



ME - MTech(Res) Thesis Colloquium



Microbial induced calcite precipitation under Perchlorate Stress: Towards Bio-Based Construction on Mars

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August 31, 2026 at 12:30PM

Venue – AR Auditorium, ME@IISc

ABSTRACT

The prospect of sustained human presence on Mars demands the development of reliable, resource-efficient construction methodologies that minimize dependence on Earth-supplied materials. The rocket equation imposes severe constraints on payload delivery to Mars, rendering the wholesale transport of conventional construction materials economically and logistically untenable. In-Situ Resource Utilisation (ISRU) — the systematic exploitation of locally available planetary resources — offers a compelling alternative, with Microbially Induced Calcite Precipitation (MICP) emerging as a particularly promising bio-mediated consolidation strategy. MICP harnesses the ureolytic activity of specific bacterial strains to enzymatically hydrolyse urea, generating carbonate ions that combine with available calcium to precipitate CaCO_3 , progressively binding loose regolith particles into a cohesive, load-bearing matrix.

A critical and previously underexplored challenge for MICP on Mars is the ubiquitous presence of perchlorate (ClO_4^-) in Martian regolith at concentrations of 0.4–0.6% by mass — a potent oxidizing agent known to be cytotoxic to organic matter. This information though available did not trigger experimentation due to non-transportability of Martian simulant with perchlorate due to its explosive characteristics. This study presents a systematic, multi-disciplinary investigation of the effects of perchlorate stress on MICP-competent bacteria and on the mechanical properties of bio-consolidated bricks fabricated from MGS-1 Martian Global Simulant.

A novel ureolytically active bacterial strain — *Sporosarcina* sp. strain SI_IISc_isolate — was isolated from local soil and validated for MICP competence through phenol red urease assays, pH profiling, scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), and X-ray diffraction (XRD), confirming biogenic calcite precipitation. This isolate was evaluated alongside the reference strain *Sporosarcina pasteurii* (ATCC 11859) across graduated perchlorate concentrations. The minimum inhibitory concentration (MIC) of perchlorate for bacterial growth was established as 2% (w/v) in synthetic medium and 3% in nutrient broth for strain SI, demonstrating a broader tolerance profile than SP. Multi-modal morphological analysis — encompassing Gram staining, field emission SEM, and LIVE/DEAD fluorescence staining — revealed concentration-dependent stress responses including extracellular matrix (ECM) upregulation, multicellularity-like cellular aggregation, and the formation of filamentous ECM extensions physically bridging bacterial cells to inorganic precipitates, herein designated microbridges.

Bioconsolidation experiments were carried out with perchlorate containing Martian regolith simulant creating 'bio-bricks'. Counterintuitively, bio-consolidation experiments incorporating 1% (w/v) perchlorate in MGS-1 bricks supplemented with 1% (w/v) guar gum produced a compressive strength of 6.71 MPa — a significant enhancement over perchlorate-free controls. This finding is mechanistically attributed to perchlorate-induced ECM and microbridge production augmenting the biopolymer consolidation network. Guar gum supplementation was identified as the single most critical determinant of structural viability, while nickel (10 mM NiCl_2) as a urease co-factor provided consistent additional strength gains across treatment groups.

ABOUT THE SPEAKER

Group Captain Shubhanshu Shukla, AC, is an Indian Air Force test pilot and astronaut. In June 2025, he piloted Axiom Mission 4 to the International Space Station, becoming the first Indian to visit the ISS, and was subsequently conferred the Ashoka Chakra, India's highest peacetime gallantry award. He is currently completing a master's degree at the Indian Institute of Science, Bengaluru.

