"Investigation into hydrated, frozen and cemented soils in support of NASA's in-situ resource utilization efforts"

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AY [2019-2020] Progress Report

Background & Significance

The Apollo program's six human missions to the moon tested existing hypotheses regarding the composition of lunar regolith and confirmed 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 or inhabit these extraterrestrial bodies. Therefore, it is important to reliably simulate the expected regolith properties for geotechnical aspects of space exploration such as landing, walking, and investigating potential uses of lunar resources to develop extraterrestrial habitats. Although there has been a considerable time gap, there is a revitalization of NASA's lunar program 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 its associated geotechnical properties.

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

Representative data from ongoing and prior work are included below and highlight: 1) five regolith simulant types, 2) conditions of various moisture content and pore fluid phase state, and 3) strength measurements using two different techniques. The F-75 sand simulant does not contain fines (particles less than 75μm in diameter) but was mixed with crystalline silica powder (CSP) at two different ratios (50-50 and 70-30); whereas the GRC-3 and JSC-1A are comprised of at least 30-percent fines by mass. Figures 1 and 3 indicate a trend of increased unconfined compressive strength of granular regoliths (F-75 sand and GRC-3) with increased ice fraction and photographs of the test specimens are found in Figures 2 and 4. Current work is exploring experimental test setup for the investigation into split box testing and its ability to be used to measure low levels of cohesion/soil tensile strength. Figure 5 shows the measured tensile strengths using a split box laboratory device for regolith simulants F-75/CSP (50-50), F-75/CSP (70-30), JSC-1A, and GRC-3. Figure 6 shows the test setup for the split box laboratory test device equipment referenced in Figure 5.

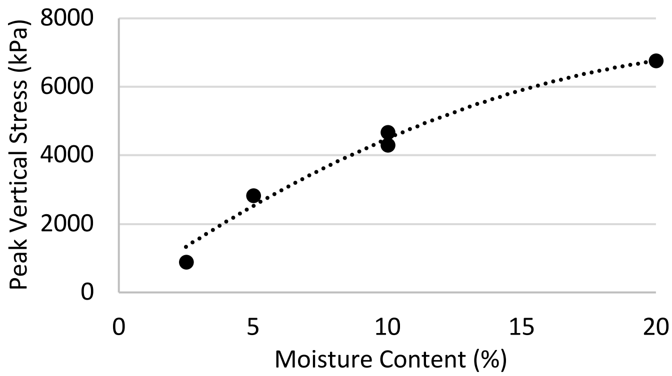

Figure 1. *Unconfined compressive strength with respect to moisture content of frozen regolith simulant (F-75 sand).*

Figure 2. *Unconfined compressive strength failed specimen (2.5% moisture content) of frozen regolith simulant (F-75 sand).*

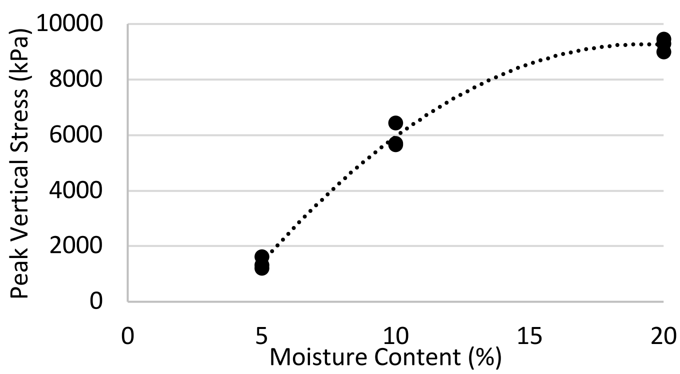

Figure 3. *Unconfined compressive strength with respect to moisture content of frozen regolith simulant (GRC-3).*

Figure 4. *Unconfined compressive strength failed specimen (10% moisture content) of frozen regolith simulant (GRC-3).*

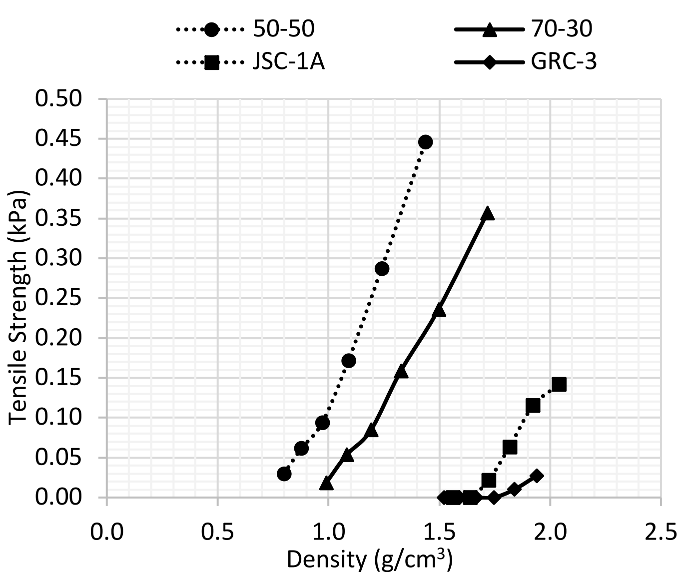

Figure 5. *Tensile strength with respect to density of regolith simulants (F-75 sand/CSP 50-50 ratio, F-75 sand/CSP 70-30 ratio, JSC-1A, and GRC-3).*

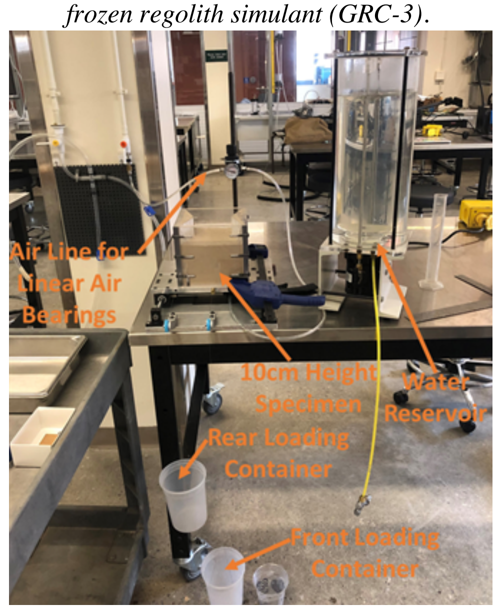

Figure 6. *Split box laboratory test device.*