

Evaluation and Strength Estimation of Glass Fibre Reinforced Lightweight Aggregate Concrete

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ABSTRACT

Lightweight Aggregate Concrete (LWAC) has emerged as a sustainable alternative to conventional concrete due to its reduced density and improved thermal performance. However, its relatively lower tensile strength and brittle behavior restrict its structural applications. The present study investigates the strength performance and structural efficiency of Glass Fibre Reinforced Lightweight Aggregate Concrete (GFRLWC). Lightweight aggregates were incorporated as partial replacement of conventional coarse aggregates to reduce the density of concrete. Glass fibres were added in controlled proportions to enhance tensile and flexural performance. An experimental program was conducted to evaluate workability, density, compressive strength, split tensile strength, and flexural strength at 7 and 28 days of curing.

The results demonstrate that glass fibre addition significantly improves tensile and flexural strength due to crack-bridging action and improved stress transfer within the matrix. Although a slight reduction in workability was observed, the values remained within permissible construction limits. The density reduction confirms the lightweight nature of the developed concrete. Overall, GFRLWC shows balanced mechanical performance and structural suitability for modern sustainable construction practices.

Keywords: Lightweight Aggregate Concrete, Glass Fibre, Fibre Reinforcement, Compressive Strength, Flexural Strength, Density Reduction.

1. INTRODUCTION

Lightweight Aggregate Concrete plays an important role in modern construction, particularly in high-rise buildings and seismic zones where reduction of dead load is essential. The use of lightweight aggregates reduces structural weight, improves thermal insulation, and enhances energy efficiency.

Despite these advantages, LWAC exhibits lower tensile capacity and brittle fracture characteristics. Fibre reinforcement has been widely adopted to improve tensile behavior and crack resistance. Glass fibres offer advantages such as high tensile strength, corrosion resistance, and uniform dispersion.

The long term durability is determined by means of permeability of concrete. The deterioration of concrete and reinforcement is caused by the water and harmful substances absorbed by the permeable concrete. The strength and durability properties of concrete are influenced by the interfacial zone between aggregate and the cement matrix (Kockal & Ozturan 2010).

This study evaluates the mechanical behavior of GFRLWC and compares its performance with conventional lightweight concrete.

2. MATERIALS AND EXPERIMENTAL PROGRAM

2.1 Materials Used

Cement

The cement used in this study for all the mixes was Ordinary Portland Cement with 53 grade, conforming to IS 12269:2013. The compressive strength of cement mortar was found to be 29, 42 and 55 N/mm² at 3, 7 and 28 days respectively.

Fine Aggregate

Natural river sand conforming to zone II as per IS 383:2016 was used as the fine aggregate. The sand was air-dried and sieved to remove any foreign particles prior to mixing. The specific gravity, fineness modulus and water absorption were determined and given in Table grading of fine aggregate is given in Table.

Table 1 Properties of fine aggregate

Properties	Experimental Value
Specific Gravity	2.62
Water Absorption	0.33%
Fineness Modulus	2.66

Coarse Aggregate

Crushed granite coarse aggregate of particle size 20 mm having angular shape and confirming to IS 2386 – 2016 was used for this investigation. In all the mixes 20mm size lightweight pumice aggregate was used as the replacement of coarse aggregate. The properties of coarse aggregate and grading of coarse aggregate are given in Tables respectively. The properties of pumice aggregate and grading of pumice aggregate are given in Tables respectively. The sample of pumice aggregate is shown

Table 2 Properties of coarse aggregate

Properties	Experimental Value
Specific Gravity	2.78
Water Absorption	0.67%
Impact value	16.6%
Crushing value	29.3%
Fineness Modulus	6.87

Glass Fiber

The diameter of the glass fiber was 15 μm and relative density was 2.54. The strength of glass fibers used was 2000 N/mm². The aspect ratio of glass fiber used was 800. The properties of fibers used are reported in Table as given by the supplier. The sample of glass fibers is shown



Glass Fiber

Table 3 Properties of fibers

Fiber Type	Relative Density (no unit)	Diameter in μm	Tensile strength in N/mm^2	Modulus of elasticity in N/mm^2
Glass	2.54	15	2000	72000

Super Plasticizer

In this research, 0.8% of chloride free superplasticizer (Sulphonated naphthalene polymers) was added by cement weight to attain good workability. The percentage of superplasticizer added was constant for all the mixes.

