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Evaluation of Mechanical Properties of Mortar Generated by using Lunar Soil Simulant

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Abstract*: This study investigates the mechanical properties of mortar produced using lunar soil simulant, with the aim of assessing its suitability for construction in extraterrestrial habitats. Various tests including fineness test, specific gravity, standard consistency and compressive test were conduct to evaluate the performance of the mortar. Factor such as particle size distribution, binder type, curing conditions and environmental influences were scrutinized to gain comprehensive insights into the material's suitability for construction purposes. The findings provide insights into the feasibility of utilizing lunar soil simulant based mortar for future space missions and lunar colonization efforts*

Keywords: *LSS: Lunar Soil Simulants, JSC 1 A and LMS-1: Johnson space centre, Lunar Mare Simulant, LHS-1 : lunar highland simulant, CHENOBI: These are the soil simulant sample tests made by,AGK-2010: Polish lunar simulant, FARO: Frasier and Raab orthopedics*

I. INTRODUCTION

Lunar soil, also known as regolith, is composed of fine particles like dust, gravel, and rocks. However, there are several challenges and considerations when it comes to using lunar soil for construction:

Regolith Properties: Lunar regolith varies in composition and may contain abrasive and fine-grained particles that can pose challenges for construction materials and equipment.

Lack of Binding Agents: Unlike Earth soil, lunar regolith lacks organic matter or binding agents that help hold the soil together. This may necessitate the addition of binding materials or the development of new construction techniques.

Harsh Lunar Environment: The lunar environment exposes materials to extreme temperature variations, radiation, and the vacuum of space. Construction materials need to withstand these conditions.

Microgravity Challenges: The moon has a much lower gravitational force compared to Earth. This affects the behavior of construction materials and the structural integrity of buildings. Engineers must consider the effects of microgravity on the stability of structures.

Resource Processing: Efficient methods for extracting and processing lunar regolith to create construction materials need to be developed. This includes techniques for sintering or binding regolith particles into durable building materials.

Despite these challenges, researchers and space agencies have been exploring the idea of using lunar regolith for construction. Concepts include 3D printing structures using lunar regolith, creating bricks or blocks from compacted regolith, and using sintering techniques to form solid material

Building a self-sufficient base on the Moon is expected to be one of the next steps in human space exploration. To create such permanent base, a few criteria must be met. One of fundamental conditions is the availability of building materials.

It is impossible to transport building materials from Earth thus in-situ resource utilization (ISRU) and in-situ fabrication and repair (ISFR) should be fully addressed. The erection of a base, landing pad or storage facilities on the Moon will create a very unique and complex situation both from materials and technological points of view.

Therefore, significant research effort is needed to develop full-scale lunar construction technologies and building materials.

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II. TEST SPECIMEN

2.1 Material used

Cement:

- Ordinary Portland cement (OPC) of 53 grade of Birla Cement is used in this experimental work.
- The standard consistency of cement sample is found to be32%.
- Fineness modulus was obtained 0.77%.

Aggregates:

- Crushed Sand having SpecificGravity2.84.
- Water absorption2.55%.

Lunar Soil Simulant:

- Soil Type: Rock Soil
- Local Name: KarraduMannu
- Available Location: Across the hilly slopes
- Visible Identification: Rough soil, mixed within flat surfaces big & small rocks,improper to plough unless the major size rocks aren't removed
- District: Namakkal
- Taluka: Rasipuram
- The standard consistency of cement sample is found to be32%.SpecificGravity2.40.

Sodium Hydroxide (NaOH)

This was the alkaline chemical used for binding of Lunar Soil Simulant which we used for generating mortar. Hence, 1mole=40gms.

Mix proportion and casting procedure

Firstly, the procedure of casting mortar cubes we determined the value of cement and fine aggregate which we passed through 90microns and 2.36mm respectively. The process of casting cubes were measured in the ratio of 1:3 (where, 1=cement & 3=fine aggregate)IS(4031 PART 6)1988.

Fig. 1 Lunar Soil Simulant.

Cement of 200gms and fine aggregate of 600gms with alkaline chemical(NaOH) and was mixed thoroughly. Water was added while the mixing was in continuous. Mortar was then placed in IS specified moulds in three layers, each layer was being compacted by standard tamping rod with more than 35 strokes. Exposed surface was finished with trowel to avoid uneven surface. A total of 27(i.e 9cubes of conventional mortar, 9 cubes of Mix 2, and 9 cubes of Mix 3) mortar specimen of dimension 70.6x70.6x70.6mm for compressive test and similarity, mix2 was generated with the help of

3.75 moles and mix3 was generated with 5 moles. Then cubes were kept for oven drying for temperature curing. Specimen for strength test, for each percentage variation were cured and tested for 3rd, 7th and 28th days.

