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Evaluation of Stamps and Latex Shell Influence on Stabilometer Testing Results - Modeled with Simulia Abaqus

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ABSTRACT: Triaxial tests are often used, along with other research methods, in order to define parameters of geotechnical data. The main topic being conferred in work is analysis of influence, exerted by stamp and latex shell, upon the results of triaxial machine soil tasting. The stabilometer modeling and verification was produced. Calibration of soil model parameters, derived from triaxial tests, is brought in work. The necessity of three dimensional simulation of soil testing process is pointed out in order to take into account stamp and shell influence.

Keywords: Triaxial machine test, soil model, Simulia Abaqus modeling, stamp and shell influence, modified Drucker-Prager/cap plasticity model.

1. INTRODUCTION

Nonlinear models are frequently used in geotechnical computational mechanics, which allow various implementation features of soil behavior to be taken into account. In order to define parameters of nonlinear soil models, data of triaxial tests is often used, along with other research methods.

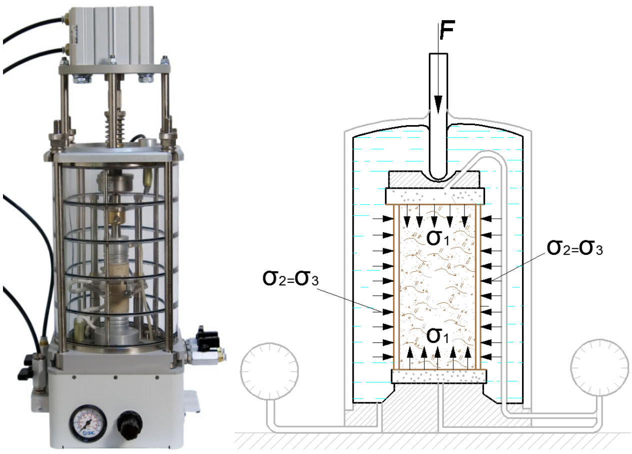

Fig. 1. Triaxial machine (NPO «Geotek»), and its principal scheme

As generally known, uniform hydrostatic pressure is maintained in the triaxial machine camera. In order to divide mediums of stabilometer camera and soil pores the sample is contained inside a flexible latex shell around the specimen, while the deviatoric load is imposed on the soil sample via firm upper and lower stamps (Fig. 1.). As a result, during the experiments the soil sample interacts with the stamps and the latex shell via their contact surfaces.

Therefore, based on the triaxial tests we obtain parameters of a model that describes the system behavior of stamps, soil sample and latex shell.

Stamps and latex shell influence in the triaxial machine is well known [4, 5].

Also, many investigators tried to reduce such influence by adding a sliding interface between specimen and triaxial machine stamps [4, 6, 7, 8].

However, it is necessary to use model parameters, which simulate a soil behavior only. In other words, testing of a system (stamps – soil sample – latex shell), but using parameters for soil model, in case of geotechnical goals.

The main purpose is to obtain parameters of the soil sample only, considering that an "ideal" triaxial machine, which would test the soil sample without stamps and latex shell influence, does not exist.

This work set outs an analysis of stamps and latex shell influence on the results of soil tests in a triaxial machine.

In order to evaluate the influence of stamps and latex shell in the triaxial machine, a modeling of a three-dimensional system of the "stamps – soil sample –and latex shell" is carried out through the program complex of Simulia Abaqus, following 4-stages:

1. The first stage involves creation of a three-dimensional system model of stamps – soil sample – and latex shell. It will be referred to as a stabilometer model further on.
2. The second stage includes verification of stabilometer model parameters to conform to behavior of triaxial machine test. Verification has to be carried out for each soil sample separately. In the given example it is middle-size grain sand and loamy clay.
3. The third stage requires exclusion of the stamps and latex shell from the stabilometer model, thereby obtaining an "ideal" stabilometer model.
4. The final stage involves a comparative analysis of the behavior of the stabilometer model and the"ideal" stabilometer model, in order to evaluate the influence of the stamps and latex shell.

