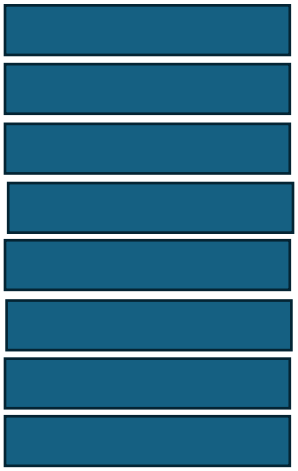
FROM MOON DUST TO MOON HOME:

(Testing Regolith Concrete for Space Habitats)

A Research Paper Presented to Southern Arizona Research, Science, and Engineering Foundation

By



Physics and Astronomy

BACKGROUND RESEARCH

Structures for Astronauts

With space agencies such as NASA planning prolonged lunar missions, ensuring the safety and durability of astronaut habitats presents a significant challenge. Previous research has shown that adding binders and reinforcing materials can significantly improve the strength of regolith-based concrete, making it more suitable for constructing safe and durable habitats for astronauts on lunar missions.

Lunar Regolith

Although regolith is abundant on the Moon, it cannot be used on its own for construction because it is brittle and lacks natural binding properties. To make it suitable for building habitats, regolith must be mixed with binders or processed into a stronger composite material.

NASA's Project

NASA is investigating In-Situ Resource Utilization (ISRU), a strategy that leverages lunar resources rather than relying on supplies transported from Earth.

ISRU helps reduce mission costs and enables astronauts to construct larger, more permanent habitats.

Advances in space concrete technology are essential for human space exploration and building structures beyond Earth, representing a major step in adapting to and using extraterrestrial environments.

STATEMENT OF THE PROBLEM

General Problem:

NASA is investigating In-Sit Resource Utilization (ISRU), a strategy that leverages lunar resources rather than relying on supplies transported from Earth.

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Specific Problem:

To be specific, this project answered the following questions:

1. How do added binders and mineral additives affect the structural performance of regolith concrete for lunar construction applications?
2. Which regolith-based concrete mixture produces the greatest strength and durability when tested

HYPOTHESIS

The enhanced regolith mixture will exhibit greater impact resistance and load-bearing capacity than the unenhanced control regolith mixture, as measured by drop tests, load tests, and force plate data.

VARIABLES

Independent variable: Type of regolith-based concrete mixture (MixA and Enhanced Mix A (with chitosan, gum Arabic, ground glass, FeO2)

Dependent variable: The amount of load, impact resistance, surface strength, and thermal stability.

Constants: The amounts of materials used (regolith, mold size, drying time, drop height, weight during load testing, testing method and equipment, number of trials.

RESEARCH PROGRESS

1. Gather all materials needed including regolith additives.

2. Design a regolith-based mixture for strength and durability

3. Develop a control mixture and enhanced mixtures .

4. Develop a control mixture and enhanced mixtures.

5. Begin data collection andcollect experimental results to real-world lunar habitat designs

METHODS

1) PHASE 1: Preparation and Initial Screening (Mix A-D)

Gather simulated lunar regolith and all binder and additive materials.

Label four mixing containers such as MixA, Mix B, Mix C, and Mix D.

3. Combine all dry ingredients before slowly adding liquid ingredients. Press into the mold and allow the bricks to dry for 48hrs. Remove the bricks from the molds and perform a drop and crumble test. 4. Compare results across Mix A–D to identify the strongest performing mixture.

