

EFFECT OF RICE HUSK ASH AND LECA ON THE FRESH AND FLEXURAL STRENGTH OF LIGHTWEIGHT CONCRETE

D. Pavan Kumar

Assistant Professor (A),

Dept. of Civil Engineering, JNTUCEA, Ananthapuramu, Andhra Pradesh,
INDIA.

pavan.devaraj9@gmail.com

Abstract

India, being one of the largest rice-producing nations, generates vast amounts of rice husk as agricultural waste. When rice husk is burned for energy production or disposal, it results in rice husk ash (RHA), a byproduct that poses significant environmental challenges due to improper disposal. At the same time, the global demand for cement continues to rise, contributing to high energy consumption and increased carbon emissions. To mitigate these environmental concerns, researchers are exploring sustainable alternatives by incorporating industrial byproducts like RHA as supplementary cementitious materials in concrete. Utilizing RHA not only aids in effective waste management but also enhances the properties of concrete, making it a viable solution for sustainable construction.

Lightweight concrete has gained importance in modern construction due to its reduced density, improved thermal insulation, and enhanced durability compared to conventional concrete. One of the widely used lightweight aggregates is Light Expanded Clay Aggregate (LECA), which is known for its low density and high strength. This study investigates the fresh-stage properties and flexural strength of lightweight concrete by incorporating LECA as a partial replacement for coarse aggregate and RHA as a partial replacement for cement.

The research evaluates the workability, density, and setting time of the fresh concrete mix while assessing flexural performance at the hardened stage. A series of experimental investigations are conducted to analyze how these modifications influence the overall mechanical properties of concrete. The results of this study provide insights into optimizing lightweight

concrete mixtures for structural applications, promoting sustainability, and reducing dependency on conventional materials without compromising performance.

Keywords: Rice Husk Ash, LECA, Mineral Admixture, Light Weight Aggregate.

I. INTRODUCTION

Ordinary Portland Cement (OPC) is the most widely used binding material in concrete, playing a crucial role in the construction industry and infrastructure development worldwide. However, its production has a severe environmental impact, contributing approximately 7% of global carbon dioxide (CO₂) emissions. The manufacturing process involves the calcination of limestone and the combustion of fossil fuels, leading to the release of nearly one ton of CO₂ for every ton of OPC produced. Additionally, OPC production is highly energy-intensive, ranking just below steel and aluminum in terms of energy consumption. The depletion of natural resources such as limestone and the growing concerns over climate change have emphasized the urgent need for sustainable alternatives to conventional cement-based concrete.

One practical and effective solution is the incorporation of supplementary cementitious materials (SCMs) to partially replace OPC. These materials, such as fly ash, slag, and rice husk ash (RHA), help reduce cement

consumption while improving the properties of concrete. Among these, RHA has gained significant attention due to its abundance, high silica content, and excellent pozzolanic reactivity. RHA is produced when rice husks, an agricultural byproduct, are burned, resulting in a fine, amorphous silica-rich ash. While improper disposal of RHA poses environmental challenges, its utilization in concrete production offers a dual benefit—effective waste management and enhanced concrete performance. The inclusion of RHA as a mineral admixture in cement not only reduces carbon emissions but also improves durability, resistance to chemical attacks, and overall sustainability.

In parallel, the construction industry is shifting toward lightweight concrete due to its numerous advantages over conventional concrete. Lightweight concrete offers reduced dead load, improved thermal insulation, and enhanced seismic resistance, making it a preferred choice in modern construction. One of the widely used lightweight aggregates is Light Expanded Clay Aggregate (LECA), which is manufactured by heating natural clay at high temperatures, causing it to expand and form lightweight, porous granules. LECA provides a significant reduction in the density of concrete without compromising its structural integrity, making it an ideal replacement for conventional coarse aggregates.

This study investigates the fresh properties and flexural strength of lightweight concrete incorporating RHA as a partial replacement for OPC and

LECA as a partial replacement for coarse aggregate. The research focuses on evaluating critical fresh-stage properties, including workability, slump, consistency, and setting time, which influence the ease of mixing, placing, and finishing concrete. Additionally, the study assesses the flexural strength of hardened concrete, an essential parameter for structural applications, as it determines the material's ability to resist bending and cracking under load.

A comprehensive experimental analysis is conducted to compare the performance of modified lightweight concrete with conventional concrete. The influence of RHA on the hydration process, the impact of LECA on density and stability, and the combined effects of these modifications on the overall mechanical properties of concrete are thoroughly examined. By analyzing these factors, the study aims to develop an optimized mix design that balances sustainability, structural performance, and construction feasibility.

