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A Brief Study On The Strength Properties Of Modified Concrete Using Light Expandable Clay Aggregate

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ABSTRACT:
Concrete remains the backbone of modern infrastructure, but conventional cement production is a notable contributor to global carbon emissions and energy consumption. As sustainable construction practices gain prominence, there is a pressing need to explore eco-friendly alternatives that reduce cement dependency without compromising structural performance. This research investigates the feasibility of substituting a portion of cement with Light Expanded Clay Aggregate (LECA), a thermally treated, lightweight, porous material known for its low density, good strength-to-weight ratio, and internal curing benefits due to its high water absorption capacity. Concrete mixes were prepared with 0%, 10%, 20%, and 30% cement replacement by weight with LECA, maintaining workability and mix consistency. Standard specimens were cast and subjected to compressive, split tensile, and flexural strength tests at 7 and 28 days, following relevant Indian Standard testing procedures. Results demonstrate that partial cement replacement up to 20% yields mechanical properties comparable to conventional concrete, with acceptable reductions in strength and a notable decrease in concrete density. Although 30% replacement exhibited a more marked reduction in mechanical performance, all mixes met criteria suitable for specific structural and non-structural applications. The findings suggest that LECA can serve as a viable sustainable material for partially replacing cement in concrete, optimizing both environmental impact and mechanical efficiency.

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

1.INTRODUCTION:

Concrete is one of the most extensively utilized construction materials in the modern construction industry due to its versatility, durability, and ability to be cast into a wide range of structural forms. It is a composite material made up of cement, fine aggregates, coarse aggregates, and water, where cement functions as the binding agent that significantly influences the strength and durability characteristics of concrete. The continuous expansion of infrastructure development, including residential and commercial buildings, bridges, highways, and dams, has resulted in a substantial rise in the demand for cement and concrete worldwide.

Despite its advantages, cement production is associated with serious environmental challenges. The manufacturing process of cement requires a high amount of energy and contributes significantly to carbon dioxide emissions, which are major contributors to global warming and environmental pollution. In view of these concerns, there is a growing need to develop sustainable and eco-friendly construction materials. Researchers are increasingly focusing on alternative materials that can partially replace conventional constituents of concrete, thereby reducing environmental impact while ensuring adequate strength and structural performance.

Lightweight concrete has gained attention as a viable solution to reduce the self-weight of structures and enhance sustainability. The use of lightweight aggregates not only minimizes dead load but also improves thermal efficiency and overall performance of concrete structures.

Light Expanded Clay Aggregate (LECA), also known as Expanded Clay Aggregate, is a type of lightweight aggregate manufactured by heating selected natural clay in a rotary kiln at temperatures ranging from 1100°C to 1200°C. During this high-temperature process, gases released within the clay cause it to expand, resulting in a porous internal structure enclosed by a hard and dense outer shell. This unique structure provides LECA with low density along with satisfactory mechanical strength.

2. LITERATURE REVIEW

1. **Issa and Al Asadi (2022)** investigated the mechanical properties of Lightweight Expanded Clay Aggregate (LECA) concrete and reported that concrete with a dry density of about 1823 kg/m³ and compressive strength near 32 MPa is suitable for structural lightweight applications. The inclusion of silica fume improved strength characteristics, while variations in modulus of elasticity highlighted the influence of aggregate type on concrete behavior.

2. **Uysal et al. (2024)** studied the physical and mechanical properties of LECA concrete considering different mix proportions and moisture conditions. The results indicated that dry compressive strength was approximately 9 % higher than moist state strength, whereas the modulus of elasticity significantly reduced in oven-dried specimens due to LECA's porous structure.

3. **Demir and Yilmaz (2024)** highlighted discrepancies in conventional modulus of elasticity prediction models for LECA concrete and proposed modified estimation approaches that better represent the effects of moisture condition and aggregate characteristics.

4. **Uysal et al. (2024)** further highlighted discrepancies in conventional modulus of elasticity prediction models for LECA concrete and proposed modified estimation approaches that better represent the influence of moisture condition and aggregate characteristics.

