An Experimental Investigation On Strength Properties Of Concrete Using Light Expanded Clay Aggregate

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ABSTRACT:

Concrete plays a vital role in the development of infrastructure worldwide; however, the extensive use of cement in conventional concrete significantly contributes to environmental pollution and high energy consumption. With the growing emphasis on sustainable and eco-friendly construction materials, reducing cement content in concrete has become an important area of research. The present study evaluates the performance of concrete incorporating Light Expanded Clay Aggregate (LECA) as a partial replacement material, owing to its lightweight nature, porous structure, favorable strength-to-weight ratio, and internal curing capability. Concrete mixes were proportioned with 0%, 10%, 20%, and 30% replacement levels of cement by weight using LECA, while ensuring adequate workability and uniformity. Experimental investigations were carried out on standard specimens to assess compressive strength, split tensile strength, and flexural strength at curing periods of 7 and 28 days in accordance with Indian Standard specifications. The experimental results indicate that concrete with LECA replacement up to 20% exhibits satisfactory mechanical performance comparable to conventional concrete, along with a significant reduction in unit weight. Higher replacement levels, particularly 30%, resulted in a noticeable decline in strength; however, the values remain acceptable for selected structural and non-structural applications. The study concludes that LECA can be effectively utilized as a sustainable alternative material in concrete, contributing to reduced environmental impact while maintaining acceptable structural performance.

Keywords: Light Expanded Clay Aggregate, Lightweight Concrete, Cement Replacement, Compressive Strength, Split Tensile Strength, Flexural Strength, Sustainable Construction

1.INTRODUCTION:

Concrete is a fundamental construction material extensively used across the world due to its adaptability, long-term durability, and suitability for various structural applications. As a composite material consisting of cement, fine aggregates, coarse aggregates, and water, concrete derives its strength and durability primarily from cement, which acts as the binding component. Rapid urbanization and continuous growth in infrastructure projects such as buildings, transportation networks, bridges, and hydraulic structures have led to a significant increase in the consumption of cement and concrete globally.

However, the large-scale production of cement poses serious environmental concerns. Cement manufacturing is an energy-intensive process and is one of the major sources of carbon dioxide emissions, contributing substantially to global warming and environmental degradation. In response to these challenges, the construction industry is increasingly shifting towards sustainable development practices. Researchers and engineers are exploring alternative materials that can partially replace conventional concrete constituents, aiming to reduce environmental impact while maintaining acceptable mechanical and durability properties.

In recent years, lightweight concrete has emerged as an effective solution for reducing the self-weight of structures without compromising performance. The incorporation of lightweight aggregates helps decrease dead load, enhances thermal insulation, and improves the overall efficiency of structures, particularly in multi-storey buildings and long-span structures.

Light Expanded Clay Aggregate (LECA) is one such lightweight aggregate that has gained considerable attention in sustainable concrete research. LECA is produced by firing selected natural clay in a rotary kiln at high temperatures, typically between 1100°C and 1200°C. During this process, the clay expands due to the formation of gases, creating a porous internal structure surrounded by a hard outer shell. This distinctive microstructure results in low-density aggregate with adequate strength characteristics, making LECA a promising material for lightweight and eco-friendly concrete applications.

2. LITERATURE REVIEW

1. **Issa and Al Asadi (2022)** carried out an experimental investigation on the mechanical behavior of concrete incorporating Light Expanded Clay Aggregate (LECA). Their study reported that LECA concrete with a dry density of approximately 1823 kg/m³ and compressive strength around 32 MPa satisfies the requirements of structural lightweight concrete. The incorporation of silica fume was found to enhance strength properties, while variations observed in the modulus of elasticity emphasized the significant role of aggregate type in influencing concrete performance.

2. **Uysal et al. (2024)** examined the physical and mechanical properties of LECA concrete by considering different mix proportions and moisture conditions. The experimental results showed that the compressive strength measured in dry conditions was nearly 9% higher than that in moist conditions. Additionally, a considerable reduction in the modulus of elasticity was observed in oven-dried specimens, which was attributed to the porous internal structure of LECA.

3. Murugan and Palaniappan (2025) studied the influence of pre-soaked LECA when used as a partial and complete replacement for natural coarse aggregate. Their findings indicated a gradual decrease in compressive, split tensile, and flexural strengths with increasing LECA content. However, the pre-soaking of LECA was observed to enhance workability and slump characteristics due to improved internal curing.

4. **Further investigations by Uysal et al. (2024)** highlighted limitations in conventional empirical models used for predicting the modulus of elasticity of LECA concrete. The authors proposed modified prediction equations that better account for the effects of moisture condition and aggregate properties on elastic behavior.

