Discrete Element Stress Analysis of Idealized Granular Geometric Packing Subjected to Gravity

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This paper presents discrete element analysis (DEA) models for studying quasi-static stress states in idealized granular materials subjected to gravity, and utilizes geometric packings and contact mechanics. Discretization of granular materials acts to characterize initial conditions for use in solving particle equations of motion, where transient force propagation occurs through dissipative inter-particle interactions. Using the DEA features available in LS-DYNA, idealized assemblies of spherical discrete elements are investigated to gain insights into the influence of packing density on quasi-static stress distributions (within an explicit time domain). The theoretical description of granular materials in assemblies of microscopic particles is a challenging task. The validity of such an initialization, as to whether the theoretical assemblies can simulate granular fabrics, is an open question and still debatable. The present study is, however, strictly focused on modeling disordered structures of idealized granular assemblies using dynamic packing methods. The relative density states of such disordered structures are accounted for in relation to the extremes of discrete (numerical) mass density, and specifically, through use of coordination numbers. Various geometric packings provide a means of controlling the coordination number, which is used as a model parameter of micro-mechanical contacts between discrete spheres. Cataloged coordination numbers, considered along with microscopic contact properties (i.e., inter-particle frictional resistance), are used to numerically simulate interlocking behaviors among granular particles, and subsequently, predict macroscopic shear strengths of packing assemblies. As a result, a parametric matrix of microscopic contact properties is developed, and (numerical) direct shear tests are carried out to quantify a macroscopic internal friction angle for each packing assembly. In addition, constrained chamber test simulations are performed to qualitatively characterize in-situ geostatic stress states, and comparisons are made to existing empirical correlations used in geotechnical engineering practice. Finally, the volume-averaged stresses over a control volume of the granular mass are analyzed and presented as numerical coefficients of lateral pressure of idealized granular masses at rest.