Experimental Study on Light Weight Concrete Using Lightweight Expanded Clay Aggregate

Prof.Rajkumar Jadhav[1], Kapure Ravi Vilas[2], and Gaikwad Pratap Sunil[3]
[1]*Assistant Professor, Bharat-Ratna Indira Gandhi College of Engineering, Kegaon, Solapur, Maharashtra 413255*
[2,3]*B. Tech Students, Civil department, Bharat-Ratna Indira Gandhi College of Engineering, Kegaon, Solapur, Maharashtra 413255*

Abstract-Conventional concrete is commonly used in construction, but it has some challenges. It is heavy and has limited thermal insulation. These issues are becoming more important, especially for modern high-rise buildings, energy-efficient designs, and structures that need to withstand earthquakes. This experimental study explores the possibility of making Lightweight Concrete (LWC) by substituting conventional coarse aggregate with Lightweight Expanded Clay Aggregate (LECA). This substitution occurs at volumes of 0%, 25%, 50%, 75%, and 100% in an M20 grade concrete mix following IS 10262:2019.

LECA is made by heating natural clay at temperatures between 1100°C and 1200°C in a rotary kiln. This process creates a porous structure, leading to a low bulk density of 440 kg/m³ and good thermal insulation properties. In this study, all LECA was soaked in water until it reached a Saturated Surface Dry (SSD) condition for 24 hours before mixing. The other materials used included OPC 53 Grade cement, river sand (Zone II), and a sulphonated naphthalene formaldehyde (SNF) superplasticizer, all meeting IS code standards.

Concrete samples comprised 150 mm cubes, 150×300 mm cylinders, and 100×100×500 mm beams. These samples were cast, cured with water, and tested for workability (IS 1199), compressive strength at 7 and 28 days (IS 516), split tensile strength (IS 5816), density (IS 9142), and water absorption (IS 2386).

The results show that workability declines from 80 mm with 0% LECA to 45 mm with 100% LECA due to LECA's high water absorption. Compressive strength drops from 28.0 MPa in the control mix to 14.0 MPa with 100% LECA after 28 days. Additionally, density decreases from 2400 kg/m³ to 1572 kg/m³, a reduction of 34.5%. The mix with 50% LECA achieves a compressive strength of 22.0 MPa after 28 days, meeting M20 requirements according to IS 456, and has a density of 2000 kg/m³. This mix is identified as the best option for structural uses. Higher levels of replacement (75–100%) are better suited for non-structural and insulation purposes.

The study shows that LECA concrete provides significant benefits over traditional concrete. It reduces dead weight, improves thermal insulation, enhances sound insulation, increases fire resistance, and boosts seismic performance. However, the drawbacks of lower workability and increased water absorption at higher replacement levels can be managed with careful mix design and soaking procedures.

Keywords: Lightweight Concrete, LECA, Lightweight Expanded Clay Aggregate, M20 Grade Concrete, Compressive Strength, Density Reduction, Thermal Insulation, IS 10262, Sustainable Construction.

I. INTRODUCTION

Concrete is the most widely used construction material in the world, forming the backbone of modern infrastructure ranging from residential buildings to bridges, dams, and flyovers. Conventional concrete is composed of cement, fine aggregate, coarse aggregate, and water. While it offers excellent compressive strength and durability, its high self-weight is a significant limitation in contemporary construction practice.

The density of conventional concrete typically ranges from 2200 to 2500 kg/m³. This high density imposes considerable dead loads on structural members beams, columns, slabs, and foundations demanding larger cross-sections, heavier reinforcement, and deeper foundations, all of which increase the overall cost and complexity of a project.

With rapid urbanization, population growth, and rising demand for high-rise buildings, engineers and researchers have been actively exploring alternatives that reduce the self- weight of concrete without sacrificing structural performance. This search has led to the development and widespread adoption of Lightweight Concrete (LWC) most effectively achieved through the use of Lightweight Expanded Clay Aggregate (LECA).

The present study focuses on the experimental investigation of LECA concrete by replacing conventional coarse aggregate with LECA at 25%, 50%, 75%, and 100% levels. The study evaluates workability, density, compressive strength, split tensile strength, flexural strength, water absorption, and insulation properties for each mix.

