# Microscopic features of liquefaction due to cyclic straining

Colin Thornton*[1]

[1]University of Birmingham [Birmingham] – United Kingdom

**Abstract**

Most researchers who have examined liquefaction, both experimentally and numerically, have applied stress cycling that, post initial liquefaction, results in 'cyclic mobility' and 'butterfly-shaped' stress paths. It will be argued that this is inappropriate, non-physical and leads to artificial results. Instead, we present DEM simulations of liquefaction resulting from cyclic straining.
To perform the simulations here described, the open source software YADE was employed. The DEM simulations were performed on dry granular assemblies, *i.e.* the fluid phase was ignored and all stresses were calculated from the orientational distributions of forces at the contacts between particles. Consequently, the effective stresses were calculated directly. This contrasts with laboratory experiments in which the total stresses and the pore water pressure are measured, and the effective stresses are obtained indirectly using Terzaghi's effective stress equation.

The contact law used in the tests here presented is the Hertz-Mindlin no micro-slip solution. The model considers nonlinear compression, linear rotational resistance, nonlinear tangential shearing with a Mohr Coulomb slip criterion, and nonlinear viscous damping in both the normal and tangential directions. The normal force is computed at each time step from the current overlap between two grains in contact. The tangential force, on the other hand, is updated incrementally. The rolling moment between two contacting particles is limited to a maximum value given by hR , whereas no limit is applied to the twisting moment.

Following the presentation of the macroscopic behaviour, it is shown that the onset of liquefaction occurs when the mean effective stress approaches zero and that at this point the system is isostatic with a redundancy index of one, a geometrical coordination number of two and a mechanical coordination number of three.

A cluster is a group of particles in contact at any given timestep throughout the simulation. The cluster size is defined by the number of particles in the cluster and the number of clusters includes singlets. As the mean effective stress decreases, the magnitude of the normal contact forces reduces. With continued decrease in the mean effective stress an increasing number of contact normal forces reduce to zero and contacts are lost and the maximum cluster size gradually reduces at an increasing rate.
Illustrations are provided to show the particle assembly at the onset of liquefaction, when the mean effective pressure is momentarily null and the redundancy index $IR = 1$. The figures show the complete arrangement of particles, the largest remaining cluster and the

*Speaker

force chain network within the largest cluster. Interestingly, the figures suggest that the loss of contacts is uniformly distributed throughout the assembly and that there is no breakup of the large cluster into smaller clusters, as in the case of fluidised beds. It emerges that, during the degradation of the initial large cluster, only singlets are created increasing the number of 'rattlers'. This appears to be a good example of diffuse failure.

**Keywords:** Discrete Element Methodd, liquefaction, cyclic straining