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Experimental Study on Lightweight Concrete Using Foaming Agent and LECA

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ABSTRACT

Concrete is widely used in construction, but its high self-weight increases the dead load on structures, leading to higher material consumption and cost. To address this issue, this study focuses on producing lightweight concrete by incorporating LECA (Lightweight Expanded Clay Aggregate) and a foaming agent. The aim is to reduce density while maintaining adequate strength for practical use. In this work, different concrete mixes were prepared, including conventional concrete, LECA-based concrete, foamed concrete, and a combined LECA with foaming agent mix. Standard cube specimens were cast and cured, and compressive strength tests were conducted at 7, 14, and 28 days. Density measurements were also taken to evaluate the weight reduction achieved in each mix. The experimental results showed that conventional concrete had an average density of about 2400 kg/m^3 and compressive strength of around 28 MPa at 28 days. In comparison, LECA concrete reduced density to approximately 1800 kg/m^3 with strength around 18 MPa, while foamed concrete showed a density of nearly 1400 kg/m^3 and strength of about 10–12 MPa. The combined LECA and foaming agent mix achieved the lowest density of about 1200 kg/m^3 with a moderate compressive strength of 8–10 MPa. From the results, it is concluded that the use of LECA and foaming agent significantly reduces the weight of concrete while maintaining sufficient strength for non-structural applications. This type of lightweight concrete can be effectively used to reduce dead load and improve overall construction efficiency.

1. INTRODUCTION

Lightweight concrete has become an important material in modern construction due to its ability to reduce structural dead load without compromising functional performance. Conventional concrete has a high density, which increases the overall weight of structures and leads to higher foundation costs. To overcome this limitation, lightweight alternatives are being developed using innovative materials and techniques.

One such approach involves the use of Lightweight Expanded Clay Aggregate (LECA) and foaming agents. LECA is a manufactured aggregate produced by heating clay at high temperatures, resulting in a porous and lightweight structure. Its internal voids help in reducing the density of concrete while also providing good thermal insulation and durability. On the other hand, foaming agents introduce stable air voids into the concrete matrix, further decreasing its unit weight and improving workability.

The combination of LECA and foaming agents offers a promising solution for producing ultra-lightweight concrete with balanced mechanical properties. This type of concrete is

especially suitable for non-structural applications such as partition walls, insulation layers, and low-load-bearing elements. Additionally, it contributes to sustainable construction by reducing material consumption and improving energy efficiency.

This study focuses on evaluating the performance of lightweight concrete prepared using LECA and foaming agents by analyzing its density, compressive strength, and workability characteristics.

2. MATERIAL USED

A. Cement

Ordinary Portland Cement (OPC 53 grade) was used as the binding material. It provides the necessary strength and helps in proper setting and hardening of concrete.

B. Sand

Locally available river sand was used as fine aggregate. It was clean, free from impurities, and passed through a 4.75 mm sieve.

C. Coarse Aggregate

Crushed stone aggregate of nominal size 20 mm was used in conventional concrete mixes. It contributes to strength and stability.

D. Water

Clean portable water used for mixing and curing. it was free form harmful salts and impurities.

E. LECA (Lightweight Expanded Clay Aggregate)

LECA was used as a lightweight replacement for coarse aggregate. Due to its porous structure, it helps in reducing the overall density of concrete and improves thermal insulation.



Figure 1: LECA Aggregate

F. Foaming Agent

A protein-based foaming agent was used to produce stable foam. It introduces air voids into the concrete, reducing density and improving workability.



Figure 2: Foaming Agent (Marjanol)

Table 3: Properties of Materials

Material	Specific Gravity	Density (kg/m^3)
Cement	3.15	1440
Sand	2.60	1600
Coarse Aggregate	2.70	1500
Leca	0.60 – 0.80	300 – 800
Foaming Agent	1.02	1000
Water	1.00	1000

