INVESTIGATING THE STRENGTH PROPERTIES OF CONCRETE AFTER INCORPORATING RICE HUSK ASH AND LECA AS REPLACEMENTS TO OPC AND COARSE AGGREGATE

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Abstract

India is one of the largest rice-producing countries, generating vast amounts of rice husks as agricultural waste. When rice husks are burned for energy or disposal, they produce rice husk ash (RHA), a byproduct that poses significant environmental challenges.

Simultaneously, the increasing demand for cement raises concerns due to its high energy consumption and environmental impact. To address these issues, researchers are exploring sustainable alternatives to traditional binding materials. Utilizing industrial byproducts like RHA as mineral admixtures in cement not only aids in waste management but also improves concrete properties.

Lightweight concrete has gained prominence in civil engineering due to its lower density compared to conventional concrete. 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 impact of partially replacing cement with RHA. The research evaluates the effects of these modifications on the strength and performance of concrete through experimental analysis.

Keywords:Bagasse 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 CO_2 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 rice husk ash. Among these, rice husk ash presents a sustainable alternative due to its widespread availability. Utilizing rice husk ash as a partial replacement for OPC not only reduces carbon emissions but also promotes waste management, making concrete production more eco-friendly and cost-effective.

India is one of the largest rice-producing countries, generating vast amounts of rice husks as agricultural waste. When rice husks are burned for energy or disposal, they produce rice husk ash (RHA), a byproduct that poses significant environmental challenges. However, RHA is rich in silica, making it a highly effective pozzolanic material when used in cement and concrete applications. Its fine particle size and high reactivity enhance the strength and durability of concrete, making it a valuable supplementary cementitious material.

Simultaneously, the increasing demand for cement raises concerns due to its high energy consumption, carbon emissions, and depletion of natural resources like limestone. To address these issues, researchers are actively exploring sustainable alternatives to traditional binding materials. Utilizing industrial byproducts like RHA as mineral admixtures in cement not only aids in waste management but also improves concrete properties, such as compressive strength, workability, and resistance to chemical attacks.

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 impact of partially replacing cement with RHA. The research evaluates the effects of these modifications on the strength, durability, and overall performance of concrete through experimental analysis, contributing to the advancement of sustainable construction practices.

II. MATERIALSANDMETHODOLOGY

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 concrete properties. The concrete mix design followed an M25 grade specification. To assess the impact of LECA and RHA, 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 RHA 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 RHA-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 RHA as a supplementary cementitious material and LECA as an alternative lightweight aggregate in concrete production.

III. MIXPROPORTIONS & QUANTITY OF MATERIALS

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	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	0.63612
Total	120	120	240		0.052056	1.04112

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**

IV. STRENGTHS OF CONCRETE WITH DIFFERENT MIXES

Mix Type	Cement %	Rice Husk Ash %	Fine Aggregate %	Coarse Aggregate %	LECA %	W/C	Compressive Strength N/mm2		Split Tensile Strength N/mm2	
							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	28.53	33.56	4.34	4.92
Mix – B5	95	5	100	75	25	0.5	25.61	31.23	4.02	4.58
Mix – C5	95	5	100	50	50	0.5	23.87	29.84	3.77	4.37
Mix – D5	95	5	100	25	75	0.5	21.15	27.11	3.44	4.06

Mix – E5	95	5	100	0	100	0.5	20.12	26.48	3.24	3.91
Mix – A10	90	10	100	100	0	0.5	30.34	35.69	4.48	5.08
Mix – B10	90	10	100	75	25	0.5	27.24	33.22	4.15	4.73
Mix – C10	90	10	100	50	50	0.5	25.47	31.84	3.89	4.51
Mix – D10	90	10	100	25	75	0.5	23.03	29.52	3.59	4.24
Mix – E10	90	10	100	0	100	0.5	21.02	27.66	3.31	4.00
Mix – A15	85	15	100	100	0	0.5	31.65	37.24	4.58	5.19
Mix – B15	85	15	100	75	25	0.5	28.85	35.18	4.27	4.86
Mix – C15	85	15	100	50	50	0.5	27.09	33.86	4.02	4.66
Mix – D15	85	15	100	25	75	0.5	24.40	31.28	3.69	4.36
Mix – E15	85	15	100	0	100	0.5	21.77	28.64	3.37	4.07
Mix – A20	80	20	100	100	0	0.5	31.00	36.47	4.53	5.13
Mix – B20	80	20	100	75	25	0.5	28.04	34.20	4.21	4.80
Mix – C20	80	20	100	50	50	0.5	26.28	32.85	3.95	4.59
Mix – D20	80	20	100	25	75	0.5	23.71	30.40	3.64	4.30
Mix – E20	80	20	100	0	100	0.5	21.39	28.15	3.34	4.03

