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Concreting On Mars Concreting beyond the Earth's Envirnoment

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ABSTRACT: A significant step in space exploration during the 21st century will be human settlement on Mars. Instead of transporting all the construction materials from Earth to the red planet with incredibly high cost, using available material to construct a site on Mars is a superior choice . This study has been undertaken to investigate the various building material's properties for concreting on the Mars .

KEYWORDS: Concreting on Mars ,Concreting beyond the earth's atmosphere , Mars , Martian Concrete , Sulfur Concrete , Human tissue - a binder etc.

HYDRAULIC CONCRETE : LIMITATION AND SOLUTION

A) Aggregates : Martian regolith would presumably be used as natural aggregate .

B) Binders : Most binders also require water as part of the concrete formation. Initially binders are carried out from earth .

C) Availability of water : Liquid water is not thermodynamically stable on or near the surface, but might occur and be recovered from the sub – surface or could be produced by melting ice . There are substantial and common place reserves of superficial or near surface ice at latitude > 50 N or S , particularly near the pole . Closer to the equator , ice reserve are more localize and less plentiful.

D) Mixing and casting : Due to the temperature and pressure conditions of the Martian surface , fresh concrete made with water (i.e. using POP ,OPC,AAC,GC,MSBB or water as binder) would boil until the freezing if directly exposed to the atmosphere. Accordingly , concrete made using these binders will have to be mixed , transport ,cast and compacted in either a pressure controlled environment. .

E) Statics loads : Due to the weak Martian gravity , comparable objects would exert a load 62% smaller than on Earth .

F) Mass transfer and freeze thaw : The weathering mechanism of carbonation has been suggested as particularly important on Mars because the partial pressure of CO_2 is about 5 times more then earth .

G) Energy sources : The Martian surface lacks for both fuel and Oxygen for combustion based energy production would not generally be scalable .Therefore , it has been proposed that energy should be produced from wind , solar or nuclear sources .

NON- HYDROLIC CONCRETE :

Due to limitation and hard solution of hydraulic concrete , researchers works on non-hydraulic concrete . Some non-hydraulic concrete are –

1) Concreting by Sulpher

Mars has long been considered a ''sulfur-rich planet", a new construction material composed of sand and molten sulfur is developed.

Sulfur concrete products are manufactured by hot-mixing sulfur and aggregate. The sulfur binder first crystalizes as monoclinic sulfur and then the mixture cools down while sulfur transforms to the stable orthorhombic polymorph , achieving a reliable construction material.

Strength of Sulfur concrete is nearly 35 MPa and it is not useful for higher temperature.

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2) Martian Concrete

In addition to the raw material availability for producing sulfur concrete and a strength reaching similar or higher levels of conventional cementitious concrete, fast curing, low temperature sustainability, acid and salt environment resistance, 100% recyclability are appealing superior characteristics of the developed Martian Concrete.
Three point bending, unconfined compression and splitting tests were conducted to determine strength development, strength variability, and failure mechanisms. The test results show that the strength of Martian Concrete doubles that of sulfur concrete utilizing regular sand. It is also shown that the particle size distribution plays an important role in the mixture's final strength. Furthermore, since Martian soil is metal rich, sulfates and potentially polysulfates are also formed during high temperature mixing, which might contribute to the high strength. The optimal mix developed as Martian Concrete has an unconfined compressive strength of above 50 MPa. The formulated Martian Concrete is simulated by the Lattice Discrete Particle Model (LDPM), which exhibits excellent ability in modelling the material response under various loading conditions.

3) Concreting byBlood, sweat, and tears [mechanical stabilization of regolith]

Early extra terrestrial colonies will likely exploit loose unconsolidated rock and dust (also known as regolith) as a bulk material for radiation and meteor shielding . The loose, particulate nature of Lunar and Martian regolith will likely necessitate some form of mechanical stabilization to prevent erosion from high-velocity exhaust plumes or Martian dust storms — wind speeds on Mars can exceed 100 km per hour . , Use of human serum albumin (HSA) as a binder for the fabrication of ERBs (extraterrestrial regolith biocomposites). ERBs comprised of nothing but simulated moon or Mars regolith.

