

EXPERIMENTAL INVESTIGATION ON STRENGTH PROPERTIES OF LIGHT WEIGHT AGGREGATE CONCRETE WITH AGRICULTURAL WASTE ASH AS A REPLACEMENTS TO OPC

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Abstract

India is a major maize-producing country, generating substantial quantities of maize cobs as agricultural waste. When these cobs are burned for energy or disposal, they produce maize cob ash (MCA), a byproduct that poses both environmental challenges and potential opportunities for sustainable construction materials.

The increasing demand for cement raises concerns due to its high energy consumption and carbon emissions. To mitigate these issues, researchers are exploring eco-friendly alternatives to conventional cementitious materials. MCA, rich in silica and other pozzolanic compounds, has emerged as a promising mineral admixture that can enhance concrete performance while addressing waste management challenges.

This study investigates the potential of MCA as a partial replacement for cement in the development of lightweight aggregate concrete. By incorporating Light Expanded Clay Aggregate (LECA) as a substitute for coarse aggregates and MCA as a supplementary cementitious material, the research aims to assess the effects of these modifications on the mechanical properties, durability, and overall performance of concrete through rigorous experimental analysis.

The findings of this study could contribute to sustainable construction practices by reducing cement consumption, promoting agricultural waste utilization, and enhancing the structural efficiency of lightweight concrete

Keywords:Maize cob Ash, LECA, Mineral Admixture, Light Weight Aggregate.

I. INTRODUCTION

Ordinary Portland Cement (OPC) is the primary binding material in concrete and plays a crucial role in global

infrastructure development. However, its production has a significant environmental impact, contributing approximately 7% of the world's carbon dioxide emissions. The manufacturing process involves the calcination of limestone and the combustion of fossil fuels, releasing 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 energy consumption.

Given the environmental concerns and the depletion of natural resources like limestone, reducing cement consumption is imperative. A practical approach to achieving this is by incorporating supplementary cementitious materials (SCMs) such as fly ash, slag, and agricultural waste-derived ashes. Among these, maize cob ash (MCA) has emerged as a promising alternative due to its abundance and high pozzolanic activity.

India is one of the largest maize-producing countries, generating vast quantities of maize cobs as agricultural waste. When maize cobs are burned for energy production or disposal, they produce maize cob ash (MCA), which, if not utilized properly, can contribute to environmental pollution. However, MCA is rich in silica and alumina, making it an effective pozzolanic material in cementitious applications. The presence of these compounds enables MCA to enhance

the strength, durability, and resistance of concrete when used as a partial replacement for OPC.

Simultaneously, the increasing demand for cement raises concerns regarding high energy consumption, carbon emissions, and raw material depletion. To address these challenges, researchers are actively exploring sustainable alternatives to conventional binding materials. Incorporating MCA as a mineral admixture in cement not only aids in waste management but also improves concrete properties such as compressive strength, workability, and resistance to chemical attacks. Furthermore, the use of MCA can contribute to cost reduction in concrete production by decreasing the reliance on OPC.

Lightweight concrete has gained prominence in civil engineering due to its lower density compared to conventional concrete, offering benefits such as reduced dead load, better thermal insulation, and improved seismic resistance. This study investigates the development of lightweight aggregate concrete by incorporating Light Expanded Clay Aggregate (LECA) as a partial replacement for coarse aggregates. Additionally, it examines the effects of partially replacing cement with MCA. The research evaluates the impact of these modifications on the mechanical properties, durability, and overall performance of concrete through experimental analysis, contributing to the advancement of sustainable construction practices.

By promoting the utilization of MCA in cement and concrete applications, this study aims to support eco-friendly construction methodologies, reduce cement dependency, and provide an efficient solution for agricultural waste

management.

II. MATERIALS AND METHODOLOGY

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 concrete properties. The concrete mix design followed an M25 grade specification. To assess the impact of LECA and MCA, a series of concrete samples were prepared by replacing coarse aggregates with LECA at varying levels of 0%, 25%, 50%, 75%, and 100%. Additionally, cement was partially replaced with MCA at replacement levels of 5%, 10%, 15%, and 20% for each concrete mix.

To conduct a comprehensive analysis, standard concrete specimens in the form of cubes and cylinders were cast and cured. These samples underwent mechanical testing to determine key strength properties, specifically compressive strength and split tensile strength. The tests were conducted at two curing ages—14 days and 28 days—to assess the progressive development of strength over time.