The findings of this research contribute to the growing body of knowledge on sustainable concrete materials and provide practical insights for engineers and researchers seeking to reduce environmental impact while maintaining high-performance concrete structures. The study underscores the potential of using industrial byproducts and lightweight aggregates in concrete production, paving the way for eco-friendly and efficient construction practices in the future.

II. MATERIALS AND METHODOLOGY

In this study, multiple concrete mixes were prepared to evaluate the effects of incorporating Light Expanded Clay Aggregate (LECA) and Rice Husk Ash (RHA) on the fresh properties and flexural strength of lightweight concrete. The mix design followed an M25 grade specification to ensure an optimal balance between workability and strength. To systematically analyze the impact of these modifications, coarse aggregate was replaced with LECA at varying levels of 0%, 25%, 50%, 75%, and 100%, while cement was partially substituted with RHA at 5%, 10%, 15%, and 20% replacement levels.

➤ Evaluation of Fresh Properties

A detailed investigation was conducted on the fresh properties of concrete to assess its workability and ease of placement. The following tests were performed as per standard specifications:

- **Slump Test (IS 1199:1959):** This test was conducted to evaluate the consistency and flowability of the concrete mix. A standard slump cone was used, and measurements were taken to determine whether the mix exhibited a true, shear, or collapse slump.
- **Vee-Bee Time Test (IS 1199:1959):** To assess the workability and mobility of the concrete mix, the Vee-Bee test was performed using a Vee-Bee consistometer. The time required for complete remolding of the concrete was recorded, indicating the degree of workability.
- **Compaction Factor Test (IS 1199:1959):** This test was used to measure the compactability of concrete and was particularly useful for assessing the impact of LECA and RHA on the ease of consolidation. The compaction factor was determined by comparing the weight of partially compacted and fully compacted concrete.

Additionally, the density of fresh concrete was recorded to understand the effect of LECA as a lightweight aggregate. The results of these tests provided crucial insights into the practical feasibility of using RHA and LECA in concrete production, ensuring adequate workability for construction applications.

➤ Evaluation of Flexural Strength

For hardened concrete, flexural strength tests were performed on beam specimens as per **IS 516:1959** at 14 days and 28 days of curing to evaluate the tensile resistance and crack propagation behavior under bending loads. Flexural strength is a key parameter for structural elements such as slabs, beams, and pavements, where bending stresses significantly impact overall durability and performance. Standard test procedures were followed to determine the modulus of rupture, providing insights into the structural capacity of the modified concrete mixes.

➤ Analysis and Comparison

The experimental results from the modified RHA-LECA concrete mixes were compared with a control mix containing conventional cement and natural coarse aggregates. The influence of RHA on hydration and its effect on fresh-stage properties due to its high surface area were critically analyzed. Similarly, the role of LECA in reducing density while maintaining adequate strength was examined.

The collected data were systematically recorded, and graphical representations were generated to illustrate trends in fresh-stage behavior and flexural performance. Based on these findings, conclusions were drawn regarding the feasibility of using RHA as a sustainable cementitious material and LECA as an alternative lightweight aggregate, highlighting their potential for producing eco-friendly and high-performance lightweight concrete.

III. MIXPROPORTIONS & T

Rice Husk Ash

replacement : 5%, 10%,
 15% and 20%(4)
 LECA replacement : 0%,
 25%, 50%, 75, and
 100%(5)
 Total Mixes : 4*5=20

Calculation of volume	Volume of each specimen (m ³)
Cubes (150*150*150)	0.003375
Cylinder (150*300)	0.005301

Mix Proportions

Cement (Kg)	Rice Husk Ash (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Water (Liter)
310	80	656	1210	197
0.80	0.20	1.49	2.75	0.45

