BEVAHIOR OF BP-1 AND LHS-1 LUNAR REGOLITH SIMULANTS UNDER VACUUM CONDITIONS.

D. Sanchez Valencia, B. Dotson, D. McNair and D. Britt, University of Central Florida, Department of Physics, 4000 Central Florida Boulevard, Orlando, FL 32816; email da656059@ucf.edu

Introduction: Understanding geotechnical properties of granular material under vacuum conditions is required for developing infrastructure on the Moon and addressing the potential hazards posed by rocket exhaust [1]. Geotechnical properties of regolith can also be important for rover wheel design, landing pad development, or traverse planning [2]. This study examines the behavior and geotechnical properties (cohesion, shear strength, and internal angle of friction) of LHS-1 and BP-1 regolith simulants under atmospheric and vacuum conditions.

While previous studies have shown that geotechnical properties are influenced by a material's particle size distribution, sample density, and mineralogy, limited research has been conducted to demonstrate the effects of reduced ambient pressure on a material's behavior (Dotson et al., 2024) minimizes the Earth's atmospheric pressure effects, providing insight into regolith behavior on the surface of planetary bodies.

Methods: Direct shear testing was performed using BP-1 and LHS-1, provided by Exolith Lab, under atmosphere and vacuum conditions in accordance with D3080 test procedures [3]. These tests were performed using a 9 cm x 9 cm x 9 cm aluminum shear box, connected to a linear actuator and force gauge to record maximum shearing force at failure. Sample densities ranged from 1.52 to 1.79 g/cm^3 for LHS-1 and 1.60 to 1.91 g/cm^3 for BP-1 using a vibrating motor at 20-40 Hz for compaction. For both simulants, ambient pressures were between 160 and 170 mTorr with normal loads of 0.1 to 6.7 N applied. The vacuum chamber with the regolith samples required roughly 2 to 3 hours to reach the desired pressure range. We used a relatively slow change in ambient pressure over time to minimize outgassing disruption in the regolith. Because of BP-1's excessive outgassing and dust fountaining, the BP-1 samples were baked at 150 °C for 24 hours to reduce absorbed water, while LHS-1 samples were left exposed to atmosphere for comparison. (See Discussion Section)

Results: Direct shear measurements have been completed for LHS-1 in atmosphere and vacuum conditions, allowing for calculation of cohesion and internal angle of friction. Similar with previous studies, the initial results demonstrate an increase in cohesion and internal angle of friction with sample density [2].

Shear measurements for BP-1 in atmosphere and vacuum pressure conditions are still on-going, with results to be presented. Early results from this study, consistent with Dotson et al. (2024), also suggest a decrease in cohesion and increase in internal angle of friction when using both LHS-1 and BP-1 under vacuum conditions [4].

Discussion: Significant out-gassing was observed when using BP-1 under vacuum conditions, particularly with ambient pressures between 20-30 mTorr, consistent with the vapor pressure of water at room temperature. Such out-gassing caused regolith simulant to vacate the direct shear box, dynamically lofted and ingested by the vacuum pumps. To prevent the out-gassing of simulant, initial tests demonstrate that BP-1 must be baked to remove moisture prior to use under vacuum conditions; This measure is crucial to protect the safety of the vacuum pumps and lab equipment.

While similar effects from outgassing were not observed for LHS-1 samples under similar conditions, baking samples before use in vacuum is recommended. If not sufficiently baked prior to testing, out-gassing may also affect the sample density for both simulants as well. Since previous studies by Dotson et al. (2024) have demonstrated the importance of sample density on geotechnical properties, failing to sufficiently remove absorbed water from regolith simulants prior to use under vacuum conditions may alter the geotechnical properties [2].

Conclusion: Geotechnical measurements for BP-1 and LHS-1 under vacuum testing are underway, with results to be presented. Initial results for both simulants demonstrate a decrease in cohesion and increase in internal angle of friction when exposed to vacuum, ultimately changing the behavior of regolith simulant. Early results also demonstrate the importance on sample preparation prior to testing under vacuum conditions. Future studies should examine additional simulants and ambient pressures.

References: [1] Sapkota, D. et al., DPS 55 (2023). [2] Dotson, B. et al., Icarus (2023). [3] ASTM, D3080/D3080M-11 - Standard Test Method (2011). [4] Dotson, B. et al., LPSC 54 (2023), 2806.