The experimental results were compared against a control mix containing conventional cement and natural coarse aggregates. The mechanical behavior of both the normal concrete and the modified MCA - LECA concrete was analyzed to determine the impact of these replacements. The data collected from the tests were systematically tabulated, and graphical representations were generated to illustrate variations in strength properties. Based on the observed trends, conclusions were drawn regarding the feasibility and effectiveness of using MCA as a supplementary cementitious material and LECA as an alternative lightweight aggregate in concrete production.

III. MIX PROPORTIONS & QUANTITY OF MATERIALS

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	14 Days	28 Days	Total	Volume of each specimen (m ³)	Volume for mix (m ³)	Total for 20 mixes (m ³)
Cubes (150*150*150)	3	3	6	0.003375	0.02025	0.405
Cylinder (150*300)	3	3	6	0.005301	0.031806	0.6312

Total	120	120	240		0.052056	1.04112
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Mix Proportions

Cement (Kg)	Maize Cob 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

IV. STRENGTHS OF CONCRETE WITH DIFFERENT MIXES

Mix Type	Cement %	Maize Cob Ash %	Fine Aggregate %	Coarse Aggregate %	LECA %	W/C	Compressive Strength N/mm ²		Split Tensile Strength N/mm ²	
							14	28	14	28
CC	100	0	100	100	0	0.5	27.86	32.78	4.29	4.87
Mix – A5	95	5	100	100	0	0.5	30.65	35.68	4.55	5.13
Mix – B5	95	5	100	75	25	0.5	27.95	33.57	4.25	4.81
Mix – C5	95	5	100	50	50	0.5	26.43	32.40	4.03	4.63
Mix – D5	95	5	100	25	75	0.5	23.33	29.29	3.66	4.28
Mix – E5	95	5	100	0	100	0.5	22.24	28.60	3.45	4.12
Mix – A10	90	10	100	100	0	0.5	32.46	37.81	4.69	5.29
Mix – B10	90	10	100	75	25	0.5	29.58	35.56	4.38	4.96
Mix –	90	10	100	50	50	0.5	28.03	34.40	4.15	4.77

C10											
Mix – D10	90	10	100	25	75	0.5	25.21	31.70	3.81	4.46	
Mix – E10	90	10	100	0	100	0.5	23.14	29.78	3.52	4.21	
Mix – A15	85	15	100	100	0	0.5	33.77	39.36	4.79	5.40	
Mix – B15	85	15	100	75	25	0.5	31.19	37.52	4.50	5.09	
Mix – C15	85	15	100	50	50	0.5	29.65	36.42	4.28	4.92	
Mix – D15	85	15	100	25	75	0.5	26.58	33.46	3.91	4.58	
Mix – E15	85	15	100	0	100	0.5	23.89	30.76	3.58	4.28	
Mix – A20	80	20	100	100	0	0.5	33.12	38.59	4.74	5.34	
Mix – B20	80	20	100	75	25	0.5	30.38	36.54	4.44	5.03	
Mix – C20	80	20	100	50	50	0.5	28.84	35.41	4.21	4.85	
Mix – D20	80	20	100	25	75	0.5	25.89	32.58	3.86	4.52	
Mix – E20	80	20	100	0	100	0.5	23.51	30.27	3.55	4.24	

V. COMPRESION TEST

To evaluate the compressive strength of the modified concrete mixes, standard cube specimens measuring 150mm × 150mm × 150mm were cast for each mix proportion. These cube specimens were subjected to compressive strength testing using a Compression Testing Machine (CTM) at different curing ages, specifically at 14 days and 28 days. The primary objective of these tests was to determine the load-bearing capacity of the concrete when incorporating maize cob ash (MCA) as a partial cement replacement and Light Expanded Clay Aggregate (LECA) as a partial coarse aggregate replacement.

The study aimed to assess the impact of MCA and LECA on the compressive

strength of concrete by conducting a comparative analysis between the control mix (0% MCA, 0% LECA) and modified concrete mixes containing varying levels of MCA and LECA. The variations in compressive strength with increasing MCA and LECA content were systematically analyzed, and the results were presented in tabular and graphical formats to illustrate the trends in strength development across different mix proportions.

