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ADVANCING SUSTAINABLE MARTIAN HABITAT CONSTRUCTION: IN-SITU RESOURCE UTILIZATION AND BASALT-VINYL COMPOSITES FOR ENHANCED DURABILITY

Abstract

As humanity prepares for Mars colonization, sustainable construction methods using local resources have become essential. This extended study reviews the use of In-Situ Resource Utilization (ISRU) and basalt-vinyl composites as viable materials for Martian habitats. The idea emerged from basalt samples collected in the lava tubes of Mauna Loa, Hawaii, during an analog astronaut mission at HI-SEAS, where NASA's Mars simulation missions provided valuable insights into basalt's potential for extraterrestrial construction.

ISRU enables the use of locally sourced materials from bodies like Mars, the Moon, or asteroids, significantly reducing costs and resource dependence on Earth. By utilizing Martian resources, this approach promotes the sustainability of Mars missions. Our study applies ISRU principles to examine basalt-vinyl composites as a durable construction material.

The methodology involved designing a parabolic arch structure and analyzing three habitat materials through simulations. Conditions simulated included Martian factors like dust storms, extreme temperatures, and seismic activities, following the Martian Load Map's boundary conditions: an external pressure of 0.006 atm, internal pressure of 1 atm, and gravity load of 3.17 m/s.

Three models were tested for their stress tolerance. Model-1 showed a maximum principal stress capacity of 8.76 10 Pa, Model-2 a moderate improvement with 1.25 10 Pa, and Model-3 the highest resilience at 1.05 10 Pa. These results underscore the importance of structural optimization in enhancing the durability of dome-shaped basalt-vinyl structures.

Material comparisons indicate that sulfur concrete, with a Young's modulus of 13 GPa, is unsuitable for high-stress areas due to high deformation. Basalt-epoxy composites show better performance, while basalt-vinyl composites stand out with a Young's modulus of 70 GPa and excellent thermal resistance up to 250C, making them ideal for high-stress, load-bearing sections.

This research demonstrates basalt-vinyl composites' viability for Martian construction. By integrating ISRU and 3D printing, this approach minimizes reliance on Earth resources, paving the way for sustainable Mars habitats. Future research will expand with ten additional structural models and five alternative materials to optimize designs, supporting humanity's vision of becoming a multi-planetary species.