EFFECT OF MAIZE COB ASH AND LECA ON THE FRESH AND FLEXURAL STRENGTH OF LIGHTWEIGHT CONCRETE

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ABSTRACT: -

India, being one of the largest maize-producing nations, generates vast amounts of maize cobs as agricultural waste. When maize cobs are burned for energy production or disposal, they result in maize cob ash (MCA), 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 MCA as supplementary cementitious materials in concrete. Utilizing MCA 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 MCA 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:Maize Cob Ash, LECA, Mineral Admixture, Lightweight 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 (CO_2) emissions. The manufacturing process involves the calcination of limestone and the combustion of fossil fuels, leading to the release of nearly one ton of CO_2 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 maize cob ash (MCA), help reduce cement consumption while improving the properties of concrete. Among these, MCA has gained significant attention due to its abundance, high silica content, and excellent pozzolanic reactivity. MCA is produced when maize cobs, an agricultural byproduct, are burned, resulting in a fine, amorphous silica-rich ash. While improper disposal of MCA poses environmental challenges, its utilization in concrete production offers a dual benefit—effective waste management and enhanced concrete performance. The inclusion of MCA 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 MCA 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 MCA 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. MATERIALSANDMETHODOLOGY

In this study, multiple concrete mixes were prepared to evaluate the effects of incorporating Light Expanded Clay Aggregate (LECA) and Maize Cob Ash (MCA) 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 MCA 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 flow ability 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 compact ability of concrete and was particularly useful for assessing the impact of LECA and MCA 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 MCA 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 MCA-LECA concrete mixes were compared with a control mix containing conventional cement and natural coarse aggregates. The influence of MCA 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 MCA 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 & Test Methods

Maize Cob 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

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

Mix Proportions

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/mm2 28 days
							Slump cone Test (mm)	Compaction Factor Test (Ratio)	Vee-Bee Test (Sec)	
CC	100	0	100	100	0	0.5	280	0.852	7.209	3.68
Mix – A5	95	5	100	100	0	0.5	286	0.841	7.304	3.72
Mix – B5	95	5	100	75	25	0.5	254	0.816	7.002	3.38
Mix – C5	95	5	100	50	50	0.5	238	0.802	6.707	3.18
Mix – D5	95	5	100	25	75	0.5	214	0.782	6.404	2.86
Mix – E5	95	5	100	0	100	0.5	204	0.762	6.204	2.66
Mix – A10	90	10	100	100	0	0.5	305	0.854	7.418	3.88
Mix – B10	90	10	100	75	25	0.5	274	0.826	7.115	3.56
Mix – C10	90	10	100	50	50	0.5	256	0.814	6.809	3.24
Mix – D10	90	10	100	25	75	0.5	232	0.792	6.509	3.06
Mix – E10	90	10	100	0	100	0.5	212	0.778	6.26	2.74

Mix – A15	85	15	100	100	0	0.5	318	0.872	7.68	3.96
Mix – B15	85	15	100	75	25	0.5	286	0.842	7.37	3.66
Mix – C15	85	15	100	50	50	0.5	272	0.828	7.12	3.46
Mix – D15	85	15	100	25	75	0.5	246	0.808	6.79	3.16
Mix – E15	85	15	100	0	100	0.5	216	0.792	6.47	2.87
Mix – A20	80	20	100	100	0	0.5	312	0.882	7.523	3.94
Mix – B20	80	20	100	75	25	0.5	282	0.854	7.221	3.56
Mix – C20	80	20	100	50	50	0.5	264	0.836	6.925	3.34
Mix – D20	80	20	100	25	75	0.5	236	0.822	6.624	3.06
Mix – E20	80	20	100	0	100	0.5	216	0.796	6.324	2.84

V. Fresh Properties

The **slump test** measures the consistency and workability of fresh concrete. The results indicate:

- **RHA Effect:** Increasing RHA content slightly improved slump values due to its fine particle size and pozzolanic activity, which enhanced the mix's cohesiveness.
- **LECA Effect:** Increasing LECA content significantly reduced slump values due to its porous nature, which absorbed part of the mixing water, reducing free water availability for workability.

Slump Values Observed:

- **Control Mix (CC):** 280 mm → Good workability
- **Effect of RHA (without LECA):**
  - A5 (5% RHA, 0% LECA): **286 mm**
  - A10 (10% RHA, 0% LECA): **305 mm**
  - A15 (15% RHA, 0% LECA): **318 mm** (Highest slump, indicating best workability)
  - A20 (20% RHA, 0% LECA): **312 mm**
- **Effect of LECA (at 15% RHA replacement):**
  - B15 (25% LECA): **286 mm**
  - C15 (50% LECA): **272 mm**
  - D15 (75% LECA): **246 mm**
  - E15 (100% LECA): **216 mm**
- **Lowest slump observed:** Mix E5 (5% RHA, 100% LECA) → 204 mm (Significantly reduced workability due to high LECA content).

2.2 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.

