Investigation of Properties of Icy Lunar Regolith in Cryogenic Temperature Environments on the Moon.

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Abstract: In this study a basaltic lunar simulant was used to predict the geotechnical behaviors of icy lunar regolith in cryogenic conditions. Strength tests including uniaxial compressive strength (UCS) and Brazilian tensile strength (BTS) were conducted following a testing matrix with various water content and temperatures. The testing indicated that icy lunar regolith at cryogenic temperatures has behaviors similar to that of soft rock, and the UCS and BTS of the icy lunar regolith are correlated to changes in the water content and temperature. This paper will discuss the procedures for preparation of samples, the test procedures, test results, data analysis, and the implications of the results on mechanical properties of the icy lunar regolith, pertinent to drilling and excavation activities for future exploration and mining operations on the Moon.

Introduction: Ever since the LCROSS data helped confirm the existence of water in lunar regolith, interest in developing In Situ Resource Utilization (ISRU) activities on the Moon such as mining water as a source of propellants for deep-space exploration has peaked[1, 2]. However, measurements from NASA instruments highlight drastic differences of the environment on the lunar surface compared to the surface of the Earth. For example, the lunar surface experiences temperature extremes varying from approximately -233°C to 123°C with mean surface temperatures during the daytime and nighttime of 107°C and -153°C, respectively[3]. It is therefore important to have a better understanding of the properties of icy lunar regolith in such environments that could control the exploration and excavation processes on the moon for ISRU purposes.

Strength Tests: In order to estimate UCS and BTS values of the icy lunar regolith, 2 inch diameter UCS and BTS specimens were cast using a modified proctor compaction system following ASTM guidelines. Strength tests were performed in different water contents that varied from 3 to 9 percent by mass and different cryogenic temperatures that varied from -190°C to -130°C. Figure 1 shows casted UCS and BTS specimens, as well as a modified strength testing system, which combines the temperature monitoring and the standard MTS press and data acquisition and monitoring system used in strength testing program.

Fig. 1 A modified strength testing system and UCS and BTS specimens of frozen regolith simulant

Figure 2 shows the summary of UCS and BTS tests results at -190°C to predict the effects of different water contents on the strength of the icy lunar regolith. Figure 3 shows the results of UCS and BTS tests performed at 6% water content to observe the effects of different cryogenic temperatures (-190°C, -160°C, and -130°C) on the strength of the icy lunar regolith.

UCS and BTS properties of the icy lunar regolith in the cryogenic environment are more sensitive to water content changes than temperature variations. In preset cryogenic environments with -190°C, the estimated UCS values increase from an average of

5.85MPa to an average of 40.25MPa when the water content increases from 3% to 9%. In the same testing conditions, the estimated BTS values increase from an average of 1.16MPa to an average of 3.00MPa. In addition, a linear correlation is observed both on the UCS values and BTS values as a function of water content in the cryogenic environment of -190°C.

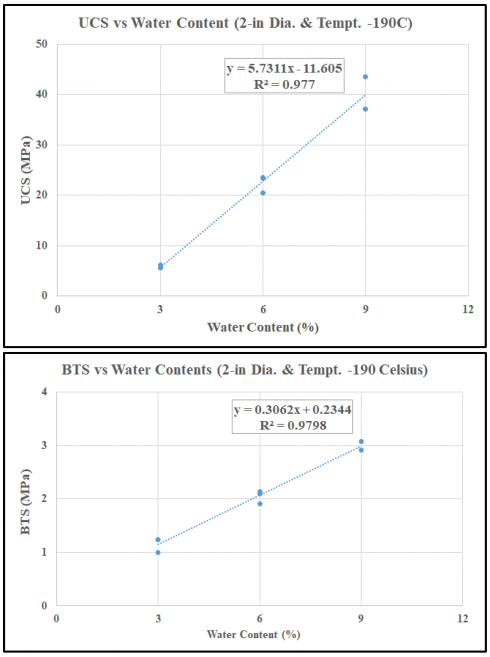

Fig. 2 Estimated UCS and BTS values of the icy lunar regolith as a function of water content

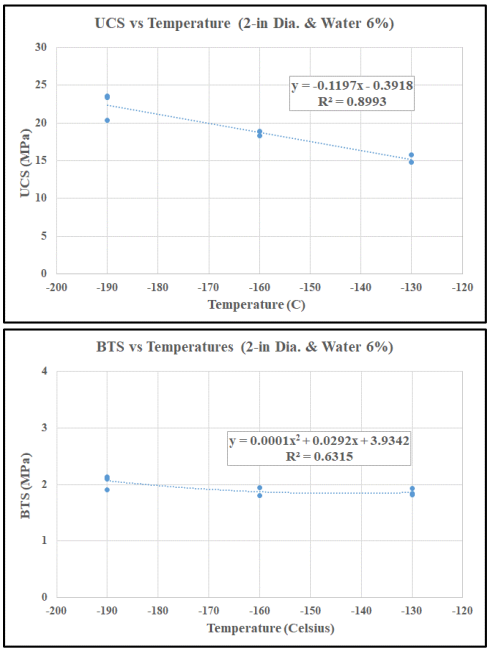

Fig. 3 Estimated UCS and BTS values of the icy lunar regolith as a function of temperature

In pre-designed moisture content of 6 percent water by mass, the predicted UCS values of the icy lunar regolith decreases from an average of 22.41MPa to an average of 15.27MPa while the temperature warms up from -190°C to -130°C. A linear correlation is also captured for the UCS values as a function of different cryogenic temperatures. However, in the same moisture conditions, increasing cryogenic temperatures from -190°C to -130°C generate slight effects on the BTS properties and lead to decrease in the tensile strength from an average of 2.06MPa to an average of 1.86MPa.

Conclusions: Changing of cryogenic temperatures and surely the water content can impact strength properties of the frozen regolith as represented by the UCS and BTS properties of the icy simulant. These properties should be measured to allow for performance assessment for the drilling and excavation systems to be deployed in such working environment.

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