Mechanical properties of CI carbonaceous asteroid regolith simulant. C. D. Schultz$^{1,2}$ and D. T. Britt$^{1,2}$, $^1$Physics Department, University of Central Florida, Orlando, FL 32816, $^2$Center for Lunar and Asteroid Surface Science (CLASS), University of Central Florida, Orlando, FL 32816 edsclutz@knights.ucf.edu.

Introduction: To visit, explore, and utilize the resources on asteroids we must characterize the structural and mechanical properties of regoliths that are likely to exist on these bodies. One of the outstanding questions about primitive asteroid surfaces is the strength of regolith and boulder material and how it changes as a result of thermal cycling in near-Earth space. Theoretical work suggests that thermal shock may be the dominant disaggregation/erosion phenomenon contributing to regolith evolution and development on small Near-Earth Asteroids [1]. This process may prove to be particularly effective for a variety of reasons including the close proximity and strong thermal input of the sun contrasted to the cold thermal sink of deep space, the lack of a mediating atmosphere, the rapid diurnal cycles, the high thermal absorptivity of the low albedo of carbonaceous chondrite surfaces, the low tensile strength of volatile-rich carbonaceous chondrites [1], and the differences in the coefficients of thermal expansion for the range minerals that make up the asteroid regolith. While significant thermal shock is limited to only the outer few centimeters of the regolith, the precise characterization of the thermal skin depth is unknown.

Meteorites sample the mineralogy, chemistry, and some mechanical properties of asteroidal surfaces, providing fundamental data. However, due to their cost and very limited supply they are simply unavailable in the quantities needed for destructive or large-scale scientific and engineering investigations. Our group [2], [3], [4] in partnership with Deep Space Industries (DSI), has created a family of asteroid regolith simulants based on the mineralogy, particle size, and mechanical properties of key meteorites. The first simulant developed is based on the CI carbonaceous asteroid Orgueil, which is rich in clays, phyllosilicates, carbon compounds, and volatiles. The parent asteroids of this type of material are attractive targets for future exploration and ISRU (In-situ Resource Utilization) missions. Our research has focused on understanding the structural and mechanical properties of this asteroid regolith simulant.

Using this simulant, we conducted a series of instrumented thermal cycling experiments to characterize the thermal skin depth, response to thermal shock, and possible cohesion degradation using a well-controlled thermal oven environment. Test specimens were also created for mechanical compression testing to determine the ultimate strength at which the material fails under compression. We will present data on the hardness and compressive strength of our simulant and the effects of this simulated diurnal cycling.

The test specimens were prepared using the UCF/DSI Orgueil-type CI simulant and shaped into “pucks” having dimensions of 3 inches by 1.5 inches. The pucks were cast by wetting the simulant powder at a ratio of one gram (or milliliter) of de-ionized water for every 4 grams of simulant. The water was mixed until a frosting-like consistency was achieved and then the simulant mixture was transferred to a mold for casting. Several of the finished pucks are shown in Figure 1.

Once cast and prior to cycling some of the physical properties of the simulant pucks were determined. The bulk density was found to be $1.80 \pm 0.01 \text{ g/cm}^3$. The grain density was determined to be $2.74 \pm 0.01 \text{ g/cm}^3$. The porosity was found to be $34.3 \pm 0.4\%$.

The simulant pucks were then thermal cycled from 40º C to 250º C over a four hour period to mimic the rotational heating and cooling of an asteroid day/night cycle. We performed a total of 677 cycles and measured the Vickers hardness of the puck surface at regular intervals. Prior to thermal cycling the hardness of the surface material was found to be approximately 5.9 HV. The hardness of the surface material dropped by approximately 50% to 2.7 HV over the first 380 cycles and then leveled out to a constant hardness for the rest of the testing period as shown in Figure 2.
Carbonaceous chondrites are conglomerates composed of a variety of dissimilar materials each with their own thermal expansion characteristics. The simulant mimics this conglomerate nature and mineralogy of the CI asteroid regolith. These experimental results suggest that differences in the coefficient of thermal expansion do weaken the surfaces of asteroidal materials, but that the weakening is limited and rapidly achieves a steady state.

![Figure 2: Vickers hardness as a function of thermal cycles](image)

The depth of thermal shock in the pucks was also tested by measuring the Vickers hardness at depths of 0 mm (surface), 1 mm, 3 mm, and 5mm from the surface. These data are shown in Figure 3. Down to 3 millimeters the hardness is essentially flat and reflects the values at the surface. However, at 5 millimeters the hardness rises substantially to an HV of 4.4. This suggests that the thermal expansion weakening is restricted to the near surface environment. This may be an identification of the thermal skin depth of this material.

![Figure 3: Hardness with depth](image)

Test specimens for mechanical compression testing were prepared in a similar fashion except cast into cylindrical molds having dimensions of 1 inch by 2 inches. Our test specimens failed at approximately 2.1 MPa.

From these studies, we hope to supply future researchers with insight into the mechanical evolution of asteroid surfaces and inputs for the design of robotic spacecraft and other future technologies that will interact with these alien surfaces.

References: