Producing Martian “Bricks” by Using Raw Martian Soil Simulants. B. J. Chow1 and Y. Qiao1,2,*, 1 Department of Structural Engineering, University of California – San Diego, La Jolla, CA 92093-0085, 2 Program of Materials Science and Engineering, University of California – San Diego, La Jolla, CA 92093 (Email: yqiao@ucsd.edu).

Summary: We discovered that, by simply compressing martian regolith under a sufficiently high pressure, strong and robust “bricks” can be formed. No terrestrial materials components are required. The processing is fast and energy-efficient, working for both primordial and secondary martian soils.

Importance and Relevance: While the first-generation martian habitats must be produced and transported from the Earth, it is desirable that the maintenance and expansion of martian bases/outposts can rely on locally harvestable resources (LHR), e.g. martian soils. Martian-soil-based infrastructural materials can also be utilized to construct habitable edifices, launch/landing platforms, pavements, protection layers for martian dust mitigation, insulation layers, permanent waste disposal chambers, and heavy and massive structural parts in research facilities, such as supports of large-scale space telescopes, to name a few.

Martian soils: Martian soils in general reflect the local bedrock composition. The bedrock composition is often basaltic and igneous in character. The entire martian crust has undergone large-scale changes in alteration from both wind and water. The water content in equatorial regions is generally drier on the surface than in polar regions (from <1 to 4 wt%) than in polar regions (from 5 to 8 wt%). The result of the sedimentary alteration is the formation of iron (III) oxides, clays, and salts.

Martian Soil Simulants: Martian soil simulants may be classified into two main categories: basaltics and clays, for primordial and secondary martian soils, respectively. In our research, the basaltic simulant was chosen as JSC Mars-1a, based upon its physical characterization and geological background. The near-infrared/visible reflectance spectrum of Mars-1a is indicative of the chemical state of iron (III) oxides consistent with purported nanoparticulate iron oxides and oxyhydroxides detected in actual martian soil. The clay simulant was chosen as montmorillonite, a common clay mineral that has been extensively studied and reported on the surface of the Mars.

Experimental Work: The martian soil simulants were vacuum-dried at 600°C to remove possible organic contaminants and excess moisture. Thermogravimetric analysis (TGA) was conducted to confirm that the water content was similar to that of the actual martian environment. The dried particles were immediately compressed at room temperature either quasi-statically inside of a hardened steel dye consisting of a cylindrical bore and two matching steel pistons, or dynamically by dropping a cylindrical steel hammer on them. The quasi-static compression pressure ranged from 100-800 MPa; the impact hammer mass ranged from 1.7 kg to ~5 kg, and the drop distance was 0.2 m.

The compacted soil sample was cut chord-wise into flexural strength measurement samples (Fig.1a), and observed under a TEM (Fig.1b). Three-point bending tests were performed to measure the flexural strength, $R$ (Fig.1c and Fig.1d).

Results and Discussion: It was found that both Mars-1a and montmorillonite simulants can be compacted into strong and robust solid, as long as the compression pressure or impact energy is sufficiently high. The flexural strength of the quasi-statically formed “bricks” is comparable with steel reinforced concrete. The dynamically formed samples are much stronger, comparable with hardwoods or cast copper alloys. TEM microscopy reveals that the bonding among Mars-1a grains is achieved through the iron oxides phase. The oxide nanoparticles cleave easily under pressure, and the flat and clean cleavage facets can subsequently fuse together, bridging the basaltic grains into a solid.

Our research finding contributes to the promise of allowing economical and self-sustainable production of martian infrastructural materials without periodic supplies from the Earth. For instance, the dynamic formation of martian “bricks” can be carried out either manually by an astronaut or by a simple and small-sized drop-tower machine powered by solar panels.

Figure 1 (a) A Mars-1a “brick”; the inset at the upper-left corner shows the raw Mars-1a grains. (b) A TEM image of the bonding between two Mars-1a grains. (c) Flexural strength of quasi-statically formed “bricks”, as a function of the compression pressure. (d) Flexural strength of dynamically formed “bricks”, as a function of the dynamic impact energy.