Mix	Purpose	Ingredients
Mix A (Control)	Baseline regolith brick	Regolith – 200 g, Flour – 30 g Glue – 30 mL , Water – 50 mL

Mix B (Biopolymer)	Natural binder comparison	Regolith – 200 g , Chitosan Powder – 5 g Gum Arabic Powder – 5 g , Flour – 25 g Water – 40 mL
Mix C (Geopolymer)	Advanced chemical reinforcement	Regolith – 180 g, Ground Glass – 10 g Sodium Hydroxide (10 M) – 10 mL Water – 10 mL, Urea – 2 g Calcium Bentonite – 3 g
Mix D (Mineral Reinforced)	Density & durability enhancement	Regolith – 160 g, Iron Oxide – 10 g Titanium Oxide – 5 g , Glue – 25 mL Water – 30 mL
Enhanced Mix A	Optimized final design	Regolith – 200 g , Flour – 45 g Glue – 30 mL, Water – 50 mL

		Chitosan Powder – 5 g , Gum Arabic – 5 g Ground Glass – 10 g , Iron Oxide – 10 g

2) PHASE 2: Creating the Enhanced Mix A

a. Select Mix A as the base material because it showed the highest durability and least damage.

b. Combine Mix A and add reinforcement materials (chitosan powder, gum Arabic, ground glass, iron oxide, and additional flour).

c. Mix and transfer into the molds and let it air dry.

d. Remove the enhanced bricks once fully dry.

3) PHASE 3: Advance Mechanical Testing

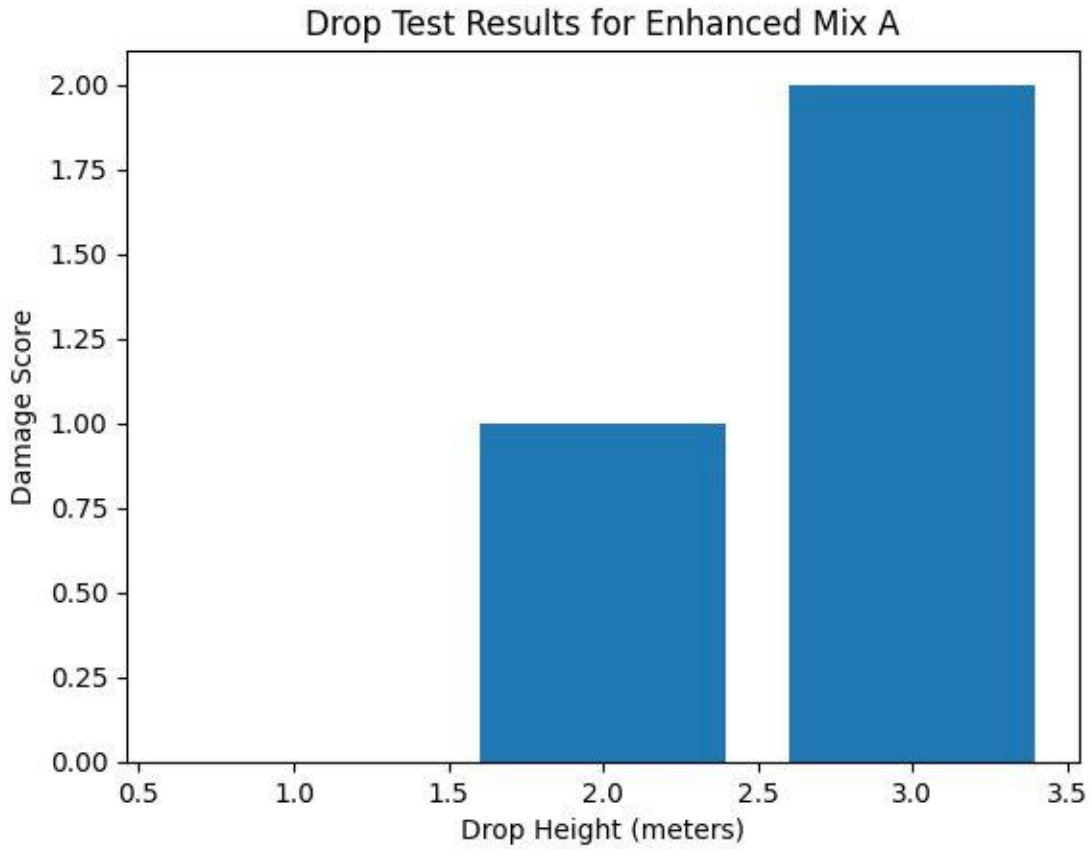
a. Conduct Drop Test by dropping each brick (1 meter, 2 meter, and 3 meters.

b. Performed crumble tests by applying consistent pressure.

