IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Development Of Lightweight Concrete By Using LECA Balls

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Abstract: Lightweight concrete is a modern construction material designed to reduce structural weight while maintaining strength and durability. This project focuses on developing and evaluating lightweight concrete using alternative materials such as pumice stone, expanded clay, and fly ash as partial or complete replacements for traditional aggregates. Various mix proportions were tested for workability, compressive strength, density, and durability following IS standards. Results showed that lightweight concrete has a significantly lower density than conventional concrete while retaining sufficient strength for structural applications. The mix containing pumice stone and fly ash provided the best balance between weight reduction and strength. Additionally, using fly ash supports sustainability by reducing cement use and industrial waste. Overall, the study concludes that lightweight concrete is a strong, eco-friendly, and economical option suitable for structural and non-structural applications, including high-rise buildings, precast components, and bridge decks.

Index Terms: Lightweight concrete, pumice stone, expanded clay, fly ash, compressive strength, density reduction.

I. INTRODUCTION

1.1 Background

Concrete is the most commonly used material in construction due to its strength and durability. However, its high self-weight increases the dead load on structures, leading to higher costs and larger structural members.

1.2 Need for Lightweight Concrete

Lightweight concrete provides an efficient alternative by reducing density while maintaining sufficient strength. It improves handling, reduces material usage, and enhances thermal and sound insulation.

1.3 Role of LECA

Lightweight Expanded Clay Aggregate (LECA) is a thermally treated material with a porous structure that makes concrete lighter and more energy-efficient. It offers better insulation and fire resistance compared to traditional aggregates.

1.4 Objectives of the Study

This study aims to develop lightweight concrete using LECA as a partial replacement for natural coarse aggregates. The work evaluates compressive strength, density, and workability to determine the optimal mix for structural applications.

II. LITERATURE REVIEW

2.1Overview

Research on Lightweight Expanded Clay Aggregate (LECA) highlights its effectiveness in producing lightweight concrete with reduced density and adequate strength. Replacing coarse aggregates with LECA improves workability, thermal insulation, and fire resistance, though higher replacement levels may slightly lower compressive strength. Its porous structure enhances internal curing, while durability issues such as water absorption or freeze-thaw damage can be mitigated using admixtures like fly ash or silica fume. Overall, LECA is recognized as a sustainable material that promotes energy efficiency and reduced structural weight.

2.2 Key Studies:

- **ISSA Al-Asadi (2022):** Replaced natural coarse aggregates fully with LECA, achieving 32 MPa strength and 1823 kg/m³ density. The addition of silica fume improved tensile and overall mechanical performance.
- **R. Kumar & P. Gupta (2020):** Found up to 50% LECA replacement maintained similar strength to normal concrete with reduced density and improved workability.
- **J. Zhang et al. (2018):** Reviewed LECA's ability to produce lightweight concrete with good thermal and fire performance and emphasized optimized mix design.

2.3 Studies on LECA as a Lightweight Aggregate:

Full or partial replacement of coarse aggregates with LECA produced densities between 1610–1965 kg/m³ and compressive strengths up to 67 MPa when combined with silica fume or limestone. LECA mixes showed reduced density but maintained reasonable strength for structural use, confirming their suitability when properly proportioned.

2.4 Research Gaps Identified:

- **Optimal Replacement Ratio:** Need for clearer data on strength–density balance for various LECA percentages.
- **Durability Tests:** Limited studies on long-term resistance to acid, sulfate, chloride, and freeze-thaw conditions.
- **Combination with Recycled Materials:** Few studies explore LECA with recycled aggregates for greater sustainability.

III. METHODOLOGY

3.1 Experimental Program

This study focuses on developing M25 grade lightweight concrete using LECA as a partial replacement for natural coarse aggregates. Mixes were prepared with 0%, 25%, 50%, 75%, and 100% LECA. Cubes and cylinders were cast, cured for 7 and 28 days, and tested for compressive strength, density, and workability (slump test). The aim was to observe how increasing LECA content affects both fresh and hardened concrete properties.

