“Investigation into hydrated, frozen and cemented soils in support of NASA’s in-situ resource utilization efforts”

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Background & Significance

The Apollo program’s six human missions to the moon tested exiting hypotheses of lunar regolith and confirmed the surface condition observations made during the unmanned Surveyor Program. Understanding the expected surface regoliths, to accurately simulate their composition and characteristics will influence humans’ ability to explore, exploit, or habitat on these extraterrestrial bodies. Although there has been a considerable time gap, there is a revitalization of NASA’s lunar program as a catalyst for the goal of going from the “Moon to Mars.” The renewed interest in human lunar missions is in part to use the lunar environment as a test bed for training and technology demonstrations. As interest in human missions to the moon, Mars, and other extraterrestrial bodies grow, we will need to bolster our understanding of the lunar regolith, and extrapolate the geotechnical information gleaned from the Apollo missions to future missions to other extraterrestrial bodies such as Mars.

Project Goals

The research objectives are to: Investigate the potential regolith cases on the Moon where water could be present for ISRU purposes; Group these into general categories that provide excavation and drilling challenges (e.g., 'consolidated wet soil', 'hydrated soil', 'frozen soil' and ‘cemented soil’); Identify the mechanical properties relevant to each group of regoliths; Identify analog materials for laboratory testing; and Perform representative laboratory testing to determine mechanical properties of select 'consolidated wet soil', 'hydrated soil', 'frozen soil' and ‘cemented soil’.

Summary of Key Findings

Lunar and Martian regoliths are similar to terrestrial soils in that they appear granular but are expected to contain a small amount of cohesion. As such, cohesion in extraterrestrial regoliths pose challenges for future space operations such as In-situ Resource Utilization (ISRU). Current work has been focused on to evaluating two methods -- vertical cut and simple direct shear testing – and assess their efficacy in reliably measuring small amounts of cohesion in lunar simulants; JSC-1A and GRC-3. Findings indicate that vertical cut testing cohesion estimates for JSC-1A at relative densities 0-80% ranged between 0.115 kPa and 0.971 kPa and cohesion estimates for GRC-3 at relative densities 0-80% ranged between 0.190 kPa and 1.872 kPa. Additionally, results show vertical cut testing provides monotonically increasing cohesion estimates with increased relative density which is not always the case when compared to cohesion estimates using simple direct shear testing.

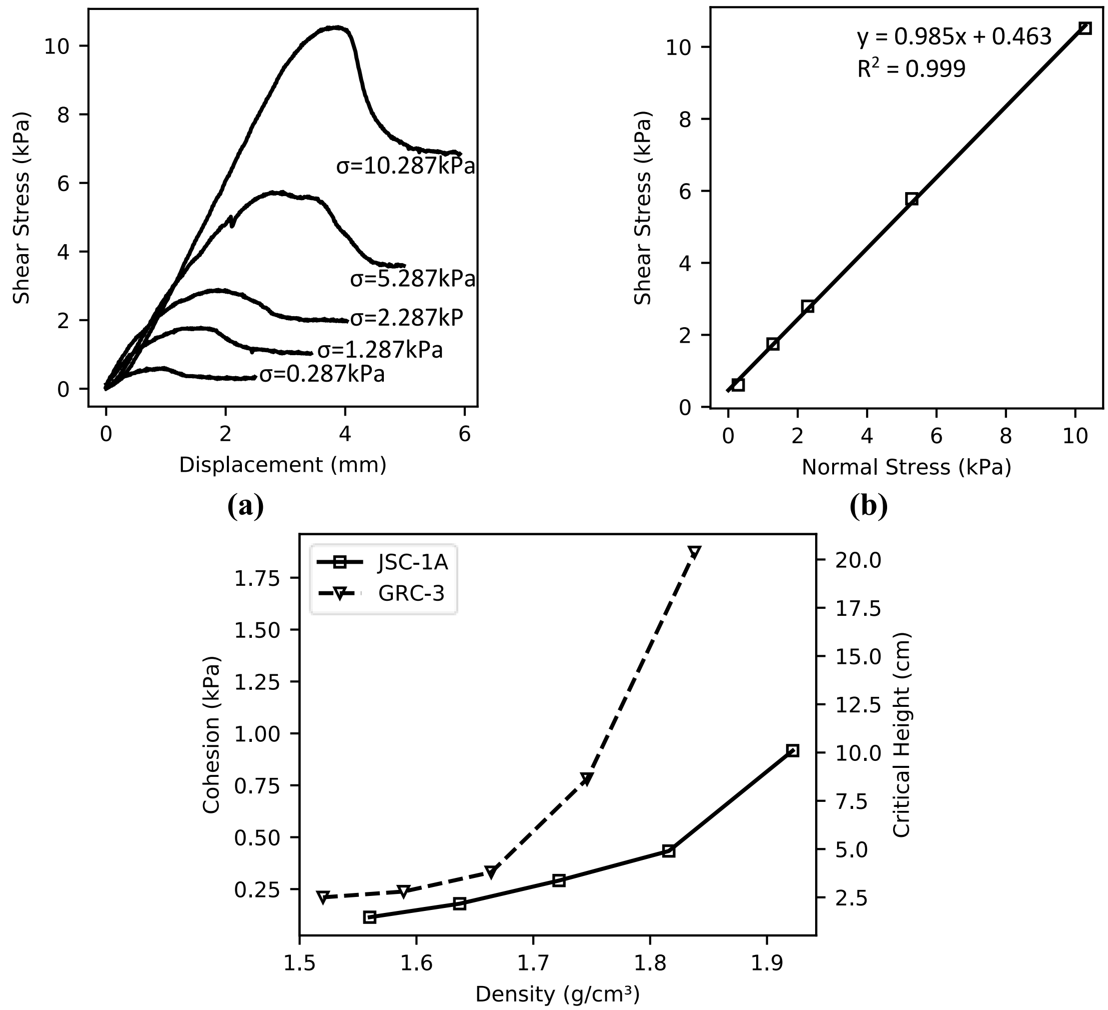

Figure 7: GRC-3 lunar simulant (a) displacement vs. stress curves at D_r 80%, (b) shear-normal curves for D_r 80%, and (c) vertical cut laboratory test cohesion estimates for Lunar simulants JSC-1A and GRC-3.