2.2 Mix Proportions

Mix ID	% Lightweight Aggregate	% Glass Fibre	Water-Cement Ratio
M1	100%	0%	0.45
M2	100%	0.5%	0.45
M3	100%	1.0%	0.45
M4	100%	1.5%	0.45

2.3 Specimen Details



Figure 4.1 casting of specimen



Figure 4.2 Curing of specimen



Figure 4.3 Specimen s after demoulding

Table 4: Specimen Dimensions

Test Type	Specimen Size
Compressive Strength	150 mm × 150 mm × 150 mm
Split Tensile Strength	150 mm diameter × 300 mm
Flexural Strength	100 mm × 100 mm × 500 mm

3. RESULTS AND DISCUSSION

3.1 Workability

Slump values decreased with increasing fibre content due to increased internal friction and fibre interlocking. However, slump values remained between 60–85 mm, suitable for structural concrete.

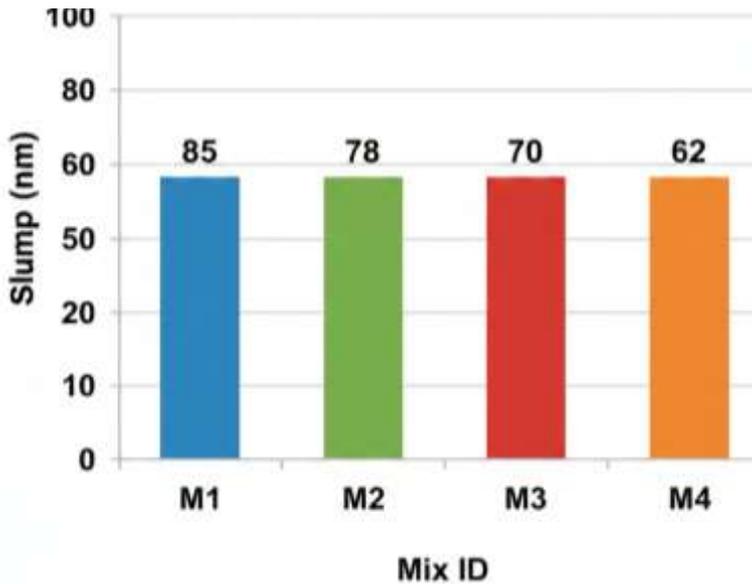


Figure 4.4 Slump test on concrete

Table 5: Slump Test Results

Mix ID	Slump (mm)
M1	85
M2	78
M3	70
M4	62

Graph-1 Workability



3.2 Density Results

Density is the mass per unit volume of concrete, usually expressed in kg/m^3 . It is an important property that affects the weight, strength, and structural performance of concrete. The density mainly depends on the type of aggregates used, mix proportions, and level of compaction. Conventional concrete has a density of about $2300\text{--}2500 \text{ kg/m}^3$ because it uses natural coarse aggregates. In contrast, **lightweight aggregate concrete (LWAC)** has a lower density, typically between $1600\text{--}2000 \text{ kg/m}^3$, due to the use of porous lightweight aggregates such as expanded clay or pumice.

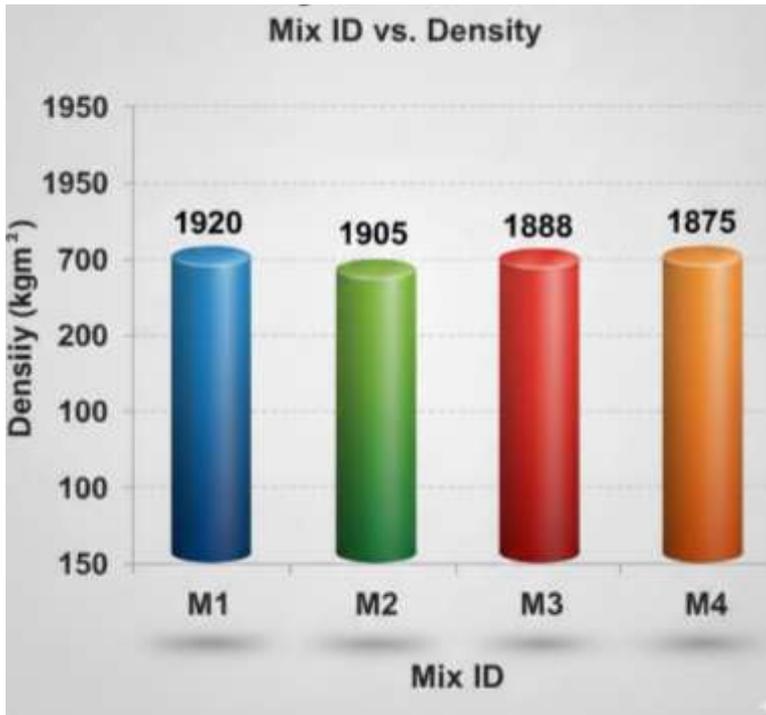
Reduced density lowers the dead load of structures, resulting in smaller structural members and economical foundation design. It also improves seismic performance by reducing earthquake forces. However, proper mix design is essential to maintain adequate strength while achieving lower density.