5. **Murugan and Palaniappan (2025)** examined the effect of pre-soaked LECA as a partial and full replacement of natural coarse aggregate. The study revealed a reduction in compressive, split tensile, and flexural strengths with increased LECA content, although pre-soaking improved workability and slump characteristics.

6. **Murugan and Palaniappan (2025)** also analyzed durability aspects such as resistance to sulfate and acid attack and concluded that although LECA improves sustainability by reducing density, durability performance requires careful mix design and material selection.

7. **Durability-focused** studies reported that LECA concrete exhibits higher sorptivity and chloride penetration due to its porous nature. Microstructural investigations using SEM and EDX confirmed that the internal pore structure of LECA significantly affects long-term durability under aggressive environmental conditions.

3. MATERIALS

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 m³ 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 Test :

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:

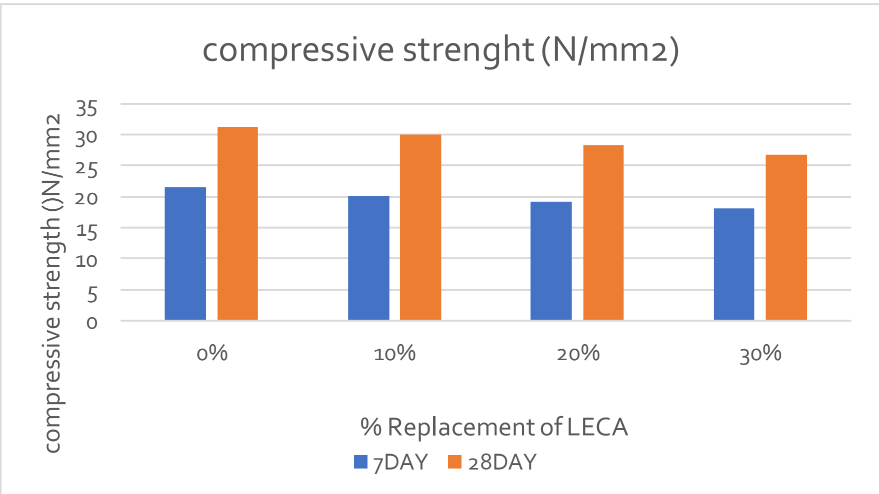
Compressive strength (N/mm^2) = P/A Where, P – Ultimate load (N)

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. Tensile Strength Test :

Tensile strength of concrete is an important mechanical property that represents its resistance to cracking under tensile stresses. Since concrete is weak in direct tension, the tensile strength test is commonly carried out using the split tensile strength method to evaluate its behavior under indirect tensile loading. In the present study, the tensile strength test was conducted in accordance with IS 5816:1999 – Splitting Tensile Strength of Concrete.

For this test, standard cylindrical concrete specimens were cast and properly cured in water. The specimens were tested after 7 days and 28 days of curing to study the development of tensile strength at different ages. During testing, the specimen was placed horizontally between the compression platens of a Universal Testing Machine (UTM). A gradually increasing compressive load was applied along the vertical diameter of the cylinder until failure occurred due to tensile cracking along the length of the specimen.

The maximum load at failure was recorded as the ultimate load. For each mix proportion, at least three specimens were tested and the average tensile strength value was considered for analysis to ensure consistency and reliability of the results.

