviator stress σ_q' /Fig. 4/. A significant changeability of coefficient K' can be observed during the consolidation process. The changeability is of a logarithmic character and a different type of changeability can be seen depending whether stresses bigger or smaller than preconsolidation pressure σ_{mp}' are applied. For the range of stresses from σ' to σ_{mp}', earth pressure coefficient K' can be described by the following equation:

$$K' = K_o - C_m \log \frac{\sigma_m'}{\sigma_{mp}'} \qquad /1/$$

where:

C_m - slope of K'-$\log \sigma_m'$ straight line for $\sigma_m' < \sigma_{mp}'$

K_o - K' at "in situ" stress state.

Since for the stress $\sigma_m' = \sigma_{mp}'$ the value of K' equals K_o^{NC} and $\frac{\sigma_{mp}'}{\sigma_{mo}'}$ equals OCR, the following equation can be proposed:

$$K_o = K_o^{NC} + C_m \log OCR \qquad /2/$$

Therefore the coefficient of earth pressure at rest depends on K_o^{NC}, C_m and OCR.

For stresses bigger than preconsolidation pressure, the relationship between K' and σ_m' can be expressed as follows:

$$K' = K_o^{NC} - C_m^{NC} \log \frac{\sigma_m'}{\sigma_{mp}'} \qquad /3/$$

where:

K_o^{NC} - K' in overconsolidation stress state

C_m^{NC} - slope of the K'-$\log \sigma_m'$ straight line for $\sigma_m' > \sigma_{mp}'$.

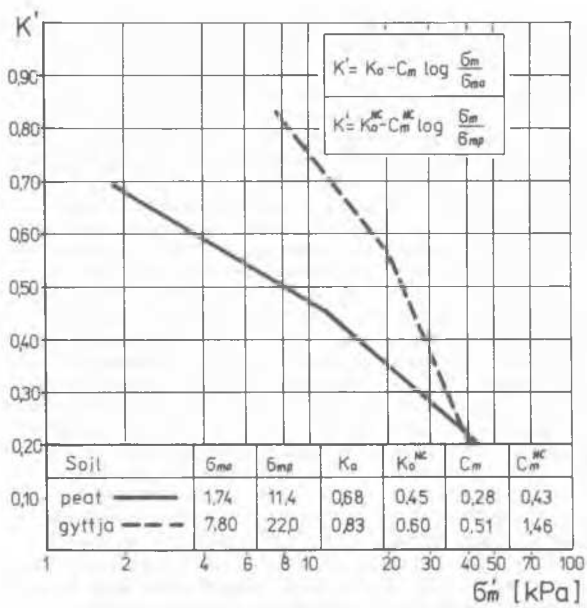

Fig. 3. Coefficient of lateral stresses K versus mean stress.

A similar changeablilty was obtained for the relationship between coefficient K' and the deviator stress σ_q'. Fig. 3 and Fig. 4 show the values of K_o, C_m, C_m^{NC}, C_q and C_q^{NC} of the tested soils.

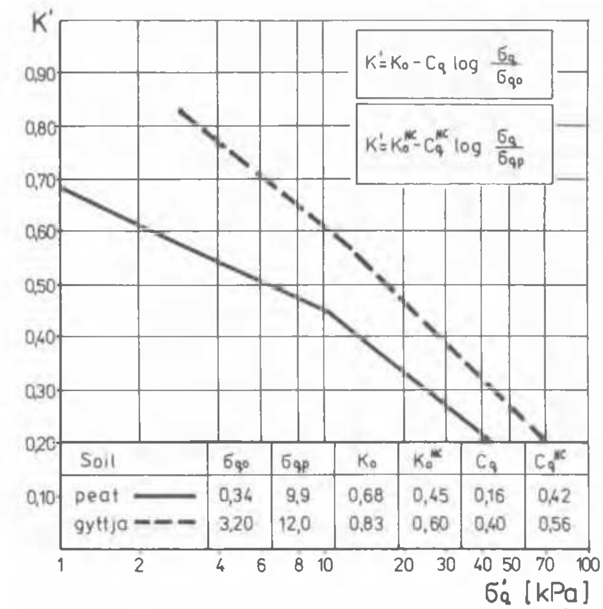

Fig. 4. Coefficient of lateral stresses K' versus deviator stress.

