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Modelling of Large Deformations in Geotechnical Engineering

Abstract

Numerical models are widely used to predict structural behaviour. However, in geotechnical simulations soil deformations can be large, which are difficult to model with traditional Finite Element Methods. To tackle these challenges, Updated Lagrangian (UL) schemes and the Material Point Method (MPM) were used to model such deformations.

Laboratory test

A small scale soil slope was built on a shaking table in order to investigate soil liquefaction.

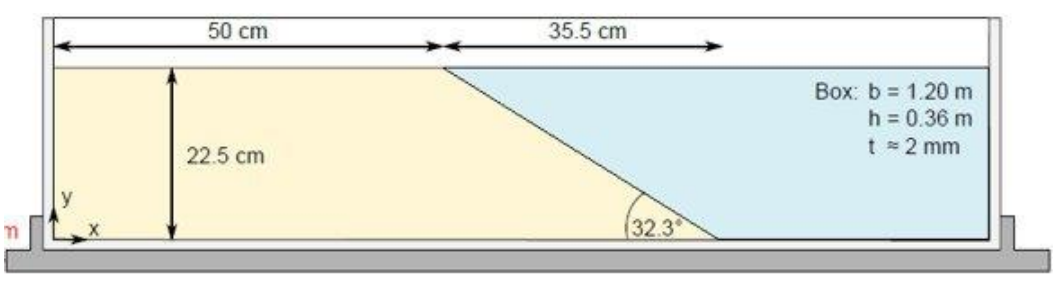

Fig. 1 Slope geometry

The liquefaction only occurs if the soil is in a loose state, fully saturated and experiences a dynamic load, *e.g.*, during an earthquake.

UL Scheme

The experiment was modelled using the Updated Lagrangian Method using the NumGeo software:

- A 2D model was created assuming plain strain conditions.
- After introducing geostatic conditions, the same dynamic excitation as in the laboratory test has been applied.
- Fig. 2 shows horizontal displacements of the slope. Its failure occurred similarly as in the laboratory test.
- The top image shows the displacements with a friction coefficient of $\mu = 0.1$, and the bottom image with $\mu = 0.3$. With the increase of friction, the displacements reduced.