➤ Effect of Maize Cob Ash on Compressive Strength

The experimental results demonstrated that replacing 15% of Ordinary Portland Cement (OPC) with Maize Cob Ash (MCA) led to a significant enhancement in

compressive strength compared to the control mix. This improvement can be attributed to the pozzolanic activity of MCA, which contributes to enhanced bonding and densification of the concrete matrix. The silica and alumina content in MCA react with the calcium hydroxide released during cement hydration, forming additional calcium silicate hydrate (C-S-H) gel, which improves the strength and durability of the concrete.

However, when the MCA replacement level exceeded 15%, a decline in compressive strength was observed. This reduction is likely due to an excessive amount of MCA, which results in an insufficient quantity of cementitious material for proper hydration. As a consequence, the overall structural integrity of the concrete is weakened, leading to lower strength values. The presence of excessive MCA could also increase the porosity of the mix, further impacting its mechanical performance negatively.

➤ **Effect of LECA on Compressive Strength**

The compressive strength tests conducted at 14 days and 28 days revealed that concrete incorporating LECA as a partial coarse aggregate replacement exhibited lower compressive strength compared to conventional concrete. This reduction in strength is primarily attributed to the lower crushing strength of LECA in comparison to natural coarse aggregates. Since LECA is a lightweight material with a porous structure, its inclusion in the mix reduces the overall density and load-bearing capacity of the concrete.

However, despite the reduction in compressive strength, the use of LECA offers significant advantages in terms of reduced concrete density, which can be highly beneficial in structural applications where weight reduction is a critical requirement. The

lighter weight of LECA-modified concrete makes it suitable for high-rise buildings, precast structures, and seismic-resistant constructions, where minimizing the dead load is advantageous.

Through extensive experimental testing, it was determined that replacing 25% of the coarse aggregate with LECA is the optimal proportion. This percentage maintains an acceptable level of compressive strength while simultaneously achieving the benefits of reduced density, improved workability, and enhanced thermal insulation properties.

➤ **Presentation of Experimental Results**

All experimental findings related to the compressive strength of concrete produced with Maize Cob Ash (MCA) and LECA are depicted in Figures 1 to 4. These figures illustrate the variations in compressive strength for different concentrations of MCA as a percentage replacement of OPC. The graphical representations provide a clear understanding of the strength trends, enabling further analysis and comparison of the performance of MCA-LECA-modified concrete.

This research contributes to sustainable construction practices by demonstrating the potential of MCA as a viable supplementary cementitious material and LECA as a lightweight aggregate, offering an environmentally friendly alternative to conventional concrete. The findings highlight the balance between strength, durability, and sustainability, paving the way for innovative applications in modern infrastructure.

