Adaptive Finite Cell Method for Tunnel Engineering Simulation

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ABSTRACT

The finite cell method (FCM) is an effective fictitious domain technique to incorporate boundary descriptions into numerical simulations by penalizing the strain energy outside the physical domain. This proves to be very suitable for tunnel advancement simulations allowing to alter the track design during the planning phase.

In our work, the computational efficiency of the finite cell method is enhanced by using adaptive mesh refinement (AMR) on a structured mesh. In addition, on cut cells, the material points are reduced by employing a moment-fitting based technique. This approach is expected to provide more accuracy in the vicinity of the boundary, yet is more reliable by avoiding the small cut fractions, which can lead to the deterioration of the condition number of the resulting stiffness matrix.

In our model, we study the effect of the tunnel excavation process to the surface infrastructure by incorporating buildings on the ground. The tunnel geometry is included in the model via employing FCM with a background soil mesh. The volumetric building geometries are generated automatically from the surface CAD data, obtained from public cloud services, and then connected to the ground mesh by using mesh tying technique based on the mortar method. The ground is assumed to be fully saturated and modelled by means of the mixture theory, with the constitutive relation of the soil skeleton governed by the Mohr-Coulomb law.

The talk is concluded by presenting representative benchmarks to validate the AMR concept for finite cell method and synthetic examples of tunnel simulations.

REFERENCES

[1] Düster A., Parvizian J., Yang Z., and Rank E. The finite cell method for three-dimensional problems of solid mechanics. *Comput. Methods Appl. Mech. Engrg.* (2008) **197**:3768-3782.

[2] Schillinger D. and Ruess M. The Finite Cell Method: A Review in the Context of Higher-Order Structural Analysis of CAD and Image-Based Geometric Models. *Arch. Computat. Methods Eng.* (2015) **22**:391-455.

[3] Kasper T. and Meschke G. A 3D finite element simulation model for TBM tunnelling in soft ground. *International Journal for Numerical and Analytical Methods in Geomechanics.* (2004) **28**:1441–1460.

[4] Nagel F. and Meschke G. An elasto-plastic three phase model for partially saturated soil for the finite element simulation of compressed air support in tunnelling. *International Journal for Numerical and Analytical Methods in Geomechanics.* (2010) **34**:605–625.