STRUCTURAL MEMBERS PRODUCED FROM UNREFINED LUNAR REGOLITH SIMULANT

S. Indyk[1], H. Benaroya[2], [1]Honeybee Robotics, 398 W. Washington Ave, Suite 200, Pasadena, CA 91103, indyk@honeybeerobotics.com. [2]Rutgers University, 98 Brett Rd, Piscattaway, NJ 08854, benaroya@soe.rutgers.edu.

Introduction: The potential of utilizing lunar regolith as the raw material for manufacturing structural members is very appealing for future exploration of the Moon [1,2]. Future lunar missions will depend on in-situ resource utilization (ISRU) for structural components. Manufacturing structural components directly from unrefined lunar regolith would have the advantage of needing less specialized material processing equipment in comparison with refining the lunar regolith for its raw elements. Sintering lunar regolith has been proposed as a structural material by previous researchers but has not been evaluated for its elastic material properties. Sintering can be a highly variable process and only with the material constants can a structure be designed from this material.

Background: Sintering of actual lunar regolith has been accomplished by Taylor and Meek [3] using microwaves. However, there is not enough lunar regolith available for destructive testing to accurately quantify the mechanical material properties of sintered regolith. Lunar simulant substituted for lunar regolith in experiments then becomes the commonplace. The lunar simulant JSC-1A has become the standard for researchers in the topic of structural ISRU. Through a geothermic reaction produced by the inclusion of additives, JSC-1A has been used to fabricate bricks for constructing a voissoir dome as performed by Faierson et al. [4]. In addition, Balla et. al. [5] has utilized JSC-1A, filtered for particle size, as the base material in a selective laser sintering (SLS) machine to prove the simulants additive manufacturing potential. As a proof of concept, fabrication of small solid cylinders was performed and the parameters for the SLS machine were evaluated. Focusing on developing an optimal method of sintering lunar simulant, Allen, et al. [6] compared the fabrication of bricks with two unrefined simulants, JSC-1and MLS-1.

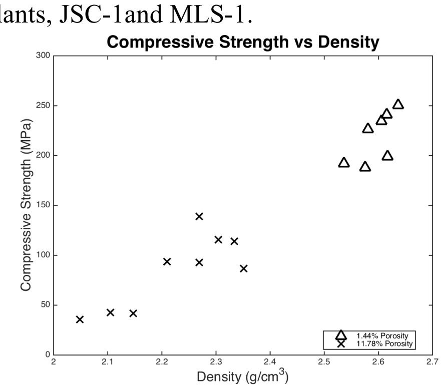

Figure 1. Compressive Strength Vs Density of the sintered specimens.

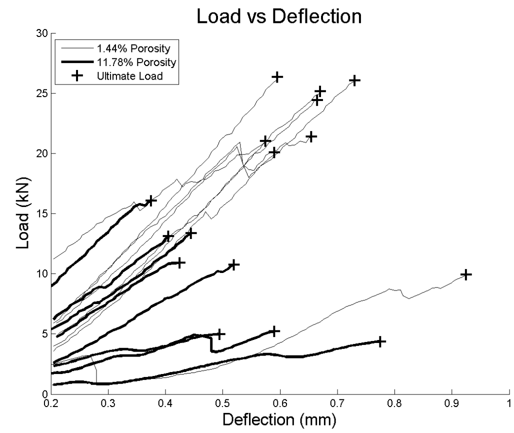

Figure 2. Load vs deflection for all compression tests.

Test Results and Data Analysis: Two batches of sintered lunar regolith simulant, JSC-1A samples with porosities 1.44% and 11.78% underwent compression testing. This is a followup of last years presented research work for quantification of the material properties. Analysis of the data sets continued and were reevaluated based on the comparative material density. Compressive strength compared to the density as shown in Figure 1 shows two clear classes of material quality. The average compressive strengths of the 1.44% porosity material were 219 MPa, and 85 MPa for the 11.78% porosity material. Material properties were evaluated from the load vs. deflection data acquired. Stress, strain, modulus of elasticity, toughness, the compression strength, bulk modulus. Figure 2 shows the load vs deflection until failure of each specimen. By comparing these values with other ISRU derived structural materials, sintered lunar regolith is expected to be one of the strongest material derived from lunar sources.

References: [1] Benaroya, H., et al., Engineering, design, and construction of lunar bases. Journal of Aerospace Engineering, 2002. [2] Benaroya, H. and Bernold, L. Engineering of lunar bases. Acta Astronautica, 2008. [3] Taylor, L.A. and Meek, T.T., Microwave Sintering of Lunar Soil: Properties, Theory, and Practice, Journal of Aerospace Engineering, 2005. [4] Faierson, E.J., et al., Demonstration of Concept for Fabrication of Lunar Physical Assets Utilizing Lunar Regolith Simulant and a Geothermite Reaction, Acta Astronautica, 2010. [5] Balla, V.K. et al. First demonstration on direct laser fabrication of lunar regolith parts, Rapid Prototyping Journal, 2012. [6] Allen, C.C., Graf, J.C. and McKay, D.S., Sintering Bricks on the Moon", Proceedings of the ASCE Specialty Conference (Space'94), 1994.