V. COMPRESION TEST

To determine the compressive strength, standard cube specimens (150mm x 150mm x 150mm) were cast for each mix. These cubes were tested using a Compression Testing Machine (CTM) at curing ages of 14 days and 28 days to measure the load-bearing capacity of the concrete.

The effect of cement replacement with RHA and coarse aggregate replacement with LECA on compressive strength was analyzed. A comparison was made between the control mix and the modified concrete mixes to evaluate how strength changed with increasing RHA and LECA content. The results were presented in tabular and graphical forms to illustrate strength variations across different mixes.

The experimental results indicate that replacing **15% of Ordinary Portland Cement (OPC) with Rice Husk Ash (RHA)** enhances the **compressive strength** of concrete compared to the control mix (0% replacement). This improvement is attributed to the pozzolanic reaction of RHA, which enhances the bonding and densification of the concrete matrix. However, beyond **15% replacement**, a decline in compressive strength was observed. This reduction is likely due to an excess of RHA, which leads to insufficient cementitious material for proper hydration, thereby weakening the overall structure of the concrete.

To predict the compressive strength at various RHA replacement levels, a mathematical equation was developed based on the experimental data. This equation provides a useful tool for estimating compressive strength values for RHA replacements of up to **20%**.
The **14-day and 28-day compressive strength tests** further revealed that **LECA-incorporated concrete exhibited lower compressive strength compared to conventional concrete**. This is primarily because LECA, being a lightweight aggregate, has a lower crushing strength compared to natural coarse aggregates, resulting in a reduction in the overall compressive strength of the mix. However, a significant advantage of using LECA is the reduced density of concrete, which can be beneficial in structural applications where weight reduction is a priority.

From the experimental results, it was found that replacing **25% of the coarse aggregate with LECA** is the optimal choice. This proportion maintains an acceptable level of compressive strength while achieving the benefits of reduced concrete density.

All the experimental results pertaining to Compressive strength of concrete produced with Rice Husk Ash and LECA are depicted in Figure Number 1 to 4 with various concentrations of Rice Husk Ash in percentages to OPC.