II LIGHTWEIGHT CONCRETE - OVERVIEW

Lightweight concrete (LWC) is defined as concrete with a dry density not exceeding 1900 kg/m³ as per IS 456 and ACI 213. It can be produced using three principal approaches:

- *Using lightweight aggregates such as LECA, pumice, fly ash sintered aggregate, or expanded shale to replace conventional aggregates.*
- *Incorporating air voids into the concrete matrix through foaming agents or autoclaving, resulting in aerated or cellular concrete.*
- *Omitting fine aggregates from the mix, producing no-fines concrete with lower density.*

III-SCOPE OF THE STUDY

The scope of this experimental study includes:

- Preparation of M20 grade concrete mixes with 0%, 25%, 50%, 75%, and 100% LECA replacement of coarse aggregate.
- Casting of cube (150×150×150 mm), cylinder (150×300 mm), and beam (100×100×500 mm) specimens.
- Testing fresh concrete workability (slump test) and hardened concrete properties at 7 and 28 days.
- Comparison of LECA concrete performance with conventional M20 concrete.
- Identification of the optimum LECA replacement percentage for structural and non-structural applications.

IV.MATERIALS

All materials used in the experimental programme were carefully selected, tested, and characterised in the laboratory before use. Standard IS code specifications were strictly followed for each material.

- Cement - OPC 53 Grade: Ordinary Portland Cement (OPC) of 53 Grade conforming to IS 12269 was used throughout the study. OPC 53 Grade is the most commonly used cement for structural concrete in India and provides high early strength, making it suitable for M20 mix design. Physical and chemical tests were performed on the cement sample before use to confirm IS 12269 compliance.

- Fine Aggregate (River Sand): Natural river sand passing a 4.75 mm IS sieve was used as fine aggregate. The sand was tested for fineness modulus, specific gravity, water absorption, and bulk density as per IS 383 and IS 2386. It falls under Grading Zone II of IS 383.

- Coarse Aggregate (Stone Chips): Crushed stone aggregate of 20 mm nominal maximum size conforming to IS 383 was used as conventional coarse aggregate in the control mix (0% LECA) and in mixes with partial LECA replacement.

- LECA - Lightweight Expanded Clay Aggregate: LECA was used as a volumetric replacement for conventional coarse aggregate. It was procured from a certified manufacturer and all physical properties were verified in the laboratory as per IS 9142 and IS 2386 before use.

- Water: Potable water conforming to IS 456 (Clause 5.4) was used for both mixing and curing.

The water was free from oils, acids, salts, alkalis, and organic matter that could adversely affect concrete strength and durability.

- Admixtures (Superplasticizer): To compensate for workability reduction caused by LECA's high water absorption, a sulphonated naphthalene formaldehyde (SNF) based superplasticizer conforming to IS 9103 was used where required. The dosage was 0.5–1.0% by weight of cement. Benefits include maintaining slump without excess water, improving flowability and compactibility, and reducing bleeding and segregation.

V. INTRODUCTION TO MIX DESIGN

Mix design is the process of selecting proportions of cement, fine aggregate, coarse aggregate (or LECA), and water to produce concrete with desired workability in the fresh state and required strength and durability in the hardened state. In this study, mix design was performed for M20 grade concrete as per IS 10262:2019. LECA mixes were derived from the same base design, with LECA replacing coarse aggregate volumetrically in increments of 25%, 50%, 75%, and 100%.

VI-CASTING OF SPECIMENS

Concrete specimens were cast for each of the five mix types (Control, 25%, 50%, 75%, 100% LECA) to enable testing at 7 and 28 days of curing. Three specimens were cast per test type per curing period; the average of three results is reported for each mix.

VII-RESULTS

Workability Results - Slump Test: The slump test was conducted immediately after mixing for each of the five concrete mixes. Results are presented in Table 1

Mix Type	LECAReplacmnt (%)	Slump	Workability Remark
Conventional Concrete	0%	80 mm	Good workability
25% LECA Mix	25%	75 mm	Satisfactory
50% LECA Mix	50%	65 mm	Moderate
75% LECA Mix	75%	55 mm	Low
100% LECA Mix	100%	45 mm	Low - Admixture recommended

Table-1

Compressive Strength Results:
Compressive strength was determined on 150 mm cubes at 7 days and 28 days of water curing. Three specimens were tested for each mix at each curing period and the average is reported.