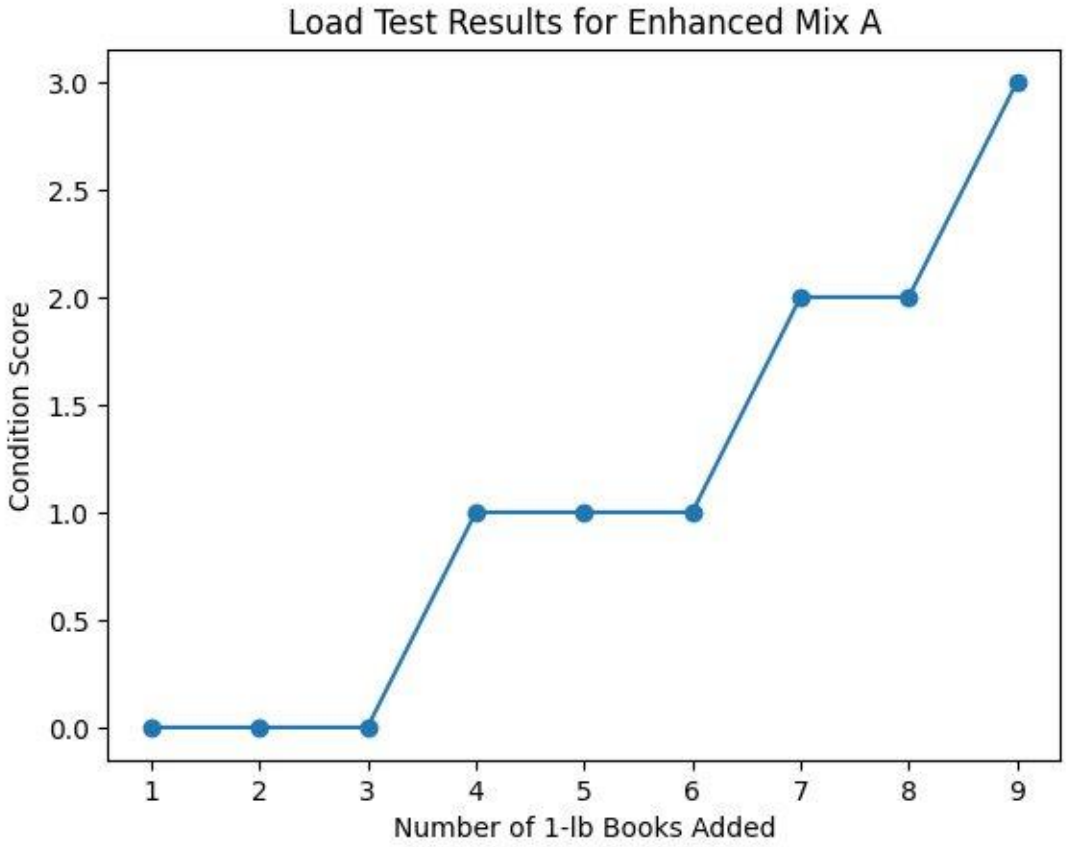
c. Complete load test by adding weights until failure.

d. Use Neulog Force Plate Logger to identify the maximum force each brick could withstand before failure.