The tensile strength is calculated using the formula,

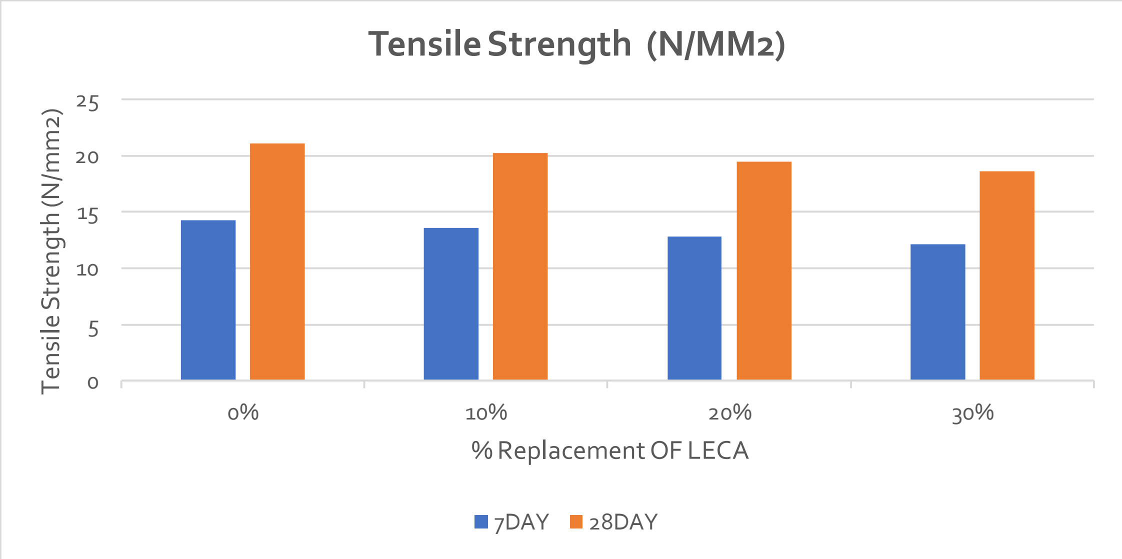
Tensile strength (N/mm^2) = 0.642P/A Where, P – Ultimate load (N)

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

Table-24: Tensile Strength Test Results for 7 and 28 Days in N/mm^2

Sr. No.	Percentage Replacement of LECA	Tensile Strength (N/mm^2)	
		7 Days	28 Days
1.	0%	14.23	21.06
2.	10 %	13.55	20.25
3.	20 %	12.85	19.45
4.	30 %	12.15	18.60

The tensile strength test results obtained at 7 days and 28 days are presented in Table-22, Table-23, and Table-24. The results indicate an increase in tensile strength with curing age, which can be attributed to improved bonding between cement paste and aggregates due to continuous hydration. These findings are useful for assessing the cracking resistance and overall structural performance of concrete.



Bar Chart-2: Tensile Strength of Concrete at 7 and 28 Days

7. Flexural Strength Test :

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:

Flexural Strength (N/mm^2) = PL/bd2

where,

P = Ultimate load applied on the beam (N)

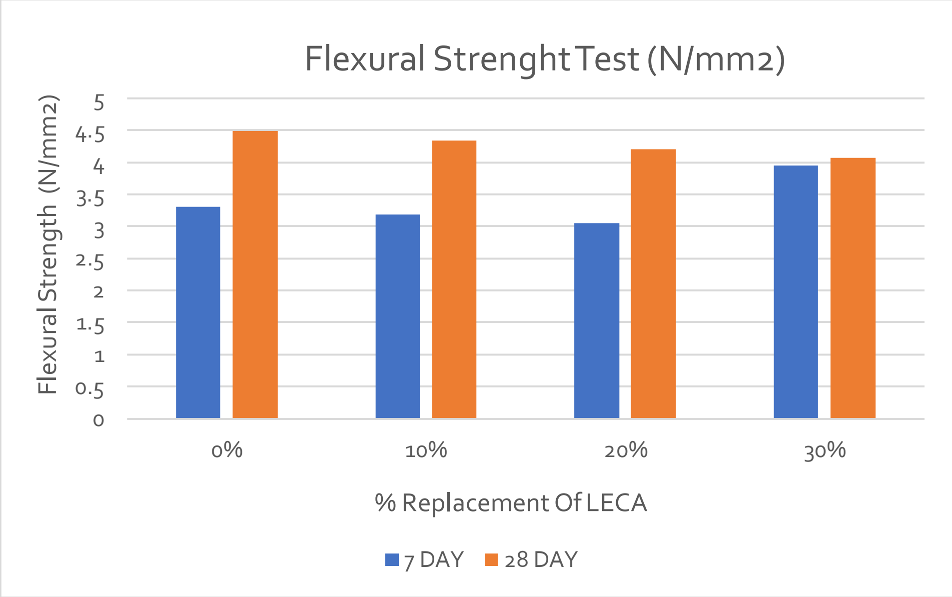
L = Effective span of the beam (mm)

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.

8. 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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10. 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.

9.Reference

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