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Dependence of the Discrete Model on the Internal Parameters Considering Grain Crushing

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Abstract: For a correct representation of the ballast material behaviour in discrete element method (DEM) it is necessary to take into account crushing of grains. The representation of crushing phenomenon is based on the replacement of the original grain by a clump of 4, 6 or 14 spheres. The replacement occurs when the equivalent stress exceeds the size dependent material strength. The crushing model depends on the material parameters such as sphere radius, reference material stregth, friction angle, etc. From the simulated experiments it is clear that the behaviour of the presented approach depends also on the non-material parameters. The inluence of these parameters, namely the loading frequency and the time period of crushing condition check, is studied in the paper.

Introduction

The model under investigation is the DEM simulation of the oedometric test which was performed at Nottingham university by Lim [1]. The dimensions of the tested cylindrical specimen are 300 mm in diameter and 150 mm in height. The cylinder is fully filled with spheres which represent the ballast grains. The size of grains is 32.5 mm in diameter. The specimen is vibrated and then loaded by a compressive force in a cycle. The loading cycle proceeds according to a sine function. The loading starts at force 0.0 N and reaches in the maximal compressive force of 1.5 MN. During the loading the sphere crushing is allowed. The crushing occurs when some equivalent stress in the grain, σ_e [2] (here determined as von Mises stress computed from fabric stress tensor [3,4]) exceeds the material strength f_t. The grain is then replaced by several smaller spheres [5].

Effect of internal non-material parameters

The results of the simulated oedometric test are affected by both the speed of loading (frequency) and the time period after which the crushing condition is repetitively checked (we call this parameter *period of crushing*). Several initial configurations of spherical grains in the oedometer were prepared. Each of them was then repetitively used for simulations using all considered combinations of studied parameters. For evaluation of effect of the internal non-material parameters low value of the reference strength f_{t0} = 3000 MPa is chosen to get a large amount of crushed grains.

The first investigated parameter is the influence of the loading frequency F. The study is performed by changing of the load increment in time step. The applied loading frequencies are F = 0.25, 0.5, 1.0, 2.0, 4.0 and 8.0 Hz. Ten simulations for each frequency are calculated, but for a clarity only the results of 5 selected simulations are shown in Fig. 1a. From the graph in Fig. 1a we conclude that average behaviour of the simulation is not influenced by loading frequency. This statement is limited only to the studied range of frequencies, we expect change of the behaviour when the frequency becomes significantly larger.

The next investigated parameter is the influence of the period of crushing. This parameter should not have any effect on the results because it does not have any physical meaning. In the simulation, the

crushing condition is checked in the discrete virtual time intervals (periods). These periods range from 0.04 s to $2 \cdot 10^{-5}$ s, and also the simulation when crushing is checked every time step is considered. 60 simulations are computed for each period. The graph in Fig. 1b shows the dependence on the period of crushing. The results have a huge variability, but the mean values, represented by blue circles, are almost constant for all periods $t < 0.005$ s.

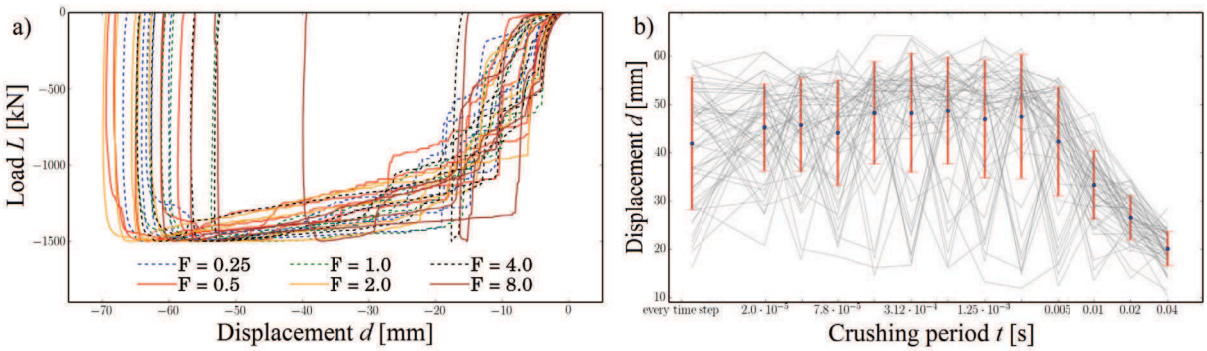

Fig. 1: Graphs of investigated non-material parameters: a) dependence of L-D diagram on the loading frequency, b) dependence of the displacement at the maximal force on the period of crushing.

Summary

Two performed studies imply that the results of a system (oedometric test) which contains large amount of crushing discrete elements are not dependent on the loading frequency. On the other hand the study of dependence on period of a crushing condition shows the undesirable dependence when the period is large. It is necessary to set the period small enough to reach such a state for which the dependence on the period is supressed.

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