Sub-particle scale plasticity in granular materials: yielding of asperities

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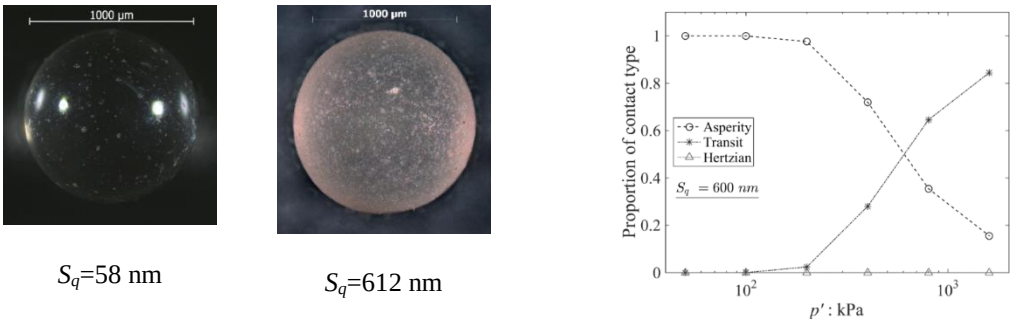
ABSTRACT

From a particle scale perspective, plasticity in granular materials is most often associated with frictional sliding at the contact points, gross particle yielding or particle crushing. However the plastic deformation of the asperities that exist on the surface of soil grains also measurably influences the macro-scale behaviour that is of interest for engineering applications. This contribution synthesizes the results of a recent combined experimental and numerical investigation of the influence of asperities on the elastic stiffness of an assembly of grains. These experiments were supplemented by discrete element method (DEM) simulations that used a new contact model proposed in [1] that develops upon the earlier work of [2].

Representative data from this study are presented in Figure 1. Figure 1(a) gives representative optical microscope images of smooth and rough ballotini; roughness was carefully controlled by milling the particles and measured using white light interferometry. The S_q parameter used to quantify roughness is given by $S_q = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\left(Z_i^2\right)}$ where m = number of discrete data points; and Z_i = elevation relative to the reference surface. Figure 1(b) presents DEM data that illustrate the variation in the proportion of contact type with stress level for the rough ballotini: initially at low pressures most of the contacts have a behaviour that is dominated by the asperities, however as the pressure level increases the asperities yield and the number of asperity dominated contacts decreases. This transition in behaviour underlies the variation in the power-law exponent in the stiffness:pressure relationship with stress level that was analytically considered by [3].



(a) Optical microscope images of representative particles

(b) Variation in proportion of particle type with mean stress (p')

Figure 1: Representative data from combined DEM – experimental study of roughness effects, including asperity yield, on small strain stiffness

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