Mix Type	7-Day Strength (MPa)	28-Day Strength (MPa)	% of M20 Strength
Conventional (0% LECA)	18.5	28.0	100%
25% LECA	16.2	25.0	89.3%
50% LECA	14.0	22.0	78.6%
75% LECA	11.5	18.0	64.3%
100% LECA	8.5	14.0	50.0%

Table-2

Split Tensile Strength Results: The split tensile strength was evaluated at 28 days for all mixes.

Mix Type	Split Tensile Strength (MPa)	% of Control Mix
Conventional (0% LECA)	2.80 MPa	100%
25% LECA	2.50 MPa	89.3%
50% LECA	2.20 MPa	78.6%
75% LECA	1.80 MPa	64.3%
100% LECA	1.40 MPa	50.0%

Table-3

Water Absorption Results: Water absorption increases with increasing LECA content, owing to the porous aggregate structure of LECA pellets.

Mix Type	Water Absorption (%)	Remark

Conventional (0% LECA)	1.8%	Low absorption — good durability
25% LECA	2.5%	Acceptable
50% LECA	3.6%	Moderate — proper curing essential
75% LECA	4.8%	High — surface treatment recommended
100% LECA	6.2%	High — sealant / coating required

VIII-DISCUSSION OF RESULTS

Slump values decrease progressively from 80 mm (0% LECA) to 45 mm (100% LECA). This reduction occurs because LECA pellets, being highly porous, absorb a significant amount of water from the mix even when pre-soaked to SSD condition. The reduction in free water decreases the lubrication between particles and lowers workability. Superplasticizers or additional water may be required for mixes with 75% and 100% LECA replacement to achieve the target slump of 75–100 mm as per IS 10262.

The density reduction is highly significant from 2400 kg/m³ (conventional) to 1572 kg/m³ (100% LECA), representing a 34.5% reduction. Even the 50% LECA mix at 2000 kg/m³ meets the lightweight concrete classification threshold. This weight reduction directly translates to lower dead loads on structural systems, enabling more economical design of beams, columns, and foundations.

IX-SPECIFIC CONCLUSIONS

Based on the experimental results, testing, and discussion presented in the preceding chapters, the following specific conclusions are drawn:

(a) Workability:
Workability of fresh concrete decreases progressively with increasing LECA content from 80 mm slump (control) to 75 mm (25% LECA), 65 mm (50%LECA), 55 mm (75% LECA), and 45 mm (100% LECA).
This reduction is caused by the high-water absorption capacity of porous LECA pellets, which reduce the free water available in the mix. Pre-soaking LECA to SSD condition and use of superplasticizer (0.5–1.0% of cement by weight) can effectively restore workability without increasing the water-cement ratio.

(b) Compressive Strength:
28-day compressive strength decreases with increasing LECA replacement — from 28.0 MPa (control) to 25.0 MPa (25%), 22.0 MPa (50%), 18.0 MPa (75%), and 14.0 MPa (100%).
The 25% and 50% LECA mixes achieve compressive strengths of 25.0 MPa and 22.0 MPa respectively, both exceeding the minimum characteristic compressive strength of 20 MPa for M20 grade concrete as per IS 456:2000. These mixes are therefore structurally adequate for use in beams, columns, slabs, and other load-bearing members.

(a) Split Tensile Strength:
Split tensile strength at 28 days decreases from 2.80 MPa (control) to 2.50 MPa (25% LECA), 2.20 MPa (50%), 1.80 MPa (75%), and 1.40 MPa (100% LECA),following a trend consistent with the reduction in compressive strength.

(b) Water Absorption:
Water absorption increases with LECA content from 1.8% (control) to 6.2% (100% LECA) due to the inherently porous aggregate structure of LECA. This highlights the importance of adequate curing duration and, where required, the application of surface sealants or waterproofing treatments for exposed LECA concrete elements.

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