Mechanical properties of fine-coarse grain mixtures of asteroid regolith

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Several lines of evidence indicate that most of the smaller asteroids (< 1 km) consist of granular material loosely bound together primarily by self-gravity; these are commonly called rubble piles [1]. While the strength of these rubble piles is valuable information on their origin and fate, it is still debated in the literature [2]. Therefore, we have started a laboratory measurement campaign on simulated asteroid regolith, studying the impact of several factors on material strength, such as grain size, size mixtures, and surface properties. In the work presented here, we focus on fine-coarse mixtures and the influence of the fraction of fines on the sample strength. Computer simulations suggest that the increase in the ratio of fine grains to coarse grains will increase the strength of the sample in all configurations [3]. In a series of table-top measurements, we have determined sample compression and shear strengths for various fine-coarse mixtures. We used confined setups (less than 10cm in length) to measure the strength of the material in constricted environments such as an asteroid’s core and unconfined setups (greater than 10cm in length) to simulate open environments such as the surface of an asteroid.

Using CI Orgeuil high fidelity asteroid soil simulant [4], we performed three measurement types to determine the strength of our samples. Samples of regolith were created by measuring percentage by volume amounts of both coarse and fine grains into the measurement container. We prepared coarse grains in two size distributions, mm-sized (Figure 1) and cm-sized. The fine fraction was composed of grains sieved between 100 and 250 µm. A shear box setup was used to obtain shear yield measurements which in turn provided values for the Angle of Internal Friction (AIF), bulk cohesion, and tensile strength of the samples. A compression setup was used to measure values for the Young’s Modulus (YM) in both confined and unconfined samples. The third setup measured the Angle Of Repose (AOR), the steepest angle of descent relative to the horizontal plane to which a material can pile before collapse. From the AOR, we determined the coefficient of friction of each sample.

For compression and AOR measurements, we find that the strength of the coarse grain samples increases with the addition of a fine fraction (Figure 2, left). These findings are intuitive and support the results from computer simulations. However, we find that the increase of the fine fraction in a sample of coarse grains does not consistently increase the sample shear strength. With increasing fine fractions, the AIF and bulk cohesion (Figure 2, right) of the mixed samples decrease (until a point of saturation). This could be indicative of the fine grains acting as a lubricant as the larger grains move across each other, aiding rolling and reducing interlocking strength.

Our findings suggest that in the case of the surface of an asteroid, the presence of fine grains does
indeed increase the strength of coarse regolith material. However, fine grains in the regolith sublayers or the asteroid interior will reduce material strength due to grain interlocking and ease disruption. Therefore, rubble piles that are depleted in fine grains will have higher internal strength compared to those composed of grain size distributions that include sub-mm sized particles.