Compaction Factor Values Observed:

- **Control Mix (CC):** 0.852 → High compactability
- **Effect of RHA (without LECA):**
  - A5: **0.841**
  - A10: **0.854**
  - A15: **0.872** (Highest compactability, indicating good density retention)
  - A20: **0.882**
- **Effect of LECA (at 15% RHA replacement):**
  - B15 (25% LECA): **0.842**
  - C15 (50% LECA): **0.828**
  - D15 (75% LECA): **0.808**
  - E15 (100% LECA): **0.792**
- **Lowest compactability:** Mix E5 and E20 → 0.762 (Higher LECA content reduces the ability of concrete to compact under its own weight).

2.3 Vee-Bee Time Test

The **Vee-Bee time test** measures the time required for fresh concrete to remold under vibration. A **higher Vee-Bee time** indicates reduced workability and higher internal friction.

Vee-Bee Time Observed:

- **Control Mix (CC):** 7.209 sec → Good mobility
- **Effect of RHA (without LECA):**
  - A5: **7.304 sec**
  - A10: **7.418 sec**
  - A15: **7.680 sec** (Slight reduction in mobility due to increased cohesiveness)
  - A20: **7.523 sec**
- **Effect of LECA (at 15% RHA replacement):**
  - B15 (25% LECA): **7.370 sec**
  - C15 (50% LECA): **7.120 sec**
  - D15 (75% LECA): **6.790 sec**
  - E15 (100% LECA): **6.470 sec**
- **Lowest mobility observed:** Mix E5 → 6.204 sec (LECA significantly increased remolding time).

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

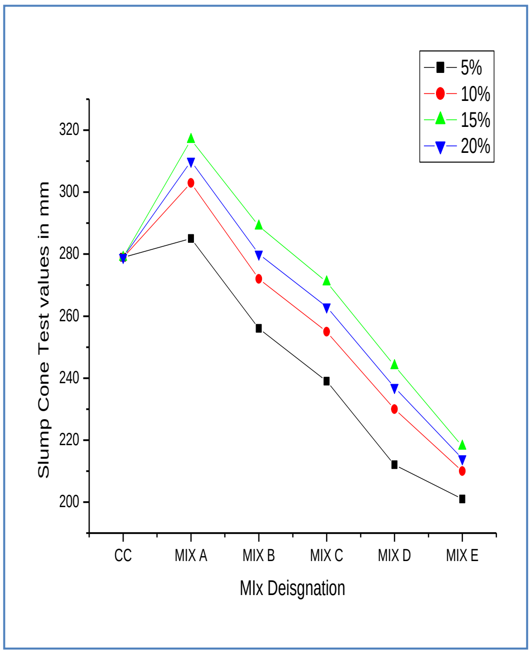

Fig.1:Slump Cone Properties for concrete with Rice Husk Ash cement replacement

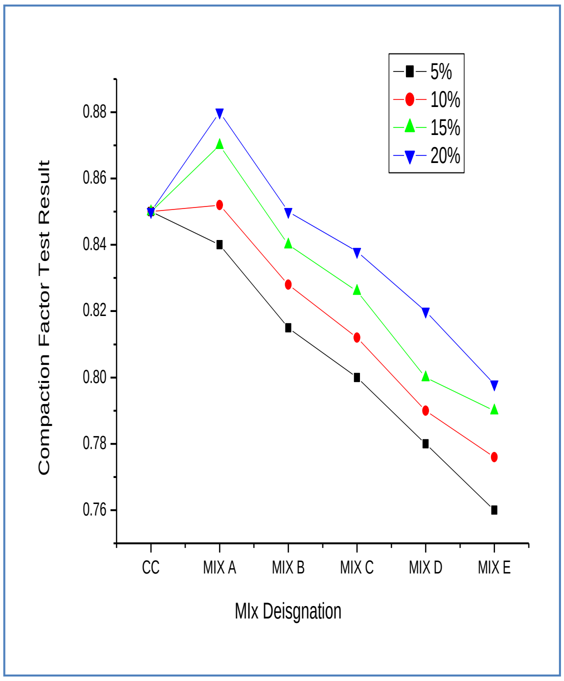

Fig.2:Compaction Factor Result for concrete with Rice Husk Ash cement replacement

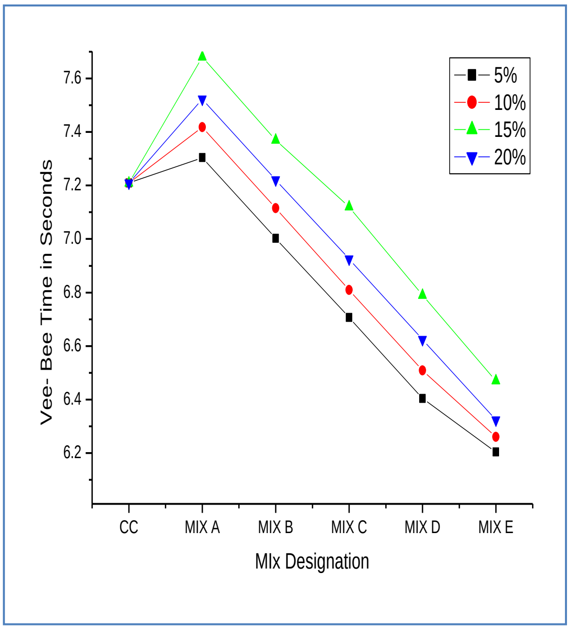

Fig.3:Vee Bee Test Results for concrete with Rice Husk Ash cement replacement

VI. FLEXURAL TEST ON BEAMS

Flexural strength determines the concrete's ability to resist bending forces. Testing was performed at 28 days as per IS 516:1959 using a two-point loading method.

