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3D numerical investigation of the identification test for soil liquefaction

(3D numerische Untersuchung des Identifikationsversuchs für Bodenverflüssigung)

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1.Introduction

Liquefaction is a phenomenon which is most common to occur in the loosely packed, well saturated, granular, silty soils, due to the monotonic or cyclic loading. State of the granular material transfers form a solid to liquid, as a consequence of the increase in the pore water pressure. When the pore water pressure builds up to the point when it equals the total stresses, the effective stress becomes zero. This results in total loss of the soil strength and causes every object to sink within the area subjected to quakes.

The main purpose of this research work was to develop a 2D model (Fig. 2), which replicates a newly developed simple cyclic shear test (Fig.1), in order to investigate the inner behavior of the saturated sand which is vulnerable to liquefaction when cyclically loaded in quasi-static conditions. Furthermore, the comparison of the results of the 2D model and 3D model was of interest.

2. Simple cyclic shear test

The newly developed simple cyclic shear test (Fig. 1) at the Institute of Geotechnical Engineering at the TU Dresden, uses a simple method in order to quickly evaluate the liquefaction potential of a coarse-grained soil material.

Fig. 1: Simple cyclic shear test.

The simple cyclic shear test of interest is consisted of a sand specimen installed in a rubber membrane onto the steel pedestal. The specimen is 10 cm high and its diameter is 5cm. The specimen is subjected to suction, once the installation of sand in the mould is finished. Suction, which is a negative pore water pressure, is applied to the bottom of the specimen. Lastly, the cyclic horizontal loading is applied to the specimen in undrained conditions.

3. Reference 2D numerical model

The two-dimensional numerical model (Fig. 2) is based on the simple cyclic shear test (Fig. 1). Present study adopts the finite element software TOCHNOG PROFESSIONAL for the simulations and GID program for the post-processing purposes, such as i.e. visualization or animation. The hypoplastic constitutive model with intergranular strain extension is used to represent the soil behavior in the numerical simulation. The analysis of the specimen is done for the entire specimen and for the three individual regions - top, middle and bottom respectively. The soil sample with a diameter of 5cm and a height of 10cm is discretized into equal 4-node two dimensional elements. The finite element mesh used for the simulation is consisted of 800 elements.

φ_c' [°]	h_{s0} [MPa]	n_0 [-]	e_{c0} [-]	e_{d0} [-]	e_{i0} [-]	α [-]	ß [-]
30	185	0.5	0.847	0.573	0.974	0.2	1.7

Table 1: Hypoplastic parameters by von Wolffersdorff

R[-]	m_R[-]	m_T [-]	$ß_r$ [-]	X [-]	θ [-]
0.00005	8	4	0.7	0.5	10

Table 2: Intergranular strain hypoplastic parameters by Niemunis and Herle

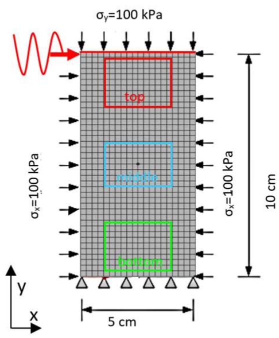

Fig. 2: Geometry and boundary conditions of the 2D numerical model

The soil sample is sinusoidally moved in x-direction with constant frequency and amplitude. Specimen is blocked only at the bottom in both x- and y-direction

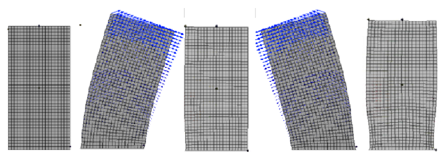

Fig. 3: Deformation mode of the 1st one full cycle

3.1 Internal behavior investigation of 2D model

There are in total five phases of interest. Each phase is characterized by the change in the mean effective stress, and the pore water pressure accordingly.

	p' [kPa]	PWP [kPa]	Δp'[%]	ΔPWP[%]	N [-]
Initial conditions	30	70	0	0	0
Phase I	24	76	20	9	2
Phase II	18	82	40	17	4
Phase III	9	91	70	30	8
Phase IV	3	97	90	39	15
Phase V	~0	~100	98	42	25

Table 3: Phases of interest

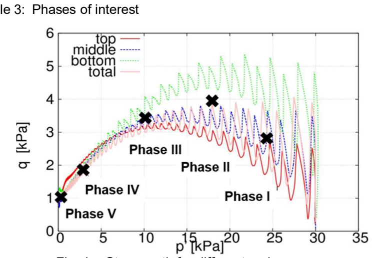

Fig. 4: Stress path for different regions

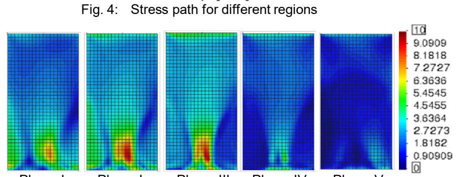

Fig. 5: Changes in the deviator stress, q (deviator part of the stress tensor)

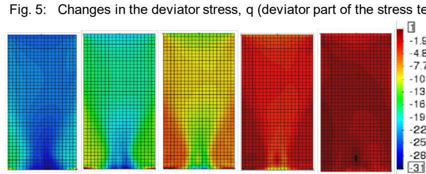

Fig. 6: Changes in the mean effective stress, p'

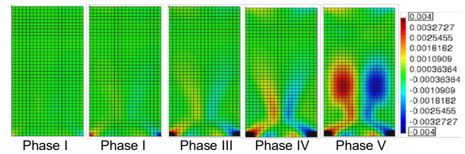

Fig. 7: Shear Strain evolution, γ

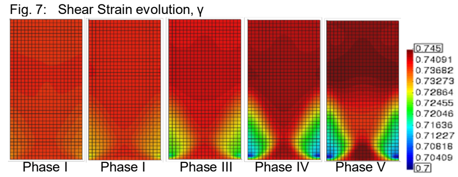

Fig. 8: Changes in the void ratio , e

4. Comparison of the 3D & 2D model

The 3D model (Fig. 9) is compared to the 2D model with the reference to the total volume of the specimen. 3D model adopts the same conditions as the 2D model. For this, the two-dimensional model is extended with one more dimension and converted into the three-dimensional model.

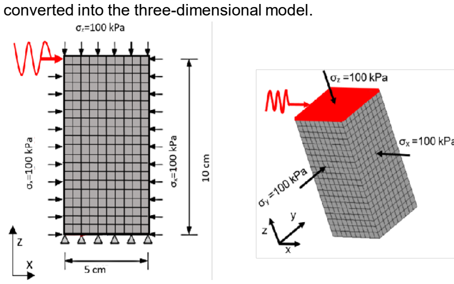

Fig. 9: Geometry and boundary conditions of the 3D numerical model

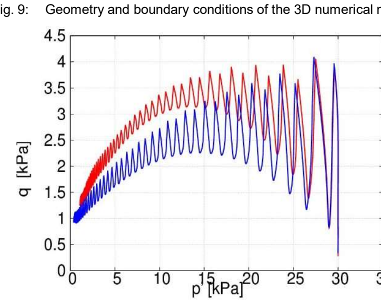

Fig. 10: 2D model & 3D model comparison – stress path

5. Summary

The simulations done on the 2D numerical model show the qualitative correspondence of the specimen behavior with the experimental procedure. The representation of the controlling parameters, such as distribution and magnitude of e.g. stresses, pore water pressure, is preserved according to the loading conditions.

The comparison of the results of the 2D model with the 3D model shows that the overall response of the 2D model and the 3D model differs quantitatively but shows the same qualitative response.

Projekt
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