

Enabling Evaluation of In-Situ Regolith-Based Construction Materials with Modified Methods for Testing Compressive Strength of Non-Cement Mortar Specimens Using Simulants & Analog Site Soils

Sarah Seitz¹, Colin MacDougall², and Brian Glass¹

¹NASA - Ames Research Center, Moffett Field, California, United States of America (sarah.j.seitz@nasa.gov)

²Department of Civil Engineering, Queen's University, Kingston, Ontario, Canada

Abstract

Objectives for Phase II of NASA's Artemis Program include establishment of lunar surface infrastructure to support a sustainable, long-term human presence on the Moon. Terrestrially, awareness of climate impacts from cement and concrete production has led to renewed interest in traditional building materials using earthen and pozzolanic binders with locally sourced aggregates [1, 2, 3]. In remote, austere, and resource-constrained environments, use of site-sourced materials is often an economic necessity in addition to being valuable for local autonomy and self-sufficiency. This study evaluates modifications to ASTM cement mortar testing methods, incorporating details from European standards for earthen plasters and lime-based mortars. Development of consistent, simplified methods for evaluating in-situ materials will be essential not only for meeting future climate goals and sustainable construction needs, but also for conducting autonomous robotic manipulation and evaluation of regolith construction materials.

Introduction:

Recent studies of in-situ derived simulant-based building materials for construction on the surface of the Moon and Mars have drawn on traditional building techniques and their renewed use in sustainable construction [4, 5]. Humans have experience spanning millennia building with site soils and locally-derived mineral materials. In addition to examples found at archaeological sites and historic buildings surviving to the present, some earthen building traditions (adobe, mud plastering) continue to be practiced to this day [6, 7], while others are seeing broader adoption in innovative construction techniques using 3D printing [8, 9].

In this study, a selection of these formulations were adapted for use with planetary analog site soils to assess the suitability of these methods in evaluating potential regolith construction materials for in-situ construction on planetary surfaces [10]. These studies focused on curing and compressive strength testing of preliminary mix formulations using small mortar specimens in ambient conditions.

Materials Testing Methods for Mortars and Extruded Materials:

Basic evaluations of soil-based building materials begin with particle size distribution and compressive strength. In North America, these assessments are often conducted following ASTM C-109, "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50 mm] Cube Specimens)" [11] in conjunction with ASTM C-144 (Standard Specification for Aggregate for Masonry Mortar) [12] and ASTM C-136 (Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates) [13]. Key details of ASTM C109 requiring submersion of specimens in water during curing preclude its use with non-cementitious binders. Techniques used in evaluation of traditional clay plasters (DIN 18947) [14], lime mortars (EN 1015) [15] and pozzolanic materials were adapted here for use with

specimens prepared from construction site mixes using local soils, industrial byproducts, organic additives and bagged materials from masonry and ceramic suppliers.

Key Findings & Opportunities:

Drawing upon European standards for traditional building materials and sustainable building products to modify ASTM methods can enable study of site-sourced, minimally-processed non-cement materials for terrestrial and planetary surface construction. Experience in refining these methods alongside researchers in sustainable construction demonstrates that: 1) tradespeople and craft builders in traditional construction have a valuable contribution to offer to the study of materials for in-situ construction on planetary surfaces, and 2) that development of consistent, simplified methods for use in preliminary testing of varied simulant and in-situ soil formulations for construction may enable opportunities for interdisciplinary collaboration with mutual benefits for terrestrial sustainable building and in-situ regolith construction on the Moon and Mars.

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