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Liquefaction of fluid-saturated granular material under shear

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The coupled mechanics of fluid-filled granular media controls the physics of many Earth systems such as saturated soils, fault gouge, and landslide shear zones. It is well established that when the pore fluid pressure rises, the shear resistance of fluid-filled granular
systems decreases, and as a result catastrophic events such as soil liquefaction, earthquakes, and accelerating landslides may be triggered. Alternatively, when the pore pressure drops, the
shear resistance of these geosystems increases. Despite the great importance of the coupled mechanics of grains-fluid systems, the basic physics that controls this coupling is far from understood. Fundamental questions that need to be addressed are what are the processes that control pore fluid pressurization and depressurization in response to deformation of the granular skeleton? and how do variations of pore pressure affect the mechanical strength of the grains skeleton? To answer these questions, a formulation for the pore fluid pressure and flow is developed from mass and momentum conservation, and is coupled with a granular dynamics algorithm that solves the grain dynamics, to form a fully coupled model. The pore fluid formulation reveals that the evolution of pore pressure obeys a viscoelastic rheology in response to pore space variations. Elastic-like behavior dominates with undrained conditions and leads to a linear relation between pore pressure and overall volumetric strain. Viscous-like behavior dominates under well drained conditions and leads to a linear relation between pore pressure and volumetric strain rate. Numerical simulations reveal the possibility of liquefaction under drained and initially over-compacted conditions, which were often believed to be resistant to liquefaction. Under such conditions liquefaction occurs during short compactive phases that punctuate the overall dilative trend. In addition, the more established generation of elevated pore pressure under undrained compactive conditions is observed. Simulations also show that during liquefaction events stress chains are detached, the external load becomes completely supported by the pressurized pore fluid, and shear resistance vanishes.