5. **Murugan and Palaniappan (2025)** also evaluated durability-related parameters such as resistance to sulfate and acid attack. Their study concluded that although the use of LECA contributes to sustainability by reducing concrete density, achieving satisfactory durability performance requires careful mix proportioning and appropriate material selection.

6. **Demir and Yilmaz (2024)** similarly reported inconsistencies in traditional modulus of elasticity prediction models for LECA concrete. They suggested revised estimation approaches that more accurately represent the influence of aggregate characteristics and moisture conditions on the elastic properties of lightweight concrete.

3. MATERIAL USED

3.1 Cement

Cement is a manufactured material possessing both adhesive and cohesive properties, enabling it to effectively bind other materials. It primarily consists of finely ground limestone, silica, alumina, and iron ore, which undergo high-temperature processing in a rotary kiln at approximately 1600°C to form **clinker**. The clinker is subsequently cooled and ground into a fine powder to produce the final cement product. When mixed with water, cement undergoes hydration, forming a rigid and durable matrix that imparts strength and stability to concrete. Cement plays a crucial role in determining the mechanical and durability characteristics of concrete.

3.3 Coarse Aggregate

Coarse aggregates are particles retained on a 4.75 mm sieve, providing bulk, strength, and durability to concrete. Their properties, including size, shape, texture, and gradation, significantly affect the bonding with cement paste and overall mechanical performance. Angular coarse aggregates are preferred for superior interlocking and load distribution. Coarse aggregates must be clean and free from dust, clay, or organic impurities to ensure optimum concrete performance.

3.4 Fine Aggregate

Fine aggregates are particles passing through a 4.75 mm sieve and retained on a 75 µm sieve. Common examples include natural river sand or manufactured sand. Fine aggregates fill voids between coarse aggregates, improving workability, cohesion, and surface finish of concrete. Critical properties include fineness modulus, specific gravity, cleanliness, and gradation, which directly influence water demand, packing density, and final strength of concrete.

3.5 Water

Water is essential for cement hydration and mix workability. Its quality and quantity directly affect strength, setting time, and durability. Water should be clean and free of impurities such as chlorides, sulfates, acids, alkalis, oils, or organic matter. The water–cement ratio (w/c) is a critical parameter, influencing compaction, porosity, cracking potential, and overall performance of hardened concrete.

3.6 Light Expanded Clay Aggregate (LECA)

Light Expanded Clay Aggregate (LECA), also referred to as IECA, is a lightweight, porous aggregate produced by heating selected natural clay in a rotary kiln at 1100–1200°C. During heating, organic compounds burn off, and gases released expand the clay, forming a porous core with a hard outer shell. This results in lightweight aggregates with high strength-to-weight ratio and excellent bonding properties.

3.7 LECA has the following notable characteristics:

- **Shape & Texture:** Round to oval particles with rough surfaces enhancing cement matrix bonding.
- **Porosity:** Absorbs and gradually releases water, supporting internal curing and reducing shrinkage.
- **Mechanical Properties:** Low density, moderate compressive strength, thermal insulation, fire resistance, and chemical stability.
- **Sustainability:** Derived from natural clay, reduces self-weight, dead load, cement consumption, and environmental impact.

In this study, LECA is employed as a partial replacement of coarse aggregate at 0%, 10%, 20%, and 30% by weight of cement to evaluate its effect on mechanical properties such as compressive, split tensile, and flexural strength.

Figure 3.4: Light Expanded Clay Aggregate

Table-6: Chemical Properties of LECA

Sr. No.	Chemical Component	Values (%)
1.	Silicon Dioxide (SiO_2)	60 – 70
2.	Aluminum Oxide (Al_2O_3)	15 – 20
3.	Ferric Oxide (Fe_2O_3)	5 – 8
4.	Calcium Oxide (CaO)	2 – 5
5.	Magnesium Oxide (MgO)	1 – 3
6.	Sodium Oxide (Na_2O)	1 – 2
7.	Potassium Oxide (K_2O)	1 – 2
8.	Loss on Ignition	< 5
9.	pH Value	6.5 – 7.5
10.	Chemical Nature	Inert and non-toxic

4. MIX DESIGN AND PROPORTION:

Concrete mix design was carried out for M30 grade concrete in accordance with IS 10262:2019 guidelines by trial mix method for 1 m^3 of concrete. In this study, Light Expandable Clay Aggregate (LECA) was used as a partial replacement of conventional coarse aggregate by weight in the proportions of 0% (Control mix), 10%, 20% and 30%.