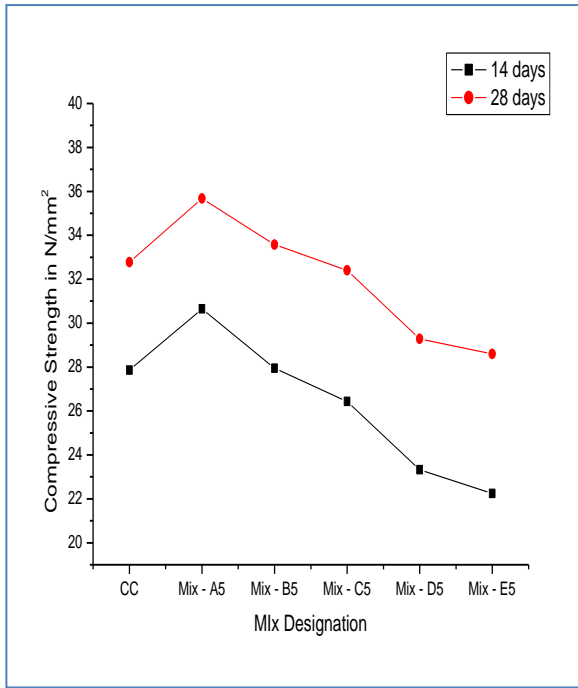


Fig.1:Compressive Strength for concrete with 5% Maize Cob Ash cement replacement

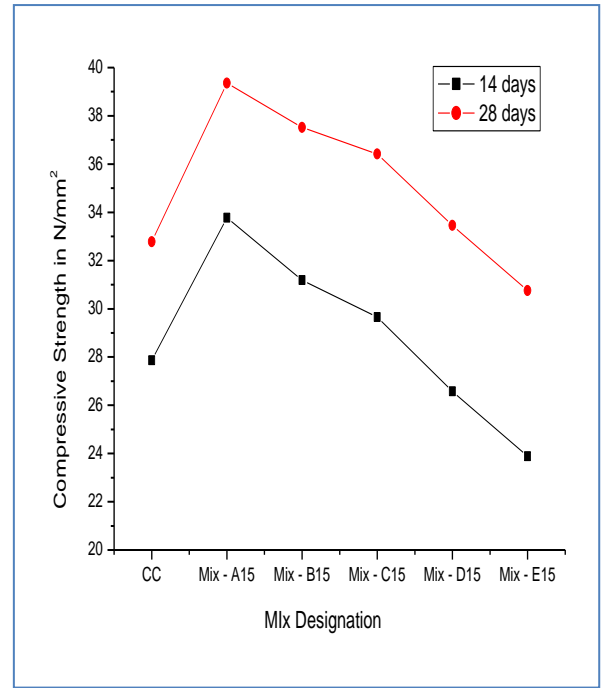


Fig.3:Compressive Strength for concrete with 15% Maize Cob Ash cement replacement

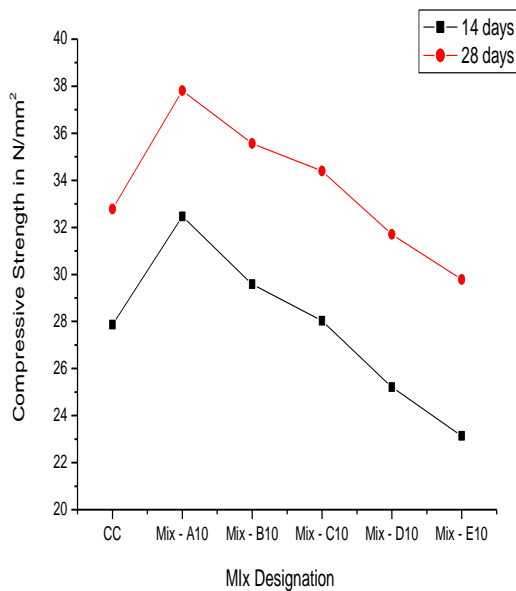


Fig.2:Compressive Strength for concrete with 10% Maize Cob Ash cement replacement

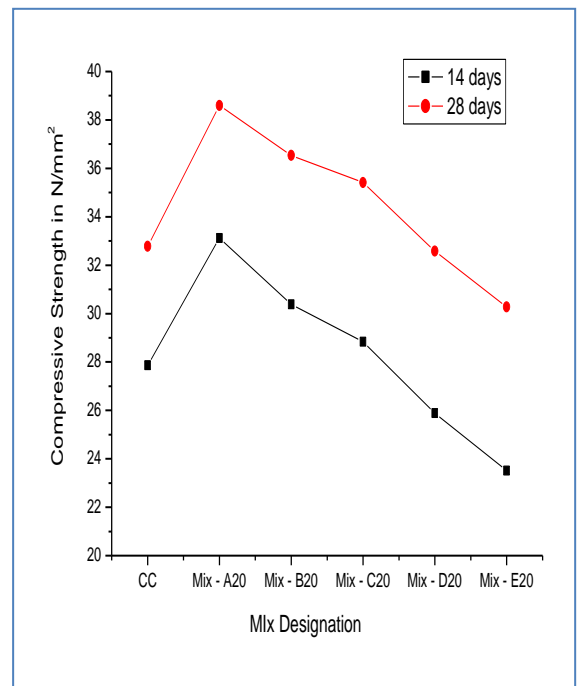


Fig.4:Compressive Strength for concrete with 15% Maize Cob Ash cement replacement

VI. SPLIT TENSILE TEST

The split tensile strength of concrete is a crucial parameter that determines its resistance to indirect tensile stresses, which is essential for preventing cracking and structural failure under tension. To assess the tensile strength characteristics of concrete containing Maize Cob Ash (MCA) as a partial cement replacement and Light Expanded Clay Aggregate (LECA) as a partial coarse aggregate replacement, standard cylindrical specimens were prepared and tested according to established methodologies.

