MOMENTUM ENHANCEMENT β MEASUREMENTS OF BASALT-BASED RUBBLE PILE SIMULANTS IMPACTED BY ALUMINUM SPHERES AT OVER 5 KM/S. J. D. Walker[1], S. Chocron[1], D. J. Grosch[1], D. D. Durda[2], S. Marchi[2], [1]Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas, 78238. james.walker@swri.org, [2]Southwest Research Institute, 1050 Walnut Street Suite 300, Boulder, Colorado.

Background: Prior to the DART spacecraft impact into Dimorphos, our group performed impact experiments into rock structures measuring momentum enhancement [1,2]. Our two-stage light gas gun arrangement is horizontal and we measure momentum enhancement through the swing of a target pendulum. One target was a collection of rocks held in place by cement. A binder was required owing to our targets being hung in a vertical pendulum inside an evacuated target chamber. The measured momentum enhancement β with this assembly of rocks was 3.4 for an impact of a 3-cm-diameter aluminum sphere at 5.44 km/s [1].

Technical Approach: With the approach of the DART spacecraft to Dimoprhos, photographs were taken before impact which showed the surface morphology. Examination of the photographs of the Dimorphos surface allowed us to propose simulants for the asteroid to perform additional impact experiments to study momentum enhancement due to hypervelocity impact on the simulated surfaces.

Within the DART community, nearly all computations are being performed with basalt as a surrogate for the Dimorphos surface material [3]. Because of this, it is very relevant to pursue building targets of basalt since 1) basalt is viewed by many as an appropriate analog to the asteroid material and 2) basalt is being used by DART Investigation Team members and others in their computations. Because of this, we based our targets to simulate asteroids, and Dimorphos in particular, to the extent possible, on crushed basalt. The use of basalt-based targets will allow the results to be directly comparable to computations performed by DART Impact Modeling Working Group.

We procured crushed basalt in a variety of sizes (Figure 1). Initial measurements of density of these pieces was performed. We explored a number of approaches to holding the material in place for our vertical pendulum, and we will report on the different mixtures of grout and sand that were used and the resulting target strength. We mix sand with the grout to reduce the cohesive strength. The DART Impact Modeling Working Group explored a wide range of cohesive strengths from the matrix, ranging from lows of 1 to 10 Pa, to midrange of 10s of kPa, to some even larger values on the high end [3]. The various modeling groups state that reasonably good β values can be obtained with each of these scales of numbers. Thus, it is difficult with the momentum enhancement results alone to bound the cohesive strength of the material. Our target cohesive strength is on the upper end of considered strengths, but it appeared to be difficult to go to much lower strengths and still have target integrity in our vertical arrangement.

Figure 1. Basalt rock sizes compared with a 3-cm-diameter aluminum sphere impactor.

Using our large two-stage light gas gun (Figure 2), we impacted 3-cm-diameter aluminum spheres into five large targets made of crushed basalt held together with grout and sand (Figures 3, 4). The targets are on the order of 60 x 60 x 30 cm in size with masses exceeding 200 kg. The impact speeds exceeded 5 km/s. Different crushed basalt rock size distributions were used in the targets. Three arrangements were used, where the largest characteristic size was smaller, comparable, or larger than the impactor (Figure 2). We will report the measured momentum enhancement βs and any dependences observed based on the distribution of characteristic rubble size vs. impactor size.

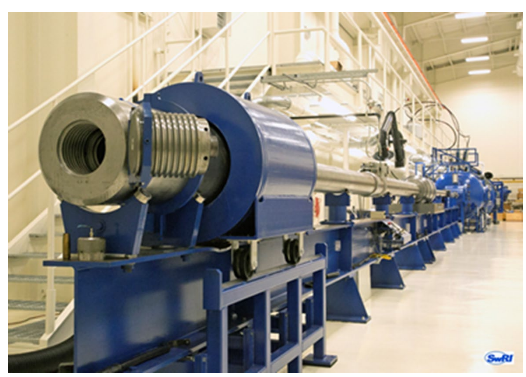

Figure 2. Two-stage light gas gun with 38-mm-diameter launch tube and evacuated impact chamber (on the right rear).

Figure 3. Crushed basalt target hanging in the pendulum before the impact experiment (LGG 407).

Figure 4. Target in pendulum showing arrangement with mirror for high-speed video camera view of the impact in the large target tank (LGG 407). Red dot in center of target is the laser bore alignment for the experiment.

These experiments will hopefully play an important role in the DART analysis by producing specific β data points with a well characterized experiment at impact speeds of interest for the DART program. These targets are not perfectly characterized, in that CT scans were not made to know the specific rock arrangement, but with a knowledge of the constituent rock sizes and cohesive strength it should be possible to model the targets reasonably well (Figure 5). We will present some of our related computations.

References: [1] Walker J. D., Chocron S., Grosch, D. J., Marchi S., and Alexander A.M. (2022) *Planetary Science J.* 3:215 https://doi.org/10.3847/PSJ/ac854f. [2] Walker J. D., Chocron S., Grosch D. J., Marchi S., and Alexander A. (2022) Hypervelocity Impact Symposium, Alexandria, VA. [3] Stickle A. M. et al. (2022) *Planetary Science J.* 3:248 https://doi.org/10.3847/PSJ/ac91cc

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Figure 5. Post-experiment photograph of target in pendulum showing debris (target tank door is open in back) (LGG 407).