ERB fabrication procedure

In a typical procedure, 3 g of HSA (lyophilized powder, >96% purity by agarose gel electrophoresis) was dissolved in 7 g of deionized (DI) water with gentle mixing at 40 C to produce a 30 wt% solution. The density of water was taken as 1 g / mL and measured volumetrically. Note, higher mixing temperatures (>60 C) will cause the protein to denature and form a gel. The solution would be used within 48 h and kept at 4 C when not in use. Meanwhile, approximately 4 g of either Lunar Highlands Simulant 1 (LHS-1) or Martian Global Simulant 1 (MGS-1) were loaded into a 5 mL syringe and lightly packed with the syringe plunger manually. The precise composition of LHS-1 and MGS-1 is given in the SI. Following this, the HSA solution was infused into the pores of the regolith powder via another syringe, connected with Luner-lock attachments and PTFE tubing . Note that small incisions were made at the end of the regolith-containing syringe with a razor blade to allow for pressure equalization. The masses of each empty syringe, syringe with regolith, and syringe with regolith and HSA solution were measured to allow for the calculation of binder-to-regolith mass ratio. The HSA-solution infused regolith syringes were then placed on a hot plate maintained at 65 C overnight (ca. 20 h) with occasional removal of the supporting plastic syringe within the first 5 h to facilitate dehydration and hardening. For the ERBs containing urea, the same procedure was employed, except solutions of urea (up to 3 M concentration) in DI water were employed as the solvent rather than DI water alone. The density of the urea solutions was taken as 1 g / mL .

RESEARCH METHODOLOGY :

The composition of Martian regolith is -

Table1
Majorelement composition of Martian regolith simulant JSC Mars-1A

Major element composition % by Wt.		
Silicon dioxide (SiO_2)		34.5–44
Titanium dioxide (TiO_2)		3–4
Aluminum oxide (Al_2O_3)	18.5–23.5	
Ferric oxide (Fe_2O_3)		9–12
Iron oxide (FeO)	2.5–3.5	
Magnesium oxide (MgO)	2.5–3.5	
Calcium oxide (CaO)		5–6
Sodium oxide (Na2O)	2–2.5	
Potassium oxide (K_2O)	0.5–0.6	
Manganese oxide (MnO)	0.2–0.3	
Diphosphorus pentoxide (P_2O_5)	0.7–0.9	

Microscopy study : In addition to the PSD of aggregate, other factors must play a role concerning the final strength obtained in MC experiments. By comparing the particles of MC and SC in the mesostructure pictures, a few observations are in order. Firstly, the visible average particle size of MC is much smaller than that of SC after hot mixing, although both mixes use aggregate with maximum particle size up to 1 mm. After casting and curing, the aggregate particles and their sizes can be well distinguished for SC; on the contrary,