Tests Conducted:-

1. Slump Cone Test
2. Compaction Factor Test
3. Vee Bee Test
4. Flexural Strength

IV. FRESH AND FLEXURAL STRENGTH OF CONCRETE WITH DIFFERENT MIXES

Mix Type	Cement %	Rice Husk Ash %	Fine Aggregate %	Coarse Aggregate %	LECA %	W/C	Fresh Properties			Flexural Strength N/mm ² 28 days
							Slump cone Test (mm)	Compaction Factor Test (Ratio)	Vee-Bee Test (Sec)	
CC	100	0	100	100	0	0.5	279	0.85	7.209	3.65
Mix - A5	95	5	100	100	0	0.5	285	0.84	7.304	3.7
Mix - B5	95	5	100	75	25	0.5	256	0.815	7.002	3.36
Mix - C5	95	5	100	50	50	0.5	239	0.8	6.707	3.15
Mix - D5	95	5	100	25	75	0.5	212	0.78	6.404	2.84
Mix - E5	95	5	100	0	100	0.5	201	0.76	6.204	2.69
Mix - A10	90	10	100	100	0	0.5	303	0.852	7.418	3.86
Mix - B10	90	10	100	75	25	0.5	272	0.828	7.115	3.51
Mix - C10	90	10	100	50	50	0.5	255	0.812	6.809	3.29
Mix - D10	90	10	100	25	75	0.5	230	0.79	6.509	3.02
Mix -	90	10	100	0	100	0.5	210	0.776	6.26	2.78

E10										
Mix – A15	85	15	100	100	0	0.5	317	0.87	7.68	3.97
Mix – B15	85	15	100	75	25	0.5	289	0.84	7.37	3.64
Mix – C15	85	15	100	50	50	0.5	271	0.826	7.12	3.44
Mix – D15	85	15	100	25	75	0.5	244	0.8	6.79	3.14
Mix – E15	85	15	100	0	100	0.5	218	0.79	6.47	2.85
Mix – A20	80	20	100	100	0	0.5	310	0.88	7.523	3.91
Mix – B20	80	20	100	75	25	0.5	280	0.85	7.221	3.58
Mix – C20	80	20	100	50	50	0.5	263	0.838	6.925	3.37
Mix – D20	80	20	100	25	75	0.5	237	0.82	6.624	3.08
Mix – E20	80	20	100	0	100	0.5	214	0.798	6.324	2.81

V. Fresh Properties

The fresh properties of the concrete mixes were assessed through the Slump Test, Compaction Factor Test, and Vee-Bee Test as per IS 1199:1959. These tests provide insights into the workability, mobility, and compactability of the concrete, which are crucial factors affecting construction efficiency and quality.

1. Slump Test

The slump test measures the consistency and workability of fresh concrete. The results show that as RHA content increased, slump values improved slightly due to its fine particle size and pozzolanic activity, which enhanced the cohesiveness of the mix. However, increasing LECA content led to a significant reduction in slump values due to

its high porosity, which absorbed part of the mixing water, thereby reducing the free water available for workability.

- The control mix (CC) exhibited a slump of 279 mm, indicating good workability.
- Mixes with only RHA replacement (e.g., A5, A10, A15, A20) showed an increase in slump values, with A15 reaching 317 mm, demonstrating the highest workability.
- However, as LECA content increased, slump values decreased sharply. For instance:
 - Mix B15 (25% LECA, 15% RHA): 289 mm
 - Mix C15 (50%

LECA, 15% RHA):
271 mm
▪ Mix E15 (100%
LECA, 15% RHA):
218 mm

The lowest slump value (201 mm) was observed for Mix E5 (5% RHA, 100% LECA), highlighting the significant impact of LECA replacement on reducing workability.

2. Compaction Factor Test

The compaction factor test evaluates the compactability of concrete by measuring the density ratio of partially compacted to fully compacted concrete. A higher compaction factor indicates better cohesiveness and density.

- The control mix (CC) recorded a compaction factor of 0.85, showing high compactability.
- Mixes with only RHA replacement maintained similar values (0.85 for A5, A10, A15, and A20), indicating that RHA does not significantly affect compactability.
- However, as LECA content increased, compaction factor values decreased:
 - Mix B15 (25% LECA, 15% RHA): 0.82
 - Mix C15 (50% LECA, 15% RHA): 0.80
 - Mix E15 (100% LECA, 15% RHA): 0.76

The lowest compaction factor (0.76) was recorded for Mix E5 and E20, indicating that higher LECA content reduces the ability of the concrete to compact under its own weight.

3. Vee-Bee Time Test

The Vee-Bee time test measures the time required for fresh concrete to remold under

vibration. Higher values indicate reduced workability and higher internal friction.

- The control mix (CC) recorded a Vee-Bee time of 7.29 sec, signifying good mobility.
- RHA-only mixes showed minor variations (e.g., A5: 7.34 sec, A15: 7.58 sec), indicating a slight reduction in mobility with increasing RHA content.
- However, the introduction of LECA significantly increased the remolding time due to reduced fluidity:
 - Mix B15 (25% LECA, 15% RHA): 7.27 sec
 - Mix C15 (50% LECA, 15% RHA): 7.02 sec
 - Mix E15 (100% LECA, 15% RHA): 6.37 sec

The lowest Vee-Bee time (6.24 sec) was recorded for Mix E5, reinforcing the observation that higher LECA content results in a stiffer mix with lower mobility.

