TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Bauingenieurwesen
Institut für Geotechnik
Professur für Bodenmechanik und Grundbau

NUMERICAL CALCULATION OF PWP BUILD-UP IN A LAMINAR BOX SYSTEM

NUMERISCHE BERECHNUNG DES PORENWASSERDRUCKAUFBAUS IM LAMINAR-BOX-SYSTEM

NGUYEN HA KHA

Introduction

A numerical analysis of pore water pressure (PWP) build-up from the laminar box test, a type of shaking table test was studied, investigating the effect of a variety of factors on the liquefaction susceptibility such as relative density, shaking amplitude, degree of saturation, permeability, and grain size distribution. The advanced constitutive model to simulate the behavior of sand adopted in the work is hypoplasticity with intergranular strain

Laminar Box System

The main advantage of this laminar box version is its flexibility compared to previous rigid boxes, simulating the free field condition, and minimizing boundary effects. the laminar box system is comprised of aluminum frames with roller bearings and a flexible membrane to contain the sand with internal dimension of 1m x 0.6m x 0.75m. The main components are a base plate with a supporting frame, laminar layers, and a flexible membrane. The laminar layers consist of 15 layers of rectangular aluminum frames with 2mm clearance to allow for independent movement of frames like a shear beam, while fixed rigidly at the base. The last essential component of the laminar box is the membrane, which acts as a watertight shear box, holding the sand and water, while restricting their direct contact with laminar box

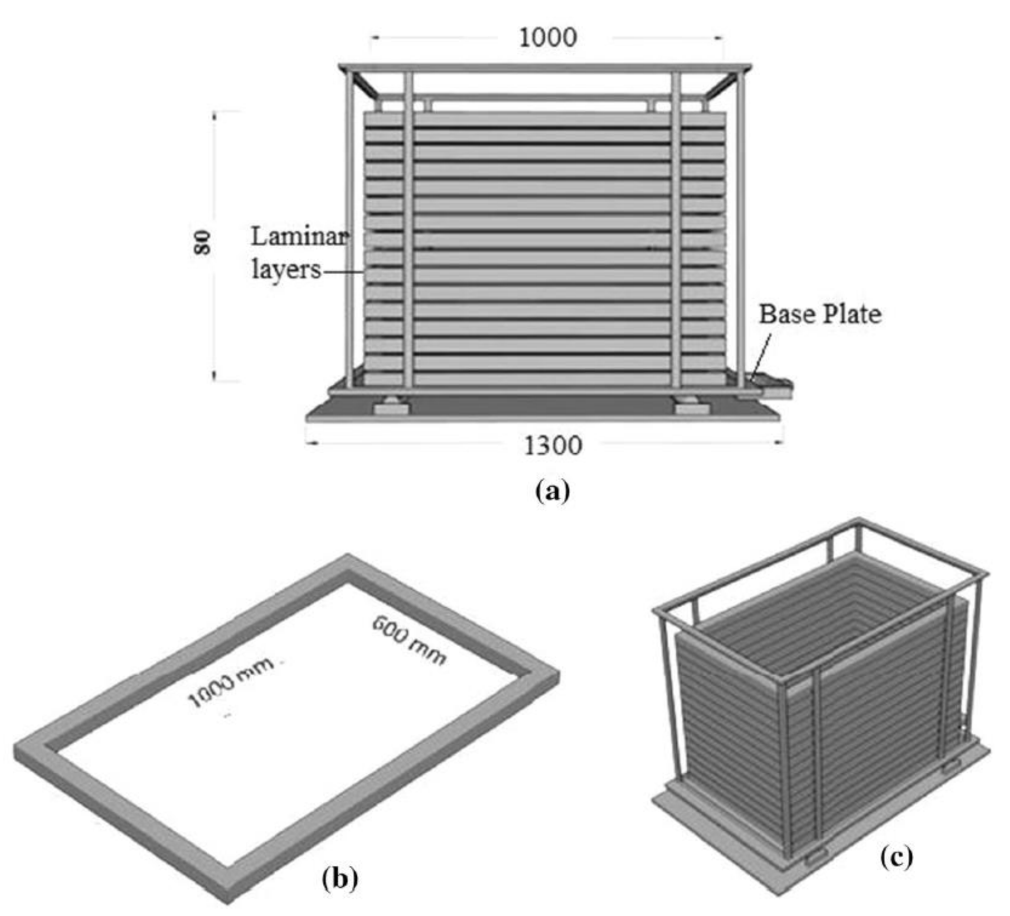

Fig.1: Laminar box system components: a) front view, b) laminar layers, c) 3D view

