EXPERIMENTAL STUDY ON COLLISIONAL DISRUPTION OF GYPSUM SPHERE: IMPLICATION FOR FORMATION OF RUBBLE PILE BODIES.

C. Okamoto[1] and M. Arakawa[1], [1]Graduate School of Environmental Studies, Nagoya University, Nagoya 464-8601, Japan (chisato@eps.nagoya-u.ac.jp).

Introduction: An understanding of collisional process in energetic impact is important to elucidate the origin and evolution of small bodies such as asteroids. Laboratory high-velocity impact experiments using solid targets such as basalts were performed to study the collisional response of small bodies, so that the impact strength of basalt was clarified in addition to the mass and velocity distributions of disrupted fragments (e.g., [1], [2]).

Meanwhile, recent ground-based observations and spacecraft missions found a lot of low-density asteroids, which possibly included a lot of pore inside. Porosity is an important physical property to control the collisional process, so that several laboratory experiments to study the effect of the porosity on the impact fragmentation were conducted. As a result, they showed that the impact strength of porous body was stronger than that of the non-porous body such as basalt because of rapid attenuation of shock wave in a porous body (e.g., [3], [4]). However, our knowledge of impact fragmentation of porous body is still insufficient. Therefore, we need systematic investigation of porous targets to clarify the elementary processes especially caused by porosity.

Experimental: We prepared spherical gypsum samples with high porosity in order to simulate porous bodies such as low-density asteroids. We used gypsum ($CaSO_4 \cdot 2H_2O$) with the density of 1100 ± 100 kg/m^3 and the porosity of 53 ± 4%. We performed impact experiments of gypsum samples by using a two-stage light gas gun set in Nagoya University, and we used nylon projectiles with the density of 1100 kg/m^3 and the mass of 7 mg. A head-on collision with the impact velocity of 3.4 ± 0.4 km/s was made for all of the runs. The collisional disruption was observed by using an image-converter camera, which was able to take successive images of 15 frames at the speeds up to 5×10^5 frames per second or a high-speed digital video camera at 1×10^4-2×10^4 frames per second.

Results and Discussion: The relationship between the largest fragment mass (m_l) normalized by the original target mass (M_t) and the energy density defined by $Q_t=1/2V_i^2\,(m_p/M_t)$, where m_p is a projectile mass and V_i is an impact velocity, was studied to obtain the impact strength of gypsum. We compared our gypsum results with the previous results for the gypsum targets [3] and basalt targets [1]. Our gypsum data showed a good agreement with the previous gypsum data at 2.8–4.2 km/s [3], and combining our gypsum data with the previous gypsum data, thus we obtain the following empirical equation for gypsum,

$$m_l/M_t = 150\times Q_t^{-0.76}. \qquad (1)$$

While, the m_l/M_t of the basalt was about one order of magnitude smaller than that of gypsum at the same range of Q_t. Therefore, we can recognize that the degree of impact disruption of porous gypsum is notably smaller than that of basalt target.

Using high-speed photography, we studied fragment velocities (V_a) at the antipode of impact site for our gypsum targets. The V_a increases from 5 to 40 m/s with the increase of Q_t at the range of 3×10^3-5×10^4 J/kg, so the following empirical relationship for the V_a and Q_t of gypsum targets is obtained,

$$V_a = 6.4\times10^{-3}\cdot Q_t^{0.79}. \qquad (2)$$

When the V_a of gypsum is compared to that of basalt at the same Q_t [1], the V_a of gypsum is several times lower than that of basalt.

In order to discuss the feasibility of rubble pile formation in the collision, we calculate the minimum body size causing the re-accretion to form a rubble pile body after the catastrophic disruption. Fujiwara and Tsukamoto (1980) showed that 70-80% of basalt target mass had velocities lower than twice of the V_a [1]. If we adopt this conclusion as re-accretion condition of the disrupted body, the minimum body size can be derived from Eq.(1) and Eq.(2) when we use m_l/M_t=0.1 to estimate Q_t^* for the catastrophic disruption. The minimum body size is derived to be about 65 km for gypsum-like porous body, which is slightly larger than those of basalt-like body of about 41 km and ice-like body of 24 km [5]. This means that the minimum size of the parental body, which can re-accrete as a rubble pile, moderately depends on the constituent material. Small bodies such Itokawa, a S-type asteroid (535 × 294 × 209 m) with rubble pile structure [6], are likely to originate from the parent bodies with the diameter larger than several tens km.

References: [1] Fujiwara and Tsukamoto (1980) *Icarus, 44*, 142–153. [2] Nakamura and Fujiwara (1991) *Icarus*, *92*, 132–146. [3] Kawakami et al. (1991) *Astron. Astrophys.*, *241*, 233–242. [4] Love et al. (1993) *Icarus*, *105*, 216–224. [5] Arakawa (1999) *Icarus, 142*, 34–45. [6] Mukai et al. (2007) *Advances in Space Research*, *40*, 187–192.