2. STABILOMETER MODELING WITH SIMULIA ABAQUS

1/8 part of stabilometer was modeled in Simulia Abaqus.

As a visualization of results, 1/8 part was reflected to receive a visual effect of the model second part presence (Fig. 2.).

Deformed model - second part (reflection/ copy of 1/8 parts relative to XY and YZ)

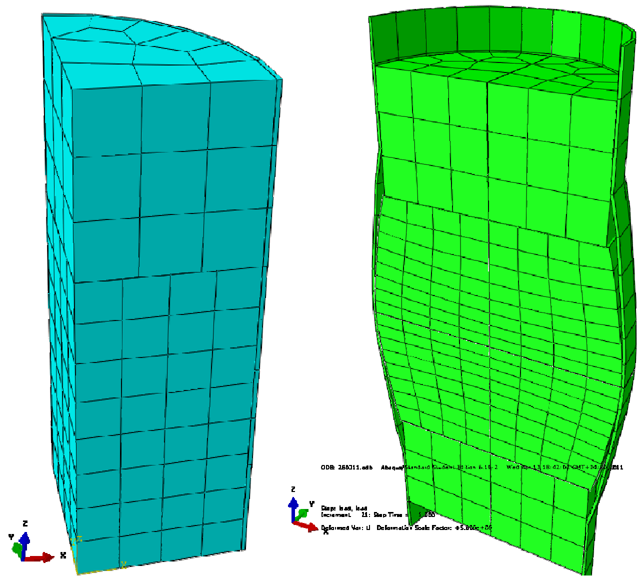

Fig. 2. Finite elements mesh – 1/8 parts, more than 900 nodes.

2.2 Soil model

In order to describe a soil behavior, modified Drucker-Prager/Cap model is used in the analysis.

The cap model is appropriate to soil behavior because it is capable of considering the effect of stress history, stress path, dilatancy, and the effect of the intermediate principal stress.

The yield surface of the modified Drucker‐Prager/cap plasticity model consists of three parts: a Drucker‐Prager shear failure surface, an elliptical Cap, and a smooth transition region between the shear failure surface and the Cap (Fig. 3.).

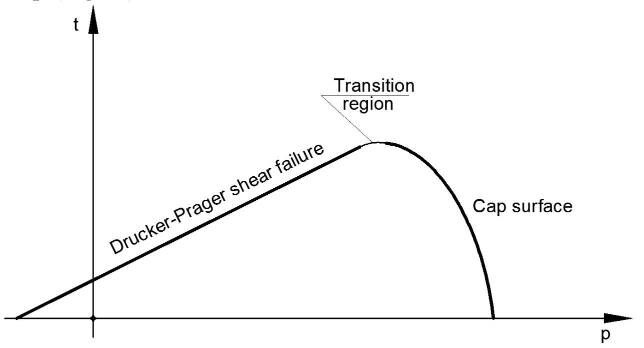

Fig. 3. Drucker‐Prager/cap plasticity model yield surface

The Drucker‐Prager shear surface is a perfectly plastic yield without hardening. Plastic flow on this surface produces inelastic volume increase - dilation.

The Cap surface bounds the yield surface in hydrostatic compression. On the Cap surface plastic flow causes the material to compact correspond to hardening mechanism. Besides, the Cap surface helps control volume dilatancy when the material yields in shear by providing softening as a function of the inelastic volume increase created as the material yields on the Drucker–Prager shear failure and transition yield surfaces. The model uses associated flow in the Cap region and nonassociated flow in the Drucker‐Prager shear failure and transition region.

The hardening/softening law is a user –defined piecewise linear function relating the hydrostatic compression yield stress, and the corresponding volumetric plastic strain.

The nonlinear elastic behavior modeled by using the porous elasticity model including tensile strength. During compression, the void ratio decreases. This behavior is expressed by the logarithmic bulk modulus.

2.3 Stabilometer modeling

Stamps and shell are modeled within the limits of linear elasticity. Steel and rubber has been accepted as materials for stamp and latex shell respectively. Non-linear contact between a stamp, soil sample and latex shell is simulated. Model was meshed by C3D8 solid elements.