Numerical model

The numerical simulation (2D model) has been carried out using the finite element Tochnog program. The boundary condition corresponds to the laminar box system

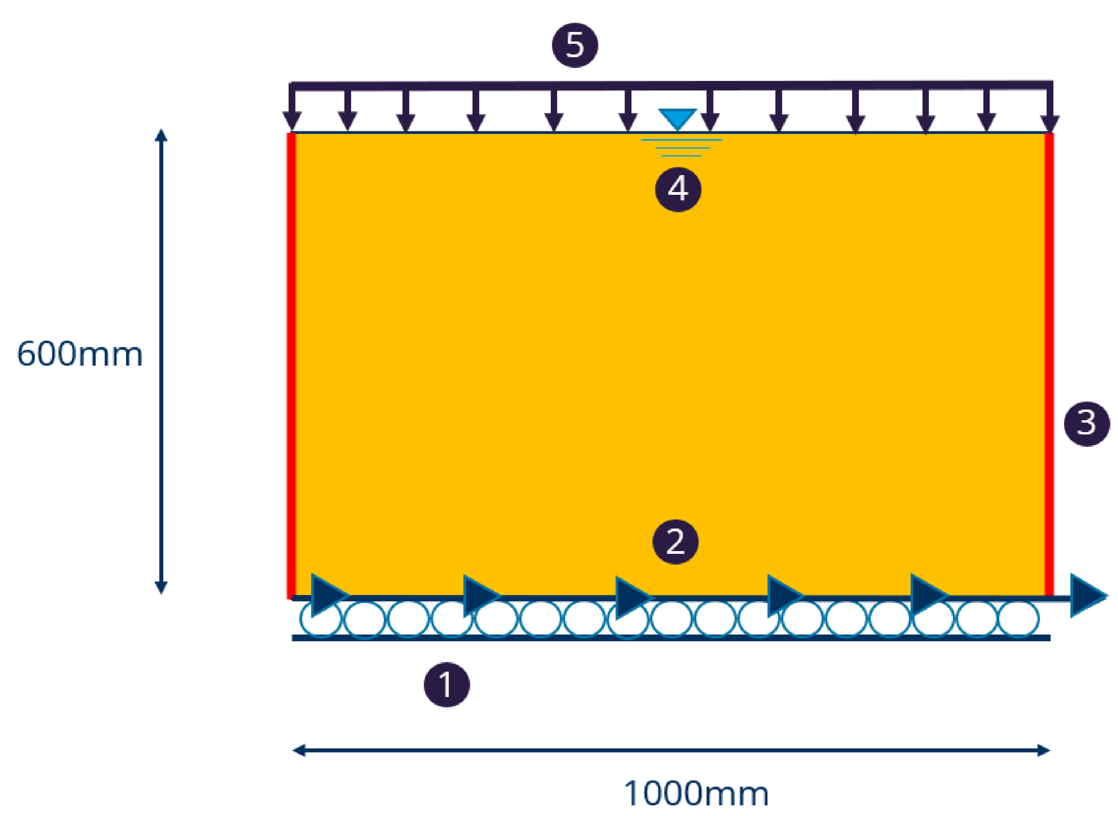

Fig. 2: Laminar test box modelling and boundary conditions.

Influence of relative density

Lower density leads to faster build-up of EPWP. the difference is very minimal because the EPWP build-ups occur immediately. In addition, as the relative increases, the stability of the simulation also improves.

