Astromaterials Research & Exploration Science

SIMULANT : JSC-1/1A

(https://www.nasa.gov/)

Overview

This low-Ti lunar mare simulant was originally named Johnson Space Center One (JSC-1)[1][2][3][4] and was later replicated as JSC-1A. JSC-1/1A is crushed from basaltic ash (JSC-1/1A Source Material (https://wiki.jsc.nasa.gov/exploration/index.php/JSC-1/1A)) mined at Flagstaff, Arizona[1]. Minimally processed JSC-1/1A Source Material (https://wiki.jsc.nasa.gov/exploration/index.php/JSC-1/1A) is also available as a lunar mare simulant. JSC-1/1A formulation does not contain any additives, however Outward Technologies (https://outward.tech/) produces JSC-1/1A-derived agglutinates that can be added to JSC-1/A to increase its lunar fidelity. The Simulant Database (https://simulantdb.com/simulants/jsc1.php) contains additional details concerning JSC-1/1A. JSC-1/1A is classified as having "standard" fidelity based on the Planetary Simulant Database's loose guidelines for fidelity (https://simulantdb.com/SimulantFidelity.pdf).

Pros and Cons

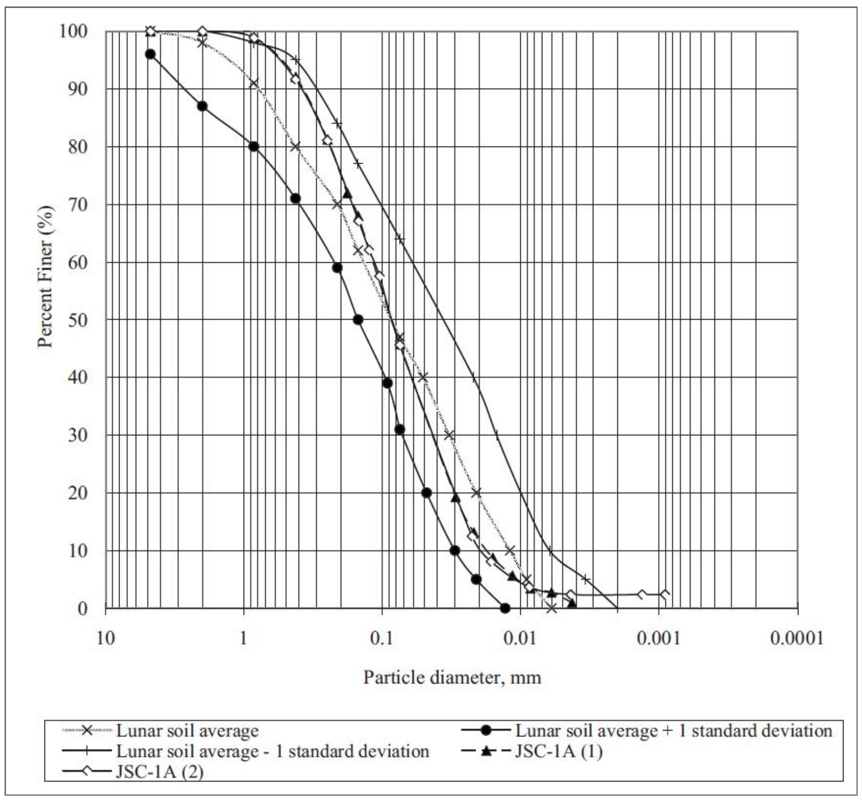
Pros

- Similar bulk chemistry to Apollo 14 soil 14163[1] and Apollo 17[5]
- Similar mineralogy to Apollo 14 soil 14164[4]
- Similar particle size distribution to Apollo 15 soil 1553[4]
- Particle shape is relatively angular[6][7]
- Naturally contains high lithic and glass fractions[5]
- At 40% relative density (loosely packed), Carrier et al. (1991)[8] found JSC-1/1A to have similar strength and deformation to lunar soil[9]
- Klosky et al. (2000)[10] described JSC-1A as a high friction, high stiffness soil with extraordinary dilatancy

Cons

- Contains both Fe^{3+} and Fe^{2+} ions where in lunar soil only reduced Fe is expected[5]
- Contains natural phosphates and Ti-magnetite instead of ilmenite[4]
- Narrower particle size distribution than Apollo reference soil[4]
- Contains particles that are subrounded[6][7]
- Lacks nanophase Fe and agglutinates[4]
- At 60% relative density (medium packed), Carrier et al. (1991)[8] found JSC-1/1A to have dissimilar deformation to lunar soil

General Properties



Particle size distribution of JSC-1/1A obtained from Zeng et al. (2010)[13]

General Properties

Lunar Surface Innovation Consortium

Lunar Surface Innovation Consortium (LSIC): Homepage (https://lsic.jhuapl.edu/)

Lunar Surface Innovation Consortium (LSIC): Lunar Simulants Working Group (https://lsic.jhuapl.edu/Our-Work/Working-Groups/Lunar-Simulants.php)

