Using Delaunay triangulations to investigate the effect of interparticle friction on critical-state DEM simulations

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ABSTRACT

It is now broadly accepted that failure in a granular material is dominated by buckling failure of strong force chains oriented in the direction of the major principal stress [1]. A recent parametric study [2] sheared granular soils, simulated using the discrete element method (DEM), to critical state using different values of interparticle friction coefficient (μ). The stability of the strong force chains was found to increase with increasing μ while the supporting weak contact network develops only at low values of μ [2]. In this paper, Delaunay triangulation is used to explore this result further. A numerical sample was created in 3D by randomly placing 20,164 polydisperse spherical particles within a periodic cell before isotropic compression to 100 kPa. The interparticle friction coefficient of the resulting stable isotropic assembly was changed to 0, 0.1, 0.25, 0.5, 0.75 or 1. Each of these six samples was subjected to drained triaxial shearing to an axial strain sufficient to reach critical state (around 54%). The contact network was obtained at the end of each simulation by joining the centroids of the contacting particles. Voro++ [3] was used to compute two types of periodic Voronoi tessellation of the particle centroids: the conventional unweighted tessellation and the radical tessellation which is weighted by particle diameter. These were converted to their Delaunay duals to facilitate direct comparison with the associated contact networks.

The numbers of edges (i.e., contacts) that are in the contact networks decrease consistently as μ is increased towards 1. This contrasts with the numbers of edges, faces or tetrahedra in the Delaunay triangulations, all of which increase with increasing μ up to μ = 0.25 and become approximately constant thereafter. The existence of a threshold beyond which the system shows little sensitivity to μ is also reported by [2]. Two quantities were defined: the percentage of faces in the triangulation comprising three contacts (P_{fc}) and the percentage of tetrahedra comprising six contacts (P_{tc}). P_{fc} shows a linearly-decreasing trend with increasing void ratio and both P_{fc} and P_{tc} decrease continuously as μ is increased; this provides additional evidence for the observations that triangular motifs become less widespread as friction increases [4] and that a weak supporting network develops during shearing only at low μ values [2].

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