Planetary Construction 3D Printing Using In-situ Resources and Mission Recyclables

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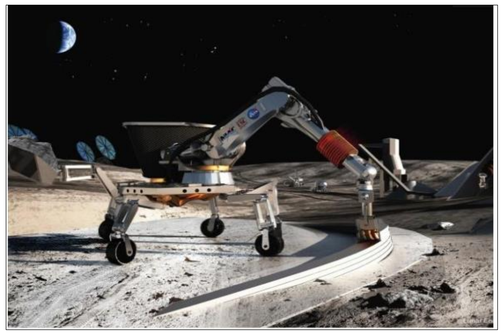
Background:

Overview:

Construction 3D printing (C3DP) is an additive manufacturing technique that involves the autonomous layer-by-layer construction of a structure or component from a 3D model.



C3DP Robot Arm mounted on a ATHLETE Rover (Photo credit: NASA/Contour Crafting)

Motivation:

- ❑ The need for supporting structures on the Moon and Mars for a long-term sustained presence
- ❑ Using in-situ resources for robotic planetary construction
- ❑ Reduce human involvement and exposure to extreme environment during construction

Research Goal:

To study and further advance planetary C3DP technology using in-situ materials and mission recyclables:

- ❑ To design and develop customized extruder to explore a wide range of printing materials
- ❑ To evaluate the influence of interlayer time gap on the deformation of 3D printed layers
- ❑ To implement and evaluate real-time extrudate scanning systems of automated deformation detection.

Indigenous Construction Materials

ISRU-Based

- ❑ Regolith soil and dust
- ❑ Basalt fiber
- ❑ Sulfur
- ❑ Extracted metals and polymers

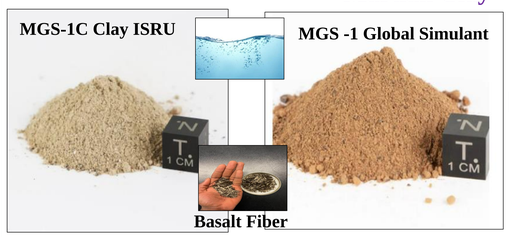
Mission Recyclables

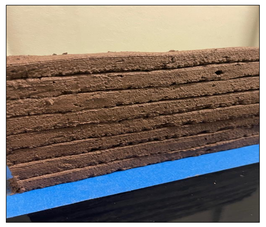
- ❑ Plastics

- ❑ Limited resources on the Moon and Mars
- ❑ ISRU enables collection, processing, storage, and utilizing local materials to support life and construction
- ❑ Reduces payloads and the cost of transporting terrestrial construction materials

Materials

Martian Clay



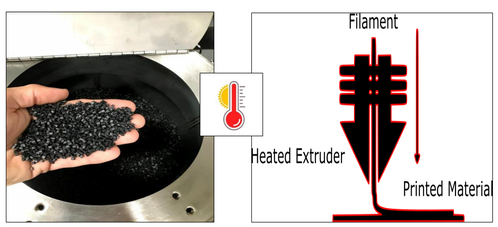


- ❑ Low Temperature Material

Sulfur Concrete

Photo credit: Yuan, 2016

PLA + Basalt Fiber



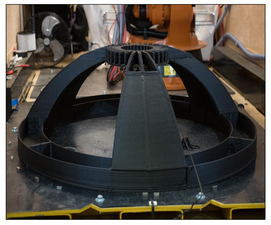
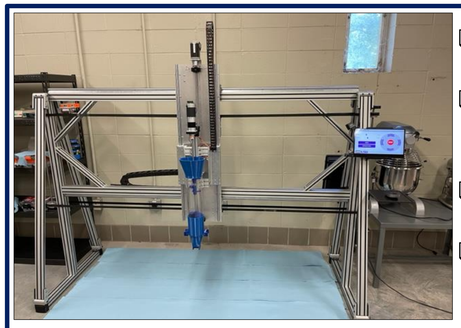


Photo credit: 3D Printed Habitat Challenge, NASA

- ❑ High-Temperature Materials.

Methods



- ❑ **Physical properties**: melting temp., water absorption, density
- ❑ **Rheological properties:** Viscosity, setting time and structural build up, yield stress and plastic viscosity
- ❑ **Mechanical properties:** Compressive and flexural strengths
- ❑ **Extrudate Scanning system:** LIDAR sensor and computer vision and structured laser light

Pumpability and Flowability

Printability

Buildability

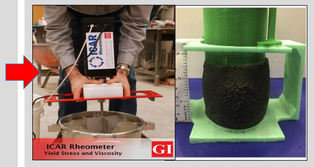


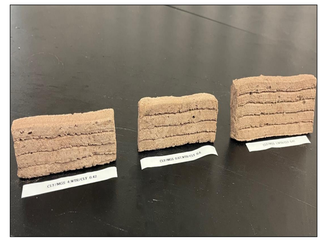
Photo credit: Kazemian et al., 2017

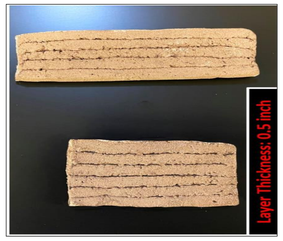
Preliminary Results

Martian Clay/Regolith Material

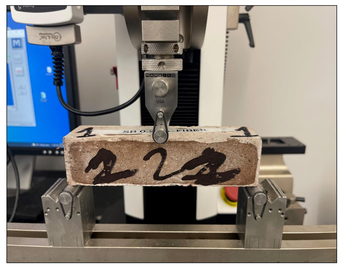
Printability Test

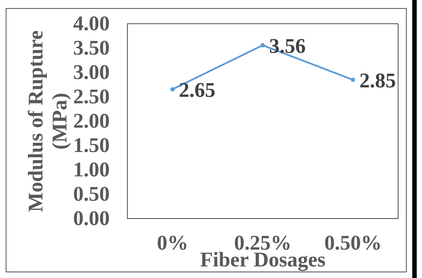
- ❑ Layered extrudates at different clay/regolith percentages and water content





Flexural Tests Results





- ❑ Flexural strength of 2.3-3.85MPa
  - ❑ Varies with curing temperature and fiber dosages
  - ❑ Potential increase in flexural strength (MOR) with addition of basalt fiber up to an optimum dosage

Sulphur Concrete

- ❑ Melting point – 115-120ºC
- ❑ Greater open time at temp > 155ºC

PLA+ Basalt Fiber

- ❑ Melting point – 160ºC
- ❑ Greater open time at temp > 200ºC

Conclusion

- ❑ C3DP offers a unique opportunity for construction of structural and non-structural infrastructures on celestial bodies to support sustained human presence on the Moon and Mars
- ❑ Using ISRU-based materials and mission recyclables for planetary construction can help resolve the constraint of transporting terrestrial construction materials to space.

References

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