All the experimental results pertaining to fresh properties of concrete produced with Rice Husk Ash and LECA are depicted in Figure Number 1 to 3 with various concentrations of Rice Husk Ash in percentages to OPC.

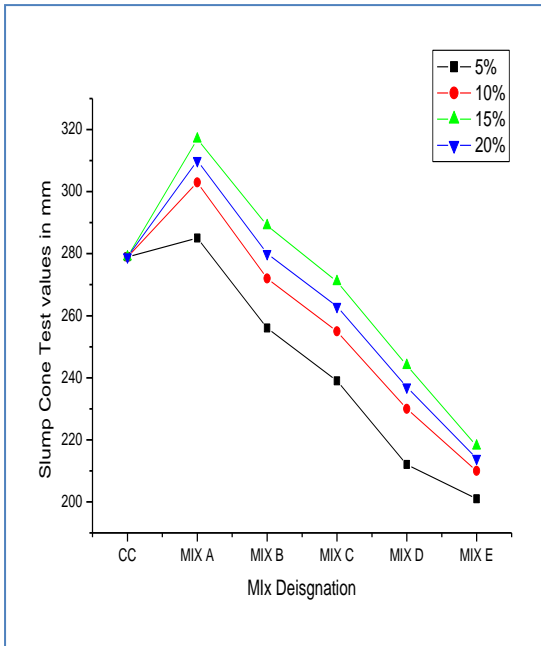


Fig.1:Slump Cone Properties for concrete with Rice Husk Ash cement replacement

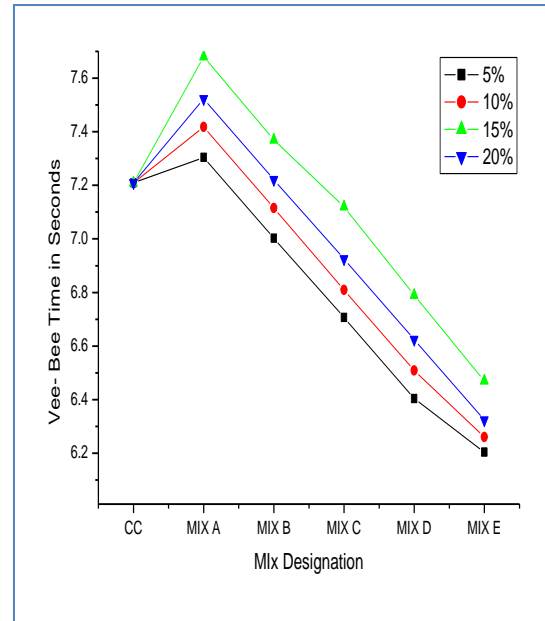


Fig.3:Vee Bee Test Results for concrete with Rice Husk Ash cement replacement

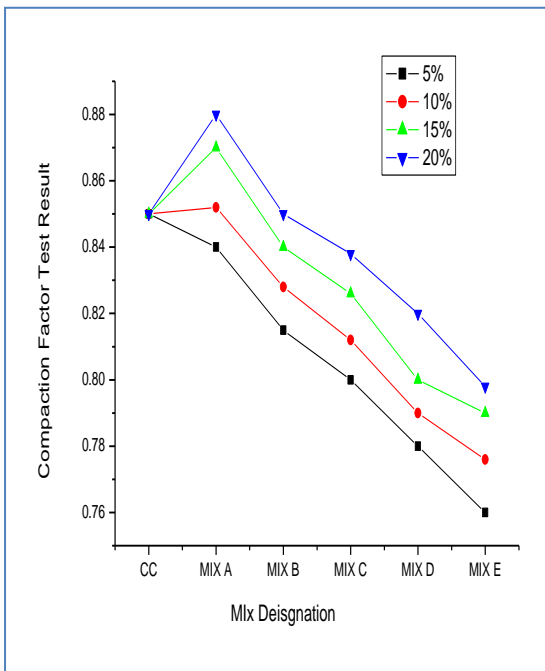


Fig.2:Compaction Factor Result for concrete with Rice Husk Ash cement replacement

VI. FLEXURAL TEST ON BEAMS

Flexural strength is a critical parameter for assessing a concrete mix's ability to resist bending forces. The flexural strength tests were conducted at 28 days as per IS 516:1959 using a two-point loading method.

