Martian Soil Simulants – Mechanical Properties and Feasibility as Building Blocks

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ABSTRACT

Efficient in-situ resource utilization is a critical component of NASA's current and future Mars exploration missions. In this CI project, the team aims to develop innovative, energy efficient and sustainable Mars-compatible processes to transform in situ Martian resources and long-term space mission organic wastes into construction materials for functional building blocks. In particular, this year's focus is on two different processes of synthesizing Martian regolith-based materials: 1) epoxy-soil composite, and 2) bio-cementation. The team aims to develop the general processing procedures of synthesizing these two kinds of materials. The manufactured materials are then characterized with advanced imaging based techniques (SEM, X-Ray CT) and are tested for their engineering properties through thermal and mechanical experiments.

MATERIALS

Epoxy-Soil Composite

- **JSC Mars-1A**
  - Most accurate simulant of the mechanical properties of Martian soil
  - Collected from the Pu'u NeNe cinder cone on Hawaii
- **Araldite GY 6010**
  - Unmodified liquid epoxy resin
  - Easy to cure with variety of hardeners
  - Superior mechanical properties
- **Aradur 956**
  - Low viscosity
  - Very reactive
  - Used for room temperature curing adhesives

Bio-Cementation

- **JSC Mars-1A**
- **Biomass**
  - 100% Artificial Sea Water (NaCl, KCl, $MgCl_2.6H_2O$,$MgSO_4.7H_2O$, $CaCl_2.2H_2O$)
  - Glucose
  - Urea
- **Bio-Cement Media**
  - $CaCl_2.2H_2O$
  - Urea
  - Biomass
- **Bio-Cement Columns**
  - Caps paved with one piece of Aluminum grid and one piece of tea bag

METHODOLOGY

Epoxy-Soil Composite Sample

- Mars-1A soil is first dried in an oven to ensure no moisture is present
- Building blocks are created by mixing Mars-1A soil with Araldite Epoxy and Aradur Hardener at different ratios
- Mixture then poured into T-bone mold and compression mold, heated in oven at 120°C for 5 hours



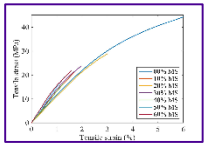
Bio-Cementation

- **Biomass**
  - Grow culture broth samples under 25°C @ 150 RPM
  - Incubate broth for 3-4 days in clean chamber
- **Bio-Cement Media**
  - Attach to Martian soil to form solid
- **Bio-Cement Columns**
  - Soil to diameter ratio is 2:1
  - Bio-cement media pumped through bottom of the column @ controlled rate overnight with tea bags in place to prevent leakage
  - Drained excess liquid, dried column in an oven under 50°C, and analyzed results

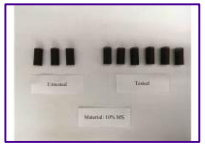
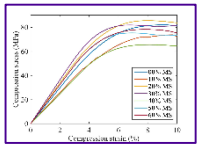


RESULTS

Epoxy-Soil Composite Sample

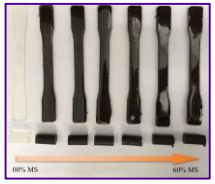
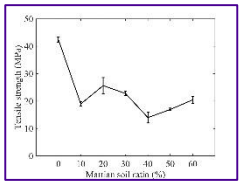
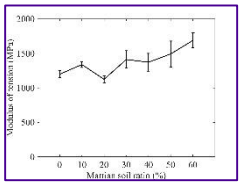
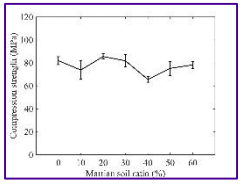
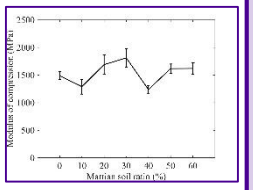



Tensile testing

Compression testing

Variant soil ratio

CONCLUSIONS

Epoxy-Soil Composite

- It is feasible to make epoxy-soil composite that cured under Mars similar environment, 100 degrees temperature or UV.
- The team investigated the mechanical properties of the varying ratios of Martian Soil Simulant to polyethylene with thermal curing technology.
- The tensile test results showed that increasing the Martian Soil ratio decreased the strength of the composite overall.
- The compression test results did not show any trends between the Martian Soil ratio and the composites' compression strength.

Bio-Cementation

- The team is using bacteria produced bio-cement as a bonding agent for the Martian soil simulant and currently working on perfecting the mixing process of the biomass and soil and also on optimizing the different variables that affect the bio-cement output.
- The primary goal now is to promote greater bio-cement production from the biomass in the medium by: increasing the amount of biomass present in a given experiment, and/or creating an environment more conducive to greater bio-cement production in the medium.

FUTURE WORK

The team plans to have the experimental procedure and setup optimized for the summer so that they can direct their attention towards testing all the different variables that affect the strength of the resulting column and the amount of biomass created. The goal is to be able to have a variety of samples created in a testable quantity so that mechanical tests can be performed either at the end of the summer or the beginning of fall semester 2017.

Acknowledgement

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