EXPERIMENTAL STUDY ON IMPACT DISRUPTION OF ROCKY RUBBLE-PILE BODIES: EFFECT OF DISRUPTION OF CONSTITUENT BOULDERS ON REACCUMULATION PROCESS.

Y. Fujita[1], M. Arakawa[2], M. Yasui[2], S. Hasegawa[3], and Y. Shimaki[1], [1]Nagoya University (Furo-cho, Chikusa-ku, Nagoya, 464-8601, Japan: fujita@eps.nagoya-u.ac.jp), [2]Kobe University, [3]Japan Aerospace Exploration Agency

Introduction: Rubble-pile bodies, which are composed of rocky boulders bounded weakly by self-gravity, are common bodies not only in asteroids but also in the solar nebula [1]. Thus, it is important to evaluate the effect of rubble-pile structure on the impact disruption. In particularly, the impact strength Q^* is the most important parameter for the collisional evolution of planetary bodies [2]. However, the experimental studies on the rubble-pile bodies are very limited [2, 3], and more detailed study on the rocky rubble-pile bodies is required to determine the impact strength of asteroidal bodies. There are two definitions of the impact strength according to attraction forces. When the body is smaller than several 100 m, the impact strength is controlled by the cohesion strength and this strength is called as a shattering strength, Q_s^*. When the body is larger than several km, the impact strength is controlled by the self-gravity and this strength is called as a dispersion strength, Q_d^* [4]. For rubble-pile bodies, the constituent boulders are bounded only by the self-gravity so that they don't have cohesion strength and the impact strength is just controlled by self-gravitational energy. However, in the case of high-velocity impacts expected among asteroids, the constituent boulders of the rubble-pile bodies could be disrupted near an impact point and it could effectively consume the impact energy. Thus, we recognize that the impact phenomena of the rubble-pile body are quite complex because we should consider not only the dispersion of the rubble-pile body but also the impact disruption of the constituents. Then, we carried out high-velocity impact experiments using several types of rubble-pile targets constructed from glass beads, and examined the dispersion condition of rubble-pile targets and the degree of disruption for constituent glass beads.

Experimental methods: Impact experiments were conducted by using a two-stage light gas gun set at Kobe University and ISAS/JAXA. A nylon cylindrical projectile with the mass of 200 mg (m_p) was impacted at the velocity (v_i) from 2 to 6 km/s. A rubble-pile target was made of glass beads with a size of 7 mm and a mass of 0.45 g (m_c). The number of beads (N_b) was changed from 4 to 1200 corresponding to the total target mass from 1.8 to 550 g (M_t). The beads were assembled by a weak bond with the structure of close-packed one. The target had three kinds of shapes, a spindle, a cylinder, and a cube. We are interested in the number of disrupted glass beads and the effect of disruption on the ejection velocities of the other intact glass beads. Thus, we used a high-speed video camera to observe the impact disruption and measured the fragment mass distribution. The impact strength of a glass bead ($Q_{s\_g}^*$) is obtained by previous studies, 400 J/kg [e.g. 5].

Experimental results: We found that a lot of unbroken beads (intact beads) of rubble-pile targets were ejected very slowly compared to the disrupted finer fragments of beads around the impact point. There are two systematic results for 2D-velocities of intact glass beads after the collision as shown in Fig. 1: one is obtained for the constant impact velocity of 2 km/s on the target with the bead number from 4 to 109 and another is obtained for the constant beads number of 109 at the impact velocity from 2 to 6.5 km/s. They have almost the same slope but the intact beads velocities obtained at the impact velocity of 2 km/s are about a half of the results obtained for the target with 109 beads. When we compare these velocities with the antipodal velocity obtained for a single bead experiment, the intact bead velocities of the rubble-pile target were several times smaller than the antipodal velocity of a single bead at the same energy density (Q=1/2$m_p v_i^2/M_t$). This means that the projectile kinetic energy was effectively dissipated around the impact region and the remaining region of the rubble-pile target did not receive the kinetic energy from the projectile.