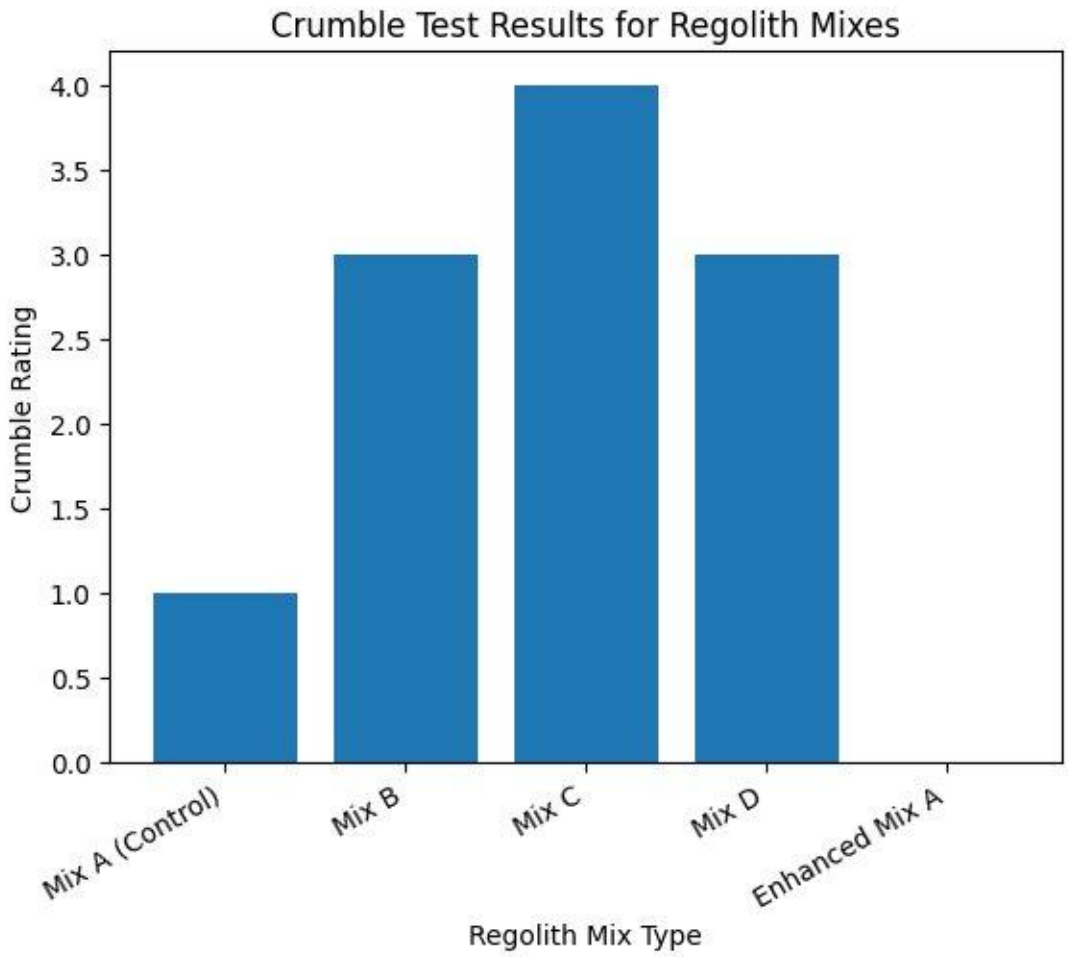
RESULTS



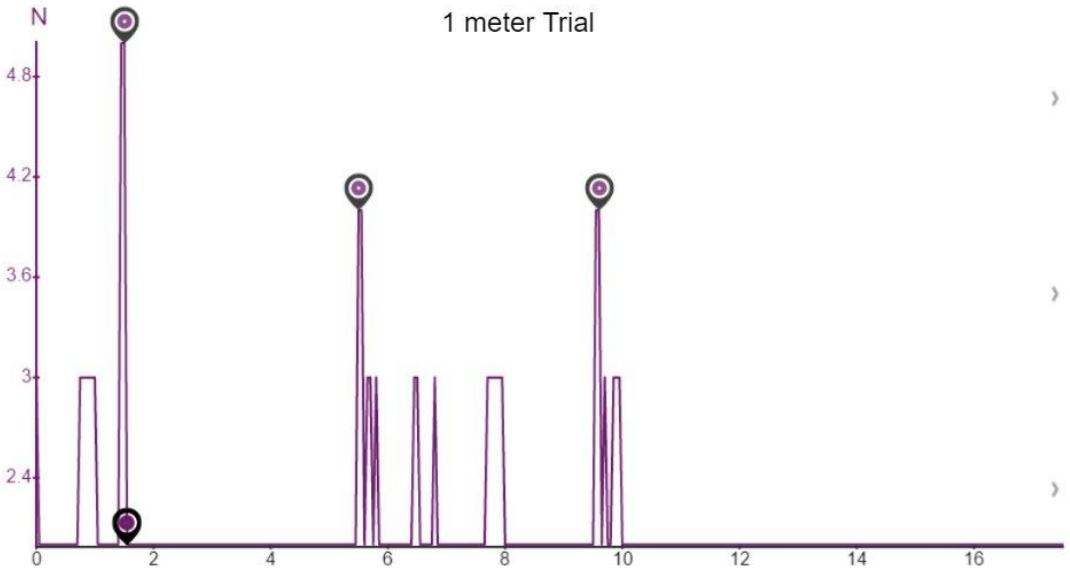
The result shows that the damage score of the Enhanced Mix A brick after being dropped from heights of 1 m, 2 m, and 3 damage increased with drop height, but the brick remained mostly intact at all tested heights.



