

Martian-Regolith Photocurable Composites: Mineralogy, Perchlorates, Atmosphere, Temperature and Processing

A qualification framework for Mars-regolith-derived particulate feedstocks in light-curable composite manufacturing

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Abstract

Martian-regolith photocurable composites sit at the intersection of simulant fidelity, reactive salts, particulate processing and environmental exposure. The largest qualification risk is to treat any basaltic simulant as a sufficient proxy for Mars. Modern Mars simulants differ in mineralogical construction, volatile inventory and perchlorate content, while polymer-processing demonstrations often address a different binder route entirely. This review defines the evidence needed to use Martian-regolith-derived feedstocks in photocurable composites, including simulant identity, salt state, optical/rheological effects, atmospheric and thermal conditions, post-processing and environmental qualification.

Keywords: Mars regolith; simulant; perchlorate; photopolymer; particulate composite; atmosphere; thermal cycling; ISRU; qualification

1. Significance and scope

Mars-regolith manufacturing literature is broader than photocurable processing, so evidence from geopolymers or thermoplastics is useful for feedstock and structural context but does not by itself establish photopolymer compatibility. The first qualification step is to state exactly what simulant or regolith analogue is being processed [1-3].

ER-448 owns extraction and preparation of ISRU feedstocks across planetary resources. This review owns the subsequent qualification of a Mars-regolith particulate phase when it is combined with a photocurable binder.

2. Simulant identity governs transferability

Mars simulants can be natural basaltic materials, mineral recipes or deliberately modified soils. MGS-1 was created as a Rocknest-based mineralogical standard [1], while JSC-Rocknest includes phases selected to reproduce evolved-gas behaviour relevant to ISRU studies [2]. These are not interchangeable material identities.

Batch records should therefore include source, recipe or provenance, particle-size distribution, crystalline/amorphous basis where available, moisture history and added salts. A “Mars simulant” label is inadequate for transferring cure or durability data.

Perchlorates and associated salts matter because they alter chemical inventory and can participate in thermal or radiolytic reactions. Their presence, absence and concentration should be declared rather than silently inherited from the simulant recipe.

3. Perchlorates and volatiles are process variables

Volatiles and hydrated phases also affect storage, heating and gas release. JSC-Rocknest was explicitly engineered to reproduce aspects of low-temperature evolved gases, illustrating why volatile inventory can be a functional property of a simulant rather than an impurity [2].

Before a Mars-regolith composite is called photocurable, the actual filled formulation must demonstrate stable dispersion, controlled cure and repeatable geometry. Successful additive manufacture with geopolymer or thermoplastic binders establishes that the particulate feedstock can be engineered, not that a photochemical route will behave similarly [3].

4. Photocurable processing must be demonstrated directly

Optical attenuation should be measured for the specific particle/binder state because iron-bearing phases, particle size and solids fraction can change absorption and scattering. Rheology should be measured after the same mixing and conditioning history used for printing.

The Martian atmosphere is thin and compositionally unlike terrestrial laboratory air. Reduced pressure changes gas-bubble expansion and volatile loss, while temperature excursions change viscosity before cure and stress after cure. Environmental processing claims therefore require pressure and temperature to be part of the method.

Perchlorate-bearing feedstocks may also create cleanliness and compatibility constraints for equipment, recovered liquids and downstream thermal processing. A qualification plan should track soluble species and residues rather than testing only bulk mechanics.

For polymer-retaining parts, radiation and thermal history can alter network and interface properties. For ceramic-conversion routes, binder removal and sintering dominate the final state. These routes should remain separate in both naming and test design.

5. Mars environment and device-level verification

Mars qualification should use the intended mission atmosphere or a justified analogue when studying uncured behaviour, bubble evolution, transfer and deposition. Earth-atmosphere printability is a baseline, not a mission simulation.

Structural verification should couple feedstock variability to dimensional and mechanical outcomes. A robust route should tolerate realistic shifts in particle size, salt inventory and moisture state without moving outside the cure/process window.

Device-level tests should include joints, channels or wall sections representative of the intended function, with dust contamination and thermal cycling where relevant. A coupon strength value cannot establish sealing, fluidic or habitat performance.

Axis	Measurement	Failure mode
Simulant identity	recipe, mineralogy, PSD, batch	basaltic analogue treated as universal Mars soil
Salts/volatiles	perchlorate and evolved-gas state	reactive inventory omitted
Photocure	attenuation, rheology, cure window	other binder route treated as VPP evidence
Environment	pressure, atmosphere, temperature	Earth-ambient printability over-transferred
Service	cycling, radiation, contamination	coupon mechanics treated as mission qualification

Table 1. Domain-specific qualification matrix for Martian-regolith photocurable composites.

6. Transfer limits and minimum reporting dataset

The boundary to ER-441 is composition and environment: lunar-regolith photocurable composites are qualified against lunar simulant and lunar environmental variables, whereas the present review requires Mars-specific mineralogical, salt and atmospheric state.

Report simulant identity and recipe, particle-size distribution, moisture and salt state, solids fraction, binder and photoinitiator, mixing/degassing, rheology, cure conditions, dimensional fidelity, porosity and post-processing.

For Mars-service claims, add pressure/atmosphere, temperature history, radiation exposure where relevant, perchlorate handling and explicit criteria for feedstock acceptance and equipment contamination.

7. Minimum qualification framework

A minimum Mars-regolith qualification programme should keep geological fidelity, chemical hazard state and photopolymer processability as separate gates. Feedstock acceptance should include simulant provenance, size distribution, major mineral phases and the presence or deliberate absence of perchlorate or other reactive salts relevant to the intended scenario.

The process qualification should then bind atmosphere, pressure, temperature, volatile content, cure wavelength/dose, rheology and post-processing to a specific material state. Environmental simulation should be introduced as a controlled factor rather than folded into an undefined “Mars conditions” label, because low pressure, thermal cycling, oxidants and radiation can affect different failure mechanisms.

8. Engineering conclusions

Martian-regolith photocurable composites should therefore be qualified as Mars-specific feedstock/process systems, not as ordinary mineral-filled resins. Transfer from a basaltic terrestrial simulant to a mission material remains an engineering hypothesis until composition, reactive-salt state, atmosphere and temperature history are all bounded.

References

- [1] K. M. Cannon, D. T. Britt, T. M. Smith, R. F. Fritsche, D. Batchelor, “Mars global simulant MGS-1: A Rocknest-based open standard for basaltic martian regolith simulants,” *Icarus* 317 (2019) 470-478. <https://doi.org/10.1016/j.icarus.2018.08.019>
- [2] J. V. Clark, P. D. Archer, J. E. Gruener, D. W. Ming, V. M. Tu, P. B. Niles, S. A. Mertzman, “JSC-Rocknest: A large-scale Mojave Mars Simulant (MMS) based soil simulant for in-situ resource utilization water-extraction studies,” *Icarus* 351 (2020) 113936. <https://doi.org/10.1016/j.icarus.2020.113936>
- [3] S. Ma, S. Fu, Q. Wang, L. Xu, P. He, C. Sun, X. Duan, Z. Zhang, D. Jia, Y. Zhou, “3D Printing of Damage-tolerant Martian Regolith Simulant-based Geopolymer Composites,” *Additive Manufacturing* 58 (2022) 103025. <https://doi.org/10.1016/j.addma.2022.103025>

Competing interest

Juan Segurola is founder, CEO and CTO of 3Dresyns by Resynr Technologies S.L., which develops and commercialises photopolymer materials and related additive-manufacturing technologies. This review is an engineering analysis and does not constitute a product-performance claim or a device qualification.