Table 1: Mix design composition (for 9 cubes)

Mix	Cement (gm)	Fine Aggregate (gm)	Coarse Aggregate (kg)	Replacement(gm)		
				LSS cement	LSS aggregate	fineNaOH content
Mix1	200	600	0	0	0	0
Mix2	0	0	0	200	600	26.39
Mix3	0	0	0	200	600	35.2

III. TEST PROGRAM

3.1 Compression testing of cubes

Mortar Cubes as casted of size 70.6x70.6x70.6 mm were tested using Compression testing machine of capacity 2000kN. Testing of mortar cubes was done at the age of 3rd, 7th and 28th day. The measuring strength of specimen is calculated by dividing the maximum load applied to the specimen during the test by the cross section area.

3.2 Calculation of LSS mortar

Quantity for 1 Cube (70.6 × 70.6 × 70.6 mm) Mix Ratio 1 : 3

The quantity of cement, standard sand and water required for each cube are as follows:

Lunar Soil (Replacing Cement)(*<90 µm*) = 200gms

Lunar Soil (Replacing Standard Sand) = 600gms

2.36 mm to 1.18 mm - 200 gms

1.18 mm to 600 µm - 200 gms

600 µm to 90 µm - 200 gms

Water $= (P/4 + 3)$% of total mass of Lunar Soil, i.e. 800 gms.

(*P is the consistency of cement as per IS : 4031 (Part 4) : 1988*)

$= (32/4 + 3)$ ∵consistency achieved is 32 %

$= 11$ %

Therefore, quantity of water = 88 gms.

Quantity for 9 cubes

3 Cubes – 3rd Day Strength

3 Cubes – 7th Day Strength

3 Cubes – 28th Day Strength

Lunar Soil (Replacing Cement)(*<90 µm*) = 200 × 9 = 1800 gms

Lunar Soil (Replacing Standard Sand) = 600 × 9 = 5400 gms

2.36 mm to 1.18 mm - 1800 gms

1.18 mm to 600 µm - 1800 gms

600 µm to 90 µm - 1800 gms

Above calculation is only for Mix having 5M NaOH solution to activate the soil.

For remaining 2 Mix (3.75 M NaOH and 5M NaOH) same material calculation will be done.

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IV. LITERATURE

A Study of lunar soil simulants from construction and building materials perspective. (2023):

The properties of only two of the analysed LSS samples are closely correlated to average values of lunar soil granulometric properties, which is important from civil engineering perspective: JSC 1 A and LMS-1.

Many of the tested LSS are not suitable for civil engineering research programmes due to lack of satisfactory similarity to the features of lunar regolith

Terrestrial Laser Scanning of Lunar Soil Simulants. (2022):

In the near future, permanent human settlements on the Moon will become increasingly realistic. Three lunar soil simulants representing highland regions (LHS-1, AGK-2010, CHENOBI) and three lunar soil simulants representing mare regions (LMS-1, JSC-1A, OPRL2N) were used in this study. Measurements were performed using three terrestrial laser scanners (Z+F IMAGER 5016, FARO Focus^{3D}, and Leica ScanStation C10).

Terrestrial laser scanning technology (TLS) is one of the fastest and most-efficient measurement methods. TLS measurements also have high accuracy. The working principle of a terrestrial laser scanner is the emission of a laser beam by transmitter.

A total of nine measurements of six LSS specimens were performed using three scanners. It is possible to conduct measurements of LSSs (Lunar soil Simulant) using TLS; hence, future applications of TLS technology on the Moon are feasible

The chemical reactivity of lunar dust relevant to human explorations of the moon. (2009):

A clear understanding of the chemistry of lunar dust is required to set the stage for extended duration lunar surface operations. All aspects of the unique environment of the Moon—micrometeorite bombardment, UV light exposure, solar wind radiation, solar particle event radiation and galactic cosmic radiation—influence the mineralogy of the Moon, and are believed to impart a high degree of chemical reactivity to lunar dust. Lunar regolith, including the fine

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fraction of lunar dust, is a complex material, formed and modified by continuous micrometeorite impacts on the lunar surface.

The bulk chemical composition of lunar dust varies across the lunar surface, but is about 50% SiO_2, 15% Al_2O_3, 10% CaO, 10% MgO, 5% TiO_2 and 5-15% iron, with lesser amounts of sodium, potassium, chromium, zirconium. To carry out a comprehensive study of the chemical reactivity of lunar dust, focused on the effects of Moon-relevant radiation. An understanding of the chemical reactivity of lunar dust will provide fundamental geoscience knowledge that may help us to understand other airless planetary bodies, such as near-Earth asteroids and other moons.