3.2 Casting and Curing of Specimens

All materials cement, sand, LECA, and water were collected and tested for standard properties. LECA was pre-soaked for 24 hours to prevent water absorption during mixing. The M25 mix was maintained with a water-cement ratio of 0.45–0.50, and coarse aggregate was replaced by LECA by volume.

Concrete cubes of 150 × 150 × 150 mm were cast, compacted, and cured in water at about 27°C for 7 and 28 days. Curing ensured proper hydration and strength gain before testing.

Fig 1: Mixing of Concrete with LECA Aggregates

3.3 Testing Procedures

- **Slump Test (Workability):**

  Conducted on fresh concrete using a standard slump cone as per IS 1199 to measure consistency and workability.

- **Compressive Strength Test:**

  Performed on cube specimens using a Compression Testing Machine (CTM) at 7 and 28 days.

- **Density Test:**

  Density was calculated by dividing the weight of the cured cube by its volume:

  This helped evaluate the reduction in density with increasing LECA content.

3.4 Research Methodology Flow

The experiment followed these steps:

- **Materials:** OPC 53 grade, river sand, crushed stone, LECA, and clean water.
- **Testing:** Checked cement and aggregate properties as per IS standards.
- **Mix Design:** M25 mix prepared using IS 10262:2019.
- **LECA Replacement:** Coarse aggregates replaced by 25%, 50%, 75%, and 100%.
- **Mixing & Casting:** Pan-mixed, cast into 150 mm cubes, and cured for 7 & 28 days.
- **Tests:** Slump, compressive strength, and density tests performed.
- **Analysis:** Results compared with normal mix to find the best LECA percentage.

IV. WORKING PRINCIPLE

This chapter describes the materials used in producing lightweight concrete and their essential properties. The study focuses on developing M25 grade concrete using Lightweight Expanded Clay Aggregate (LECA) as a partial or full replacement for conventional coarse aggregate to achieve lower density with sufficient strength.

4.1 Cement

Ordinary Portland Cement (OPC 53 Grade) was used as the main binding material. It conforms to IS 12269:1987 standards and provides high early and ultimate strength suitable for structural applications.

4.2 Fine Aggregate

Clean, natural river sand (Zone II) conforming to IS 383:2016 was used. The sand was sieved, washed, and oven-dried to remove impurities and maintain uniformity in the mix.

4.3 Coarse Aggregate (Replaced by LECA)

Conventional crushed stone was replaced with Lightweight Expanded Clay Aggregate (LECA). LECA is a porous, lightweight, and thermally treated clay material produced in a rotary kiln. It significantly reduces the density of concrete while maintaining structural integrity.

Replacement levels were set at 25%, 50%, 75%, and 100% by volume of natural coarse aggregate. Since LECA has high water absorption, it was pre-soaked in water for 24 hours before mixing to maintain the water-cement ratio.

Fig 2 : Lightweight Expanded Clay Aggregate (LECA) Balls

4.4 Water

Potable tap water was used for both mixing and curing, as recommended by IS 456:2000. The water was clean, free from acids, alkalis, oils, or organic matter to ensure proper hydration and strength development.

4.5 Summary

This chapter summarized the key materials used in the preparation of M25 grade lightweight concrete. Ordinary Portland Cement (53 Grade) served as the main binder, natural river sand as fine aggregate, and Lightweight Expanded Clay Aggregate (LECA) was utilized as a partial or full replacement for conventional coarse aggregate.

