



Abstract #1688

English

Basalt Derived Feedstock for ISRU Manufacturing.

Introduction: Being able to utilize available resources found on the Moon, Mars or any other extraterrestrial body in which humans are planning to set up a base will be critical for the success of the mission. Both on the Moon and Mars, regolith is the most abundant and readily available resource and therefore should be considered as the primary material to be utilized for construction. Between the summer of 2015 and the spring of 2016, NASA's Swamp Works and the Pacific International Space Center for Exploration Systems (PISCES) worked together under a project called Additive Construction with Mobile Emplacement (ACME) to design, construct and test a VTVL Pad in Hilo, HI using Hawaiian basalt regolith as the construction material. Sintered basalt pavers manufactured for the project exceeded residential concrete's compressive and flexural strength. These basalt sintered materials have been produced with minimum manipulation of the raw materials and could be used for construction of roads, landing pads, thermal wadis, shelter, tools and other structural parts. A second sample sintered at a higher temperature profile resulted with flexural and compressive strengths three times stronger than that of specialty concrete.

French

No abstract title in French

No French resume

Author(s) and Co-Author(s)

Mr. Rodrigo Romo
PISCES Program Manager
1Pacific International Space Center for Exploration Systems (PISCES),

Mr. Christian Andersen
Engineering Manager
1Pacific International Space Center for Exploration Systems (PISCES),

Mr. John Hamilton
EPO: Logistics Manager
PISCES - Pacific International Space Center for Exploration Systems

Mr. Robert P Mueller
Lead Senior Technologist
NASA Kennedy Space Center



Profile of Mr. John Hamilton

General

Email(s): jch@hawaii.edu

Position: EPO: Logistics Manager

Preferred Language: [Language not defined]

Addresses

Business

PISCES - Pacific International Space Center for Exploration Systems
PO Box 615
Pepeekeo
Hawaii
United States
96720

Home

Biographies

Biography submitted with the abstract

John Hamilton is on faculty with the Department of Physics and Astronomy at the University of Hawaii at Hilo, on the majestic island of Hawaii. As the Research Operations Manager of the newly formed PISCES (the Pacific International Space Center for Exploration Systems) in 2007 at the university, he managed multiple field tests with NASA, CSA, DLR, and ESA with surface technologies and ISRU. PISCES later was spun off as a State Agency, where John serves in the dual role of Education/Public Outreach and Logistics manager. Field tests with various GLXP teams and universities continued.

Biography in the user profile

Collaborators

Author(s) and Presenter(s)

Author(s):

Mr. John C. Hamilton

EPO: Logistics Manager
PISCES - Pacific International Space Center for Exploration Systems

Presenter(s):

Mr. John C. Hamilton
EPO: Logistics Manager
PISCES - Pacific International Space Center for Exploration Systems

Basalt Derived Feedstock for ISRU Manufacturing

Romo, R., Pacific International Space Center for Exploration Systems
Andersen, C., Pacific International Space Center for Exploration Systems
Hamilton J.C., Dept of Physics & Astronomy, University of Hawai'i Hilo
Mueller, R.P., NASA Kennedy Space Center, Swamp Works

CIP 2017 Convention
Planetary & Terrestrial Mining Sciences
May 1st – 3rd, 2017
Montreal, QC



PACIFIC INTERNATIONAL SPACE CENTER FOR
EXPLORATION SYSTEMS | PISCES.HAWAII.GOV

I.S.R.U

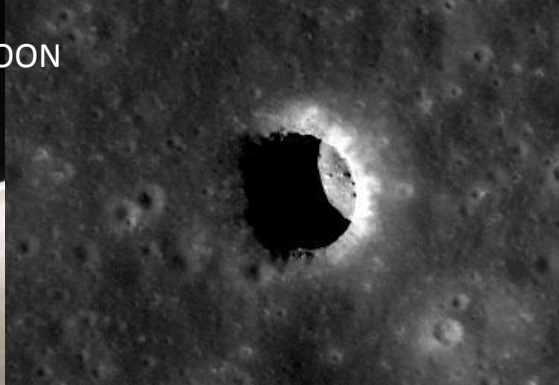
In Situ Resource Utilization: The Collection, processing, storing and use of materials encountered in the course of human or robotic space exploration that replace materials that would otherwise be brought from Earth to accomplish a mission critical need at reduced overall cost and risk.

(Sacksteder & Sanders, 2007)