Rheological Properties of Lunar Mortar. (2021):

In the conducted research the influence of powder simulating the granulometry and morphology of lunar regolith on rheology of lunar micromortors and mortars was tested.

The microscopic observations confirm the sharp edge morphology of LRS particles, characteristics of lunar soils which unfortunately affects negatively the consistency of mixes of cementitious composite with these fillers.

Physical properties of concrete made with apollo 16 lunar soil sample. (1975):

Forty grams of lunar soil were evaluated determine if the material is suitable as fine aggregate for making mortar specimen.

Examination by optical microscope so that angularity of the particles would be like to cause lunar concrete mixes to require more mixing mortar than well grounded.

Physical and mechanical properties of the lunar soil (a review) (2014):

The physical and mechanical properties of the lunar soil include main parameter such as granulometric composition, density and porosity, cohesion and adhesion, shear strength of loose soil, the compressibility, bearing capacity, etc.

In its loosest state, the lunar regolith demonstrates very low strength properties and high compressibility. By its behavior, the soil, when being loaded, approaches a compressible liquid that is its angle of internal friction is small. The cohesion is insignificant and the lateral pressure coefficient is high.

When the soil compaction grows the cohesion and internal friction angle increase, the compressibility coefficient drops, and the bearing capacity increases.

A proposition for a lunar aggregate and its simulant. (2020):

Aggregate is a key ingredient for the production of any kind of concrete. On Earth, we do not use soil for concrete production and for the same reasons, we should not use soil for concrete production on the Moon.

All proposed lunar concrete solutions, such as sulphur or polymeric concretes, as well as 3-D printed concretes, are based on utilizing lunar soil in its raw state.

LUNARCRETE- A REVIEW. (2012)

The idea of construction on moon is gaining momentum day by day given the need for building on moon for conducting research in astronomy.

Lunarcrete which should be prepared in materials on the Lunar surface itself.

The paper also discusses the various regolith stimulants materials prepared so far and predict their behaviour in Lunar environment.

Lunar soils, simulants and lunar construction materials: An overview (2022)

This wide research topic mainly covers learning about ground conditions and soils of these extraterrestrial bodies, looking for means of using the soil in producing construction materials, designing structures appropriate for local conditions, and finally choosing construction techniques to be applied using mainly these materials. In this paper, as the title indicates, an overview is presented on three aspects of using local materials in lunar construction activities: nature of in-situ soils obtained with lunar missions, the variety of lunar soil simulants produced on Earth, and their use in producing lunar construction materials.

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Assessment of dynamic properties of a new lunar highland soil simulant (LSS-ISAC-1) developed for Chandrayaan missions. (2022):

The distinct difference between the lunar surface (Moon) and the Earth forced space research organizations (SRO) and researchers to study the geotechnical properties of the lunar soils for the successful execution of lunar missions. The planned Chandrayaan Missions of the Indian Space Research Organization include constructing lunar structures on the lunar surface for the future Moon colonization. The stability of such lunar structures is completely dependent upon the foundation systems adopted. The foundation systems of these lunar structures are expected to encounter various types of vibrations due to moonquakes on the lunar surface. The analysis and design of a foundation system with respect to ground motion and vibration rely on the dynamic properties of the lunar soil. Also, the characterization of dynamic soil properties like shear modulus, damping ratio, and Poisson's ratio is essential for the safe design of foundation systems. Therefore, it is imperative to evaluate the dynamic properties of the lunar soil against moonquake-induced vibrations. Past research has utilized lunar soil simulants were used to assess the lunar soil's geotechnical properties. In that order, this study explains the dynamic properties of the new lunar highland simulant LSS-ISAC-1 under simulated moonquake conditions using cyclic triaxial tests. The shear modulus and damping ratio were determined from the cyclic triaxial tests for the different relative densities (30%, 63%, and 80%), confining pressures (5 kPa–75 kPa), and frequencies to represent the loose, medium, and dense states of the lunar surface.

V. PROBLEM STATEMENT

The successful establishment of human settlements and infrastructure on the Moon necessitates a deep understanding of lunar soil simulants and their suitability for construction materials. While some simulants exhibit properties closely aligned with lunar regolith, facilitating civil engineering research, others lack the necessary resemblance. Additionally, factors such as chemical reactivity of lunar dust, rheological properties of lunar mortar, and the physical and mechanical characteristics of lunar soil pose significant challenges for the development of robust construction materials. Thus, there exists a critical need to address these challenges comprehensively, aiming to identify suitable lunar soil simulants, characterize their properties accurately, and develop construction techniques tailored to the unique lunar environment. This research aims to bridge existing knowledge gaps and provide insights crucial for the successful implementation of lunar construction projects, paving the way for sustainable lunar colonization and exploration.

