**IMPACT STRENGTH OF POROUS- AND DUCTILE-ROCKY PLANETESIMALS IN GRAVITY DOMINATED REGIME.** M. Arakawa[1], T. Nagano[1], S. Ishida[1], Y. Minami[1], K. Shirai[1] and S. Hasegawa[2], [1]Graduate School of Science, Kobe University (1-1, Rokkodai-cho, Nada-ku, Kobe, 6578501, Japan, masahiko.arakawa@penguin.kobe-u.ac.jp), [2]Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science.

**Introduction:** Impact strength is one of the most important properties to study the collisional accretion process of planetesimals and the evolution of the size frequency distribution of asteroids and Kuiper belt objects [1]. It is well known that the impact strength is controlled by the materials strength for target bodies with the size smaller than a few hundred meters, and this impact strength in the strength regime is called shattering strength ($Q_S^*$). The impact strength for target bodies larger than a few hundred meters would be controlled by self-gravity of a target body, and it is called dispersion strength ($Q_D^*$). The shattering strength has been studied by laboratory impact experiments for various types of simulated planetesimals such as basalt, glass, porous gypsum, sintered glass beads etc., and these results are now followed by sophisticated numerical simulations [2].

While the dispersion strength has been studied by numerical simulations because the simulation is suitable for examining the effects of target gravity and reproduce the re-accretion process of the disrupted target body [2]. Recently, the numerical simulation clearly showed that the dispersion strength is not only affected by the self-gravity proportional to the size but also by the material properties such as porosity, cohesion, and friction [3].

Arakawa et al. (2022) conducted impact disruption experiments for porous gypsum and froze clay targets and firstly obtained their mass-velocity distributions (MVD) of all the impact fragments by using Flash X-ray radiography [4]. They determined the $Q_D^*$ from the median velocity ($v^*$) obtained from the MVD, where the $v^*$ is the ejection velocity of impact fragments in the center of mass system, and the impact fragments with a half of the original target mass have the ejection velocity below the $v^*$. Then, they determined $Q_D^*$ by assuming that the $v^*$ is equal to the escape velocity of the original target body. This semi-theoretical consideration for $Q_D^*$ was checked by the numerical simulation and it was proposed that the escape velocity was chosen for a half of the original target body and this simple assumption was valid for the target size larger than 10km [4]. Following the previous study, we conducted the similar impact disruption experiments by using Flash X-ray to measure the MVD for porous and ductile rocky targets. In this study, we examined the effects of the porosity and the friction on the MFD for rocky target, thus we prepared a porous dried clay target (porous clay) and clay targets mixed with silicon oil (mixed clay target): We expected that the silicon oil reduced the porosity and the friction among target particles.

**Experimental methods:** The impact experiments were conducted by using a two-stage light gas gun at ISAS/JAXA, Japan, and the projectile was horizontally launched at the velocity from 2 to 4.5 km/s; the projectile was made of polycarbonate and a spherical shape with the diameter of 7 mm. We prepared two types of targets using bentonite power: They are a porous target and a ductile target. The porous target was made by drying clay which was bentonite powder mixed with water. Their density and the porosity were 1.64 gcm$^{-3}$ and ~50%., respectively, and the tensile strength was 0.3 MPa. The ductile target was made by mixing bentonite powder with silicon oil with the viscosity of 10 Pas and 60 Pas; the density and the porosity were 1.78 gcm$^{-3}$ and ~30 %, respectively. All the targets have a spherical shape with the diameter of 60 mm. For the Flash X-ray radiography, the twelve stainless steel balls with the diameter of 3 mm were included in each target, and these stainless balls were set at each center plane of the target as tracer particles. Using the same method described in Arakawa et al. (2022), we conducted head-on collision experiments and measured the movement of tracer particles before and after the catastrophic disruption using X-ray radiography. According to these measurements of the tracer particle movements, the ejection velocity distributions of the target interior were obtained. With the assumption that the impact fragments had the ejection velocity of the nearest tracer particle, we estimated the mass-velocity distribution of the impact fragments. Moreover, we analyzed the relationship between the cumulative mass of the target whose velocity was smaller than some velocity and the ejection velocity; the median velocity, $v^*$, of the relationship was obtained for each experiment: A half of the impact fragment mass had the ejection velocity lower than $v^*$.

**Results:** Figs.1a and b show the flash X-ray images taken at 0.8 -1ms after the collision for a porous clay and a mixed clay target, respectively; the impact velocity was ~1.8 kms$^{-1}$. The small black circles in the targets are tracer particles, and the displacements of these tracers were measured to obtain the velocity distribution of the target interior. Figs. 1c and d show the velocity distributions of tracers in the targets corresponding to the experiment of Fig.1a and Fig.1b, respectively. The velocity vectors are indicated in the center of mass system. It is very clear that the velocities of all the tracers for the porous clay target are smaller than that for the mixed clay target though both experiments had almost the same specific energy, $Q$, of ~2x$10^3$$Jkg^{-1}$. This means that the silicon oil filling the pores inside the clay target could reduce the energy loss though the porosity remained to be still 30 %.

