A novel systematic method to estimate the contact parameters of particles in discrete element simulations of soil

Roy Lichtenheldt*

* German Aerospace Center (DLR)
Institute of System Dynamics and Control
Münchener Straße 20, 82234 Wessling, Germany
e-mail: Roy.Lichtenheldt@dlr.de, web page: http://www.dlr.de/sr

ABSTRACT

Recent advances in simulation of granular matter and computation hardware let the discrete element method (DEM) evolve into the field of dynamic simulation of soils, enabling to simulate physical effects of soil deformation at particle interaction-scale. However, DEM is still lacking a generally accepted method to determine material-specific but application-independent particle contact parameters. Common parameter estimation approaches are based on calibration by preliminary parameter estimation simulations, which need to be updated for every new model and soil. Other strategies are based on experience [1,2] but lack the adaption to geometric properties of the simulation domain and the particular load situation. Often both strategies are combined in order to lower the number of parameters to be calibrated. In this article a novel, systematic method to directly determine the contact parameters of the particles is proposed. These parameters are divided into two groups: 1) independent parameters whose values are measurable, real soil properties and 2) dependent parameters whose values are set according to sufficient, modeling-intrinsic requirements.

Dependent parameters do not directly affect the shear strength of the granular material, they are: particle-size and size distribution, normal and tangential stiffness/damping related parameters, as well as the particle inertia tensor and mass. Since the shear strength sensitivity is low, their values can be chosen according to computational efficiency aspects only: sufficiently high but as low as possible. This choice is done by empirical equations based on other contact-, simulation domain- and load-parameters (e.g. particle's YOUNG's Modulus or particle size by tool-particle resolution).

Independent parameters are directly influencing the shear strength of the simulated soil. In the contact model described in [3] these are: grain shape aspect ratio, inter-particle friction, tool-particle friction and particle density. In order to avoid complex measurements of unknown parameters, e.g. inter-particle friction, look-up tables of outputs from DEM-simulated standard soil tests (triaxial test, Bevameter tests) at variation of the unknown parameters are prepared. The corresponding result of the identical but physical test applied to the real soil is then mapped onto the computed look-up table. The best match is found by minimizing the difference of real and computed test output graphs with help of optimization strategies. The identified optimum defines the set of unknown parameters.

With the proposed parameter estimation strategy, the number of parameters which actually need to be chosen by look-up tables has been decreased to one single parameter. Additionally, the look-up table is only computed once and reused for every new type of soil. Thus the method is time efficient and does not repeatedly need preliminary calibration simulations. Using this strategy the time required to develop a mature and valid model is drastically reduced. In the article the parameter setting method is exemplified for a quartz sand, used to simulate the impact-driven penetration of the HP^3-Mole. A proof of the validity of the proposed parameter estimation method is given by corresponding experimental measurements.

REFERENCES

[1] T. Tsuji et al., "3-D DEM simulation of cohesive soil-pushing behavior", *Journal of Terramechanics*, **49**, (2012).

[2] M. Obermayr, *Prediction of Load Data for Construction Equipment using the Discrete Element Method*, Dissertation, University of Stuttgart, (2013).

[3] R. Lichtenheldt and B. Schäfer, "Planetary Rover Locomotion on soft granular Soils - Efficient Adaption of the rolling Behaviour of nonspherical Grains for Discrete Element Simulations", *3rd International Conference on Particle-Based Methods*, 807-818, ISBN 978-84-941531-8-1, Stuttgart (2013)