VI. OBJECTIVES

- Characterize LSS (lunar soil simulant): Understand its physical and chemical properties.
- Prepare Mortar Samples: Blend LSS with cementitious binders and aggregates.
- Conduct Mechanical Tests: Evaluate compressive strength.
- Compare with Traditional Mortar: Assess the influence of LSS on mortar performance.
- Analyze Microstructure: Investigate the interaction between LSS particles and the cementitious matrix.
- Optimize and Recommend: Improve LSS-based mortar composition and suggest applications.
- Future Implications: Discuss implications for lunar construction materials and suggest further research avenues.

VII. DISCUSSION

Our project focuses on evaluating lunar soil simulants for their suitability in construction on the Moon and aims to develop innovative construction materials and techniques. By assessing various simulants, prioritizing those closely resembling lunar regolith, and integrating advanced technologies like Terrestrial Laser Scanning, we seek to obtain precise measurements and analyses of simulant characteristics. Understanding the chemical reactivity of lunar dust is crucial for ensuring material durability, and we will explore additives and mixing techniques to optimize the consistency of lunar mortar. Additionally, integrating dynamic soil properties into our designs will be essential for ensuring stable foundations for lunar structures. Through interdisciplinary collaboration among materials scientists, engineers, and space exploration experts, our project aims to address construction challenges effectively. Success in our endeavor holds significant implications for sustainable human habitation on the Moon, paving the way for future lunar exploration and colonization efforts.

VIII. ACKNOWLEDGMENTS

The experimental work was carried out in the laboratories of the Civil Engineering Department, ICEM, Pune. The authors would like to thank the faculties and students of the Civil Engineering Department, ICEM, Pune for their help in the experimental works related to this study.

IX. CONCLUSION

As the test specimen after comparison of Lunar Soil Simulant mortar with the Conventional mortar, results of LSS failed as a mortar. The various uses in civil engineering of experimental generation of mechanical properties of LSS can be done. Replacing soil with cement passed through 90microns and standard fine aggregate as LSS fine aggregate 2.36mm was not a successful experiment as being a civil engineer we can have a liberty of use different applications as experimental conditions. We can use the mix design mortar with hiogh strength of compression by binding with different alkaline chemicals like FeO, KOH, NaOH, CaOH, etc. If we consider the mortar cubes as a replacing agency of red soil or cyporex brick could be a conditional provision for experimenting and generating different mechanical properties. The soil which we used for mortar generation was a anorthosite soil from terrestrial rocks forming a Lunar Soil Simulant. We could prove that only temperature at different degree or farhenheit could cure and settle lunar soil simulant and alkaline composite mortar.

REFERENCES

[1]. Raju, P.. (2012). Lunarcrete -- A Review (Paper ID AR84AS). pp-886.

[2]. Yusuf Cengiz Toklu, Pinar Akpinar, Lunar soils simulants and lunar construction materials: An overview, Advances in Space Research Volume 70, Issue 3, 1 August 2022, Pages 762-779, https://doi.org/10.1016/j.asr.2022.05.017

[3]. Sokołowska, Joanna, Woyciechowski, Piotr, Kalinowski, Maciej 2021/07/28 6961 Rheological Properties of Lunar Mortars 11 10.3390/app11156961 Applied Sciences

[4]. Physical properties of concrete made with Apollo 16 lunar soil sample,T. D. Lin and Hugh Love and David C. Star, year={1992},https://api.semanticscholar.org/CorpusID:120226028

[5]. Slyuta, E.N. Physical and mechanical properties of the lunar soil (a review). Sol Syst Res 48, 330–353 (2014). https://doi.org/10.1134/S0038094614050050

[6]. SS. Asad, iRavali.KoppulaVarikunta, .Bhargavi Sai, M.V. RajuInternational Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 3, March 2017, pp. 816–823 Article ID: IJCIET_08_03_082

[7]. Paweł K. Zarzycki, Jacek Katzer, A proposition for a lunar aggregate and its simulant, Advances in Space Research, Volume 65, Issue 12, 2020, Pages 2894-2901, ISSN 0273-1177, https://doi.org/10.1016/j.asr.2020.03.032.

[8]. BOOK Raju, P.2012/01/01pp EP - 886 Lunarcrete -- A Review (Paper ID AR84AS)

[9]. JOUR Asadi, Chowdary, Koppula Sai, V.B. M.V., Raju 2017/01/01 816Preparation of soil analysis for construction of commercial complex: A model study