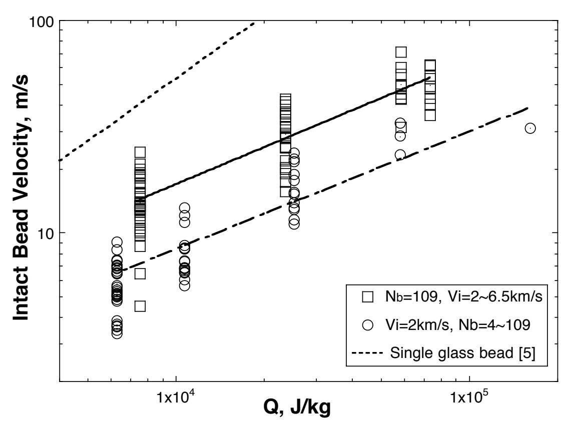

Fig.1. 2D-velocities of intact glass beads vs. Q

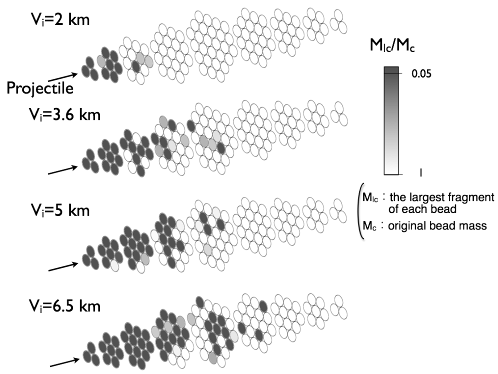

Fig. 2. Disruption map of the constituent beads at different impact velocities from 2 to 6.5 km/s.

In order to discuss the degree of disruption of the constituents, we reconstructed the disruption map of the constituent beads (Fig. 2). It is very clear that the disruption region gradually propagates with the increase of the impact velocity, and we notice that more than a half of beads are catastrophically disrupted at the impact velocity of 6.5 km/s. According to this figure, we can count the total number of disrupted beads (N_d) and compare the N_d with the calculated beads number of disruption (N_p) defined as the ratio of the projectile kinetic energy to the energy required for single bead disruption ($Q_{s\_g}^* m_c$). The relationship between N_d and N_p is shown in Fig. 3, and we found that the N_d is two orders of magnitude smaller than N_p. This means that the constituent beads of rubble-pile target is more than 100 times difficult to be disrupted compared to a single glass bead. This could be an important feature of the disruption of rubble-pile bodies.

According to Figs. 2 and 3, we can roughly estimate the energy fraction, *f*, defined by the kinetic energy of the projectile transferred into the kinetic energy of the intact beads and found that the energy fraction *f* is from 0.001 to 0.01 for rubble-pile target (Fig. 4).

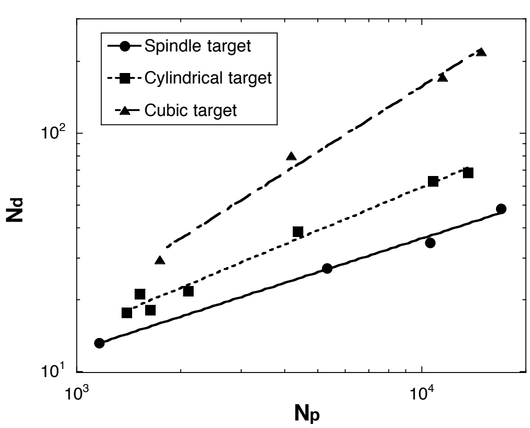

Fig.3. Relationship between N_d and N_p for different shape targets: spindle, cylinder, and cube.

This extremely small value of *f* indicates that most of projectile kinetic energy is transferred into the kinetic energy of finer fragments generated by the disruption of the beads near the impact point.

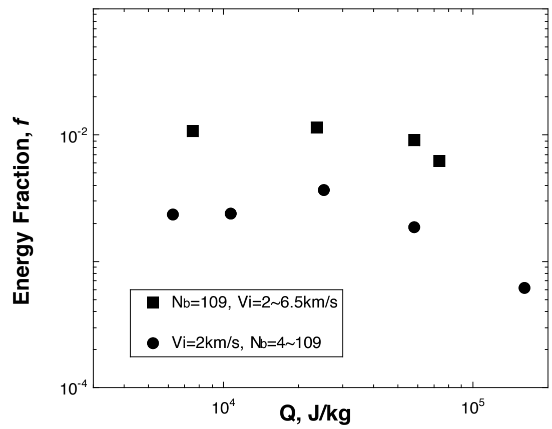

Fig.4. Relationship between *f* and *Q* for rubble-pile targets

Discussions: From these results, we estimated the Q_D^* of rubble-pile bodies from the re-accumulation condition of the dispersed intact constituents. As a result, it was found that Q_D^* for rubble-pile bodies was larger than that estimated only from the gravitational potential energy. Therefore, the re-accumulation of intact rubble-pile constituents is easy to occur. This indicates that rubble-pile body is a very strong body against the impact disruption by high-velocity impacts.

References: [1] Davis D.R. et al. (1979) In *Asteroids* (T. Gehrels, ed.), Univ. of Arizona, Tucson, pp.528-537. [2] Ryan E.V. et al. (1991) *Icarus, 94,* 283-298. [3] Ryan E.V. et al. (1999) *Icarus, 142,* 56-62. [4] Melosh H.J. and Ryan E.V. (1997) *Icarus*, *129*, 562-564. [5] Okamoto C. and Arakawa M. (2008) *Icarus, 197, 627-637*.