PRE-FAILURE BEHAVIOUR OF GRANULAR SOILS

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The aim of this presentation is to study the pre-failure behaviour of granular soils, both dry and water saturated in undrained conditions. The starting point to the analysis is extensive set of experimental data obtained from triaxial compression tests, performed in a modern apparatus that enables measurement of lateral strains. The experiments were performed for various initial states of samples, i.e. loose or dense and contractive or dilative, and for various loading paths. The results of experiments are presented in the form of stress-strain curves or the effective stress paths in the case of saturated soils, tested in undrained conditions. The experiments have confirmed that there exists, in the effective stress space, the object designated as the instability line which has interesting properties. For example, in the case of initially dilative dry soils or saturated, but tested in drained conditions, the sample first compacts when sheared and after approaching the instability line the process of dilation begins. The behaviour of initially contractive samples is different as the shearing causes only compaction, so the instability line cannot be detected during such experiments. More interesting behaviour can be seen during the undrained tests, because the instability line corresponds to the maximum shear stress that can be supported by initially contractive soil. After reaching this line by the effective stress paths, the shearing stress rapidly decreases and the sample liquefies, i.e. it behaves macroscopically as a liquid. This process is accompanied by the increase of pore pressure and reduction of the mean effective stress. The undrained behaviour of initially dilative samples is similar before the effective stress paths approaches the instability line, and then becomes different as the pore pressure begins to decrease and subsequently the mean effective stress begins to increase. As a result of this behaviour, the dilative samples can support higher shear stresses, and eventually may fail if the effective stress path reaches the Coulomb-Mohr surface.

The important aspect of the analysis presented is the distinction between the initially contractive and dilative states of granular soils, which is different from traditional classification on the initially loose and dense samples. The combination of two following parameters decides whether this initial state is dilative or contractive, namely: e = void ratio and p' = mean effective stress. These parameters define the point in the space log $p' - e$, where is also defined the object designated as instability line. The contractive soils correspond to the points lying above the instability line, and the dilative to those below. At present, the only method of determination of the instability line is based on many experiments, which unfortunately cannot be performed easily in a standard geotechnical laboratory. We show such results obtained for the model “Skarpa” sand.

The second part of presentation deals with theoretical description of the experimental results obtained. The first attempts dealt with application of some elasto-plastic and hypoplastic models of soils, but the results were not promising. Therefore, it was decided to apply the most straightforward approach, that is based on empirical description of the soil behaviour for some simple stress paths, and then on generalization of the obtained equations for arbitrary stress paths. Obviously, the basic constitutive equations should be formulated in the incremental form, as the soil behaviour is path dependent. For the triaxial configuration considered, the following shape of these equations is proposed:

$$d\varepsilon_v = Mdp' + Ndq\,,$$
$$d\varepsilon_q = Pdp' + Qdq\,,$$

where: p' = mean effective stress; q = stress deviator; ε_v = volumetric strain; ε_q = deviatoric strain;

M, N, P and *Q* = some functions depending on the effective stress invariants, and perhaps on some other variables.

The functions *M, N, P* and *Q* appearing in these equations were determined experimentally for some simple stress paths, as isotropic loading and pure shearing at constant mean effective stress. The shape of these functions is different for loading and unloading, and in some cases different for initially contractive and dilative soils. These processes have been defined separately for the spherical and deviatoric parts of the stress and strain tensors, and this definition is different from that widely applied in elasto-plastic modeling of materials, not to mention hypoplasticity. The important problem of loading and unloading is also discussed in this presentation.

The functions *M, N, P* and *Q* were determined for dry soils or saturated but in free draining conditions. The empirical model was verified using the data for the stress paths, in drained conditions, different from those used in the calibration of the model. We have also used the data obtained from undrained tests in order to verify the model. The comparison of the model predictions with experimental data seems to be quite good.

The approach presented is an alternative to commonly applied elasto-plastic models of soils, which are often distant from the behaviour of real materials. We have been trying to find the way to describe the real behaviour of granular soils, which could be useful in practical applications, and which is consistent with the experimentally observed behaviour of these materials.

References

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