Estimating the angle of friction of blocks on rubble-pile asteroid Itokawa

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The angle of internal friction and cohesion are measures of the mobility or strength of granular material and are key parameters that control granular processes such as landslides. The shape and spin of a rubble pile or self-gravitating body are dependent on these parameters [1]. These are also thought to be responsible for the crater-formation process [2]. Therefore, it is important to be able to estimate these parameters to better understand how granular processes work on rubble- pile bodies and regolith surfaces.

This paper presents an estimate of the angle of internal friction of blocks on the surface of the near-Earth asteroid Itokawa [3]. Our analysis is based on a study of terrestrial granular particles that showed a linear relationship between the angle of friction and the circularity of the two-dimensional projected image of the particles [4]. The circularity is defined as $4\pi A/L^2$, where A and L denote the projected area and the circumference, respectively. The circularity of the contour of the Itokawa block was measured using Image-J [5]. Similar image analyses were conducted for a range of granular materials in the laboratory. The figure shows that the circularity of the Itokawa blocks is similar to that of collisional fragments [6] and silica sand particles.

We measured the angle of internal friction for some of the granular materials used in the shape analyses in a direct shear test and obtained a linear relationship between the circularity and angle of internal friction. Using this empirical relationship and the measured circularity of the Itokawa blocks, we estimated that the angle of internal friction of the Itokawa blocks is about 40 degrees. This is consistent with the slope distribution of the Itokawa surface: most of the surface of Itokawa is inclined within 40 degrees [3].

We use the resulting angle of internal friction to discuss the stability of a large boulder, called Pencil. Pencil has a distinct positive relief, as if part of the boulder were embedded in the local terrain [7]. Based on the estimated inclination angle of the boulder to the local surface, the gravity acceleration, and the estimated angle of internal friction, we suggest that more than 30 % of the total length of Pencil is embedded beneath the surface.

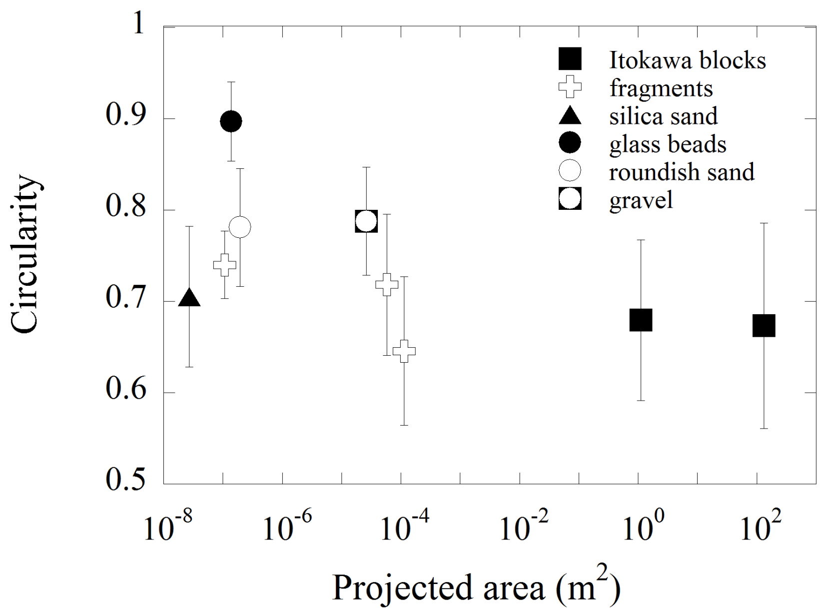

Figure: Circularity of Itokawa blocks and various granular materials versus the projected area of the particles.

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