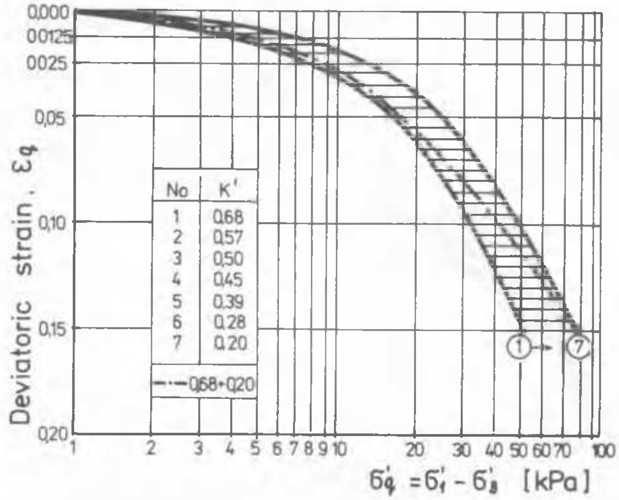

Fig. 7. Deviator strain versus deviator stress for peat.

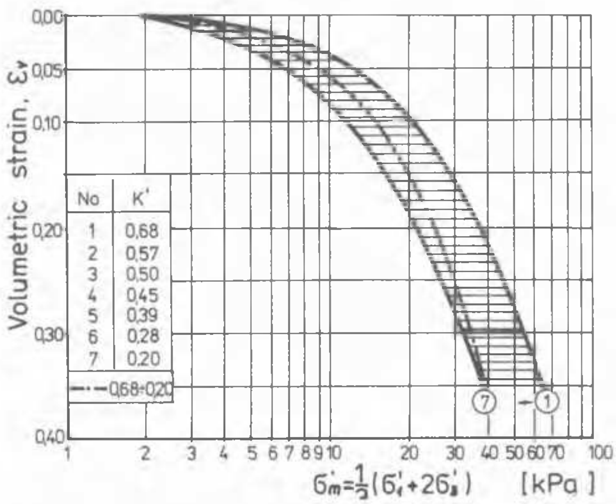

Fig. 5. Volumetric strain versus mean stress for peat.

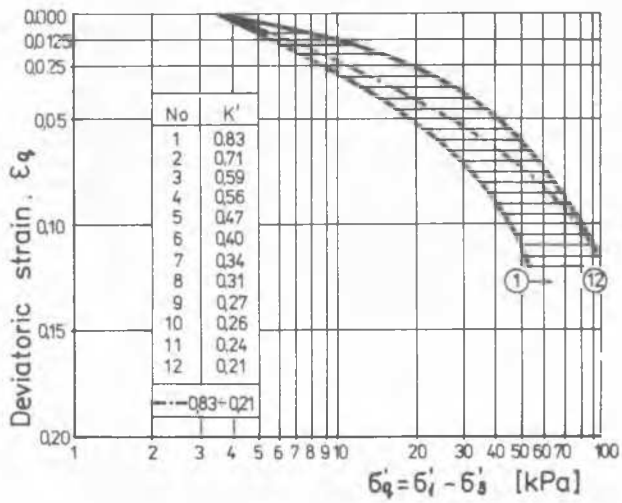

Fig. 8. Deviator strain versus deviator stress for gyttja

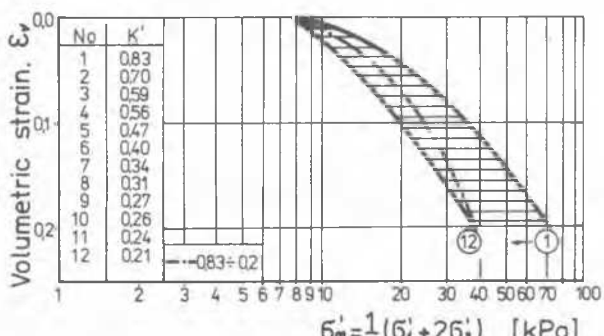

Fig. 6. Volumetric strain versus mean stress for gyttja

Since in the consolidation process the coefficient of lateral pressure is a changeable value, the authors propose to introduce the non-linear characteristic K' as a function of stress and overconsolidation ratio OCR.

