Investigations of vortex structures in granular materials under earth pressure conditions by DEM

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ABSTRACT

Vortex-like flow patterns (swirling motion of granulates around its central region) often are observed in experiments on granular materials. These deformations become apparent when the motion associated with uniform strain is subtracted from the total particle motion. They are reminiscent of turbulence in fluid dynamics, however the amount of the cells rotation is several ranges of magnitude smaller (~0.01^o-0.1^o) then fluid vortex rotation. The mechanisms ruling the creation and diminishing of vortices in granular bodies are not fully recognized yet.

The paper presents some simulation results on vortex structures for sand under quasi-static passive earth pressure conditions with a translating rigid wall using the discrete element method (DEM). A three-dimensional spherical discrete element model YADE was used which was developed at University of Grenoble [1]. The model takes advantage of the so-called soft-particle approach (i.e. the model allows for particle deformation which is modelled as an overlap of particles). The shape of sand grains was approximately modelled with spheres including contact moments [2], [3]. The 2D calculations were carried out with initially dense sand. The global results by DEM were compared with the experimental results. In order to mathematically describe a vortex in granular shear zones, 3 different methods were used: 1) based on the mean pure rigid body rotation, 2) based on tangential displacement fluctuation vectors of neighbouring single spheres and c) based on orientation angles of displacement fluctuation vectors of neighbouring single spheres. The last one [4] turned out to be the most effective method. The evolution of vortex structures was combined with the evolution of local changes of void ratio, grain rotations, grain displacements and force chains.

The major contribution of the discrete simulation analyses is the numerical evidence of the correlation between a location of vortex structures and force chains and the estimation of the frequency of the vortices and anti-vortices appearance within granular shear zones.

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