IMPACT DISRUPTION EXPERIMENTS OF SINTERED GLASS BEADS AGGREGATE CONSISTING OF MILLIMETER-SIZE PARTICLES. N. Machii[1], A. M. Nakamura[1] and Y. Fujii[2], [1]Graduate School of Science, Kobe University, [2]Graduate School of Science and Technology, Kobe University, machii@stu.kobe-u.ac.jp

Introduction: Impact disruption experiments of homogeneous dense materials such as rocks have been performed in previous studies in order to investigate fragment mass distribution and ejecta velocity. More recently, impact experiments of targets having weaker bulk strength than consisting material such as soda-lime glass beads [1, 2] have been conducted. In those experiments, the radius, r, of the consisting particles is much smaller than the target radius, R, i.e., r/R is much smaller than unity. However, some of porous small bodies may have internal structure of non-negligible r/R, for example, impact disrupted and reaccumulated icy small bodies may consist of large chunks bounded by self-gravity and bonded physically by sintering.

Collisional experiments using aggregates which have weak bond and non-negligible r/R was performed by a few previous works. Ryan et al. [3] conducted experiments at low velocity (~ 1-12 m/s) using gravel pebble aggregates of r/R = 0.1 bonded by glue. Impact strength (Q^* = the energy density or specific kinetic energy, at which a given target material undergoes a fragmentation such that the resultant largest fragment mass has half the mass of the original body) of 6 (± 3) × 10^5 erg/cm^3 was obtained. They found that weakly bonded aggregate could have unexpectedly high impact strength due to energy dissipation among the constituent particles. Ryan et al. [4] performed experiments in which aluminum projectile, fractured ice and solid ice projectiles were impacted at 100-200 m/s into porous ice targets (r/R = 0.18), and obtained the impact strength of > 5 × 10^5 erg/cm^3. They suggested that the porous ice targets behaved as strongly as solid ice in collision due to energy apparently well dissipated by the void spaces within the targets. Giblin et al. [5] carried out experiments using porous ice targets (r/R = 0.24) and solid ice projectiles with impact velocity of 90-155 m/s and determined the impact strength of 2.1 × 10^5 erg/g. They found that the fraction of collisional kinetic energy that is partitioned into ejecta velocities was between 1-15 % for the ejecta with velocity of ~2-20 m/s.

Experiments: We conducted impact experiments of aggregates with non-negligible r/R and well-characterized structure and strength, using a helium gas-gun installed at Kobe University. Impact velocity was about 277 ± 2 m/s. Projectile was soda-lime glass sphere of 3.14 ± 0.01 mm in diameter and 0.043 ± 0.001 g in mass.

We prepared two-body sintered aggregates, i.e., dumbbell shaped sintered glass in which two 4.9 ± 0.1 mm diameter glass spheres are bonded by a neck by sintering. Figure 1 shows the maximum tensile and bending forces necessary to break the two-body. Figure 2 shows the set-up of the tensile tests, in which strings were glued to the both ends of the particles. Then the particles were pulled by a strength testing machine. In the bending tests, one particle was fix on a glass substrate with adhesive and force was applied onto another sphere in the direction parallel to the neck cross section. The force needed to break the neck in the bending test is approximately one third of those in the tensile test.

Targets for the impact experiments were larger sintered aggregates of the 4.9 mm glass spheres. First, spherical and disk-shaped sintered aggregates were produced with maximum heating temperature of 600 ºC. Disk shaped ones were compressed from the side by the strength testing machine for brazil-disc test. The aggregates were broken into two major pieces by internal tension induced by the compression. The targets for impact were the spherical aggregate and the ones of the two major pieces from the disk-shaped ones. The target properties are summarized in Table 1. The average force per neck necessary for breaking these aggregates is also shown in Figure.1, indicating that the force necessary to break a disk-shaped sintered aggregate into two is approximately the sum of the tensile force necessary to break each neck in the cross section of the disk.

Results: As shown in Figure 3, all of the necks of the targets were broken by the impact except for Ikura7, which is the strongest target. Figure 4 shows the 2D velocities of the separated particles from Ikura9 which originally consisted of about 92 particles before the impact. The 2D velocities of 38 particles were determined using high speed camera images taken at 4000 fps. As a result from the measurements, mean 2D velocity of the particles was found to be 1.7 ± 1.1 m/s and the maximum 2D velocity, 5.7 m/s.

Summary and Future work: We performed preliminary impact experiments of the targets with r/R > 0.1, and well-characterized strength and internal structure. The targets were catastrophically disrupted, because of their small strength. We demonstrated that we can track more than one third of the constituent particles and determine the 2D velocity of them. Next we perform impact experiments under the condition where the largest remnant is about the half of the original target and then we will discuss about the relationship between the outcome and properties of the target, such as the strength and *r/R*.