For soil initial conditions production the Geostatic Abaqus procedure was applied.

Load is imposed to a model in two stages, repeating laboratory experiments in stabilometer, according to the CD scheme [1]:

The first stage involves sample recompression via a uniform hydrostatic pressure σ_2 (σ_3) to the natural level of a proper soil weight stress σ_v. This stage is a very important because this will determine the initial stresses in all soil elements.

On the second stage, vertical pressure σ_1 is increased with a maintained compression σ_2 (σ_3) till a relative vertical strain achieves ε_1=12% [1].

During the triaxial tests, soil samples, which are used, are those of moist middle-size grain sand and loamy clay, of 38 mm in diameter and 76 mm in height.

The latex shell thickness is 0,1mm.

3. STABILOMETER MODEL VERIFICATION

First of all, parameters of a soil model are calibrated for a full compliance with results of laboratory tests according to relation $\varepsilon_1(\sigma_1)$. Calibration is carried out for several curves with a different value of the uniform compression σ_2 (σ_3). Example of the compliance of stabilometer model behavior with the results of triaxial tests of one of the curves is illustrated on the Fig. 5.

For verification, deflected mode of stabilometer model was examined and compared to the features of laboratory sample behavior.

Analysis of a deflected mode of the stabilometer model is given below.

Following features, relevant for a given process, are shown in the Fig. 4:

5. Maximum magnitudes of stress intensity in a soil are located in the shape of a “cross”, which is registered on computed tomography using of full-scale sample [3].
6. Relative sliding and local break away of the latex shell from the stamps and soil.
7. The soil sample, consequently, acquires a barrel-type shape [2].
8. The soil flowing under the latex shell [2].
9. The stress intensity has a similar distribution in both

models made in Abaqus and LS-DYNA [2] programs.

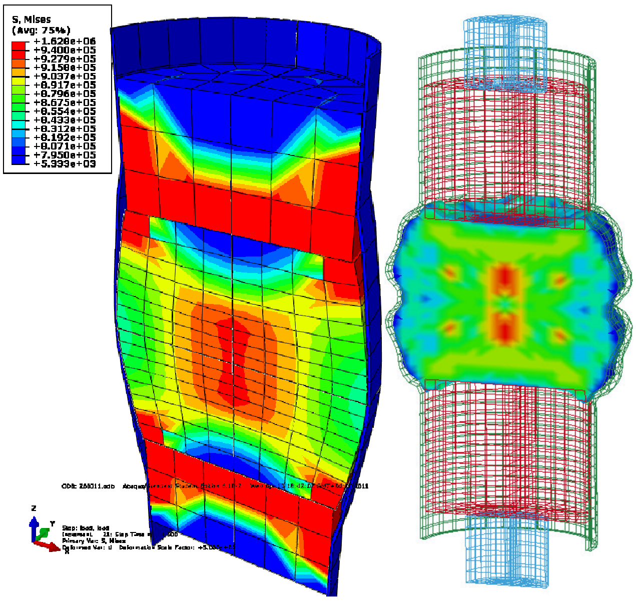

Fig. 4. Stress intensity according to Mises criterion, Pa. Left fig. – Simulia Abaqus; Right fig. – LS-DYNA [2]

All listed features are basis for deduction about the qualitative similarity in the behavior of stabilometer model and laboratory triaxial machine.

4. THE STAMP AND LATEX SHELL INFLUENCE EVALUATING

Specific differences in the behavior of stabilometer model and "ideal" stabilometer model are represented on the graphs below Fig. 5.

