## Experimental studies of slow flow past obstacles in a dense granular ensemble

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Slow flows in granular materials are predominantly characterized by a high solid fraction and force transfer through sustained inter-particle contact. Slow flows past obstacles have interesting kinematics, and have applications in many problems including shallow foundations, mixing, deformation processes such as drilling etc. Intrusion of objects into a granular ensemble can also be studied as the flow of a granular ensemble past an obstacle.

An experimental study has been made in order to understand the velocity and deformation fields in a model granular ensemble of sand flowing past a flat punch. Under nominal plane strain conditions obtainable in a lab, an ensemble of rounded sand particles was used to study the extent and characteristics of the deformation field around a stationary obstacle (i.e. a flat punch). High-speed and high-resolution images were obtained during the traverse of the granular ensemble. These images were analyzed using a hybrid piv-ptv and optical flow algorithm. Kinematics of the deformation such as the velocity field, strain-rate field and the accumulated strain were discernible through these image analysis results.

Interesting features of deformation in the granular ensemble have been identified, such as "a zone of participation", "a dead wedge", initiation and propagation of shear bands etc have been identified in this deformation field. Severe jumps in the velocity of the granular medium renders a deformation field akin to the velocity fields observed during indentation of solids. Comparison of these results to existing analytical and numerical solutions of this problem have also been made.