Table-9: Mix Proportion (Kg/m3) and Mix Ratio for M30

Water (Kg/m^3)	**Cemen(Kg/m^3)**	**Fine Aggregate / Sand (Kg/m^3)**	**Coarse Aggregate (Kg/m^3)**
197.16	469.43	628.23	1146.83
0.42	1	1.33	2.44

5.Compressive strength Results and Discussion :

Compressive strength is one of the most important mechanical properties of concrete and represents its ability to resist axial compressive forces that tend to reduce its size. In the present experimental investigation, the compressive strength of concrete was determined in accordance with IS 516:1959 – Method of Tests for Strength of Concrete.

For this test, standard cube specimens of size 150 mm × 150 mm × 150 mm were cast using steel moulds. Fresh concrete was placed into the moulds in three layers, and each layer was compacted properly to ensure uniform density and to eliminate air voids. After 24 hours of casting, the specimens were demoulded and subjected to water curing. The compressive strength test was conducted after 7 days and 28 days of curing to evaluate the early-age and later-age strength development of concrete.

The test was performed using a Universal Testing Machine (UTM). Each cube specimen was placed centrally between the compression platens of the testing machine, and a gradually increasing load was applied uniformly on the specimen until failure occurred. The maximum load carried by the specimen at the time of failure was recorded as the ultimate load. For each mix proportion, a minimum of three cube specimens were tested, and the average value was considered as the representative compressive strength to ensure accuracy and reliability of the results.

The compressive strength of concrete was calculated using the following expression:

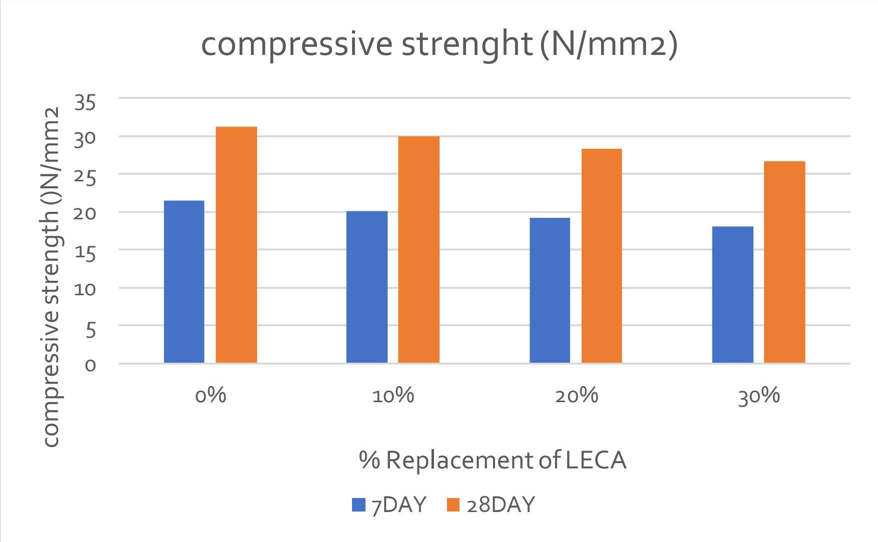
Compressive strength (N/mm^2) = P/A Where, P – Ultimate load (N)

A – Cross-sectional area of specimen (mm^2

Table-21: Compressive Strength Test Results for 7 and 28 Days in N/mm^2

Sr. No.	**Percentage Replacement of** LECA	**Compressive Strength (N/mm^2)**	
		7 Days	**28 Days**
1.	Conventional Concrete (0% LECA)	21.50	31.28
2.	LECA Concrete (10%)	20.10	29.95
3.	LECA Concrete (20%)	19.20	28.30
4.	LECA Concrete (30%)	18.10	26.70

The compressive strength results obtained at 7 days and 28 days are presented in Table-19, Table-20, and Table-21, respectively. The results indicate a significant increase in compressive strength with an increase in curing period, which can be attributed to the continuous hydration process of cement. These results are essential for assessing the structural performance and suitability of concrete for construction applications.



Bar Chart-1 compressive strength of LECA concrete at 7 days and 28 days

6. Flexural Results and Discussion :

Flexural strength of concrete represents its ability to resist bending stresses and is an important parameter for evaluating the tensile behavior of concrete in structural elements such as beams and slabs. In the present study, the flexural strength test was carried out in accordance with IS 516:1959 – Method of Tests for Strength of Concrete.

