Development of Geopolymers for 3D Printing on Mars

Honours Programme Delft

cohort 2023 2024

Assessing Geopolymer Parameters and Feasibility for ISRU Habitat Construction in Martian Lava Tubes – Rhizome 2.0

Geopolymers have been established as a promising material option for in-situ construction on Mars due to their inherent material properties and availability of raw materials across the globally consistent basaltic composition of Martian regolith. This research project aims to extend current understanding by conducting material experiments and acts as a method of testing the 1:1 constructible scale of the architectural shelters for the empty lava tubes on Mars (Fig.1).

While there is extensive research on alkaline-activated geopolymers, the material experiments (Fig.2) focuses on phosphate-activated formulations with various regolith substitutes and simulants (Fig.4) to address the requirements of low-temperature curing, material adaptability, and in-situ resource utilization. The synthesis pathway and regolith substitutes were selected based on resource mapping and chemical properties to refine a procedure for geopolymerization that would be adaptable to a wider range of Martian substrates that can be found across the planet. Two main criteria are used to evaluate the geopolymer specimens in the experimental phase – mechanical performance (Fig.5), which indicates its structural capability, and rheology, which indicates its printability for robotic additive manufacturing on site. The results of the preliminary tests and literature review indicate phosphoric acid-based geopolymer synthesis as a viable approach.

The research results in the production of a geopolymer recipe using Mars simulant regolith and will be used as a foundation for future steps in robotic 3D printing experiments with industry partners such as Vertico and Concrefy, refining scalable methods for fabricating structural components in off-earth environments.