NASA LSIC Simulant Survey (https://docs.google.com/forms/d/e/1FAIpQLSeHoq6_XvUPfY4jV5Z
uohynKtu3RWzlVg/viewform)

Dust Testing Facilities

Summary of Lunar Dust Testing (/projects/simulants/lunar-dust-testing.html)

- Johnson Space Center (JSC) (/projects/simulants/dust-testing-facilities/johnson-space-center.html)
- Glenn Research Center (GRC) (/projects/simulants/dust-testing-facilities/glenn-research-center.html)
- Jet Propulsion Laboratory (JPL) (/projects/simulants/dust-testing-facilities/jet-propulsion-laboratory.html)
- Kennedy Space Center (KSC) (/projects/simulants/dust-testing-facilities/kennedy-space-center.html)
- Ames Research Center (ARC) (/projects/simulants/dust-testing-facilities/ames-research-center.html)
- White Sands Test Facility (WSTF) (/projects/simulants/dust-testing-facilities/white-sands-test-facility.html)
- Stennis Space Center (SSC) (/projects/simulants/dust-testing-facilities/stennis-space-center.html)
- Langley Research Center (LARC) (/projects/simulants/dust-testing-facilities/langley-research-center.html)
- Goddard Space Flight Center (GSFC) (/projects/simulants/dust-testing-facilities/goddard-space-flight-center.html)
- Marshall Space Flight Center (MSFC) (/projects/simulants/dust-testing-facilities/marshall-space-flight-center.html)
- External Environments (/projects/simulants/dust-testing-facilities/external-environments.html)
- Industry Facilities (/projects/simulants/dust-testing-facilities/industry-facilities.html)
- Non-NASA Facilities (/projects/simulants/dust-testing-facilities/non-nasa-facilities.html)
- Academia Facilities (/projects/simulants/dust-testing-facilities/academia-facilities.html)

Comprehensive Dust Testing Facility Table

(/projects/simulants/_resources/comprehensive_dust_testing_facility

Particle Shape Range	Particle Size Range (μm)	Mean Particle Size (μm)
angular to subrounded[7][2]	10-1000[3]	-
Particle Size Distribution (by site/sample)	**Chemical Composition (by sample/site)**	**Mineralogical Composition**
Apollo 15 soil 15530[1][2][11]	Apollo 14 soil 14163[1]	Apollo 14 soil 14164[12][1]

Texture

naturally high glass and lithics fraction[1][5]

Modal Mineralogy

Mineral	Abundance (%) [12]
Glass	49.3
Plagioclase	37.1
Olivine	9.0
Cr-spinel	1.1
Ti-magnetite	0.4
K-silicate	1.4
Sulfide	1.0
Albite	0.3
Quartz	0.2
Chlorite	0.1
Apatite	<0.1
Clinopyroxene	<0.1
Ilmenite	<0.1

Major Element Chemistry

Oxide	Apollo 14 Average Soil wt. %[3]	JSC-1/1A wt. %[1][3]	JSC-1/1A wt. %[12]	JSC-1/1A wt. %[5]
SiO_2	48.1	47.71	47.4	45.7
TiO_2	1.7	1.59	1.56	1.9
Al_2O_3	17.4	15.02	16.1	16.2
Cr_2O_3	0.23	0.04	0.03	-
Fe_2O_3	-	3.44	11.4	12.4
FeO	10.4	7.35	-	-
MnO	0.14	0.18	0.18	0.2
MgO	9.4	9.01	7.72	8.7
CaO	10.7	10.42	10.5	10.0
Na_2O	0.7	2.7	2.94	3.2
K_2O	0.55	0.82	0.80	0.8
P_2O_5	0.51	0.66	0.59	0.7
LOI	-	0.71	0.3	-
Total	99.8	99.65	99.6	99.8

Geomechanical and Physical Properties

Geomechanical Properties

Hardness (Mohs scale)	Specific Gravity (g/cm^3)	Angle of Repose (°)	Void Ratio
4-5	2.9[14] 2.91[2] 2.875[13]	37[15]	0.61-1.18[16] 0.410-0.826[13]

Density (g/cm^3)

Bulk	Relative Max	Relative Min
1.5-1.7[1] 1.57-1.64[10] 1.62-1.72[17] 1.7-1.88[11] 1.8-1.9[18] 1.9[8]	1.83[10] 1.91[17] 1.80[16] 2.03[13]	1.43[10] 1.43[17] 1.33[16] 1.57[13]

Triaxial: Shear Strength		Uniaxial	
Cohesion (kPa)	**Friction Angle (°)**	**Young's Modulus (MPa)**	**Tensile Strength (kPa)**
1.0-1.4[1] 0.1-2.5[18] 0.2-1.8[16] 1.4-2.4[11] 2.4-3.8[8] 3.9-13.4[17] 3.9-14.4[10] <1.0[2] 2.0-5.0[14]	43.9-45[1] 42.9-48.8[11] 44.5-49[16] 41-60[18] 44.4-52.7[17] 45[2] 48.8-55[8] 43.6-44.4[10] 57[13] 37-48[14]	18-60, 65-110[10]	0.93-2.00[11]

Simulant Development Lab Analytical Results

Pending analyses.