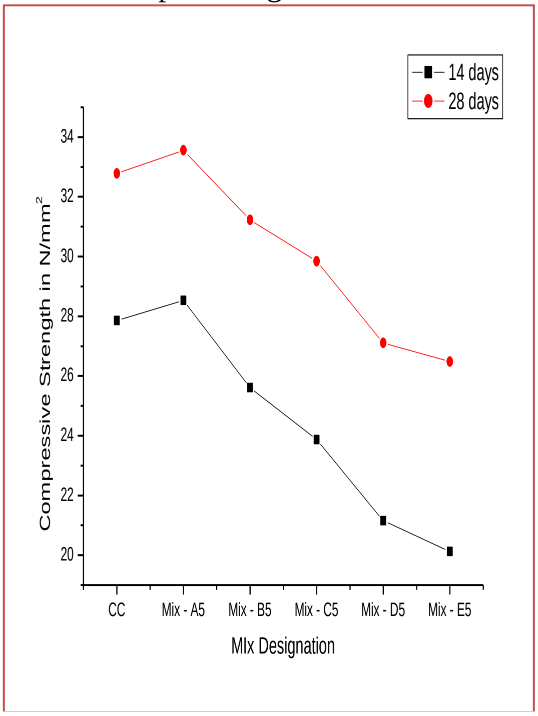

Fig.1:Compressive Strength for concrete with 5% Rice Husk Ash cement replacement

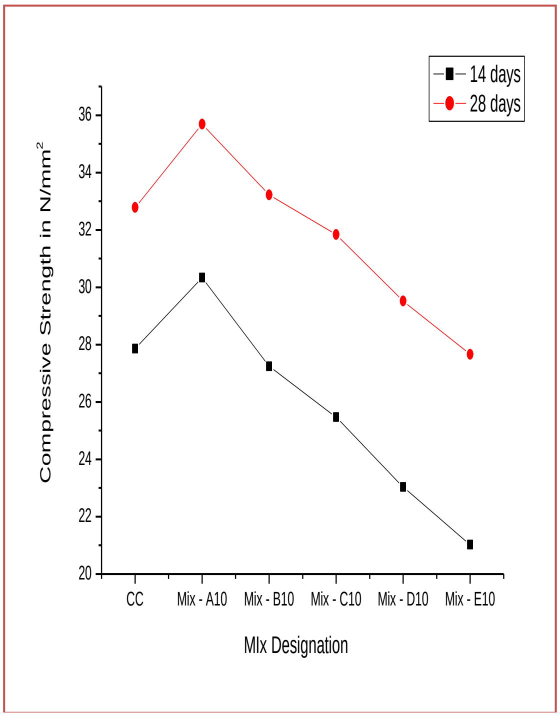

Fig.2:Compressive Strength for concrete with 10% Rice Husk Ash cement replacement

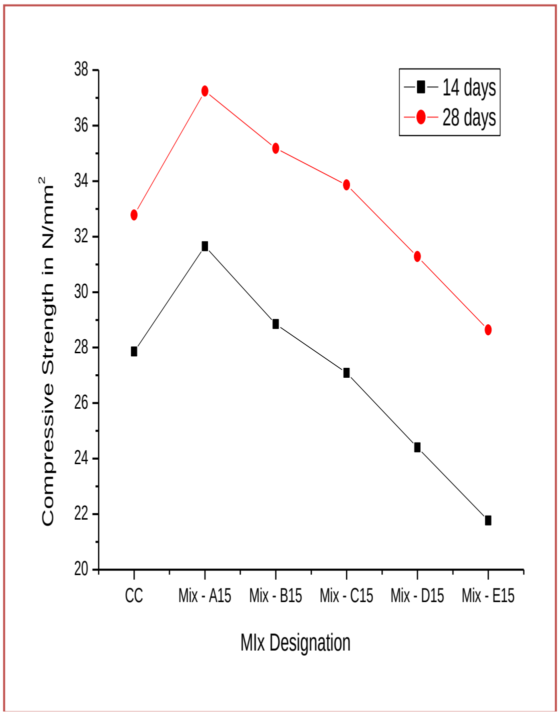

Fig.3:Compressive Strength for concrete with 15% Rice Husk Ash cement replacement

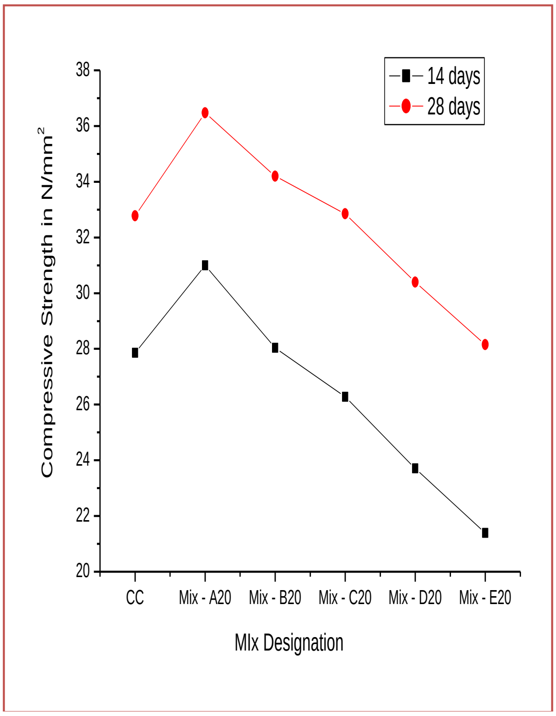

Fig.4:Compressive Strength for concrete with 15% Rice Husk Ash cement replacement

