Investigation of stiffness parameters of fine sands for Hardening Soil model

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ABSTRACT

Complex soil nature is not as simple as its prediction with a Mohr-Coulomb model, that is commonly used in numerical analyses. Using advanced constitutive models such as Hardening Soil is necessary to obtain accurate results in cases of tunnel drilling, or retaining wall excavation [1]. Reliable approximation of displacements is possible due to additional stiffness parameters such as E_{50} (secant modulus corresponding to 50% of q_f) or E_{ur} (unloading-reloading stiffness) [2].

In this study the experimental data was obtained. The parameters E_{50} and E_{ur} in fine sands samples during triaxial tests where analysed. These parameters were obtained on the basis of stress-strain characteristics from triaxial tests with the possibility of water outflow (CD test – consolidated drainage test). The values of measured deformation modules during shearing correspond to the range of deformations, which starts from 5 · 10-2%. The determination of the E_{ur} parameter required conducting a sample of unloading during shearing.

KEY WORDS

> traxial test
> shear test
> stiffness of soil
> hardening soil model
> sand properties

HARDENING SOIL MODEL

Problems such as the bearing capacity of soil or slope stability can be easily designed using Mohr-Coulomb model. This perfect linear elastic model requires five input parameters to express the stress-strain behaviour and due to simplicity of formulation and input data determination is widely spread. One of the weaknesses of this model is lack of distinction between loading and unloading/loading also constant stiffness is a problem on issues related to excavations [5].
Hardening Soil (HS) model is the one of the isotopic hardening double surface plasticity models which lead to predict more reliable parameters of displacement patterns for working conditions [3]. The movement patterns do not influence on the fine elements boundary conditions [4].

> Three types of stiffness have been defined in Hardening Soil model

Secant stiffness in standard drained triaxial test

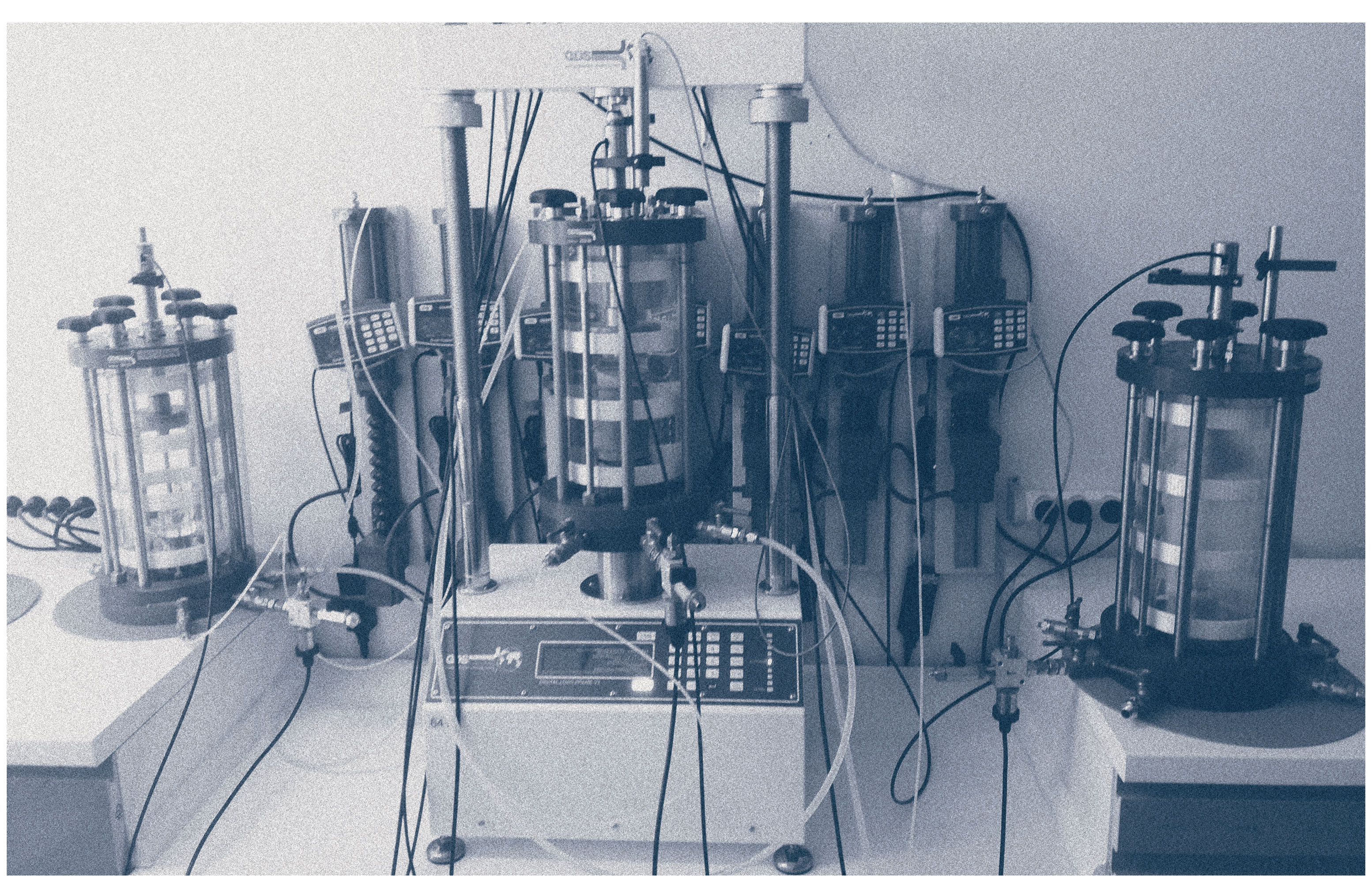
Tangent stiffness for primary oedometer loading