Concrete beam specimens of size 150 mm × 150 mm × 700 mm were cast with varying levels of fine aggregate replacement ranging from 0% to 30%. After casting, the specimens were kept under saturated conditions for 24 hours, following which they were demoulded and subjected to water curing. Flexural strength tests were conducted at the curing ages of 7 days and 28 days. Prior to testing, the specimens were air-dried to remove surface moisture.

The maximum load carried by the beam at failure was recorded as the ultimate load.

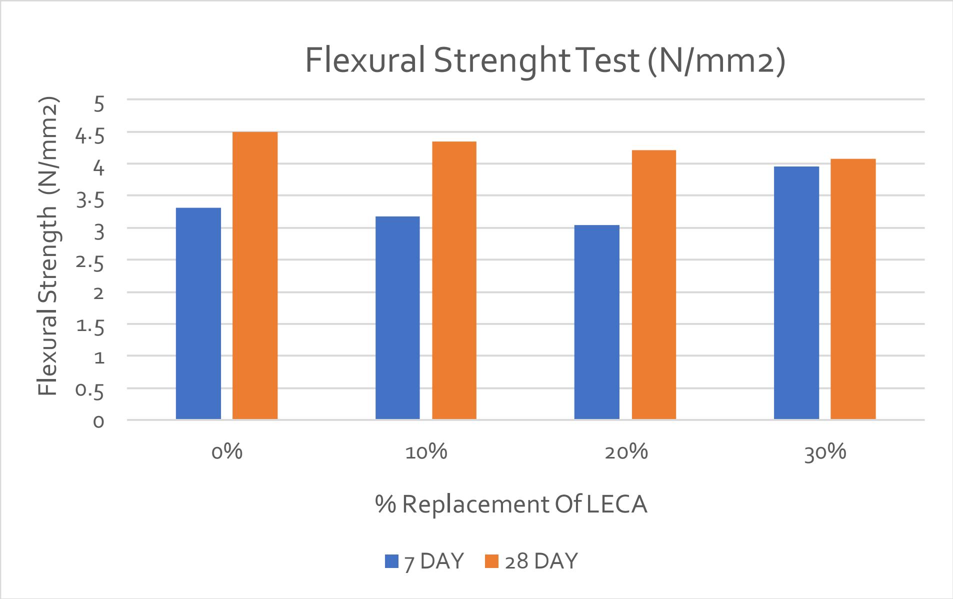
The flexural strength was calculated using the formula:

$$\textbf{Flexural Strength (N/mm}^2\textbf{)} = PL/bd2$$

where,
P = Ultimate load applied on the beam (N)
L = Effective span of the beam (mm)
b = Average width of the beam specimen (mm)
d = Average depth of the beam specimen (mm)

Table-27: Flexural Strength Test Results at 7 and 28 Days in N/mm^2

Sr. No.	Percentage Replacement of LECA	Flexural Strength (N/mm^2)	
		7 Days	28 Days
1.	0 %	3.31	4.49
2.	10 %	3.18	4.34
3.	20 %	3.05	4.21
4.	30 %	3.95	4.07



Bar Chart-3: Flexural Strength of Concrete at 7 and 28 Days

The flexural strength results obtained at 7 days and 28 days are presented in Table-8. The results indicate that flexural strength increases with curing age due to improved bond strength and continued hydration of cement. The study highlights the influence of fine aggregate replacement on the flexural performance of concrete, which is crucial for structural applications where bending stresses are predominant.

7. CONCLUSION

1. Compressive strength of concrete decreases gradually with an increase in the percentage replacement of conventional aggregate by LECA at both 7 and 28 days of curing.

2. Conventional concrete (0% LECA) exhibited the highest compressive strength, while concrete with 30% LECA showed comparatively lower strength due to the lightweight and porous nature of LECA.

3. Concrete mixes containing up to 20% LECA replacement achieved compressive strength values within acceptable limits for structural lightweight concrete applications.

4. Tensile strength results showed a similar decreasing trend with an increase in LECA content, indicating reduced resistance to cracking under tensile stresses.

5. The reduction in tensile strength is mainly attributed to weaker interfacial bonding between LECA particles and the cement matrix.
6. Flexural strength values showed only marginal variation with the incorporation of LECA, indicating that bending performance of concrete is not significantly affected.

7. LECA concrete demonstrated adequate flexural strength even at higher replacement levels, making it suitable for elements subjected to bending stresses.

8. Overall, partial replacement of conventional aggregate with LECA up to **20%** can be effectively adopted to produce lightweight and sustainable concrete without significantly compromising mechanical properties.

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