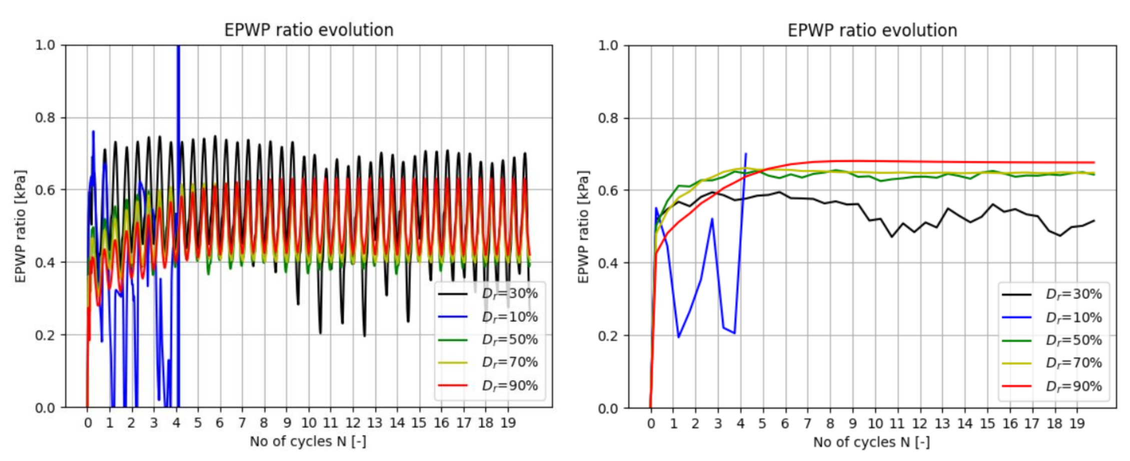

Fig. 3: EPWP build-up for soil with different relative density

Influence of base shaking amplitude

Shaking amplitude representing earthquake magnitude is an important factor to investigate. Simulation with different shaking amplitudes of 0.1g, 0.16g and 0.2g have been carried out, where the sinusoidal velocity was used as input.

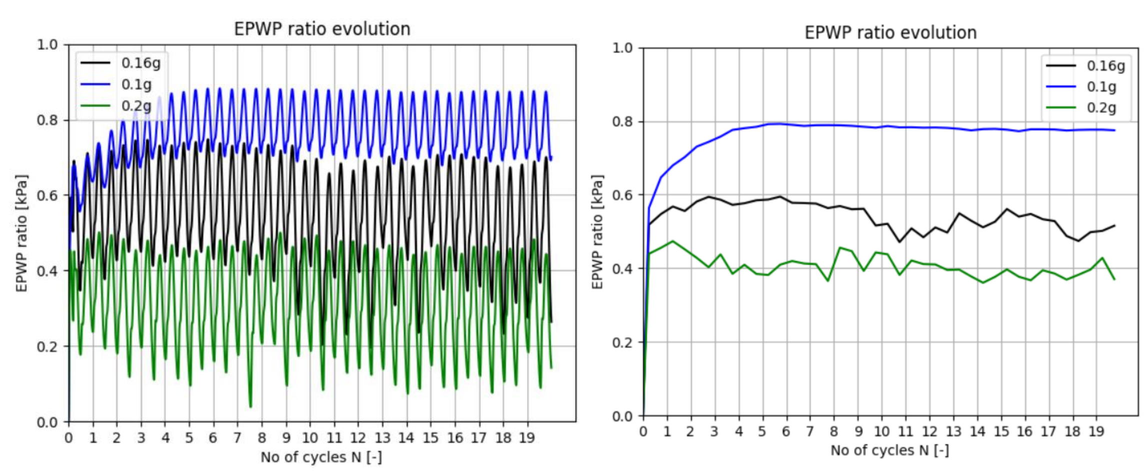

Fig. 4: EPWP build-up for soil with varied base shaking amplitude

Influence of degree of saturation

A series of simulations with different degree of saturation have been performed to study the corresponding effects.