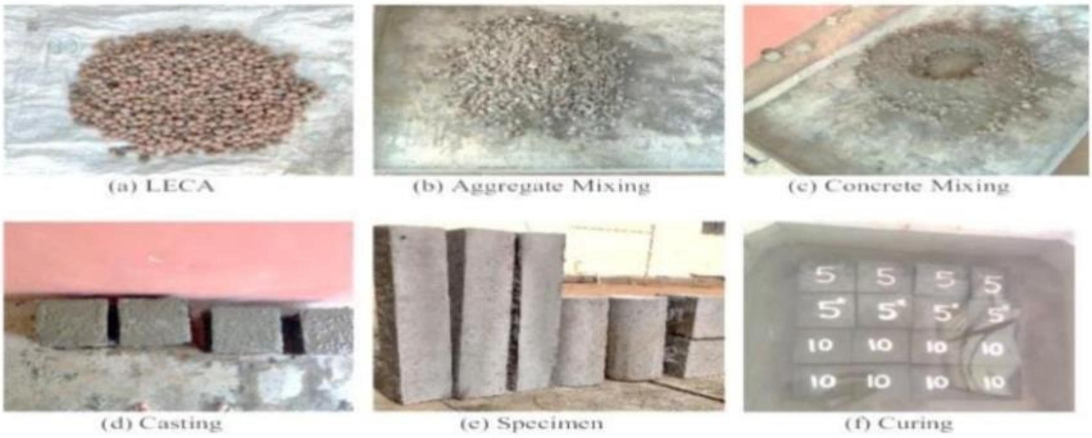

Fig 3 : LECA-Based Concrete Blocks

V. MIX DESIGNS

5.1 Mix Design for Normal Concrete (M25)

The mix design targets an M25 grade concrete with a characteristic strength of 25 MPa at 28 days. The desired workability is a slump between 75–100 mm under standard exposure conditions.

Step 1: Material Properties

- Cement: OPC 53 grade
- Maximum aggregate size: 20 mm
- Specific gravity – Cement: 3.15, Fine aggregate: 2.65, Coarse aggregate: 2.70
- Water–cement ratio: 0.45
- Water content: 186 kg/m³
- Cement content = 186 / 0.45 = 415 kg/m³
- Coarse aggregate volume = 0.62, Fine aggregate = 0.38

Final mix proportion (by weight)

Cement : Fine Aggregate : Coarse Aggregate : Water = 1 : 1.5 : 2.7 : 0.45

This serves as the control mix for comparison with LECA-based lightweight concrete.

5.2 Mix Design for Lightweight Concrete (LECA)

Step 1: Properties of LECA

- Specific gravity ≈ 1.4
- Bulk density ≈ 450 kg/m³
- Water absorption = 10–18%
- Rounded and porous, requiring pre-soaking for 24 hours

Step 2: Volume Replacement

LECA replaces coarse aggregate **by volume**, not by weight:

- 25%, 50%, 75%, and 100% replacements are prepared to study performance variation.

Step 3: Mix Adjustments

Due to LECA's high absorption, water content is slightly increased or LECA is pre-soaked. Effective w/c ratio ≈ 0.45–0.50. Density decreases with higher LECA content, producing lighter concrete.

Step 4: Example – 100% LECA Mix (for 1 m³)

- Cement = 415 kg
- Water = 190–200 kg
- Fine Aggregate = 650–700 kg
- LECA = 300–350 kg

Approximate mix ratio (by weight)

1 : 1.6 : 0.85 : 0.48 (Cement : Sand : LECA : Water)

Step 5: Adjustments for Other Replacements

For 25%, 50%, and 75% mixes, coarse aggregate is partially replaced by LECA by volume. Minor adjustments are made for workability and compaction.

Key observations:

- Water demand increases with LECA content.
- Workability generally improves but requires proper vibration.
- Density decreases while strength slightly reduces yet remains structurally adequate.

VI. COMPARISONS

6.1 Overview

Lightweight concrete (LWC) provides reduced density while maintaining sufficient strength and durability. For M25 grade concrete, a target compressive strength of 25 MPa at 28 days can be achieved with up to 25% lower density, making LWC suitable for multi-storey structures, precast units, and non-load-bearing applications.