Fig1_Robotic 3D printed Rhizome 1.0 prototypes using concrete

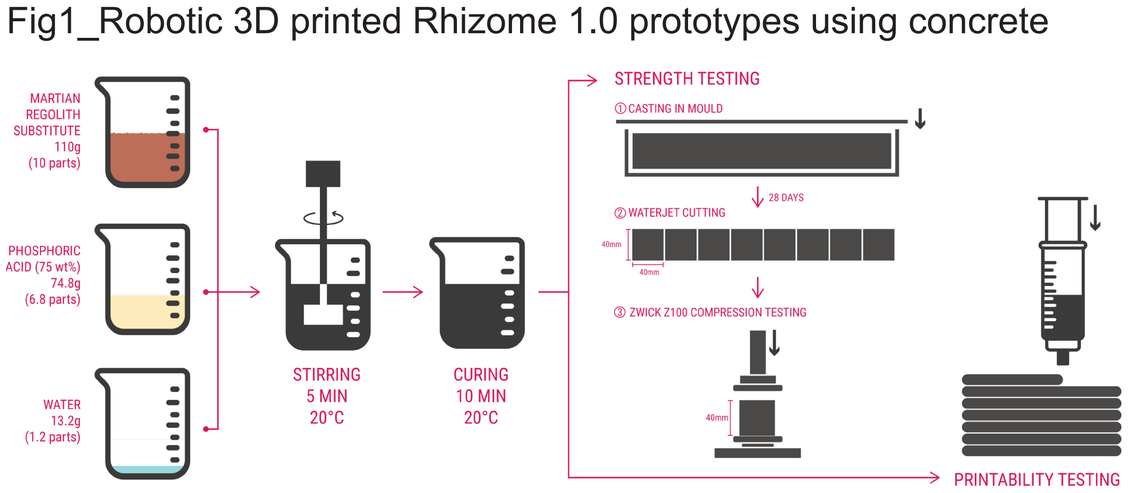

Fig2_Experimental and testing procedure

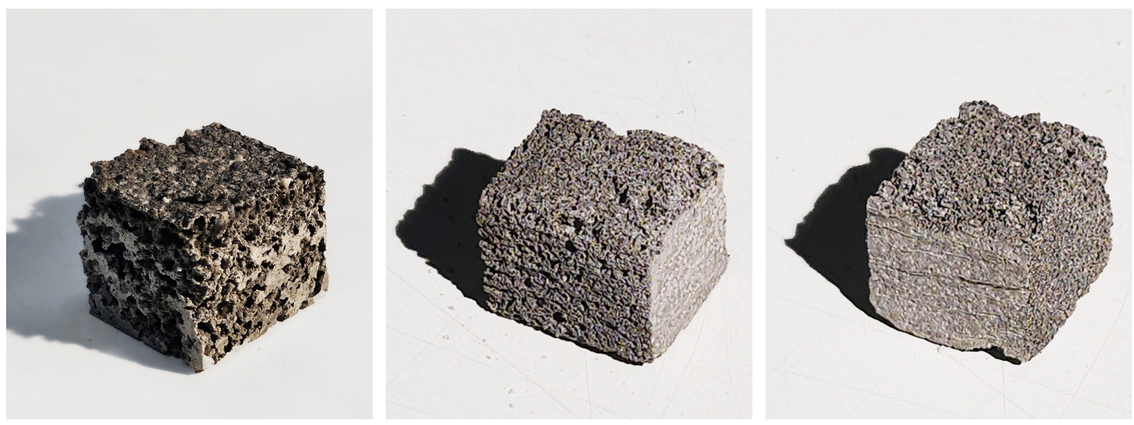

Fig3_ Material specimens with varying particle size and porosity

Volcanic Basalt Flour Composition *(PRAXIS)*	SiO2 39 wt%, K2 O 2.3wt%, CaO 16.9wt%, P2 O5 1.2wt%, Na2 O 2.6wt%, MgO 10wt%, Fe2 O3 12.3 wt%, Al2 O3 10.4 wt%
MGS-1C Clay ISRU Composition *(Exolith Lab)*	SiO2 56.13 wt%, Cr2 O3 0.02wt%, CaO 2.02wt%, P2 O5 0.35wt%, TiO2 0.21 wt%, SO3 1.16wt%, Na2 O 1.91wt%, FeOT 8.24wt%, Al2 O3 16.89 wt%, MgO 12.57wt%, K2 O 0.47wt%, MnO 0.04wt%
MGS-1S Sulfate ISRU Composition *(Exolith Lab)*	SiO2 29.29 wt%, Cr2 O3 0.13wt%, CaO 14.81wt%, P2 O5 0.32wt%, TiO2 0.27 wt%, SO3 18.71wt%, Na2 O 2.11wt%, FeOT 11.25wt%, Al2 O3 6.37 wt%, MgO 0.07wt%, K2 O 0.45wt%, MnO 0.07wt%

Fig4_Regolith simulants

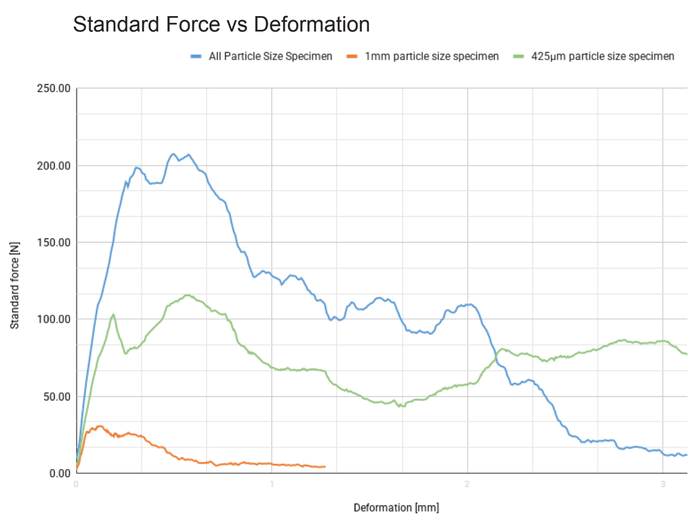

Fig 5_Outcomes of compression testing

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