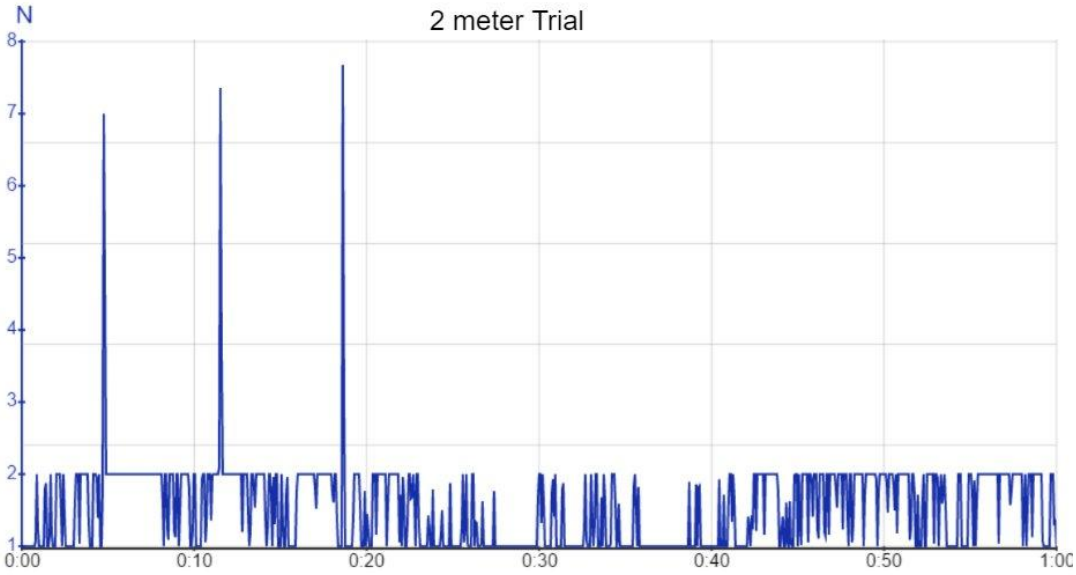
The result shows how the structural condition of the Enhanced Mix A brick changed as weight was gradually added. The brick showed no damage at lower loads, developed cracks as weight increased, and failed after supporting 9 pounds.