Unloading / reloading stiffness in drained triaxial test

EXPERIMENTAL

The scope of the research in triaxial test with isotropic consolidation in conditions with outflow (CD): 9 tests in 3 series of 3 samples. Additionally, the sieve analysis were conducted. The parameters E_{50} and E_{ur} were obtained on the basis of stress-strain characteristics from triaxial CD tests. The values of measured deformation modules during shearing correspond to the range of deformations, which starts from 5 · 10-2%

> Triaxial apparatus



MEASUREMENT PROCEDURE

1 Saturation stage

The equalization pressure inside the samples was raised in a linear manner by approximately 100 kPa / min, until to reach the value of 1200 or 1400 kPa.

2 Consolidation stage

The samples were consolidated in an isotropic manner at various effective stresses. In the case of fine sands, the consolidation occurs almost immediately.

3 Shear stage

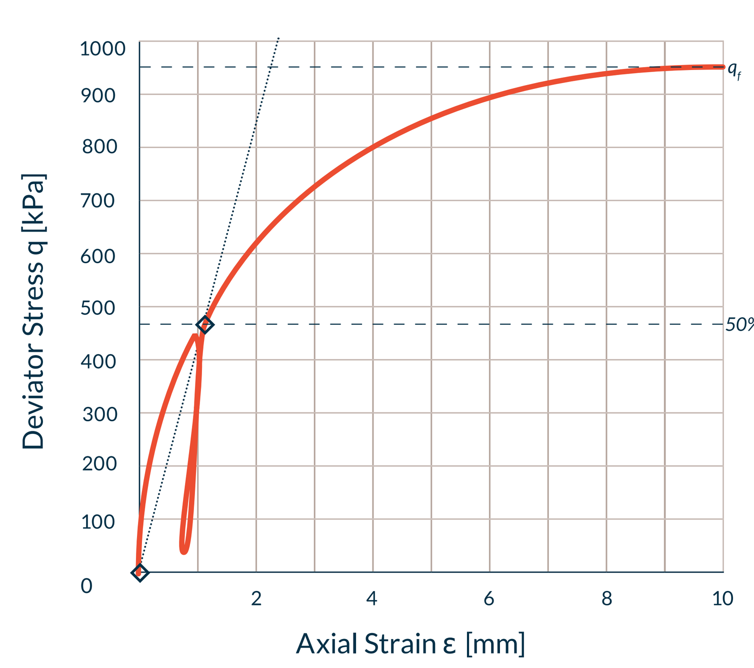
Due to the need to determine parameters for the Hardening Soil model in the case of CD test at some stage the shear was interrupted and the sample was loaded until the moment when the deviator of stresses reached the value of 20 kPa. The sample was then loaded again. Both loading as well as the unloading was carried out at a constant deformation rate of 0.15 mm / min

