Comparison of selected lunar regolith simulants and implications on their potentials for ISRU-related applications.
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Introduction: Dozens of lunar regolith simulants have been developed worldwide to assist with testing the new generation lunar exploration equipment, both surface missions and remote sensing applications. Among these application tests, lunar in-situ resource utilization (ISRU) is a highly favourable approach to sustainably explore and settle on the Moon, significantly reduces the cost of launching supplies and supports the development of space mining technologies.

Although the most discussed application of ISRU is extracting resources from the lunar regolith, thus require high fidelity in chemistry and mineralogy of the simulants used in testing related equipment, a few other cases, such as infrastructure construction, may heavily rely on the physical properties [1]. Since it is extremely challenging to replicate both physical and chemical details of the lunar regolith, users need to critically consider how to choose the appropriate simulant for their intended tests.

For this study, we collected and characterized a set of simulants produced in China, Japan, Germany, and USA to compare their fundamental physical and chemical properties [2], some of which are especially important for ISRU tests.

Table 1. Summary of selected simulants

Name	Country	Type	Model
CAS-1	China	Low-Ti Mare	Apollo 14
EAC-1	Germany	Mare	Unknown
FJS-1	Japan	Low-Ti Mare	Apollo 14
OPRL2N	USA	Mare	Mare avg
OPRH2N and Agglutinates	USA	Highland	Apollo 17

Results: CAS-1 is the most glass-rich simulant in this set with highly angular particle shapes. Although its specific gravity is lower [3] compared to other products, it may support the study of particle interaction and anti-abrasive materials in lunar architecture and construction designs.

EAC-1 is intended to be produced in a very large quantity for EAC's lunar simulation facility and is inevitably lower in chemical fidelity [4] and thus not recommended for resource extraction studies. However, it has the highest specific gravity in this set of simulants [2], close to the representative value of lunar regolith, it can be used to develop extraction and construction tools.

FJS-1 is Japan's flagship simulant produced in the mid-1990s and has been widely used for both physical and chemical ISRU studies [5], but lacks glass component and is not of high mineralogical fidelity compared to its 2 other variations FJS-2 and -3 [6].

OPRL2N and H2N are the general-mechanical simulants produced at Off Planet Research by mixing basalt and anorthosite feedstocks into different proportions [7]. OPR is actively developing technologies to produce agglutinates as an add-on product. Since agglutinates are highly porous and rich in glass and nanophase iron (np-Fe), they will thus affect the geotechnical, mechanical and spectral properties of simulants [8,9]. Although the internal structure of the OPRH2N agglutinates sample is not examined yet, scanning electron microscope images show that the particles are indeed of complex shapes, and np-Fe-like features were found on some particle surfaces.

Discussion: All simulants chosen for this study were produced from crushing basalt and/or anorthosite rocks into desired grain sizes except OPRH2N agglutinates. This is the most economical and common method to produce simulants in large quantities but unfortunately cannot guarantee high fidelity in chemistry and mineralogy. Because of this limitation, the simulants selected for this study may not be the ideal candidates to test material processing and/or resource extraction but could contribute to civil and mechanical engineering for in-situ construction projects. Both developers and users need to understand if the chosen simulant(s) will effectively serve the intended test purposes.

References: [1] Sanders, G. (2017), UCF ISRU Graduate Seminar. [2] Zhang, X. et al. (2019) LPSC, Abstract #3071. [3] Zheng, Y. (2005) *Chinese Academy of Sciences* (dissertation). [4] Nash, V. et al. (2017), *5th European Lunar Symposium* (poster). [5] Uyama et al. (2018), 19th Space Resources Roundtable. [6] Kanamori, H. et al. (1998) *ASCE*, 462-468. [7] Off Planet Research (2019) https://www.offplanetresearch.com/listofsimulants [8] Matsushima, T. et al. (2010) *Journal of the Japanese Society for Planetary Sciences, 19,* 105-111. [9] Taylor, L.A. and Liu, Y. (2010) *ASCE, 106-118.*