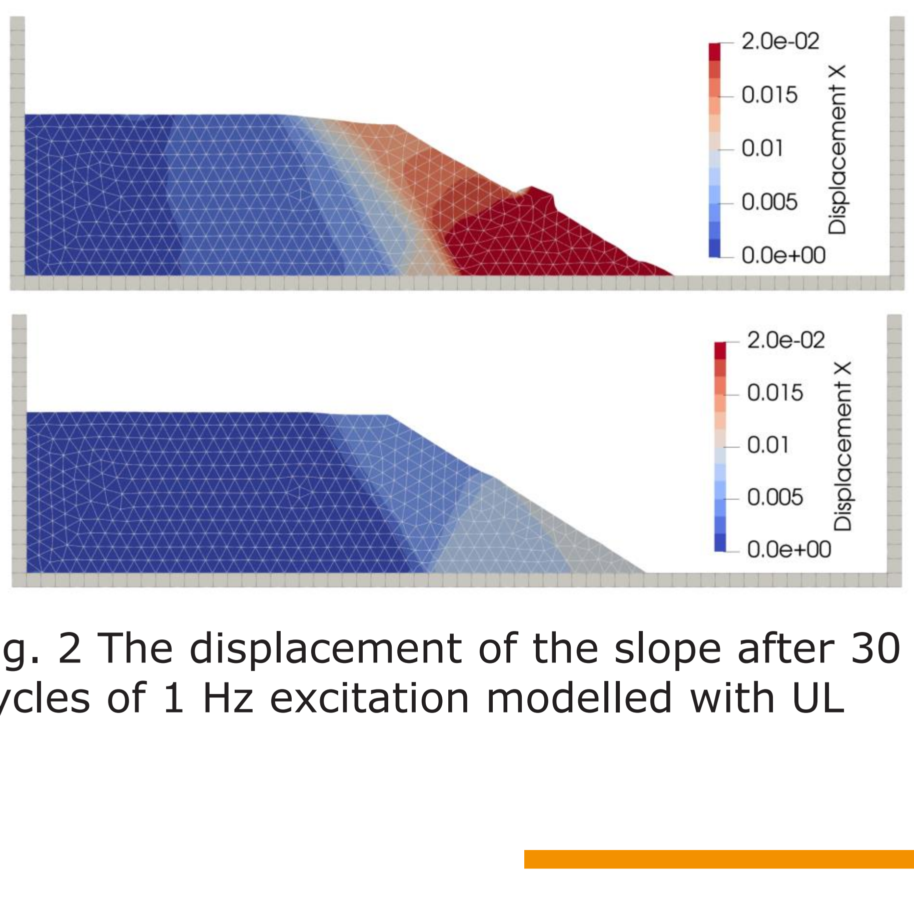

Fig. 2 The displacement of the slope after 30 cycles of 1 Hz excitation modelled with UL

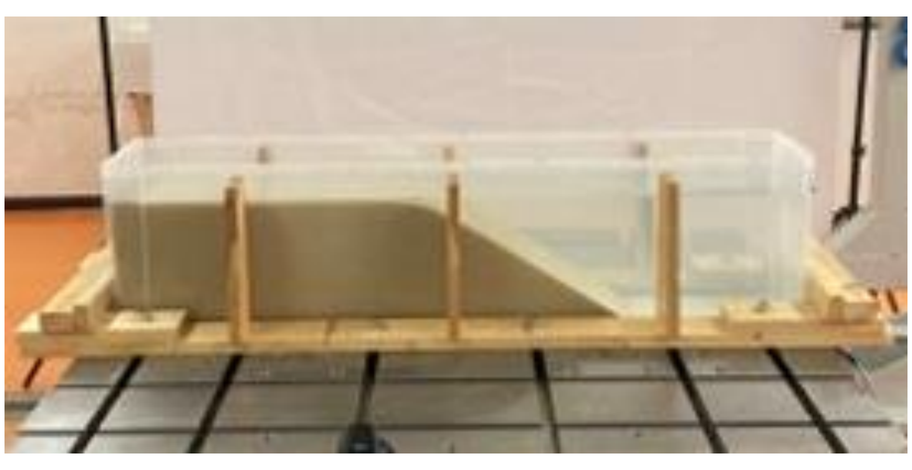

Fig. 3 Small scale physical model

MPM

The Material Point Method is used to simulate the behaviour of the continuum under large deformations.

An inhouse code, called Material Point Analysis Program, was adopted, which is using material points instead of conventional Gauss points, such that material points can move through the mesh. Von Mises material, 2x2cm mesh and strength reduction were used for modelling the large deformations of the sand slope.

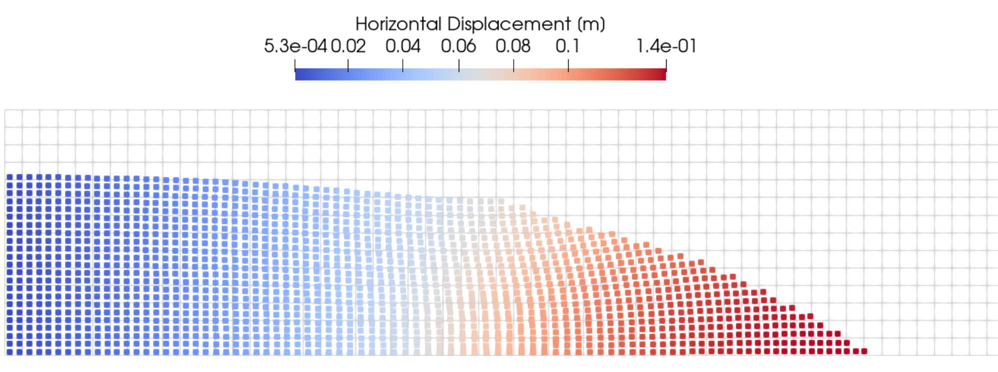

Fig. 4 Slope under large deformation in x-direction

In Fig. 4 the horizontal deformations calculated by the MPM model can be seen. Compared to the UL scheme, MPM is more suitable to simulate large deformations in this model.

Conclusions

Small scale models (physical and numerical) were used to analyze large deformations. Some conclusions can be drawn:

- Some phenomena in geotechnics are difficult to model by means of small scale physical models (1*G*) and numerical models
- Using Updated Lagrangian schemes many difficulties in standard FEM methods (*e.g.*, mesh distortion) can be overcome
- Material Point Methods are a powerful tool to model geotechnical problems with large deformations.

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