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Author: Mr. Carlo Giovanni Ferro
Politecnico di Torino, Italy

Dr. Alessandro Aimasso
Politecnico di Torino, Italy
Dr. Roberto Torre
European Space Agency (ESA/EAC), Germany
Dr. Andrea Emanuele Maria Casini
German Aerospace Center (DLR), Germany
Dr. Aidan Cowley
ESA, Germany

ENHANCING LUNAR HABITAT CONSTRUCTION: AN EXPERIMENTAL EVALUATION OF THERMAL PERFORMANCE AND DURABILITY OF FBG SENSOR-EMBEDDED LUNAR BRICKS

Abstract

More than five decades have elapsed since Apollo 17 astronauts last set foot on the lunar surface, underscoring the enduring significance of space exploration for our technological and scientific advancement. National and international space agencies have prioritized lunar colonization and the establishment of a sustainable lunar economy as critical objectives. The utilization of local resources is recognized as a crucial strategy for reducing reliance on Earth. As such, the construction of future lunar bases will necessitate materials that are sourced and processed on the Moon. Additionally, the maintenance of surface outposts will demand the fabrication of spare parts, everyday tools, and safety-critical components from local materials. The harsh lunar environment poses unique challenges and objectives, necessitating innovative design methodologies and the implementation of effective monitoring systems. The increasing interest in lunar habitation underscores the importance of developing intelligent construction materials that leverage local resources while reducing the dependency on imported binders. In this framework, efforts were made to develop a composite material, maximizing the weight percentage of lunar regolith and prioritizing a simple and low energy demanding manufacturing process. After having demonstrated the mechanical performances of standardized structural elements (bricks) produced with this approach, we moved to integrate Fiber Bragg Grating (FBG) sensors inside them to evaluate their thermal characteristics and structural integrity in an environment that closely simulates lunar conditions. This research focuses on the thermal performance of the bricks. The experimental framework subjected these sensor-integrated bricks to severe temperature variations and vacuum conditions. The results demonstrate that the embedded FBG sensors deliver precise and reliable data, highlighting their suitability for continuously monitoring and evaluating lunar habitat structures. This investigation confirms the practicality of incorporating FBG sensors into lunar building materials and emphasizes the advantages of smart components for the efficient use of in situ resources. The results pave the way for the development of advanced, autonomous construction elements, marking a significant step toward creating more sustainable and robust habitats beyond Earth.