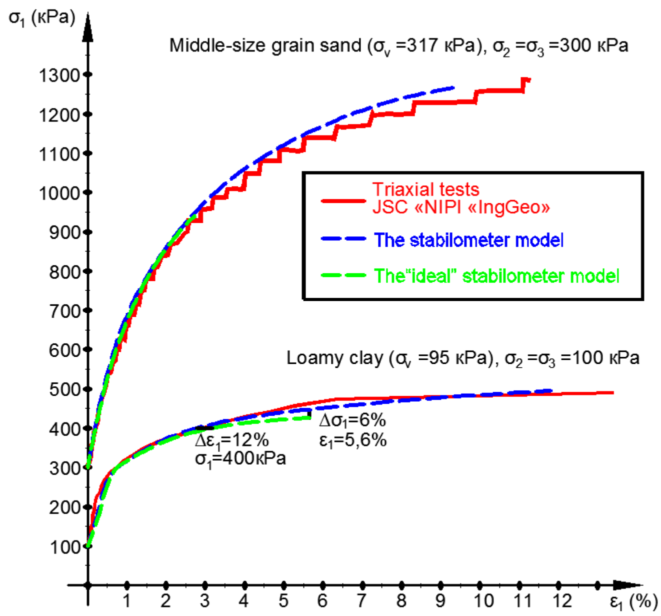

Fig. 5. Relation graph $\varepsilon_1(\sigma_1)$

As is obvious from the graphs, the sample destruction occurs significantly earlier without the influence of stamps and latex shell.

Behavioral curves of a sandy soil register an insignificant influence of stamps and shell in the stabilometer model. This type of a soil is often used as a base for high buildings pile foundations in the city of Krasnodar.

Stamps and shell influence in the system with a clay soil may comprise up to 6% in stress and 12% in strain. Therewith, loamy clay is used as a base for building foundation slabs in the constructions in Krasnodar, reaching 16-17 floors.

It is necessary to compare plastic strain in the stabilometer model and the"ideal" stabilometer model, in order to evaluate the influence of the stamp and latex shell.

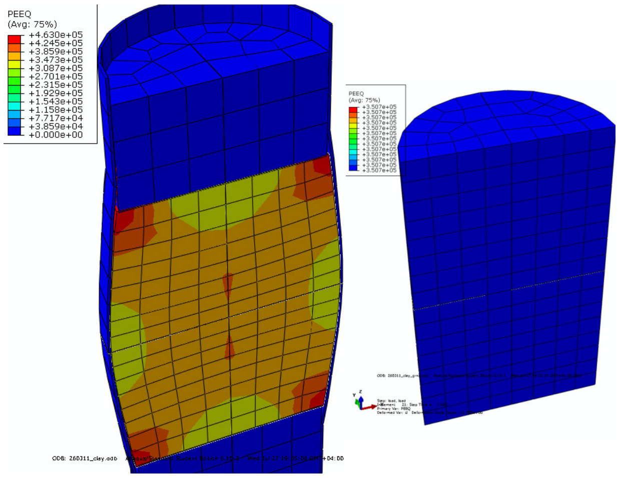

Fig. 6. Equivalent plastic strain.
Left fig. – The stabilometer model; Right fig. – The "ideal" stabilometer model

Apparently from the Fig. 6, the soil samples undergo various deformed states. Soil in the stabilometer model has a barrel-type shape, while the soil sample in the "ideal" stabilometer model has a cylindrical shape.

Moreover, intensity of plastic strain in the stabilometer model is placed in a shape of a "cross". In the "ideal" stabilometer model, intensity of plastic strain is distributed equally in the whole sample.

To summarize, it can be resumed that the stamps and shell influence is not only in quantity, but also in quality.

5. CONCLUSION

Via Simulia Abaqus program complex, a system model "stamps – soil sample – latex shell", has been simulated, which makes it possible to predict laboratory tests in the triaxial machine.

In order to detect parameters of a soil model, it is necessary to take into account stamp and shell influence by means of three-dimensional simulation of a sample testing process. Stabilizing influence of the shell and stamps enables the soil sample to describe the curve ε_1 (σ_1) of a twice length greater till the moment of destruction.

The contribution of stamps and shell considerably increases the system stiffness of "stamps, soil sample and latex shell", in case of soft soil tests (clay soil of plastic consistency, loose fine sand etc.).

The stamps and shell make quantitative and qualitative influence.

Stabilometric experimental curves represent a combined behavior of stamps, soil sample and shell. Consequently, model parameters, based on these curves, which are used for predictions of a soft soil behavior, should be applied with adjustments.

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