RESULTS AND DISCUSSION

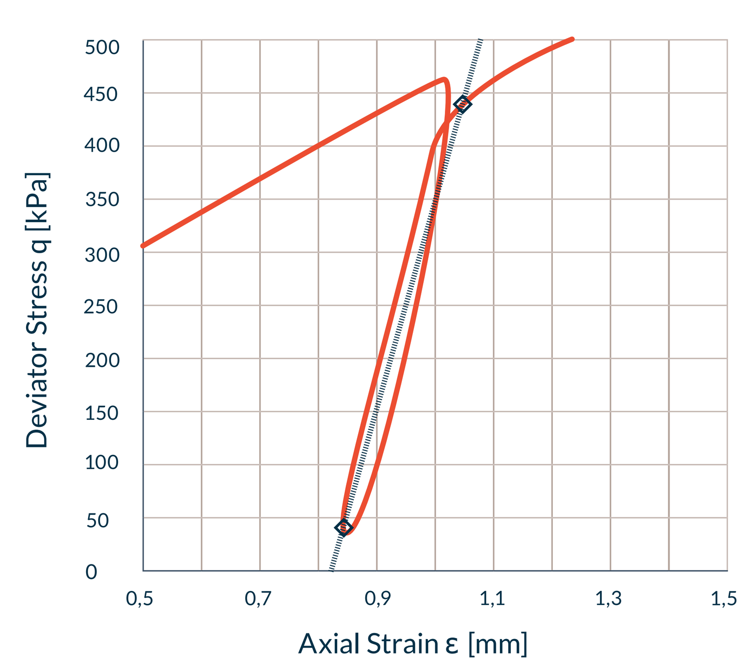
According to measurement procedure, the CD tests were conducted. The friction angle and cohesion were determined and additionally the HS model parameters. The results are given in the table below .

Sample	Type of soil	Type of sample	Density Index [-]	Consolidation stress [kPa]	Friction angle φ [°]	Cohesion c [kPa]	E50 [MPa]	E_{ur} [MPa]
A	FSa	Reconsituted	0,73	100	33	0	14	89
			0,73	200			24	147
			0,73	400			44	214
B	FSa	Reconsituted	0,95	100	38	0	42	120
			0,90	200			67	191
			0,90	400			130	285
C	FSa	Reconsituted	0,85	100	35	0	25	91
			0,85	100			36	137
			0,85	100			77	224

> Determination of E_{50} parameter for Sample A - σ'3 = 400 kPa

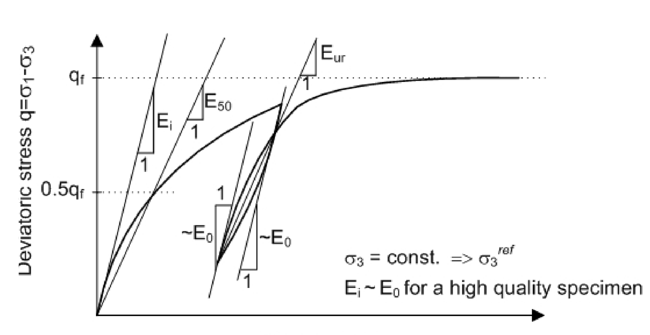


> Determination of E_{ur} parameter for Sample A - σ'3 = 400 kPa



Stress-strain characteristic — Secant modulus corresponding to 50 % of q_f — Unloading-reloading stiffness — Value of q_f

> Scheme of E_{50} and E_{ur} parameters determination [2]



FINAL COMMENTS

> During the measurements, the strength and stiffness parameters for Hardening Soil model were determined. Friction angle and cohesion are also useful for Mohr-Coulomb soil model.
> Strength parameters such as friction angle increase with increasing compaction of soil
> Stiffness parameters such as E_{50} and E_{ur} increase with increasing compaction of soil

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