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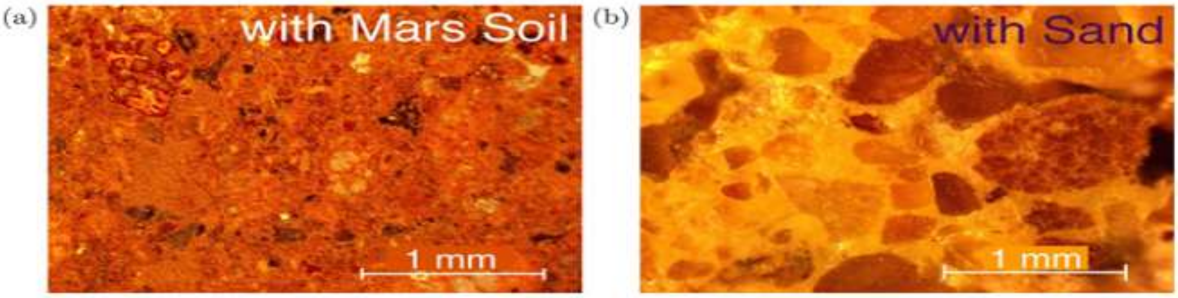
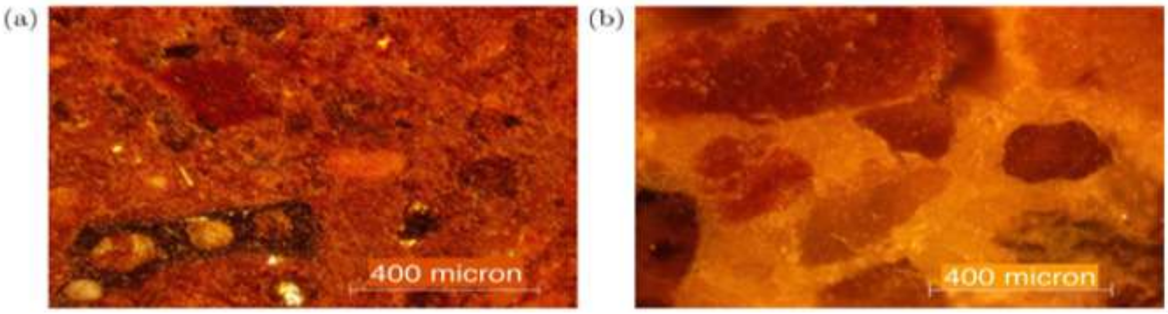
the majority of MC particles are below 500 microns. Secondly, the MC mix has many red areas, dark spots and almost no voids, while the SC mix shows distinguishably yellow areas of sulfur, opaque orange to dark red spots related to sand particles and a number of voids of around 200 microns. These observations, along with preliminary X-ray photoelectron spectroscopy (XPS) tests, suggest that the metal elements in Mars-1A react with sulfur during hot mixing, forming sulfates and polysulfates, and altering the PSD of aggregates to lower ends, which further enhance the MC strength. SC does not have such phenomena because silica sand does not react with sulfur at the aforementioned casting conditions. In other words, in MC the aggregate is chemically active whereas in SC it is inert and sulfur only serves as ‘‘glue” for the sand particles. The existence of sulfates and polysulfates in MC are qualitatively confirmed by XPS by analyzing the chemical state of sulfur and individual metal elements within 900 micron-diameter areas of a thin MC sample. Definitely, further research is needed to clearly identify the chemical products characterizing MC internal structure.

Microscopic study of Sulfur with Martian soil and regular sand -



(a) 50% sulfur and 50% Martian soil simulant (b) 25% sulfur and 75% regular sand and a maximum particle size of 1 mm.
(a) 50% sulfur and 50% Martian soil simulant (b) 25% sulfur and 75% regular sand and a maximum particle size of .4 mm.



Physical parameter are Martian concrete is mentioned in Table 2 -

Table 2 Parameters for Martian Concrete LDPM simulations.

Normal modulus [GPa]	10
Densification ratio [–]	1
Tensile strength [–] [MPa]	3.7
Yielding compressive Stress [MPa]	300
Shear Strength Ratio [–]	4
Tensile characteristic length [mm]	55
Softening exponent [–]	0.2
Initial hardening modulus ratio [–]	0.12
Transitional strain ratio [–]	4
Initial friction [–]	0.1

RESULTS AND DISCUSSION

The hydraulic concrete is not an effective building material as well as new emerging building material on mars. The developed sulfur based Martian Concrete isfeasible for construction on Mars for its easy handling, fast curing,high strength, recyclability, and adaptability in dry and cold environment. Sulfur is abundant on Martian surface and Martian regolith simulant is found to have well graded particle size distributionto ensure high strength mix. Both the atmospheric pressure andtemperature range on Mars are adequate for hosting sulfur concretestructures.

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