3. Methodology:-

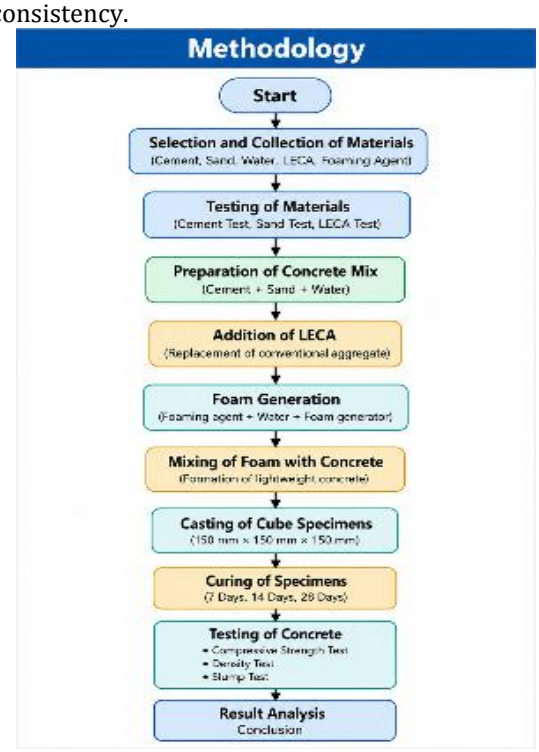
A. Selection of Mix Types

Four different concrete mixes were considered for comparison:

- Conventional Concrete (CC): Prepared using normal aggregates.
- LECA Concrete (LC): Coarse aggregate partially or fully replaced with LECA.
- Foamed Concrete (FC): Prepared by adding preformed foam to the cement slurry.
- LECA + Foaming (LFC): Combination of LECA and foaming agent to achieve minimum density.

B. Batching and Mixing

All materials were measured as per the required mix proportions. Dry materials such as cement and sand were first mixed thoroughly. Coarse aggregate or LECA was then added and mixed uniformly. For foamed mixes, foam was generated separately using a foaming agent and then added to the mix to obtain a uniform, workable consistency.



C. Casting of Specimens

Concrete was placed into standard cube moulds of size 150 mm × 150 mm × 150 mm. The moulds were filled in layers and compacted properly to remove entrapped air. The top surface was finished smoothly.

D. Curing Process

After 24 hours of casting, the specimens were removed from the moulds and immersed in clean water. Curing was carried out for 7 days, 14 days, and 28 days to study strength development over time.

E. Testing of Specimens

After curing, the cubes were tested for:

- Compressive Strength using a compression testing machine
- Density by measuring weight and volume
- Workability (during mixing stage)

4. Experimental Results

The test results obtained from different concrete mixes are presented below. For compressive strength, three cube specimens were tested for each mix, and the average value was calculated. Density and workability were also measured to compare the performance of all mixes.

A. Compressive Strength Results

Table 4: Mix Type: Conventional Concrete (CC)

Cube	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)	Average
1	18.5	24.2	29.1	18.8
2	19.0	25.0	30.0	24.6
3	18.8	24.5	29.5	29.5

Table 5: Mix Type: LECA Concrete (LC)

Cube	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)	Average
1	12.5	15.8	18.2	12.8
2	13.0	16.5	18.8	16.1
3	12.8	16.0	18.5	18.5

Table 6: Mix Type: Foamed Concrete (FC)

Cube	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)	Average
1	7.5	9.5	11.0	7.8
2	8.0	10.0	11.5	9.8
3	7.8	9.8	11.2	11.2

Table 7: Mix Type: LECA + Foaming (LFC)

Cube	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)	Average
1	6.5	8.5	9.5	6.8
2	7,0	9.0	10.0	8.8
3	6.8	8.8	9.8	98



Figure 3: Concrete Cube under Compressive Strength Testing machine (CTM)



Figure 4: Failure Pattern of Concrete Cube under Compressive strength test

B. Density Results

Mix Type	Density (kg/m^3)
Conventional Concrete	2400
Leca Concrete	1800
Foamed Concrete	1400
Leca + Foamed Concrete	1200



Figure 5: Measurement of Concrete Cube Weight Density Determination using Digital Weighing Balance

C. Workability (Slump Test)

Mix type	Slump (mm)
Conventional Concrete	75
Leca Concrete	65
Foamed Concrete	90
Leca + Foamed Concrete	85



Figure 6: Slump Shape of Fresh LECA-Based Concrete Indicating Low Workability

5. Graph

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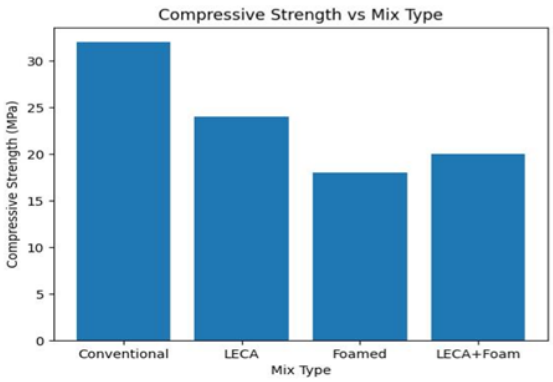
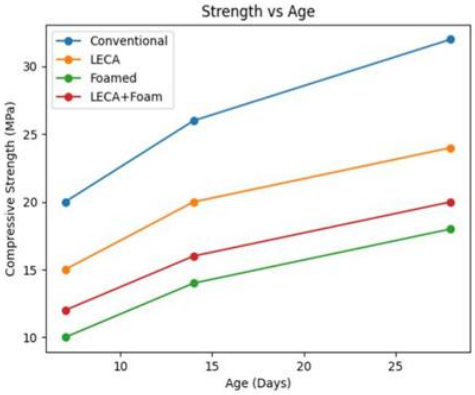


