Impact Experiments of Sintered Glass Beads Targets at Low and High Velocities. M. Setoh[1], A. M. Nakamura[1], K. Hiraoka[1], N. Onose[2], S. Hasegawa[2], and P. Michel[3], [1]Graduate School of Science and Technology, Kobe University, 1-1 Rokkoudai-cho, Nada-ku, Kobe, 657-8501, Japan (Setoh@kobe-u.ac.jp), [2]JAXA/ISAS, [3]Observatoire de la Cote d'Azur.

Introduction: Porous structures are thought to be common among asteroids [1]. The static strength (S) of porous material is usually smaller than the strength of dense ones, as is represented in an empirical formula known for ceramics [2], that is, $S = c_1 \exp(-c_2 P)$, where c_1 and c_2 are constants, and P denotes porosity. Generally, the outcome of collisional disruption is dependent upon material strength [3]. However, porosity plays a complicated role. On one hand, with increasing porosity, the target body becomes weaker from the point of view of its static strength. On the other hand, the increasing volume of void space decreases the transmission efficiency of the stress wave in the target body. Love et al. [4] conducted hypervelocity impacts of soda lime glass projectiles into four porous sintered glass beads targets with different porosity and compressive strength, and showed that the increase of target porosity leads to a greater localization of the impact damage.

In order to further study the relation between the structure of small bodies and both their thermal and collisional evolutions, we prepared porous targets and performed impact disruption experiments at low and high velocities.

Targets: Targets were made of soda lime glass beads of diameter 50 micron and density 2.5 g/cm^3 similar to some previous experiments [4, 5]. The glass beads were poured into a mold and heated in an oven at temperatures below the softening point of the glass (734 degree in C).

Experiments I (low velocity impact) [6]**:** We conducted impact disruption experiments using a gas gun at Kobe University (Japan) in air.

A tea cup-shaped mold 4.0 cm in top diameter, 3.0 cm in bottom diameter and 3.0 cm deep was used for the experiments. In total, 6 types of targets with different compressive strength ranging from 0.2 to 8 MPa but with approximately the same porosity (40%) were prepared.

Targets were placed on a mounting in front of the gun muzzle in a chamber consisting of acrylic plates. Projectiles were polycarbonate cylinders 1.4 g in mass and the impact velocity was changed between 10 and 120 m/s.

The largest fragments were collected and there mass was measured after each impact disruption. The threshold specific energy (Q*) is commonly defined as the kinetic energy of the projectile over the target's mass required to produce a largest fragment whose mass is 50 % the original one [3]. Q* was determined for each target type.

Experiments II (low velocity impact) : Another series of low velocity impact disruption experiments using another gas gun at Kobe University were conducted. We used the same projectiles as Love et al. (1993), more precisely glass spheres of 3.2 mm in diameter. Targets were cylindrical sintered glass beads, whose diameter was 48 mm and height was 24 mm, about 65 g in mass. Impact velocities were from 180 to 250 m/s.

Experiments III (high velocity impact): High velocity experimental series were carried out using a two-stage light gas gun at ISAS (Japan). Impact velocities were from 2120 to 3280 m/s. The targets were made using a spherical mold 6.0 cm in diameter. The glass beads were first sintered at 650 °C for 60 minutes. Projectiles were nylon spheres. Fig.1 shows high speed camera images taken by a FASTCAM-PCI (Photron) at 5,000 fps, and impact velocity was 3280 m/s.

Comparison with previous study: In order to produce stronger targets, we heated the targets at between 615 and 625 °C for 480 minutes twice. Table I shows the difference between the three experiments. Fig. 2 shows the relation between Q* and the compressive strength (S) of the target. The empirical relation of the Experiment I is Q* = 10.7 $S^{0.55}$, whereas Q* = 95.3 $S^{0.45}$ $(1\text{-porosity})^{-3.6}$ was previously obtained by Love et al. [4]. The upper line shows the relation between Q* and compressive strength derived for 40 % porosity targets from the Love et al's formula and the lower line shows the same relation for 12 % porosity. The values of Q* in our low-velocity experiments were found to be more than an order of magnitude lower than those derived from the empirical relation of Love et al.. However, the values of Q* in high-velocity experiments were close to the previous results. This is probably due to the difference in the degree of attenuation of the stress wave in the specimen. This suggests that not only the porosity but also the impact velocity strongly influences the outcome, everything else being equal.

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Table I : Experiment conditions

	d_p x h_p (mm)	v_p (m/s)	r_t/r_p	S_t (MPa)	P_t (%)
Experiments I	10x15	10 ~ 100	3	0.19 ~ 7.8	39 ~ 41
Experiments II	3.2*	180 ~ 250	6	0.04 ~ 1.5	40 ~ 41
Experiments III	7*	2120 ~ 3280	8	40	9.8 ~ 15.7
Love et al.1993	3.2*	6000	10	2, 7.9, 44, 280	5, 37, 39, 60

d_p : Projectile diameter, h_p : Projectile height, v_p : Impact velocity, r_t / r_p : Size ratio of target and projectile, S_t : Compressive strength of targets, P_t : Porosity of targets. * : Projectile is sphere.

Fig.1 Images of the collisional disruption of sintered glass beads at High velocity (3208 m/s). Frame rate is 3000 fps. Left image is before impact, center and right images are 2nd and 4th frames after impact. The elapsed times are 0, 2/3000 sec. and 4/3000 sec. Taget diameter is about 55 mm. The projectile was shot from the left into center-left surface of the target.

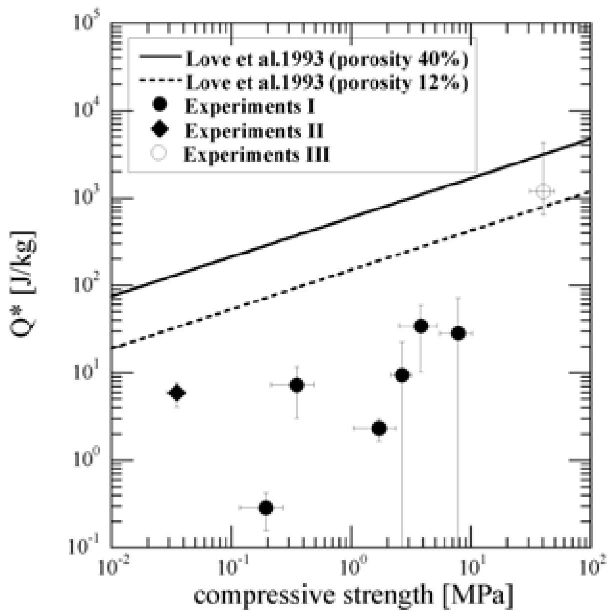

Fig.2 The relationship between Q* and compressive strength of the targets. The values of Q* in our low-velocity experiments were found to be more than an order of magnitude lower than the empirical relation derived from the Love et al's results. However, the values of Q* in high-velocity experiments were close to the previous results of Love et al. (1993).