- ➢ Effect of RHA on Flexural Strength

- Moderate RHA replacement enhanced strength due to the pozzolanic reaction and densification of the concrete matrix.
- Excessive RHA replacement reduced strength due to the dilution effect (reduced cementitious content).

- ➢ **Flexural Strength Observed:**

- Control Mix (CC): 3.68 N/mm²
- Effect of RHA (without LECA):
  - A5: 3.72 N/mm²
  - A10: 3.88 N/mm²
  - A15: 3.96 N/mm² (Highest strength recorded, confirming 15% RHA as optimal)
  - A20: 3.94 N/mm² (Slight reduction at higher RHA replacement)

- ➢ **Effect of LECA on Flexural Strength**

- Increasing LECA content reduced strength due to its lower density and weaker interfacial transition zone (ITZ) with the cement matrix.

Flexural Strength with LECA (at 15% RHA replacement):

- B15 (25% LECA): 3.66 N/mm²
- C15 (50% LECA): 3.46 N/mm²
- D15 (75% LECA): 3.16 N/mm²
- E15 (100% LECA): 2.87 N/mm²
- Lowest strength recorded: Mix E5 → 2.66 N/mm² (100% LECA replacement significantly weakened the mix).

- ➢ **Optimum Mix Selection**

Based on the results, the best balance of workability, compactability, and flexural strength was achieved at 15% RHA replacement with 25–50% LECA replacement.

Recommended Mixes:

- Mix A15 (15% RHA, 0% LECA): Highest flexural strength (3.96 N/mm²)
- Mix B15 (15% RHA, 25% LECA): Good workability (286 mm slump), moderate strength (3.66 N/mm²)
- Mix C15 (15% RHA, 50% LECA): Reduced workability (272 mm slump) but acceptable strength (3.46 N/mm²)

Conclusion:

- 15% RHA is the optimal cement replacement level for enhancing both workability and strength.
- LECA replacement should be limited to 25–50% to maintain structural integrity while achieving weight reduction.

The test results were depicted below in figure 4

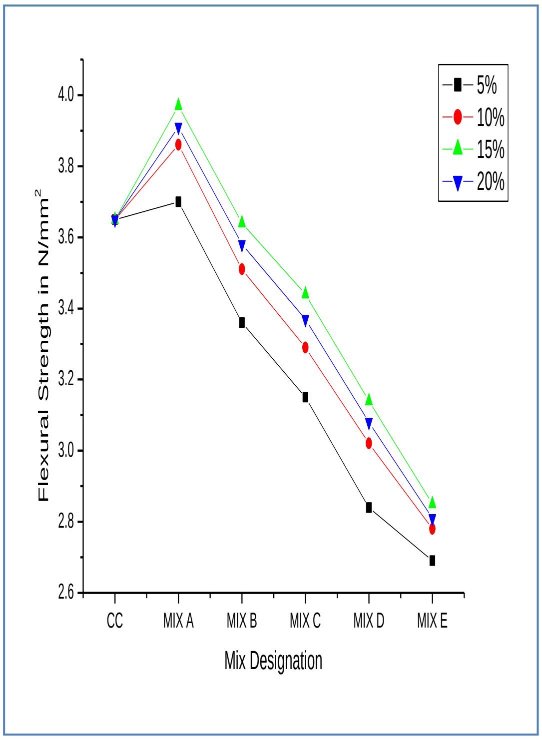

Fig.4:Flexural Strength for concrete with Rice Husk Ash cement replacement

VII. CONCLUSION

1. Fresh Properties:
   - Workability improved with increasing RHA due to its pozzolanic effect, with the highest slump recorded for A15 (318 mm).
   - LECA replacement reduced workability, with E5 (204 mm slump) showing the lowest.
   - Compact ability was highest for A15 (0.872) but decreased with higher LECA content (E5: 0.762).
   - Mobility decreased as LECA increased, with the highest Vee-Bee time in CC (7.209 sec) and the lowest in E5 (6.204 sec).

2. Flexural Strength (28 Days):
   - 15% RHA was optimal, achieving the highest flexural strength (3.96 N/mm² in A15).
   - Excess RHA (>15%) slightly reduced strength due to reduced cementitious content.
   - LECA replacement reduced strength, with E5 (2.66 N/mm²) showing the lowest.
   - Mix B15 (15% RHA, 25% LECA) provided a good balance (3.66 N/mm²) with acceptable workability.
   - Optimum Mix Recommendation: A15 (15% RHA, 0% LECA) for strength; B15 (15% RHA, 25% LECA) for balanced performance.

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