JSC-1: Lunar Simulant of Choice for Geotechnical Applications and Oxygen Production

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Abstract: Lunar simulant JSC-1 was produced as the result of a workshop held in 1991 to evaluate the status of simulated lunar material and to make recommendations on future requirements and production of such material (McKay *et al.,* 1991). JSC-1 was prepared from a welded tuff that was mined, crushed, and sized from the Pleistocene San Francisco volcanic field, northern Arizona. As the initial production of ~12,300kgs is nearly depleted, new production has commenced. The mineralogy and chemical properties of JSC-1 are described in McKay *et al.* (1994) and Hill *et al.* (this volume); description of its geotechnical properties appears in Klosky *et al.* (1996). Although other lunar-soil simulants have been produced (e.g., MLS-1: Weiblen *et al.,* 1990; Desai *et al.,* 1992; Chua *et al.,* 1994), they have not been as well standardized as JSC-1; this makes it difficult to standardize results from tests performed on these simulants. Here, we provide an overview of the composition, mineralogy, strength and deformation properties, and potential uses of JSC-1 and outline why it is presently the 'lunar simulant of choice' for geotechnical applications and as a proxy for lunar-oxygen production.

Composition: The basaltic welded tuff used to manufacture JSC-1 was selected for its glass content (~50%) and because it approximated the geotechnical properties of lunar soil. It was not chosen for its chemistry. The bulk chemical composition of JSC-1 consists of 10 wt.% FeO, approximately halfway between that of Mare (FeO = 15+ wt.%) and Highland soil (FeO = 5 wt.%). It approximates that of an Apollo 14 soil (14163) and is atypical of that of the major portion of the lunar surface. Therefore, JSC-1 may not be the best possible simulant, where chemistry and mineralogy are concerned, but it does have the glass content and the geotechnical properties that are close to those of the lunar soil in general.

Mineralogy: The major mineralogy of JSC-1 consists of olivine, pyroxene, plagioclase, and oxide minerals welded together by silicate glass. When crushed, the glassy fragments have a similar appearance to the agglutinates that are so abundant in the lunar soil. It is the glassy, friable nature of this material that imparts the necessary geotechnical properties to simulate the lunar soil.

The oxide minerals in JSC-1 consist of titano-magnetite, with a considerable Fe^{3+} content, and lesser amounts of ilmenite and chromite. These oxide phases, typically <20 µm, are infrequently associated with pyroxene or olivine and mostly are homogenously mixed in the glass. *Notably, the magnetite and magnetite component in the chromite are the cause of the relatively high magnetic susceptibility of JSC-1 that makes it is similar to lunar soil* (Taylor and Meek, 2005; Taylor *et al.,* 2005).

Geotechnical properties: Among different geotechnical properties, Klosky *et al.* (1996) compared the strength and deformation characteristics of JSC-1 with lunar soil. They found that loose packed JSC-1 soil (~40% relative density, RD) has similar strength and deformation characteristics to lunar soil (Carrier *et al.,* 1991). However, medium packed JSC-1 simulant (60% RD) has much greater deformation characteristics compared with lunar soil. Tests or an alternative simulant are necessary if the planned landing site on the Moon has a relative density that differs from the 40-60% RD of JSC-1.

Considerations for oxygen production: The process of hydrogen reduction involves the breaking of Fe to O bonds within a solid by the effects of the affinity of hydrogen for oxygen. The Fe-O bonds of a phase are a function of the structure in the phase. For example, the Fe-O bonds in an ordered silicate mineral are stronger than in a glass (i.e., material with no long-range ordering) of the same composition. Therefore, the hydrogen reduction of a Fe-bearing glass will occur significantly faster than for a Fe-bearing silicate mineral.

The Fe-O bonds of oxide minerals (e.g., ilmenite – $FeTiO_3$; ulvöspinel – Fe_2TiO_4; or chromite – $FeCr_2O_4$) are weaker still than even those of glass. Therefore, in a feedstock containing silicate and oxide minerals and silicate glass, the **kinetics of hydrogen reduction is as follows**:

OXIDE MINERALS >> *SILICATE GLASS* > *SILICATE MINERALS*

JSC-1 as a feedstock for oxygen production: The majority of FeO in JSC-1 is present as Fe-bearing oxide minerals, mainly titaniferous magnetite. Inasmuch as this oxide phase is readily reduced by hydrogen, JSC-1 is a good feedstock for the simulation of oxygen production. This property combined with new production of JSC-1 is significant considering the recent interest in Moon Regolith oxygen production, specifically from lunar simulant (NASA Centennial Challenges, 2005).

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