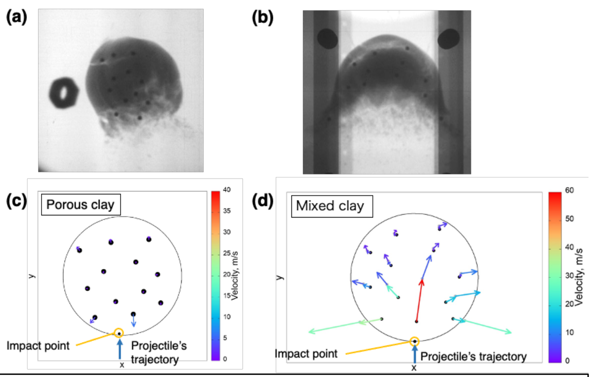


Fig.1: Flash X-ray images for porous clay (a) and mixed clay (b) impacted at 1.8$kms^{-1}$. (c) and (d) are the velocity distributions of tracers corresponding to (a) and (b).

Fig.2 shows the mass-velocity distributions for the mixed targets with the silicon oil of 10Pas viscosity at different impact velocities from 2–5 $kms^{-1}$. The tracer velocities in the center of mass system schematically increase with the increase of the impact velocity at the same cumulative mass, where the cumulative mass was normalized by the original target mass. The median velocity, $v^*$, is defined as the velocity when the cumulative mass ratio is 0.5. and the $v^*$ was obtained for all the experiments to examine the correlation with the specific energy as was studied by Arakawa et al. (2022).

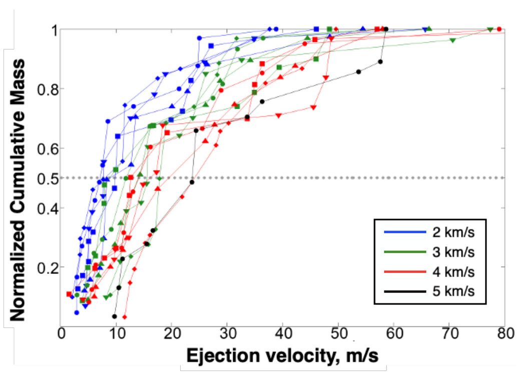


Fig.2: Mass-velocity distribution of mixed clay targets with the silicon oil of 10Pas.

Fig.3 shows the relationship between $v^*$ and $Q$ for the porous and mixed clay target with the previous study on the frozen clay and the porous gypsum targets. We found that the $v^*$ was not affected by the silicon oil viscosity included in the mixed clay target apparently, and the relationship of the mixed clay targets was almost similar with that of the frozen clay target. The frozen clay targets were brittle with the tensile strength of a few MPa but the mixed clay targets showed ductile behavior like metal and deformed to be large strain without failure. It is very curious that both targets had very similar $v^*$ although they had very different mechanical properties. The $v^*$ of porous clay target is systematically lower than that of the mixed targets, and it is similar with that of the porous gypsum target. Their porosity was almost same, but the tensile strength of the porous gypsum is several times larger than that of the porous clay target. This indicates that the cohesion does not affect $v^*$ even for the porous targets. These results enable us to speculate the dispersion strength of small porous and ductile bodies in the solar system, and they tell us that the ductile rocky bodies could have the dispersion strength similar to that of the brittle frozen bodies.

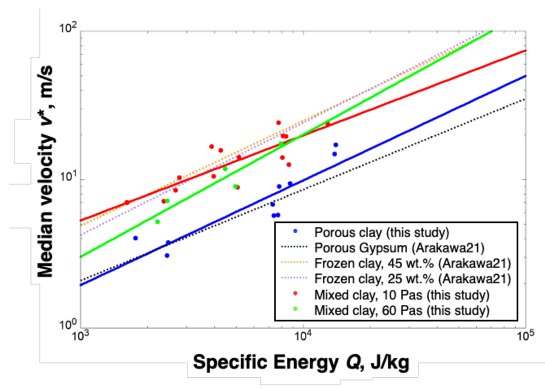


Fig.3: Relationship between $v^*$ and $Q$ for mixed clays with different silicon oils and porous clay.

**Acknowledgments:** This series of experiments were supported in part by the Hypervelocity Impact Facility at ISAS/JAXA, and by Grants-in-Aid for Scientific Research (nos. 17H06459 and 19H00719) from the Japan Society for the Promotion of Science.

**References:**

[1] Holsapple K., et al. (2002) *Asteroids III,* 1, 443-462. [2] Benz W. and Asphaug E. (1999) *Icarus*, 142, 5-20. [3] Jutzi M. (2015) *Planet. space sci.*,107, 3-9. [4] Arakawa M. et al. (2022) *Icarus*, 373, 114777.