VI. SPLIT TENSILE TEST

Similar trends were observed in the split tensile strength of the RHA-modified concrete. The 15% RHA replacement level yielded better tensile strength compared to the control mix. This improvement is likely due to the enhanced particle packing and secondary hydration reactions facilitated by the finely divided silica in RHA. However, beyond 15% replacement, the tensile strength decreased, similar to the trend seen in compressive strength.

For LECA-modified concrete, the split tensile strength values at 14 and 28 days were lower than those of conventional concrete. This reduction is attributed to the weaker interfacial bond between LECA and the cement matrix, as well as the lower tensile strength of LECA itself. Despite this, using 25% LECA as a replacement for coarse aggregate was found to be the most effective balance between strength and weight reduction.

All the experimental results pertaining to Split tensile strength of concrete produced with Rice Husk Ash and LECA are depicted in Figure Number 5 to84 with various concentrations of Rice Husk Ash in percentages to OPC

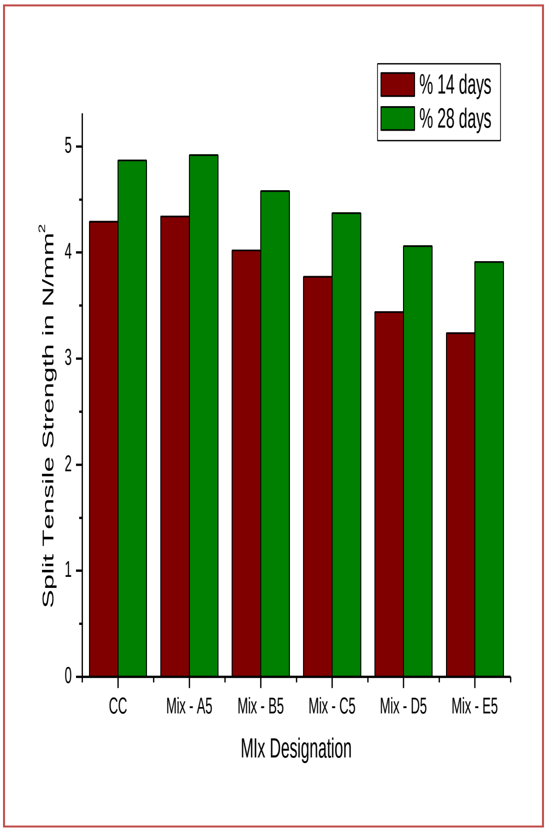

Fig.5:Split Tensile Strength for concrete with 5% Rice Husk Ash cement replacement

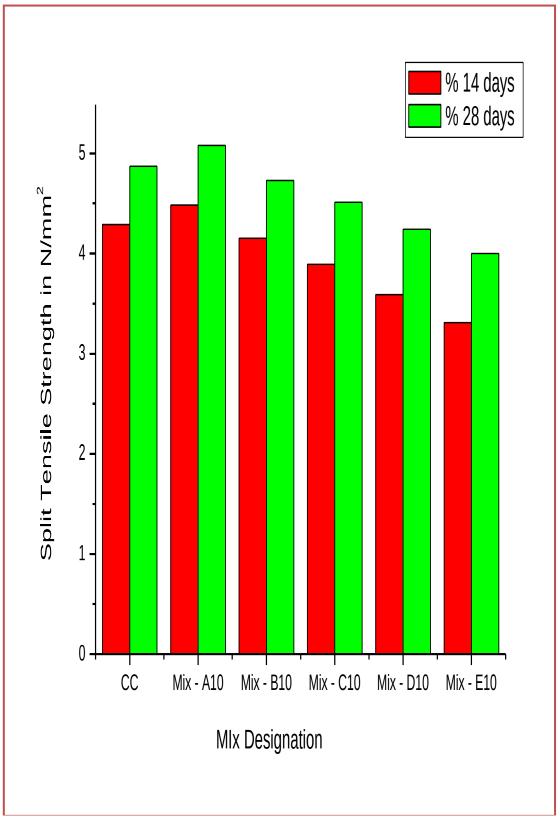

Fig.6:Split Tensile Strength for concrete with 10% Rice Husk Ash cement replacement