References: [1] Love S. G. et al. (1993) *Icarus, 105,* 216–224. [2] Setoh M. et al., *Icarus*, in press. [3] Ryan E. V. et al. (1991) *Icarus, 94,* 283–298. [4] Ryan E. V. et al. (1999) *Icarus, 142,* 56–62. [5] Giblin I. (2004) *Icarus, 171,* 487–505.

Table 1: Summary of the targets

sample name	shape	heating duration (hr)	neck radius (mm)	maximum force (N)	mass (g)
Fujiko4	sphere	4	-	-	46.52
Ikura9	broken disk	63	0.46*1 ± 0.13	267.2*2	14.70
Ikura7	broken disk	4	0.38*1 ± 0.11	65.3*2	12.26

*1 Derived from the observation of the broken cross section of the aggregate after tensile test.
*2 The force necessary for breaking the disk-shaped sintered aggregate by brazil-disc test (see text).

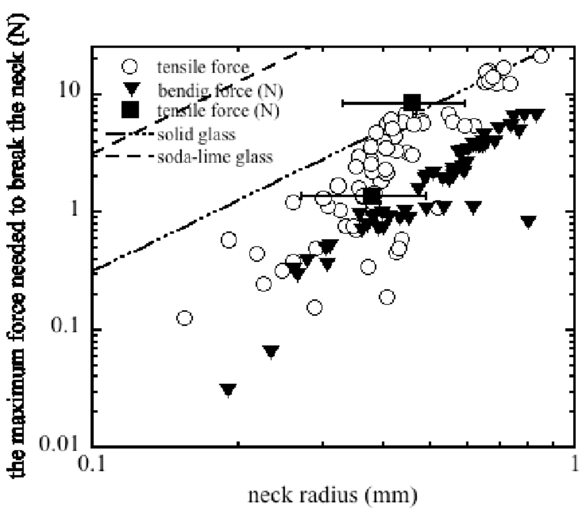

Figure 1. Relation between neck radius and the maximum force needed to break the neck. Dashed line shows the breaking condition of soda-lime glass. Dashed-three dotted line shows the breaking condition of solid glass. The filled squares show data of Ikura7 and Ikura9 (see text), while the other marks show data of two-body aggregates.

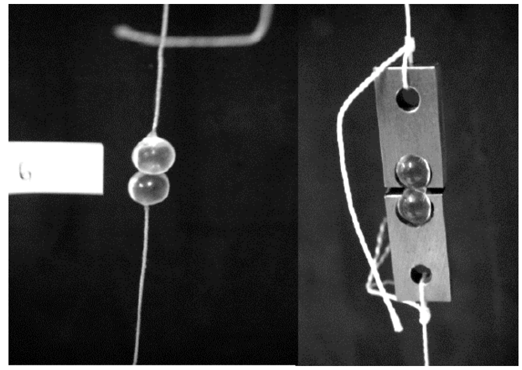

Figure2. Configuration of the tensile test for the two-body with smaller neck (left), and well-developed neck (right).

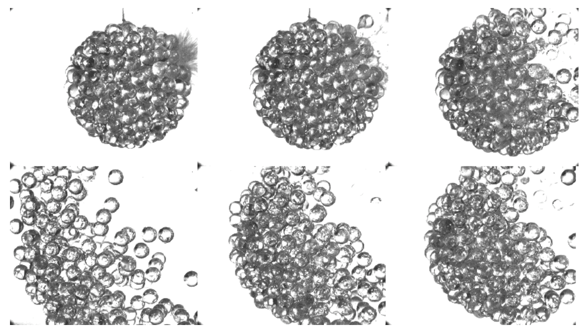

Figure 3. Successive images taken at the disruption of Fujiko4. Images at t = 0 (at the impact), 0.75, 3 ms from left top to right top, at t = 6.25, 9 and 18.75 ms from bottom right to left.

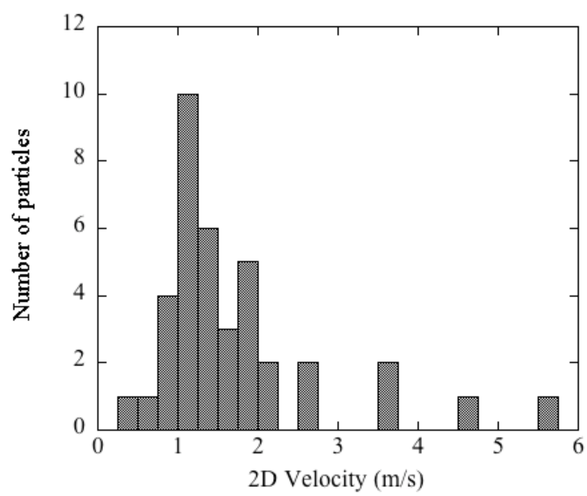

Figure 4. The 2D ejection velocities determined for Ikura 9.