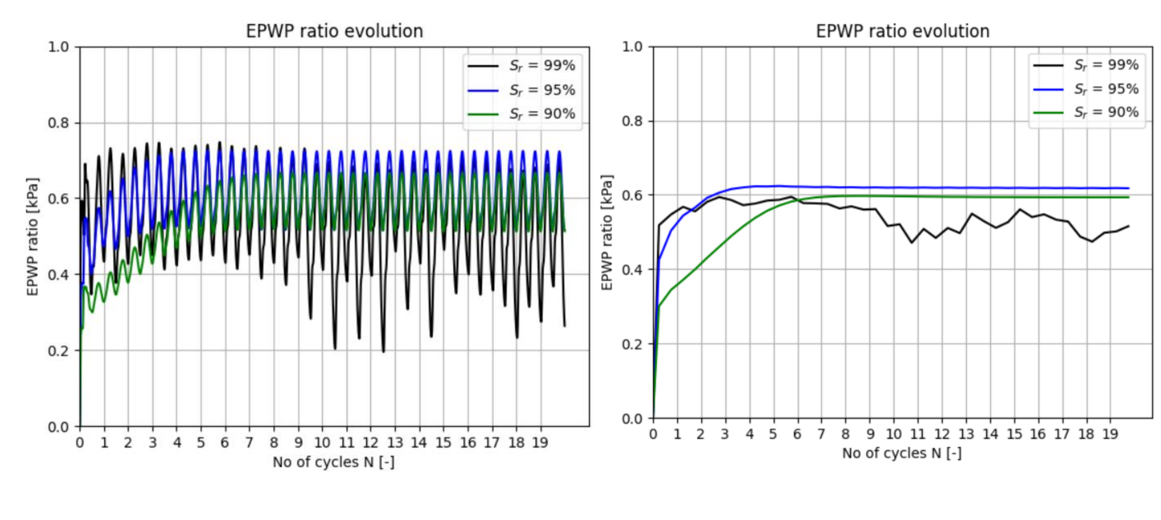

Fig. 5: EPWP build-up for soil with varied base shaking amplitude.

Influence of permeability

Conducting a series of simulations varying the permeability can provide a possible prediction of the effect on the dynamic behavior of sand in terms of EPWP

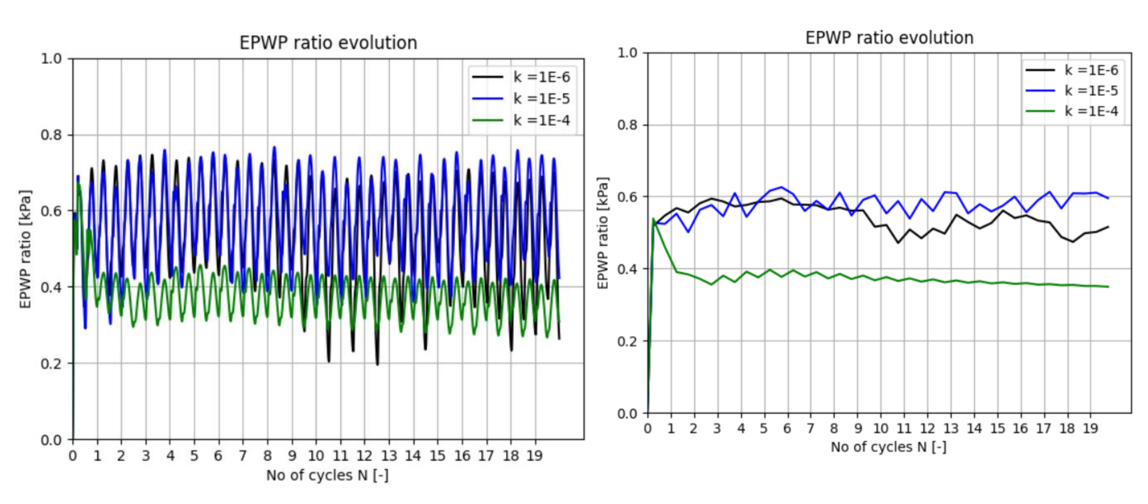

Fig. 6: EPWP build-up for soil with varied permeability.

Influence of grain size

The mean grain size has a strong impact on the generation of pore water pressure.