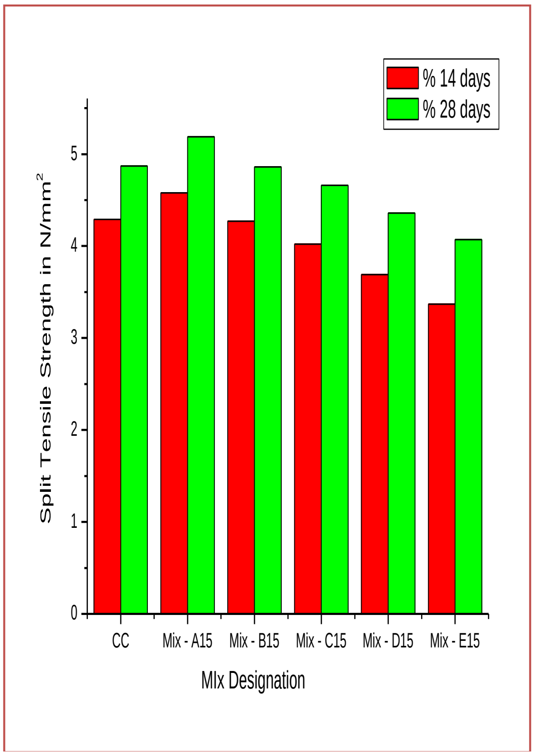

Fig.7:Split Tensile Strength for concrete with 15% Rice Husk Ash cement replacement

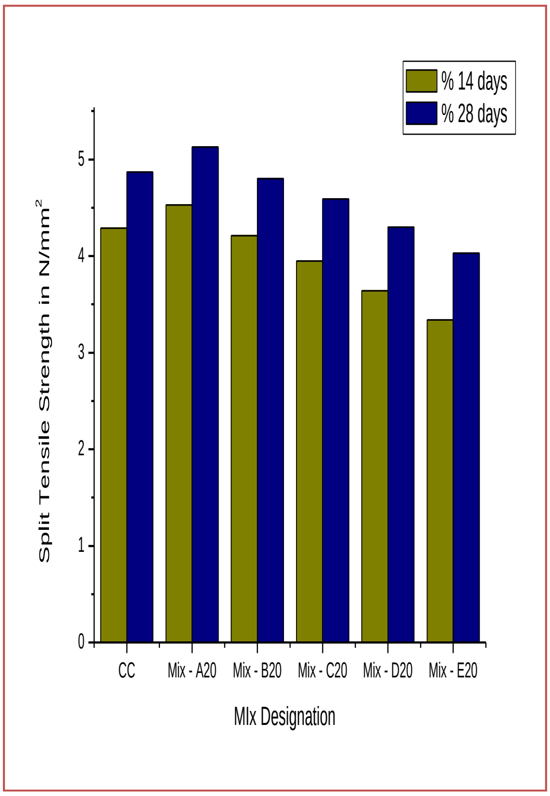

Fig.8:Split Tensile Strength for concrete with 20% Rice Husk Ash cement replacement

VII. CONCLUSION

It has been observed that the experimental result for the 15% replacement of Rice Husk Ash to OPC has increase in strength in comparison with 0% replacement. Beyond 15% replacement of Rice Husk Ash, the Strength was decreased. So we can use the developed equation of this present study for the calculation of values compressive strength and split tensile strength for Rice Husk Ash replacement with cement up to 20% replacement.The 14 and 28 days compressive strength test result gives the low compressive strength of the LECA added concrete as compare to the conventional concrete. But the density of the LECA added concrete is less than the conventional concrete. So replacing of coarse aggregate with 25% of LECA is preferable, as it gives the effective results.

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