The experimental results showed a similar trend in split tensile strength as observed in the compressive strength tests. The 15% MCA replacement level yielded a higher tensile strength compared to the control mix (0% MCA). This improvement is attributed to:

- Enhanced particle packing, which improves the microstructure of the concrete.
- Secondary hydration reactions, facilitated by the high silica content in MCA, leading to a denser and stronger cementitious matrix.

However, when the MCA replacement exceeded 15%, a decline in split tensile strength was observed. This reduction is primarily due to:

- Insufficient cementitious material for hydration, leading to weaker bonding between particles.
- Higher porosity in the concrete mix, which negatively affects tensile strength.

Despite this reduction beyond 15%, the mathematical equation developed in this study can be used to predict split tensile strength values for MCA replacement levels up to 20%, allowing for optimization of mix

proportions in practical applications.

Effect of LECA on Split Tensile Strength

For LECA-modified concrete, the split tensile strength values at both 14 and 28 days were lower than those of conventional concrete. This decrease is primarily attributed to:

- Weaker interfacial bond between LECA and the cement matrix, due to the porous nature of LECA.
- Lower inherent tensile strength of LECA, which results in reduced overall load-bearing capacity under tensile stress.

However, despite the decrease in split tensile strength, the incorporation of LECA significantly reduced the density of the concrete, making it advantageous for applications where lightweight materials are required. Based on the experimental findings, replacing 25% of the coarse aggregate with LECA was found to be the optimal proportion.

At this level, the concrete maintained acceptable tensile strength while benefiting from reduced density, which is crucial for lightweight structural applications.

➤ Presentation of Experimental Results

All experimental results related to the split tensile strength of concrete produced with Maize Cob Ash (MCA) and LECA are depicted in Figures 5 to 8. These figures illustrate the variations in tensile strength across different MCA replacement percentages, enabling a comprehensive evaluation of their impact on concrete performance.

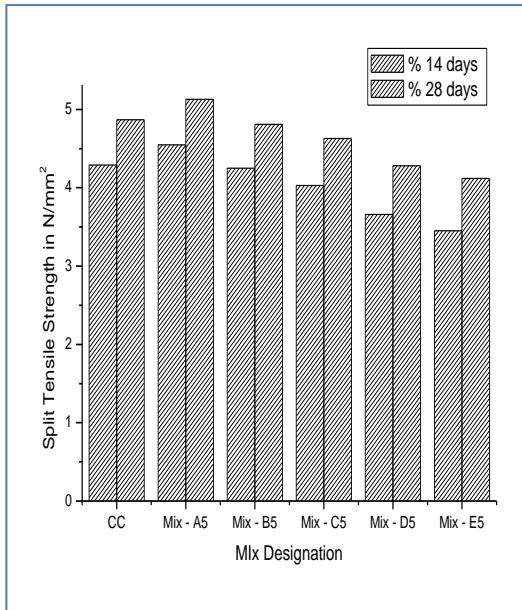


Fig.5:Split Tensile Strength for concrete with 5% Maize Cob Ash cement replacement

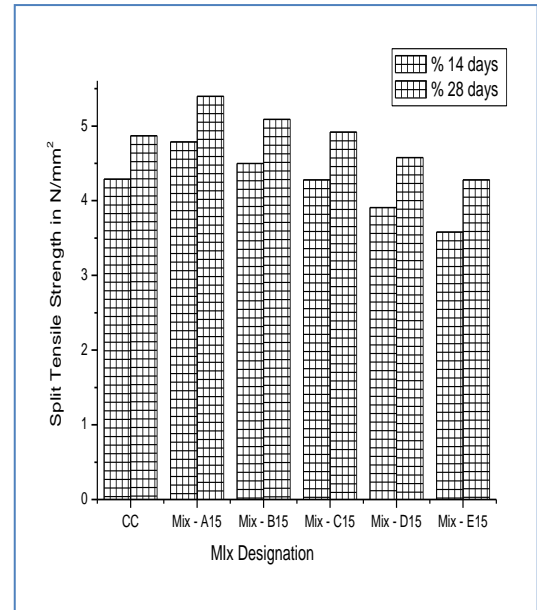


Fig.7:Split Tensile Strength for concrete with 15% Maize Cob Ash cement replacement

