Experimental study on compression property of granular material

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Porosity structure inside a planetary body and of surface regolith plays important role in collisional and thermal evolution of the body. The porosity structure is changed by presence of rocks, seismic shaking, thermal evolution, and self-gravity in particular. Porosity structure caused by soil pressure due to self-gravity gives an initial, most-possible porous structure of the body consisting of granular material. Therefore, understanding compression property of granular material is necessary. Compression properties of granular material should be controlled by various parameters such as initial porosity of granular bed, composition, size distribution, and shape of constituent particles. Moreover, the surface energy of constituent particles thought to become 100 times larger in vacuum than in atmosphere (Kimura et al. 2015). The interparticle force, and consequently the compression properties, depends on the surface energy. Therefore, general formula for the compression property of granular material in various environments is required to estimate the porosity structure of planetary bodies.
An empirical formula to estimate the initial porosity of granular bed consisting of monodisperse particles deposited by gravity was introduced by Kiuchi and Nakamura (2014) based on the ratio of interparticle force and gravity. However, this formula is only applicable to the uppermost layer of granular bed because the granular bed at some depth is compressed by soil pressure. During the compaction process of granular bed, the porosity of granular bed is decreased by rearrangements of constituent particles and this rearrangement mechanism changes with coordination number of constituent particle. When the coordination number is less than 6, the constituent particles are rearranged by rolling. When the coordination number exceeds 6, they are rearranged by sliding. The coordination number increases as the porosity decreases. The coordination number reaches 6 when porosity is ~0.7 (Wada et al., 2011).
We conducted compression experiments of various kinds of samples. Each sample has different composition and size distribution. Main compositions of the samples are Al_2O_3 and SiO_2 and the particle size is smaller than 100 μm. We sieved these samples into cylindrical container and the top part of the bed over the height of the container was leveled off. Then we compressed the sample by compressive testing machine. The applied pressure was ranged from 10^4 to 2×10^6 Pa.
The initial porosity of the granular bed was different for different samples and it was in the range of 0.54-0.86. We compared this result with the formula introduced in Kiuchi and Nakamura (2014). We found that this formula can estimate approximate porosity of granular bed constituted by polydisperse particles if we adopt the median diameter of the particles as representative particle diameter. It was shown that the slope of compression curve becomes shallower as the frictional force between particles increases in the range of the pressure between 10^4 and 2×10^6. In this range, porosities of samples are less than ~0.7. Size distribution width of sample affects compression properties too and the samples with wider size distribution are compressed easier (Omura et al., ISTS, 2015).
We conducted new compression experiments. We expanded the pressure range to lower than 10^2 Pa and we found that compaction process of granular bed is divided into three regimes: (1) Pressure is lower than the strength of granular bed accordingly the granular bed isn’t compacted. (2) Granular bed is compacted but the decrease in porosity is gradual. (3) The porosity decline-rate becomes larger than the regime 2. We will further investigate how these boundaries are determined and will present the results.

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