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Mechanical properties of asteroids analog materials

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Abstract

On-going space missions NASA's OSIRIS-REx and JAXA's Hayabusa2 are gathering more and more information on asteroid surface materials. In order to better understand how these materials respond to processes occurring in space (particularly micro-meteoroid impacts and thermal cracking), we have developed asteroid analog materials. Here, we present their mechanical properties deduced from compression and 3 point bending tests.

1. Introduction

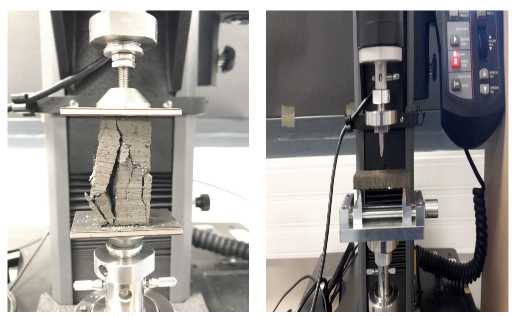
Preliminary results from the two asteroid sample return space missions that are currently on-going, NASA's OSIRIS-REx and JAXA's Hayabusa2, show that Bennu and Ryugu, the two asteroids that they are respectively exploring are made of weak carbonaceous materials [1-5]. It appears that materials on these asteroids are more porous and weaker than the large majority of meteorites that we have in our collections [4]. It is very important to understand how these materials respond to processes occurring in space, such as micro-meteoroid impacts, collision with other asteroids, and thermal cracking due to the rapid changes of temperature. For this aim, we developed asteroid analog materials that have properties similar to those of CM carbonaceous chondrite meteorites, but with mechanical properties resembling those measured on the OSIRS-REx and Hayabusa2 target asteroids. Here we present their mechanical properties, while [6] describes their response to hypervelocity impacts.

2. Samples preparation

The samples were prepared by cutting the simulants into parallelepipeds of roughly 20 x 20 x 50 mm for the compression tests and 10 x 25 x 75 mm for bending tests. Parallelepipeds of 10 x 20 x 40 mm were also cut out of the main samples for additional bending tests. After the cutting, the samples were oven-dried at 105°C for at least 24h in dry air in order to remove the humidity from the Earth atmosphere that have been absorbed by the analogs. This heating process is too weak to drive off water present within the hydrated minerals (it has been shown that heating significantly above 100 °C is necessary to alter the 2.7 μm hydration spectral band of CM2 Murchison meteorite [7]). However, this preparation improved the repeatability of the mechanical tests by limiting the influence of ambient humidity.

3. Experimental program

Simple compression mechanical tests were carried out to determine (1) the simple compression elastic modulus, E_c, and (2) the maximum compressive stress, σ_c. In addition, three-points bending tests were also carried out to determine (3) the tensile strength (or flexural strength), σ_f. Totally, seven compression tests (Figure 1a) and twelve flexural tests (Figure 1b) were performed. For the shorter samples (10 x 20 x 40 mm), the minimum aspect ratio (ratio between thickness and length of the sample) of bending-test samples was not respected. However, the normal stress distribution within a cross-section of the sample is not affected by it [8], so even these shorter samples were used for the measurement of σ_f with a good accuracy.



(a) (b)

Figure 1: Experimental device for (a) the compression tests and (b) the flexural tests.

This hypothesis is strengthened by the observed independence of σ_f on the aspect ratio in the 12 tests carried out. Even for the samples with a higher aspect ratio, the apparent Young's modulus from the flexural tests was not considered because it resulted to be significantly different from that obtained from the simple compression tests, meaning that it is a combination of compressive and tensile effects.

4. Results

Typical stress-strain curves for flexural and compression tests are shown in Figure 2 and 3 respectively, with indication of how σ_f, σ_c and E_c were obtained. Samples were cut in two perpendicular directions to assess the anisotropy of the analog materials, which resulted to be negligible. Due to the weak and brittle nature of the analog materials, it was difficult to obtain perfectly parallel surfaces for the samples. Broken corners, holes, bad surface roughness and poor parallelism between the sample's faces affected the repeatability of the tests. To this inaccuracy, one should add the inhomogeneity of the material itself.

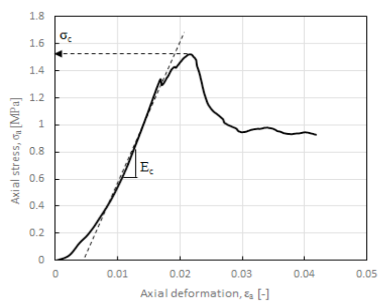


Figure 2: Typical result curve for a compression test.

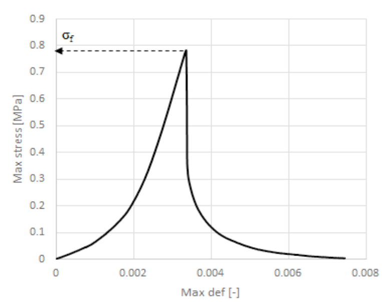


Figure 3: Typical result curve for a flexural test.

Therefore, it was assumed that the measured quantities E_c, σ_c and σ_f followed a normal distribution and accordingly, a 90% confidence interval was calculated. The results of the mechanical tests are summarized in Tab. 1.

	E_c [Mpa]	σ_c [Mpa]	σ_f [Mpa]
mean value	151.67	1.82	0.72
90% conf. interval	17.48	0.17	0.07

Table 1: Mechanical properties of analog materials

5. Summary and Conclusions

Results from our mechanical experiments indicate that compressive and tensile strengths of the CM analogs fabricated and used in this study are quite similar to those inferred for the boulders of Ryugu [4] and perhaps similar also to the materials on Bennu [1-2]

Acknowledgements

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