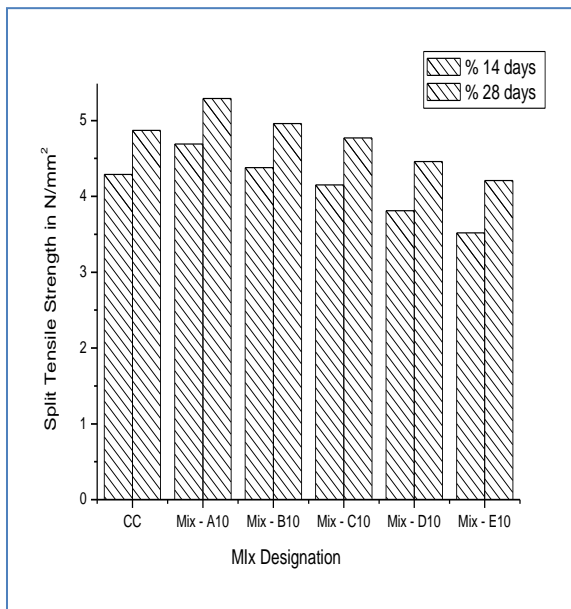


Fig.6:Split Tensile Strength for concrete with 10% Maize Cob Ash cement replacement

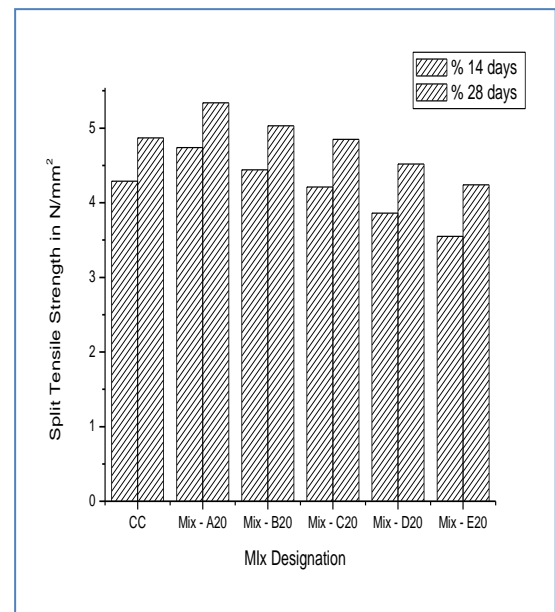


Fig.8:Split Tensile Strength for concrete with 20% Maize Cob Ash cement replacement

VII. CONCLUSION

The experimental analysis revealed a notable improvement in compressive strength

when 15% of Ordinary Portland Cement (OPC) was replaced with Maize Cob Ash (MCA). Compared to the control mix (0% MCA replacement), this substitution resulted in a significant increase in strength, highlighting the pozzolanic activity of MCA. The silica and alumina present in MCA actively react with calcium hydroxide released during cement hydration, forming additional calcium silicate hydrate (C-S-H) gel, which improves the bonding, densification, and overall strength of the concrete matrix.

However, when the MCA replacement level exceeded 15%, a gradual decline in compressive strength was observed. This reduction can be attributed to an excessive amount of MCA, which leads to insufficient cementitious material for hydration, thereby reducing the bonding capability within the concrete mix. Beyond a certain threshold, the increase in non-reactive material and porosity negatively impacts the structural integrity of the concrete, resulting in lower strength values.

➤ Effect of LECA on Concrete Strength

The compressive strength test results at 14 days and 28 days indicate that LECA-incorporated concrete exhibits lower compressive strength compared to conventional concrete. This reduction is primarily due to the lower crushing strength of LECA in comparison to natural coarse aggregates. Since LECA is a lightweight aggregate with a highly porous structure, it has a lower load-bearing capacity, which directly affects the compressive strength of the concrete.

Through extensive experimental analysis, it was determined that replacing 25% of the

coarse aggregate with LECA provides the optimal balance between strength and weight reduction. At this proportion, the concrete maintains an acceptable level of compressive strength while achieving the advantages of lower density, improved workability, and better thermal insulation properties. This makes LECA an effective alternative for applications where lightweight, durable, and energy-efficient materials are required.