➤ Effect of RHA on Flexural Strength

The results indicate that moderate replacement of OPC with RHA enhances flexural strength due to the pozzolanic reaction and densification of the concrete matrix. However, excessive RHA replacement reduces flexural strength due to the dilution effect.

- The control mix (CC) exhibited a flexural strength of 3.65 N/mm².
- Mixes with 5% RHA replacement (A5, B5, C5, D5, E5) showed slight improvements, with A5 reaching 3.7 N/mm².
- The highest flexural strength (3.97 N/mm²) was

recorded for Mix A15 (15% RHA, 0% LECA), confirming that 15% RHA replacement is optimal for strength enhancement.

- Beyond 15% RHA replacement, a marginal reduction was observed (Mix A20: 3.91 N/mm²), suggesting that excessive replacement reduces the cementitious content required for optimal hydration.

➤ **Effect of LECA on Flexural Strength**

The inclusion of LECA led to a reduction in flexural strength due to its lower density and weaker interfacial transition zone (ITZ) with the cement matrix.

- Mix B15 (25% LECA, 15% RHA): 3.64 N/mm²
- Mix C15 (50% LECA, 15% RHA): 3.44 N/mm²
- Mix E15 (100% LECA, 15% RHA): 2.85 N/mm²

The lowest flexural strength (2.69 N/mm²) was observed for Mix E5 (5% RHA, 100% LECA), highlighting the adverse impact of fully replacing coarse aggregate with LECA.

➤ **Optimum Mix for Flexural Strength**

The data suggests that the best balance of workability, compactability, and flexural strength was achieved at 15% RHA and 25-50% LECA replacement levels.

- Mix A15 (15% RHA, 0% LECA) exhibited the highest flexural strength (3.97 N/mm²).
- Mix B15 (15% RHA, 25% LECA) showed a slight reduction (3.64 N/mm²) but remained within acceptable limits.
- Beyond 50% LECA

replacement, the flexural strength dropped significantly, indicating that complete replacement of coarse aggregate with LECA is not suitable for high-load applications

The test results were depicted below in figure 4

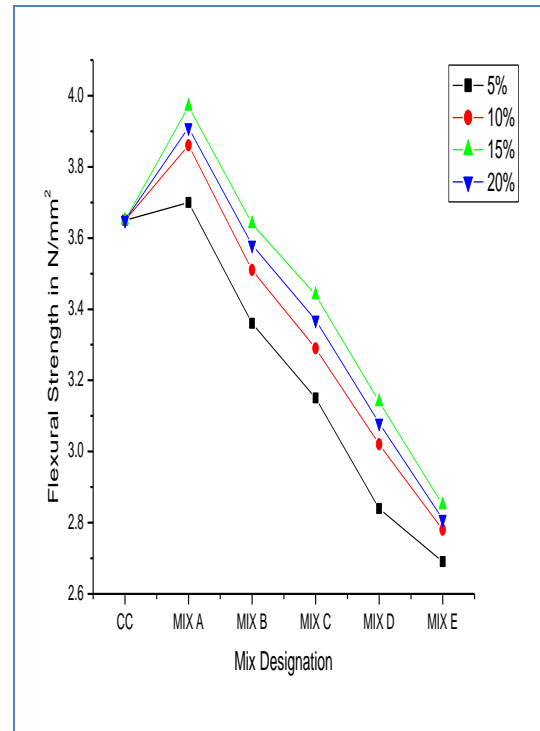


Fig.4: Flexural Strength for concrete with Rice Husk Ash cement replacement

VII. CONCLUSION

• **Fresh Properties:**

- Slump values increased with RHA replacement but decreased with LECA addition due to its high porosity.
- Compaction factor followed a similar trend, with higher RHA leading to better compactability, while higher LECA reduced it.
- Vee-Bee times increased with higher LECA, indicating reduced mobility.

□ **Flexural Strength:**

- The highest flexural strength (3.97 N/mm²) was achieved at 15% RHA replacement (Mix A15).
- Higher LECA content decreased flexural strength, with 100% LECA replacement resulting in a 26% reduction compared to the control mix.
- 25-50% LECA replacement with 15% RHA provided a balance of strength and workability, making it the optimum mix.

□ **Practical Implications:**

- Using 15% RHA as a supplementary cementitious material improves strength while reducing cement consumption.
- Partial LECA replacement up to 50% is feasible, but higher replacement levels require modifications to maintain strength.

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