6.2 Comparison of M25 Mixes

S.No	Author & Year	Mix Details	% of LECA Used	Compressive Strength (MPa)	Remark
1	K. Murugan et al. (2020)	M25, full LECA replacement	100 %	25 MPa	Low density, slight strength reduction
2	Tyagi et zl. (2025)	Coarse aggregate replaced by LECA	100 %	25 MPa	Achieved target strength

Table (i): Comparison of M25 Mixes

6.3 Comparison of M30 Mixes

S.No	Author & Year	Mix Details	% of LECA Used	Compressive Strength (MPa)	Remark
1	Arivalagan & Dinesh Kumar (2022)	M30, coarse replaced by LECA balls	40 %	30 MPa	Optimum strength, 20 % weight reduction
2	Yew M.K et al.	Recycled LECA replacing coarse aggregate	50 %	30 MPa	Eco-friendly with adequate strength

Table (ii): Comparison of M30 Mixes

6.4 Comparison of Strength Results

- **0% LECA:** Highest strength and density.
- **25% LECA:** 2–5% strength drop; 10–15% lower density.
- **50% LECA:** Near target strength (≈25 MPa); 20–25% lower density.
- **75% LECA:** 10–12% strength loss; major weight reduction
- **100% LECA:** 15–20% strength loss; >30% lighter, for non-structural use.

Conclusion: 50% LECA gives optimal strength-to-weight ratio for structural use

6.5 Durability and Physical Properties

- **Water Absorption:** Higher from LECA porosity.
- **Crack Resistance:** Improved due to energy absorption.
- **Chemical Resistance:** Lower in acids/sulphates; improved with fly ash or silica fume.
- **Shrinkage/Creep:** Slightly higher, offset by internal curing.

6.6 Cost Comparison

- **Material:** LECA costlier but used less.
- **Transport/Handling:** Lighter, cheaper logistics.
- **Overall:** Slightly higher initial cost balanced by savings in dead load, steel/concrete, and faster placement.

Final Observation:

LECA-based lightweight concrete offers structural efficiency, ease of construction, and long-term economic benefits despite marginally higher material cost.

VII. APPLICATIONS OF LIGHTWEIGHT CONCRETE

Lightweight Concrete (LWC) is widely used in modern construction for its low density, thermal efficiency, and easy handling. It helps reduce self-weight and improve insulation.

Applications:

- Marine and floating structures
- Fireproof walls and barriers
- Precast units
- Roof and floor insulation
- High-rise buildings (to reduce dead load)
- Bridge decks

LECA-based LWC offers good strength, insulation, and fire resistance, making it ideal for roofing, partitions, precast parts, and marine works. Its low weight enables faster, energy-efficient, and sustainable construction.

VIII. DISCUSSIONS

8.1 Compressive Strength

The compressive strength test was conducted at 7 and 28 days for all mixes. The control mix (0% LECA) achieved the maximum strength. At 25% and 50% LECA replacement, the strength remained close to the control mix, proving that LECA can be used without major strength loss. Strength decreased at 75% and 100% LECA replacement, but the mixes were still suitable for moderate and non-structural applications respectively.

8.2 Workability

Slump test results showed that workability improved slightly with higher LECA content. LECA's rounded particles allowed easier flow and compaction, maintaining acceptable slump values between 75–100 mm.

8.3 Strength-to-Density Relationship

The analysis indicated that 50% LECA replacement provided the best balance between compressive strength and reduced density. This ratio offers both strength and lightweight characteristics suitable for structural use in buildings and precast components.

8.4 Key Conclusions

- LECA is an effective partial replacement for coarse aggregate.
- Up to 50% replacement yields good strength and substantial weight reduction.
- 50% replacement offers the most practical balance between density and strength.
- 100% replacement is best suited for non-structural or insulation purposes.

Fig 4 : LECA-Based Lightweight Concrete Block After Curing

IX. CONCLUSIONS

- Lightweight concrete using LECA achieved slightly lower but acceptable strength compared to normal concrete, satisfying M25 requirements for structural use.
- The overall density reduction of 20–25% makes it ideal for low- and medium-load elements, decreasing dead load on structures.
- Partial LECA replacement up to 30–50% improved workability and reduced self-weight with minimal strength loss.

The M25 mix demonstrated target strength, good workability, and durability. Early-age strength was lower but reached adequate values by 28 days, proving it suitable for slabs, beams, and columns in medium-rise buildings.

The M30 mix showed higher compressive strength, better finish, and improved durability. It is suitable for heavy-duty RCC components requiring higher strength and long-term performance, such as industrial and high-load structures.

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