PACIFIC INTERNATIONAL SPACE CENTER FOR
EXPLORATION SYSTEMS | PISCES.HAWAII.GOV



MOON



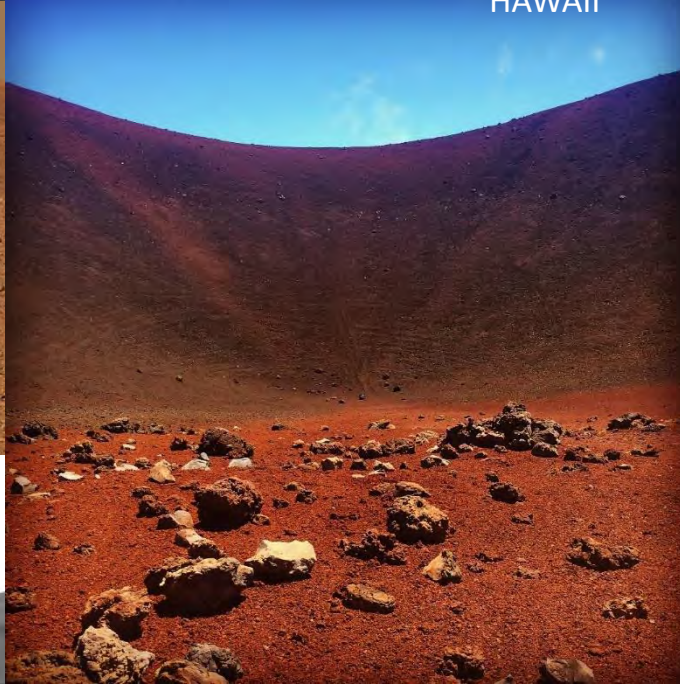
HAWAII



MARS

Regolith

MARS



PACIFIC INTERNATIONAL SPACE CENTER FOR
EXPLORATION SYSTEMS | PISCES.HAWAII.GOV

Regolith: Most Abundant Resource

Hawaii-Lunar-Mars Basalt/Regolith Characterization

Sample	MnO ppm	Fe %	Na ₂ O %	MgO %	Al ₂ O ₃ %	SiO ₂ %	K ₂ O %	CaO %	TiO ₂ %
Hawaii	1888	9.07	2.68	7.87	14.6	51.77	0.55	10.99	2.12
JSC-1A	1800	10.79	2.7	9.01	15.02	47.71	0.82	10.42	1.59
LS 14163	1000	10.5	0.7	9.6	17.8	47.3	0.6	11.4	1.6
Spirit	2500	17	3	8.7	10.2	45	0.3	6.1	1
Opportunity	3000	18	2.1	7.5	9.1	44	0.4	6.9	1.1
Curiosity	3000	21	2.1	6.5	9.5	43	0.5	7.2	1.5

Utilization/Manipulation Techniques for Basalt:

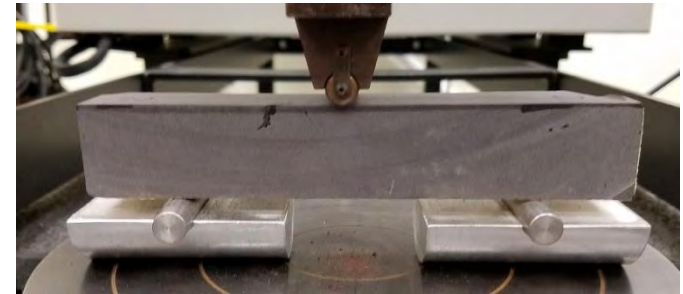
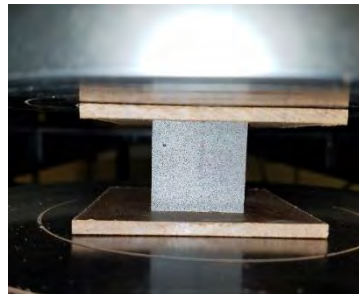
- Sintering
- Melt
- Extrusion
- Additive Manufacturing
- Fiber Manufacturing



SINTERING

High temperature sintering of Hawaiian Basalt Fines

Test	Residential Portland Cement Concrete (typical)	HHQ-Pad	Commercial Portland Cement Concrete (typical)	Specialty Portland Cement Concrete (typical)	HHQ+
Flexural Strength (psi)	500	716	800	2,000	5,852
Compressive Strength (psi)	2,500	3,116	4,000	10,000	30,825
Density (g/cm ³)		1.699			2.64



¹ The flexural strength (Modulus of Rupture) test was conducted in accordance with ASTM C133, Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories

² The cold crushing strength, or compressive strength, test was also conducted in accordance with ASTM C133.

SINTERING

Potential Applications

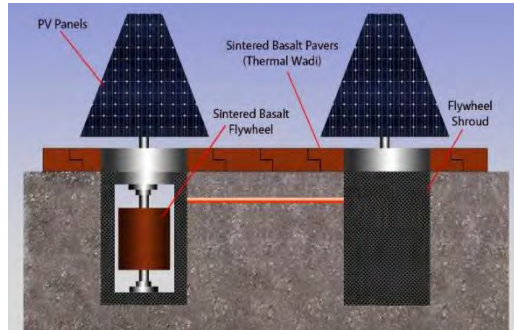
- Paver manufacturing for Thermal Wadis
- Reentry Thermal Heat Shields
- Radiation Shields.
- Indoor/Outdoor Flooring Tiles
- Tools & Parts
- Flywheels for Kinetic Energy Storage Systems
- Construction Blocks
- Thermal insulation
- Paved surfaces for dust mitigation
- Pavers for landing and launch pads



Landing Pad Pavers



Construction Blocks



Thermal Wadi



Thermal Shields



BASALT FIBER

Ideal Composition for Basalt Fiber Manufacturing

Component	Fe	Na ₂ O + K ₂ O	MgO	Al ₂ O ₃	SiO ₂	CaO	TiO ₂
Range (%)	9-14	3-5	3-5	14-19	50-60	5-10	0.5-3
Hawai'i	9.07	3.23	7.87	14.6	51.7	10.99	2.12
LS-14163	10.5	1.3	9.6	17.8	47.3	11.4	1.6
Mars Avg	18.6	2.8	7.6	9.6	44	6.7	1.2

Mesh



Rebar



Fiber

Rope

Fabric



ADDITIVE MANUFACTURING & CONSTRUCTION



- Selective Laser Melting

- Robotically-Enabled Additive Construction



- Extrusion of molten basalt



Questions



PACIFIC INTERNATIONAL SPACE CENTER FOR
EXPLORATION SYSTEMS | PISCES.HAWAII.GOV