GEOTECHNICAL PROPERTIES AND OTHER OBSERVATIONS OF SIMULATED LUNAR ICY REGOLITH. V.G. Roux[1] , M.C. Roth[1], E.L. Roux[1], [1]Off Planet Research, contact@offplanetresearch.com

Introduction: Missions to find lunar icy regoliths and test extraction methods require a better understanding of their mechanical and chemical properties and behaviors. Gaining this understanding requires the use of realistic simulants that contain as many ice components as possible, and the ices must be formed using a method that closely approximates the probable formation processes of lunar icy regoliths known as cryogenic vapor deposition.

The preliminary results from our most recent icy regolith testing in 2022 indicated that changes in the ice components have a notable effect on their mechanical properties. Observing the icy regolith simulants as they warm also provides key insights into how lunar icy regoliths and their byproducts might behave within equipment which can inform the design and operation of lunar ISRU systems.

Simulants Used: Information from the LCROSS impact experiment [1] was used to create a simulated lunar icy regolith (OPRFLCROSS1). This data established the relative abundance of the ice components and the process used to freeze the gases into the simulated regolith. It is important to remember that this information is from a single location on the Moon, and ices in other locations may have differing compositions and properties. The methods used to make the icy regolith simulant can be adjusted to create a wide range of simulated icy regoliths including intergranular, chunk, and solid forms with a variety of ice compositions. The simulants in this research emulated the intergranular icy regolith observed in the LCROSS plume.

Simulant compositions. The lunar regolith simulant used was OPRH4N containing 90% anorthosite and 10% basaltic cinder; the particle size distribution of both components is based on the average for Apollo 17 samples contained in the Lunar Source Book [2] excluding particles larger than 2mm. The test data shown is from three simulant compositions: regolith only (Dry), icy regolith simulants with ices of H_2O and CO_2 (Type 1), and a larger suite of ice components H_2O, CO_2, NH_3, H_2S, SO_2, and CH_3OH (Type 2). All of these ices were frozen directly into the regolith simulant by cryogenic vapor deposition using liquid nitrogen as a refrigerant in a helium-purged test cell.

Test equipment and methods. The geotechnical testing was conducted using a Mark-10 motorized test stand and penetrometer tips that were cooled with liquid nitrogen. The simulants were tested in loose and tamped conditions to indicate respective changes in geotechnical properties.

Testing Results:

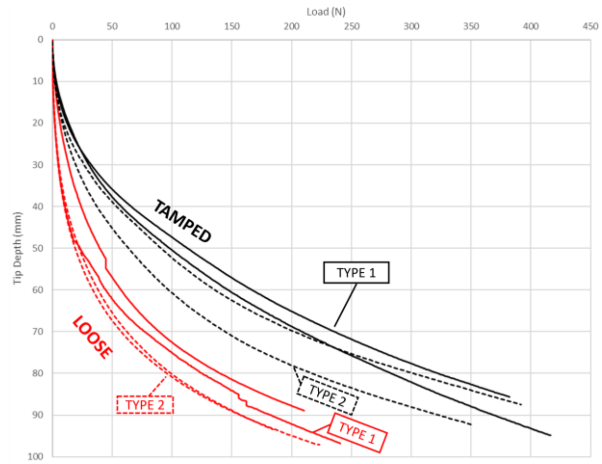

Figure 1: Cone penetrometer test results for Types 1 & 2 icy regolith simulants, loose & tamped, 60° tip, 2-inch diameter, 25mm/min.

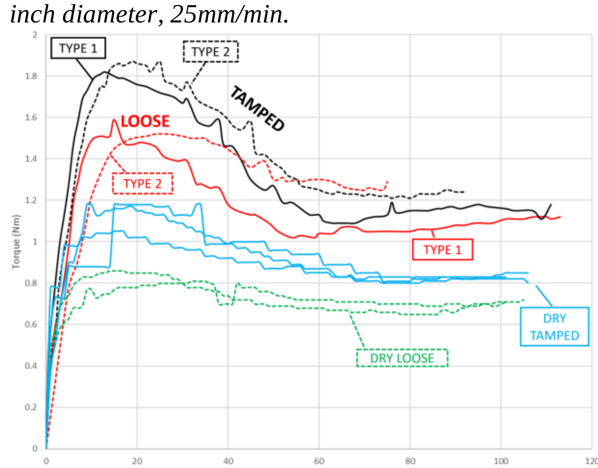

Figure 2: Lunokhod [2] shear vane test results for "Dry" & Types 1 & 2 icy regolith simulants, 3°/sec.

Conclusions and Future Work: Using more realistic simulants of lunar icy regoliths will help assure successful missions and effective ISRU and mining technologies. Future work will increase production rates and lower the temperature of icy regolith simulants using cryo-pumps or liquid helium. This will allow us to better approximate the temperatures within lunar PSRs and include more ice components such as C_2H_4, CH_4, and CO. Continued testing will produce a greater understanding of icy regoliths to help assure successful missions and a developing lunar economy.

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References: [1] Colaprete, A. et al. (2010) *Detection of Water in the LCROSS Ejecta Plume. Science* 330, 463, DOI:10.1126/science.1186986. [2] Heiken, G. et al. (1991) Figures 7.9 & 9.29, Lunar Sourcebook. Cambridge University Press ISBN 0-521-33444-6