TENSILE (FLEXURAL) STRENGTH OF RYUGU GRAIN C0002. K. Kurosawa[1], S. Tanaka[2], Y. Ino[3,2], D. Nakashima[4], T. Nakamura[4], T. Morita[4], M. Kikuiri[4], K. Amano[4], E. Kagawa[4], H. Yurimoto[5], T. Noguchi[6], R. Okazaki[7], H. Yabuta[8], H. Naraoka[7], K. Sakamoto[2], S. Tachibana[9], S. Watanabe[10], and Y. Tsuda[2], [1]Planetary Exploration Research Center, Chiba Institute of Technology (2-17-1, Narashino, Chiba 275-0016, Japan, kosuke.kurosawa@perc.it-chiba.ac.jp), [2]JAXA, [3]Kwansei Gakuin Univ., [4]Tohoku Univ., [5]Hokkaido Univ., [6]Kyoto Univ., [7]Kyushu Univ., [8]Hiroshima Univ., [9]The Univ. of Tokyo, [10]Nagoya Univ.

Introduction: JAXA's Hayabusa2 spacecraft brought back ~5 g of samples from a carbonaceous asteroid Ryugu [1, 2]. Because C-type asteroids are expected to contain water and organics, they could be one of the major sources of water and organics into the inner Solar system [3]. To understand dynamical, physical, and chemical evolution of such asteroids, there are various physical properties to be known. Ryugu samples provide us with the first opportunity to measure such properties for the first time. In this study we focus on the strength of Ryugu sample because it may control the orbital evolution of small bodies through affecting their size distribution [e.g., 5] and because it changes the crack propagation that affects the fluid-rock-organic interactions [6]. We measured the flexural strength, which is a composite of compressive and tensile stresses, of one of Ryugu grains allocated to the Hayabusa2 initial analysis stone team.

Methods: We conducted a series of three-point bending tests at ISAS/JAXA. We measured the flexural strength of the third largest grain of the Ryugu samples (C0002) with the longest dimension of ~8 mm. The grain was obtained at the second touchdown site. The sample was processed into two slices, both of which have approximately 3 x 3 mm^2 flat surfaces with thickness of 0.788 and 0.950 mm (hereafter referred to as C0002 No.3 and C0002 No.4, respectively). We used a testing machine (Shimadzu, EZ-L) with a load cell to obtain the relation between the load and the displacement. The withstand load of the cell was 50 N. The loading speed of the machine was fixed at 0.1 mm s^{-1}. Since the test pieces were much smaller than that used in conventional tests [e.g., 7], both of supporting and loading jigs were designed to optimize the sample size by the machining center of Chiba Institute of Technology. Note that the sample shape was optimized to the other measurements pertaining to physical properties, such as sound speed, specific heat, thermal expansibility, and so on [8, 9]. Since we only had a limited and very qualitative information about the sample strength prior to the test, we used the three-point bending technique as a firm method to measure the mechanical strength of unknown samples.

We shaped the slices of the Ryugu grain to be close to rectangular shapes as possible. The flexural (bending) stress σ_f was approximately estimated by assuming a rectangular shape for a test piece as follows,

$$\sigma_f = \frac{3PL}{2ab^2}, \quad (1)$$

where P, L, a, and b are load, the distance between two supporting bars (0.8 mm or 1.0 mm), the sample thickness, and the sample width, respectively. Figure 1a shows a photograph on the experimental settings. The radius of curvature and the width in the line-of-sight direction of the loading and supporting bars were 0.35 mm and 18 mm, respectively. Figure 1b shows the dimensions of the sample on the supporting bars.

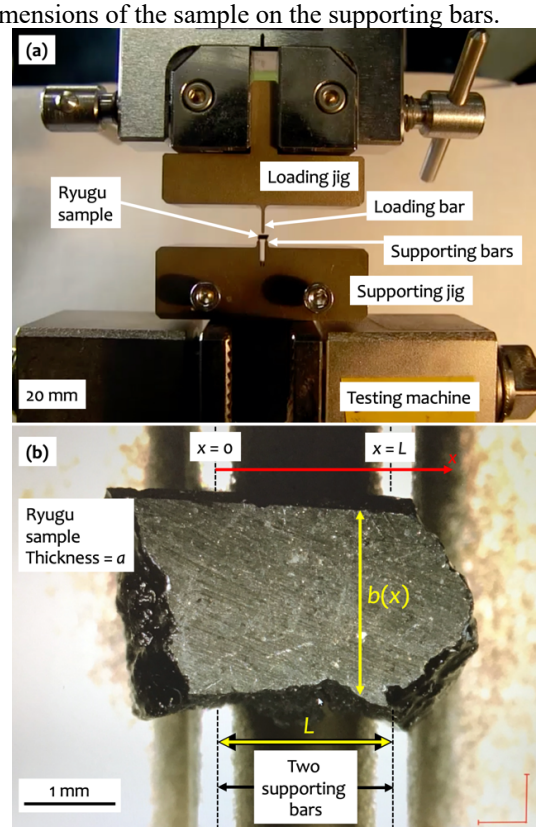

Figure 1. (a) Experimental setup. (b) The sample on the supporting jig. The definitions of the lengths used in the Eq. (1) are also shown. The loading line was located at $x = L/2$, where x is the distance from the top of one of the supporting bars. The sample width $b(x)$ is obtained as an averaged value of the line widths parallel to the loading line at different positions within the distance from $x = 0$ to $x = L$.

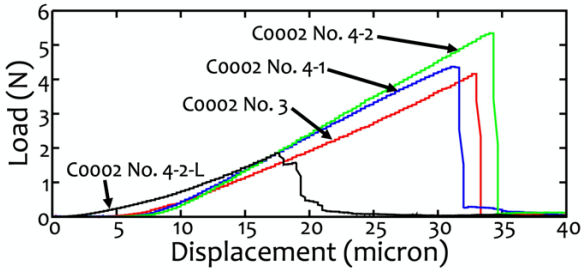

Figure 2. Load as a function of displacement. The sample IDs are shown.

We conducted four bending tests in total. C0002 No.4 was divided into two pieces prior to the test (C0002 No.4-1 and No.4-2). We also conducted an additional test for one of the fractured pieces of C0002 No.4-2 (C0002 No.4-2-L).

Results: Figure 2 shows the relations between displacement and load for four tests. Although the curve of No.4-2-L deviated from the others, the basic trend pertaining to all pieces is similar. The load steeply declined immediately after the peak value was recorded, showing that the Ryugu grain exhibited brittle failure against flexural stress. In other words, the Ryugu grain has a certain strength and is consolidated mechanically. Figure 3 shows photographs of C0002 No. 3 after the fracture. We found that the loaded surface seemed to be still intact because any traces of the loading bar are not obvious (Fig. 3a). In contrast, we observed a clear crack across the test piece at the rear surface (Fig. 3b). The crack was not a straight line but show a wavy pattern. The fractured surfaces are also shown in Fig. 3c.

Discussion & Conclusions: The flexural strength of C0002 is calculated to be 3–8 MPa by the Eq. (1) and the load at the failure (at the maximum). Although the flexural stress is a composite of compressive and tensile stress, the grain was clearly fractured by tensile stress at the rear surface (Fig. 3b). Thus, the flexural strength obtained in this study would be close to the tensile strength. Ostwski and Bryson (2019) [10] compiled the tensile strengths of carbonaceous chondrites. The tensile (flexural) strength of C0002 is several times larger than that of Tagish Lake (C2-ungrouped) and Ivuna (CI1), is comparable to that of Orgueil (CI1) and Murray (CM2), and is several times weaker than that of Kainsaz (CO3.2) and Allende (CV3).

According to the shock physics modelling of a catastrophic disruption of a hypothesized parent body of Ryugu [8, 11], a compressive pulse sweeps the entire target body. The longitudinal stress exceeds the tensile (flexural) strength obtained in this study everywhere in the parent body. This is consistent with the fact that the Ryugu samples include a lot of micro cracks [8].

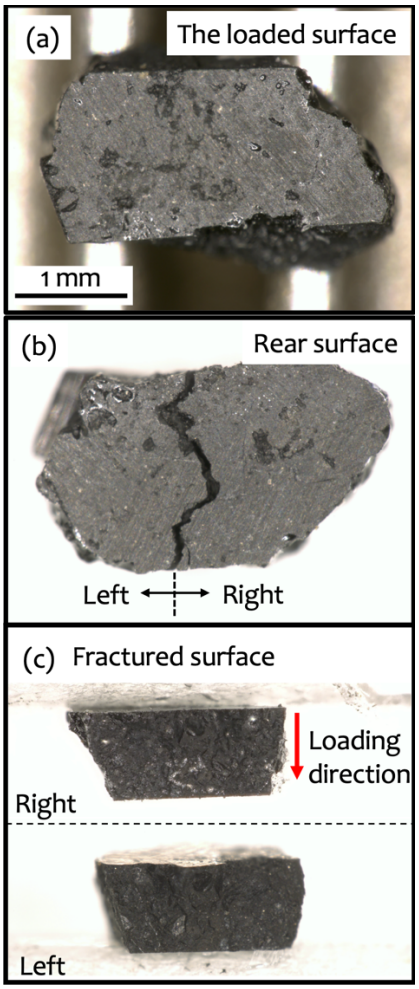

Figure 3. The sample after the fracture. (a) The Loaded surface. (b) The rear surface. (c) The fractured surfaces. The top surfaces of both fragments were loaded.

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