Thus, a proper description of variability of stress anisotropy during consolidation of loaded subsoil is possible. This is indispensable for the proper estimation of the material characteristics in laboratory tests as well as for prognosis of stress and strain. It has a particular significance in very soft organic soils, where a considerable stress-strain anisotropy occurs and soil parameters change greatly during consolidation process.

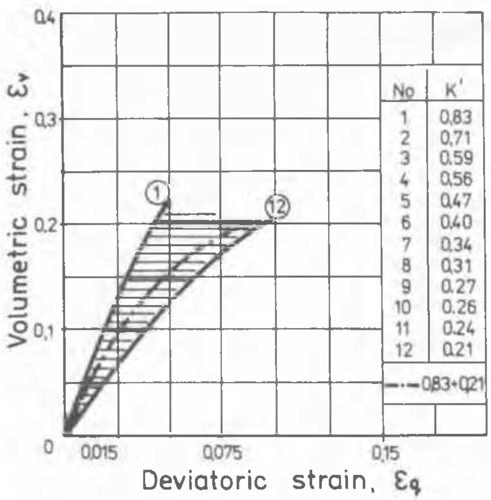

Fig. 9. Volumetric strain versus deviatoric strain for gyttja.

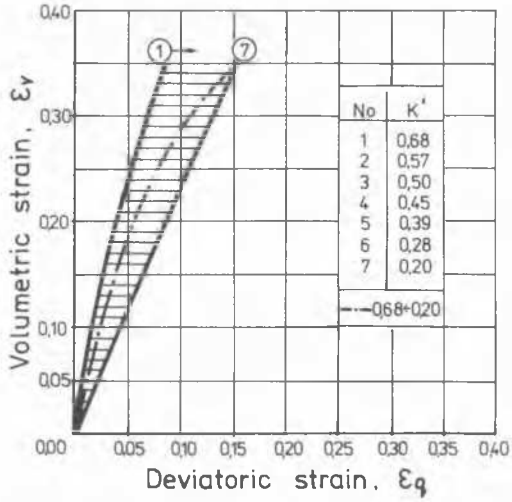

Fig. 10. Volumetric strain versus deviatoric strain for peat.

Results of an anisotropic consolidation in K state are presented as stress-strain relationships: $\varepsilon_v \sim \sigma'_m$ /Figs. 5 and 6/, $\varepsilon_q \sim \sigma'_q$ /Figs. 7, 8/ and strain characteristics $\varepsilon_v \sim \varepsilon_q$ /Figs. 9, 10/. The obtained characteristics show a definite dependence between dilatational as well as non-dilatational strain upon the value of the coefficient K' for the same effective stresses. Therefore, in order to form constitutive equations and to identify parameters for soil models it is essential to perform tests in the anisotropic stress state with properly selected K' changeability. The above has been confirmed by the tests performed with peat and gyttja with the K' values changing from 0.63 to 0.20 for peat and from 0.83 to 0.20 for gyttja /Figs. 5-10/.

CONCLUSIONS

1. The tests performed on organic soils have proved that the coefficient of lateral pressure at rest K' does not define the stress state during the loading process. Therefore in order to describe changes of stress anisotropy, the coefficient K' has been introduced. It shows a logarithmic changeability depending on effective stress and it also depends on overoonsolidation ratio.

2. The compression test of peat and gyttja has shown the occurrence of a significant preconsolidation which should be taken into account in the evaluation of lateral pressure K'.

3. Stress anisotropy which occurs during the consolidation process influences stress-strain characteristics of soils. Therefore laboratory tests should be carried out in the state of the changeable stress anisotropy resulting from the changeability of the coefficient K'.

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