REFERENCES

1. **Pourali, M.** (2024). "Laboratory Study of Reinforced Concrete with Rice Husk Ash and Microsilica in Terms of Compressive and Tensile Strength." *Journal of Civil Aspects and Structural Engineering*, Vol. 1, pp. 33–38.
2. **Reddy, S. R., Kumar, S. L., & Desai, V. B.** (2018). "A Brief Study on the Strength Properties of Modified Concrete Using Light Expandable Clay Aggregate (LECA)." *International Journal of Technical Innovation in Modern Engineering & Science*, Vol. 4, pp. 98–108.
3. **Abdulrazzaq, O. A., & Khadhim, A. M.** (2019). "Studying the Behaviour of Lightweight Deep Beams with Openings." *International Journal of Engineering Technologies and Management Research*, Vol. 6, pp. 15–25.
4. **Das, S. K., Mishra, J., Singh, S. K., Mustakim, S. M., & Patel, A.** (2020). "Characterization and Utilization of Rice Husk Ash in Fly Ash–Blast Furnace Slag Based Geopolymer Concrete for Sustainable Future." *Materials Today: Proceedings*, Vol. 28, pp. 1149–1159.
5. **Umasabor, R. I., & Okovido, J. O.** (2020). "Fire Resistance Evaluation of Rice Husk Ash Concrete." *Heliyon*, Vol. 6, e04274.
6. **Al-Gburi, M., & Yusuf, S. A.** (2021). "Investigation of the Effect of Mineral Additives on Concrete Strength Using Artificial Neural Networks." *Asian*

- Journal of Civil Engineering*, Vol. 22, pp. 987–998.
7. **Ritchie, H., Roser, M., & Rosado, P.** (2020). "CO₂ and Greenhouse Gas Emissions." *Our World in Data*, pp. 1–20.
 8. **Russel, H. G.** (2021). "Why Use High Performance Concrete?" *Technical Talk*, Vol. 15, pp. 45–50.
 9. **Gajda, J.** (2019). "Energy Use of Single-Family Houses with Various Exterior Walls." *Concrete Sustainability Report*, Vol. 13, pp. 22–30.
 10. **Olivier, P., & Hyman, T.** (2022). "Biomass Gasification and the Benefits of Biochar." *Engineering, Separation and Recycling LLC*, pp. 5–15.
 11. **BirukHailu and AbebeDinku.,** *Application of Sugarcane Bagasse Ash as a partial cement replacement material*,
 12. **AhmedSalih, E.M.** (2014) 'The Usage of the Sugarcane Bagasse Ash in Sudanese Sugar Company as Pozzolanic – Cement Binder', *IOSR Journal of Engineering*, vol.04.
 13. **Balaji, K V G D. and Santhosh Kumar, T.** (2014) 'Partial replacement of Cement in concrete with sugarcane bagasse ash – behaviour in HCl solution', *International Journal of Advanced Research in Science and Engineering*.
 14. **Kawade, U.R. and Vaishali, D.** (2013) 'Effect of use of bagasse ash on strength of concrete', *International journal of innovative research in science, Engineering and Technology* vol.2, Issue 7.
 15. **Nareshkumar, B.G. and Yashwanth, M.K.** 'An experimental study on bagasse ash as replacement for cement in lightweight concrete', *International journal of latest trends in engineering and technology (IJLTET)*
 16. **Rajiwala, B.** (2015) 'Experimental study on use of sugarcane bagasse ash in concrete by partial replacement with cement', *International Journal of Innovative Research in Science, Engineering and Technology* vol.4.
 17. **H Ceilikozyildirim, 2000, Laboratory Investigation on Mechanical properties of Light Weight Aggregate Concrete, Euro Lightcon, Economic Design And Constructive With Light Weight Aggregate Concrete Document, BE96-3942/R23, June 2000**
 18. **W GMoravia, C.A.S Oliveria, a.GGumieri, W.L Vasconcelos, 2006, Micro Structural Evaluation of Expanded Clay to Be Used the Aggregate in Structural Concrete, Ceramics Vol.52 June 2006**
 19. **Fahrizalzulkarnain, Mahyuddinramli, 2008, Durability of Light Weight Aggregate Concrete for Housing Construction, 2nd International Conference on Built Environment in Developing Countries (ICBEDC 2008)**
 20. **Mouli M, Khelafi H, 2008, Performance Characterizes of Lightweight Aggregate Concrete Containing Natural Pozzolan, Build. Environ. Vol 43, 31-36 [6] Khandaker M. Anwar Hossain, 2008, Blended Cement and Light Weight Concrete Using Scoria: Mix Design, Strength, Durability and Heat Insulation Characteristics, International**