Carbon Nanotube-Reinforced Lunar Regolith-Based Geopolymer: Microwave Radiation Curing Method. J. Prater[1], S. Wright[1], Y. H. Kim[1], G. Sumanasekera[2], M. J. Rahman[3], C. Park[4], S. Chu[4], J. Gruener[5], J. Edmunson[6], [1]Civil and Environmental Engineering, [2]Physics and Astronomy, [3]Mechanical Engineering, University of Louisville, KY 40292, [4]NASA Langley Research Center, [5]NASA Johnson Space Center, [6]NASA Marshall Space Flight Center (Contact: young.kim@louisville.edu)

Introduction: The ongoing project aims to propose a curing method of geopolymer utilizing low-power microwave radiation through the susceptibility of carbon nanotubes to electromagnetic waves.

This study is based on geopolymers using alumina and silica abundant in lunar regolith and sodium-based aqueous solutions from water on the Moon. Once geopolymerization is completed, water can be released after solidification. The released water can be recycled and repurposed for various applications, including life support systems or subsequent manufacturing process. Recently, the research team identified a potential water recapturing feature that can recover about 60 ~ 80% water used in mixtures in geopolymers with carbon nanotubes (CNTs).

The objectives of this research are to investigate the effect of microwave radiation absorption by CNTs on the water extraction features of geopolymers, using specimens without CNT as a control group.

Approaches: The experimental program tests the hypothesis that low-cost and low-power microwave radiation can be used to facilitate the curing and water extraction process in geopolymers. Using CNTs' high absorption capacity of microwave radiation, the water can be efficiently extractable from the geopolymer during the curing process. All CSM mixtures prepared with the CSM-LHT-1 lunar regolith simulant underwent various curing regimes: H (heat curing at 80℃), W (wet curing at 80 ℃), and M (microwave curing at low and high powers). In terms of availability of water moisture in the container, M series has a counterpart with the H series, while MH series has a counterpart with the W series. Wet curing was achieved with MH samples using a plastic container with the condenser.

The experiment involved varying the duration and power levels of microwave exposure, operating at 2.54 GHz with a maximum power of 700 Watts, equivalent to level 10. The power settings range from a preset 1/10th (10%) to 1/5th (20%) of a 700-watt tabletop microwave oven, while the duration varied between 20 and 130 minutes. The first instance of water extraction was recorded.

Findings: By combining carbon materials and microwave-cured geopolymer (orange hatched box in the boxplot), this process can improve the mechanical properties of CNT-reinforced geopolymers, which are substantially higher than those of the control sample (orange square data) (See Fig. 1 a).

In the microwave radiation curing procedure, 3.5 g of water was collected when microwaving three samples (two samples with CNTs (0.32% wt. of the weight of the cement-grade binder of lunar regolith simulant) and one sample without CNTs). This amount was collected over 7 minutes of microwave from when the first water drop was collected under a preset 1/5th power level of a 700-watt tabletop microwave oven's capacity.

The presence of CNTs enables the sample to withstand sudden volumetric changes caused by excessive heat. Using the various microwave curing procedures shown in Fig. 1(b), we produced three CNT-reinforced samples and one control sample for mechanical testing. Other samples experienced early spalling during microwave radiation. Further investigation is needed to understand how CNTs contribute to maintaining volume stability under microwave radiation.

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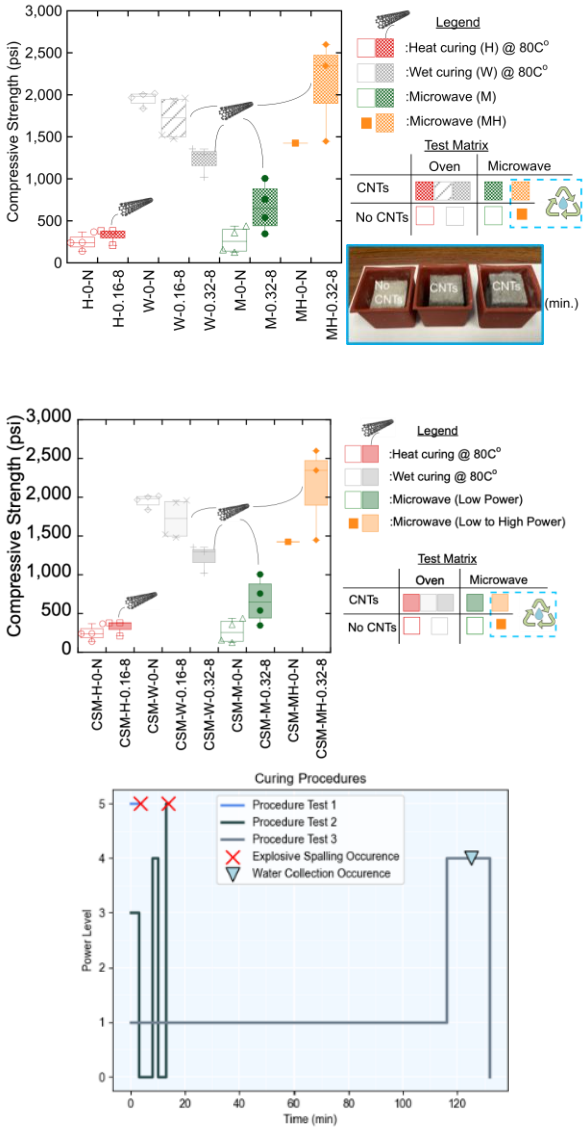

Figure 1: Comparison of geopolymer samples with CNTs and without CNTs under four types of curing conditions (H-, W-, M-, MH- series): a) compressive strength; b) Varied microwave radiation curing procedure for MH-series