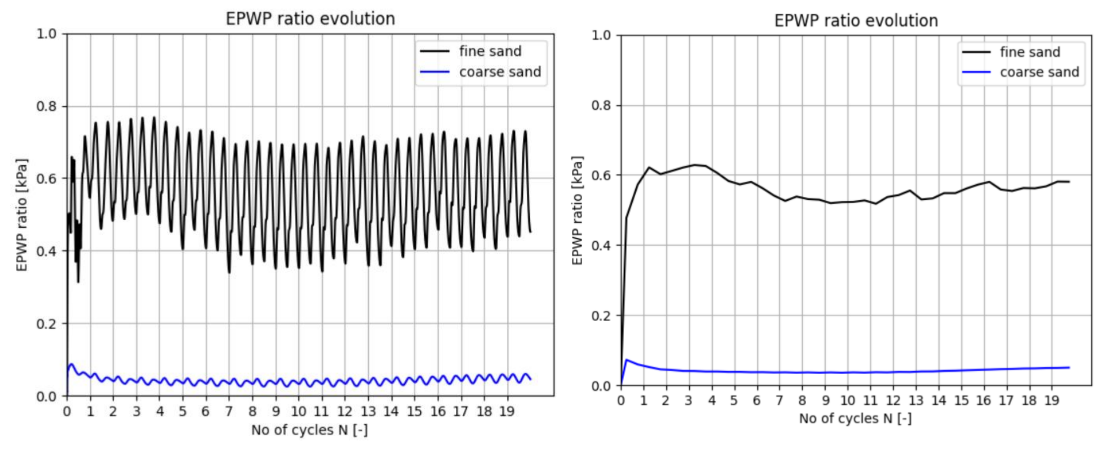

Fig. 7: EPWP build-up for soil for coarse and fine soil

Influence of stochastic distribution of void ratio

Hypoplastic model incorporates void ratio as a state variable, which facilitate the investigation of the effect of heterogeneity of void ratio distribution in the soil body on the liquefaction susceptibility

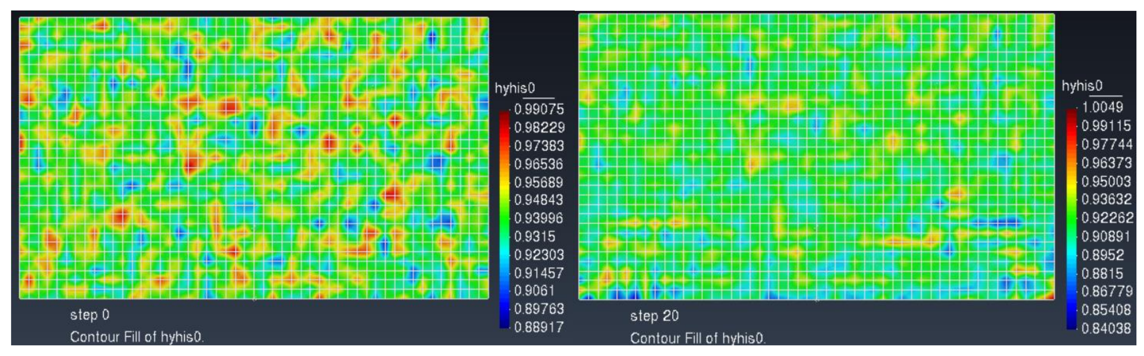

Fig. 8: Void ratio distribution at the start and final stage of test

Summary

The numerical simulations of the laminar box system featuring different varia-bles and factors has yielded some useful information regarding the test itself as well as confirmation or possible refutation of some common observations at least in the context of the test.

Testing soil under low stress condition may yield unreliable outcomes of the soil behaviour. Too low stresses render the simulation unstable and hence, cause the larger oscillation of PWP, possibly bringing the soil to tension side, which is unrealistic.

There is a strong correlation of the stability of the simulation and the capability of the soil to develop EPWP up to liquefaction state.

Contrary to observation in the earlier studies from the laboratory tests or field, higher shaking amplitude may trigger lower EPWP build-up but higher surface settlement. Notably, most of the simulations cannot reach the liquefaction state.

Full degree of saturation is hard to implement during the preparation. Failure to ensure consistent degree of saturation may jeopardize the reproducibility of the tests. Lower degree of saturation also shows to increase the time for soil to build up the PWP.

Virtually no difference in the behavior of soil with uniform relative density and soil with stochastic distribution of relative density is observed in the simulation.

Project
Master's Thesis

Professor
Univ.-Prof. Dr.-Ing. habil. Ivo Herle, TU Dresden

Supervisors
M.Sc. Bozana Bacic, TU Dresden

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