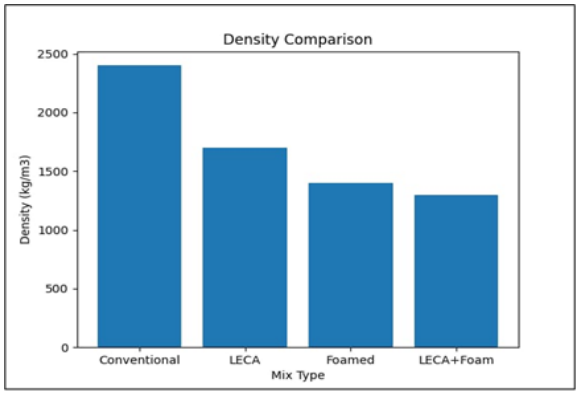
Graph 1: Compressive strength VS Mix type

This graph shows the variation I n compressive strength for different concrete mixes. Conventional concrete exhibits the highest strength, while foamed and lightweight mixes show reduced strength due to increased porosity



Graph 2: Strength VS Age (7, 14, 28 days)

The graph represents strength development with curing. All mixes show gradual strength gain, but lightweight mixes develop strength at a slower rate compared to conventional concrete.



Graph 3: Density Comparison of Concrete Mixes

This graph highlights the reduction in density achieved using LECA and foaming agent. The lowest density is observed in the combined LECA and foamed mix.

6. Result and discussion

A. Comparison: Conventional Concrete vs LECA Concrete

The conventional concrete exhibited higher compressive strength due to the presence of dense natural aggregates, which provide strong bonding with the cement matrix. In contrast, LECA concrete showed comparatively lower strength. This reduction is mainly due to the porous nature of LECA, which creates weaker interfacial bonding and increases internal voids within the concrete.

However, a significant reduction in density was observed in LECA concrete. The lightweight structure of LECA particles contains internal air voids, which reduces the overall unit weight of concrete. As a result, LECA concrete is more suitable for applications where reduction of dead load is important

B. Comparison: Foamed Concrete vs LECA + Foaming Agent Concrete

Foamed concrete showed lower compressive strength because of the introduction of air bubbles through the foaming agent. These air voids reduce the solid matrix, leading to a decrease in load-carrying capacity.

When LECA was combined with a foaming agent, the compressive strength further decreased slightly compared to foamed concrete alone. This is due to the combined effect of porous aggregate and entrained air voids, which increases the overall porosity of the mix.

On the other hand, the density of LECA + foaming agent concrete was found to be the lowest among all mixes. This is because both LECA and foam contribute to reducing the weight by introducing voids at different scales—LECA through internal pores and foam through air entrainment.

C. Discussion on Strength and Density Behavior

The variation in compressive strength and density is mainly governed by the internal structure of concrete.

Strength reduction: The decrease in strength is directly related to an increase in void content. More voids lead to less solid material available to resist applied loads, resulting in lower compressive strength.

Density Reduction: The reduction in density is due to the replacement of solid aggregates with lightweight materials and air voids. LECA reduces density through its porous structure, while the foaming agent introduces controlled air bubbles, making the concrete lighter

CONCLUSION

Weight Reduction:

- Conventional concrete showed the highest density.
- LECA concrete resulted in noticeable weight reduction due to its porous aggregate structure.
- Foamed concrete further reduced density because of air voids.
- The combination of LECA and foaming agent achieved the maximum reduction in weight, making it the lightest mix among all.
- Strength Suitability:
- Conventional concrete provided the highest compressive strength and is suitable for structural use.
- LECA concrete maintained moderate strength and can be used in semi-structural elements.
- Foamed concrete showed lower strength and is suitable for non-load-bearing applications.
- LECA + foaming agent mix had the lowest strength due to higher porosity, limiting its use to lightweight and insulation purposes.

Best Mix Selection:

- For high strength requirement → Conventional concrete is the best option.
- For balance between strength and weight → LECA concrete is the most suitable mix.
- For maximum weight reduction and insulation → LECA + foaming agent mix is the best choice.

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