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Feasibility of Sulfur Concrete for Martian Constructions

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Abstract:

A significant step in space exploration during the 21st century will be the human settlement on Mars. Instead of transporting all the construction materials from Earth to the red planet with incredibly high cost, using Martian soil to construct a site on Mars is a superior choice. Mars has long been considered a "sulfur-rich planet". Studies of Martian meteorites suggest elevated sulfur concentrations in the interior, and Martian surface deposits contain high levels of sulfur (SO_3 up to ~37 wt%, average ~6 wt%), likely in the form of sulfate salts[1]. To let the thoughts become facts, a new construction material using simulated Martian soil and molten sulfur is developed. In fact, sulfur concrete is not a new concept. The utilization of sulfur as a molten bonding agent can be traced back to prehistoric times[2]. Sulfur concretes are being produced by first hot-mixing sulfur (or modified sulfur) and aggregates, which allows the sulfur binder crystalize as monoclinic sulfur (S_β), then letting the mixture cool down while sulfur transform to the stable orthorhombic polymorph (S_α) to achieve a reliable building material. In addition to the raw material availability, the utilization of sulfur concrete has many advantages compared to conventional Portland cement concrete. The strength reaches similar levels while the fatigue life, low temperature sustainability, and the curing time are superior, a minimum of 70-80 % of the ultimate compressive strength is reached within 24 hours.

Utilizing commercially available sulfur and Mars soil simulants, various casting procedures have been investigated in a specially developed high-temperature-mixer. Different percentages of sulfur are studied to obtain the optimal mixing proportions. Three-point-bend tests on beams of 1"x1"x5", observed by Digital Image Correlation (DIC), and unconfined compression tests using 1'' cubes cut from the beams are conducted to determine strength development, strength variability, and failure mechanisms. The testing results, potential problems of sulfur concrete application on Mars, as well as future studies will be presented and discussed.

[1] King P.L. and Mclennan S.M. (2010) *"Sulfur on Mars," Elements, An International Magazine of Mineralogy, Geochemistry, and Petrology, April 2010, v. 6 no. 2 p.107*
[2] Sheppard, W.L. (1975) *"Sulfur Mortars," Corrosion and Chemical Resistance Masonry Materials Handbook, p. 222*