Safety

Please view the JSC-1/1A (_resources/JSC-1A_SDS.pdf) and JSC-1A (_resources/BlackCinder_SDS.pdf) source material (black cinder) Safety Data Sheets (SDS) for specifications, PPE requirements, and hazards.

Recommendation

JSC-1/1A is recommended for geotechnical testing that involves loose simulant. JSC-1/1A is also recommended for ISRU testing that does not depend on iron redox or ilmenite. More detailed recommendations come from the Lunar Regolith Simulant User's Guide[19]. View the Simulant Testing Matrix (/projects/simulants/lunar-dust-testing.html) and/or contact the JSC Simulant Development Laboratory (/projects/simulants/development-lab.html) for information concerning simulant recommendations.

Excavation / Flow

Recommended
Relatively angular particles, reasonable PSD.

Drilling

Recommended with reservations
Uncertain but probably reasonable fidelity to highland abrasiveness.

Abrasion / Wear

Recommended with reservations
Uncertain but probably reasonable fidelity to highland abrasiveness.

Oxygen Production

Recommended with reservations
Chemistry: FeO is significantly high relative to lunar reference (≈11 vs. 5 wt.%). Mineralogy: Contains natural phosphates, Ti-magnetite instead of ilmenite. Use will likely result in unrealistically high oxygen yields; may be a good mare simulant (e.g., Apollo 14) for this use.

Human Health Studies

Possibly suitable composition
Reasonable PSD but too coarse in fine fraction.

Availability

JSC-1/1A is currently available at the JSC Simulant Development Laboratory (/projects/simulants/development-lab.html) in bulk quantities.

1. ↑ 1.00 1.01 1.02 1.03 1.04 1.05 1.06 1.07 1.08 1.09 1.10 McKay, D. S., Carter, J. L., Boles, W. W., Allen, C. C., & Allton, J. H. (1994). JSC-1: A new lunar soil simulant. Engineering, construction, and operations in space IV, 2, 857-866
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4. ↑ 4.0 4.1 4.2 4.3 4.4 4.5 Taylor, L. A. (2015, October). Status of lunar regolith simulants-An update. In *Annual Meeting of the Lunar Exploration Analysis Group* (Vol. 1863, p. 2012).
5. ↑ 5.0 5.1 5.2 5.3 5.4 Ray, C. S., Reis, S. T., Sen, S., & O'Dell, J. S. (2010). JSC-1A lunar soil simulant: Characterization, glass formation, and selected glass properties. Journal of Non-Crystalline Solids, 356(44-49), 2369-2374
6. ↑ 6.0 6.1 Garboczi, E. J. (2011). Three dimensional shape analysis of JSC-1A simulated lunar regolith particles. Powder Technology, 207(1-3), 96-103
7. ↑ 7.0 7.1 7.2 Rahmatian, L. A., & Metzger, P. T. (2010). Soil test apparatus for lunar surfaces. In Earth and Space 2010: Engineering, Science, Construction, and Operations in Challenging Environments (pp. 239-253).
8. ↑ 8.0 8.1 8.2 8.3 8.4 Carrier, W. D., Olhoeft, G. R., & Mendell, W. (1991). Lunar sourcebook: A users guide to the moon. *Physical Property of the Lunar Surface*, 475-594.
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12. ↑ 12.0 12.1 12.2 Taylor, L. A., Hill, E., Liu, Y., & Day, J. M. (2005). JSC-1 as the Lunar Soil Simulant of Choice. Meteoritics and Planetary Science Supplement, 40, 5180
13. ↑ 13.0 13.1 13.2 13.3 13.4 13.5 Zeng, X., He, C., Oravec, H., Wilkinson, A., Agui, J., & Asnani, V. (2010). Geotechnical properties of JSC-1A lunar soil simulant. Journal of Aerospace Engineering, 23(2), 111-116
14. ↑ 14.0 14.1 14.2 Alshibli, K. A., & Hasan, A. (2009). Strength properties of JSC-1A lunar regolith simulant. Journal of geotechnical and geoenvironmental engineering, 135(5), 673-679
15. Jump up ↑ Calle, C. I., & Buhler, C. R. (2020). Measurement of the Angle of Repose of Apollo 14 Lunar Sample 14163. *LPICo, 2141*, 5030.

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Eileen K. Stansbery (mailto:eileen.k.stansbery@nasa.gov)
Responsible NASA Official

ARES Developers (mailto:jsc-ares-developers@mail.nasa.gov?subject=Site: /projects/simulants/jsc-1-1a.html&body=This message originates from visiting the page: https://ares.jsc.nasa.gov/projects/simulants/jsc-1-1a.html)
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