Computer Simulations of Granular Materials

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The mechanical properties of amorphous materials are a result of many-body, complex and collective phenomena at the level of the constituent particles that make up the solid. Yet, on an everyday level, only macroscopic, bulk behavior is often investigated. To connect between between particle scale properties and bulk behavior requires information spanning multiple length scales. Granular materials present as a prototypical, disordered solid exhibiting features often found in myriad disordered solids far from thermodynamic equilibrium. As such granular materials allow us to bridge the gap between length scales and explore themes common to a wide range of environmentally, industrially, and technologically relevant materials. A primary property of a material is its mechanical stability. One common method to probe mechanical properties of a granular system involves applying localized force perturbations then extracting the resulting static stress profile in response to the perturbation. Such methods are sometimes referred to as the Green Function technique. Although results for elastic solids are well known, it turns out that granular packings exhibit a range of stress response profiles that span the gamut of possibilities. Ranging from traditional, linear, isotropic, elastic-like behavior (top left panel in Fig. 1) to that of anisotropic, fragile matter (bottom right panel in Fig. 1). The origins of this wide ranging stress behavior remains a matter of debate, but the major components determining the underlying stress state of a granular systems include the particle friction and the structural configuration of the packing.

In many cases it is important to determine how robust a material is to dynamical perturbations such as projectile penetration. The primary factors that determine whether a material can halt ballistic interrogators not only depend on the underlying structure of the granular packing as well as the interparticle interactions, but also on the density of the material and the force with which impact occurs. Furthermore, because this is a dynamical situation, the timescale of the perturbation comes into play. There is a wide parameter space of investigation that remains largely unexplored. However, studies of such systems can potentially revolutionize our understanding of indentation mechanisms and ballistic penetration.

The REU student will participate in the running and execution of computer programs that are designed to simulate dynamical response in granular materials. Through this project the student will receive experience and training in computer simulations methodologies, work on a research project at the forefront of complex, non-equilibrium phenomena, and develop working relationships within a group of undergraduate and graduate students working in similar fields.

Figure 1: Images illustrate the importance of friction on the static stress response.