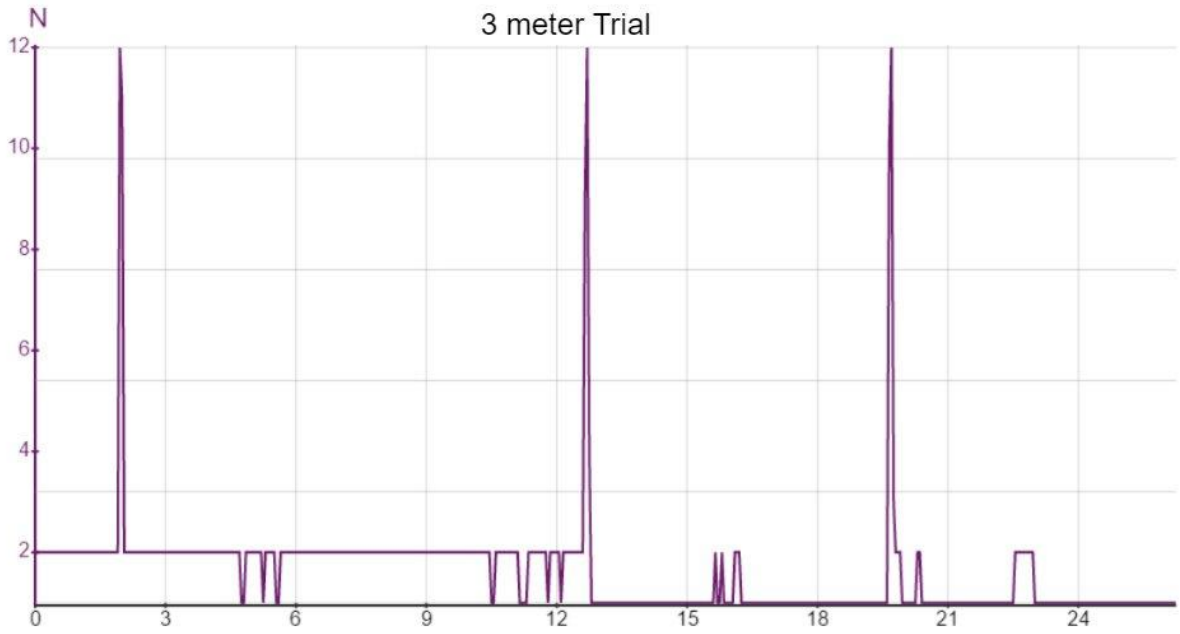
The result compares the crumble ratings of different regolith mixtures. Enhanced Mix A showed the least crumbling, while Mix C showed the highest material breakdown, indicating lower durability.



The data shows 1-meter drop test of the Enhanced Mix A brick, showing a peak impact force at the moment of contact.



The data shows 2-meter drop test of the Enhanced Mix A brick, showing ahigher peak impact force than the 1-meter trial.



The data shows 3-meter drop test of the Enhanced Mix A brick, showing the highest peak impact force.

DISCUSSION

This study investigated how enhancing a regolith-based construction material affects its strength and durability for potential lunar building applications. The results indicate that adding reinforcing materials toa regolith mixture can significantly improve its durability and strength. These findings support the idea that lunar construction materials can be engineered and optimized using locally available resources, reducing the need to transport materials from Earth.

CONCLUSION

The results of this experiment support the hypothesis that enhancing the strongest regolith mixture improves its impact resistance and load-bearing capacity. The Enhanced Mix A withstood higher drop heights, resisted crumbling, and supported up to 9 pounds before failure. Sensor-based force data confirmed that the material absorbed increasing impact forces as drop height increased.

Why are our Results Important?

These results are important because they show that lunar regolith can be strengthened using an engineering design process. By improving impact resistance and load-bearing capacity, sensor-based force data confirmed that the material absorbed increasing impact forces as drop height increased. The results of this experiment support the hypothesis that enhancing the strongest regolith mixture improves itsimpact resistance and load-bearing capacity. Future Moon habitats could be built using, materials already available on the Moon instead of transporting heavy construction materials from Earth.

FUTURE PLANS

Future work will include testing all regolith mixtures using force plate and load tests, increasing the number of samples, and evaluating additional properties such as temperature resistance and long-term durability and performance under simulated lunar conditions as well as building a Prototype Building Model. These steps would provide a more complete comparison of lunar construction materials.

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