Table 6: Density of Concrete

Mix ID	Density (kg/m^3)
M1	1920
M2	1905
M3	1888
M4	1875

The reduction in density confirms the lightweight nature of the developed concrete.

Grapg-2 Density



3.3 Compressive Strength

Compressive strength increased slightly with fibre addition up to 1.0% fibre content. Beyond this, marginal reduction was observed due to reduced compaction efficiency.

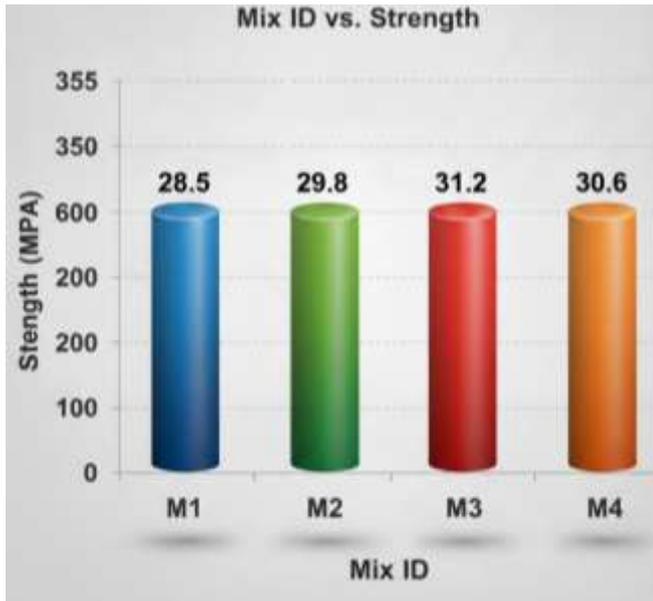


Figure 4.5 Test setup for compressive strength of concrete

Table 7: Compressive Strength Results (28 Days)

Mix ID	Strength (MPa)
M1	28.5
M2	29.8
M3	31.2
M4	30.6

Graph-3 Compressive Strength



3.4 Split Tensile Strength

Tensile strength showed significant improvement (up to 35% increase at optimum fibre content). Glass fibres act as crack bridges, transferring tensile stress across microcracks and delaying crack widening.

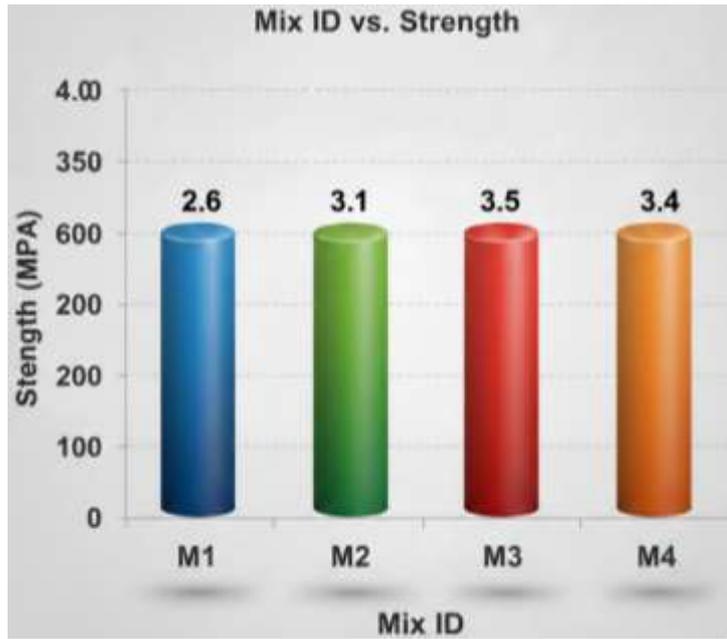


Figure 4.6 Test setup for splitting tensile strength of concrete

Table 8: Split Tensile Strength Results

Mix ID	Strength (MPa)
M1	2.6
M2	3.1
M3	3.5
M4	3.4

Graph-3 Split Tensile Strength



3.5 Flexural Strength

Flexural strength is expressed in terms of Modulus of Rupture, which is the maximum stress at the extreme fiber in bending. Flexural strength was assessed by testing concrete prism of size 100 mm x 100 mm x 500 mm.

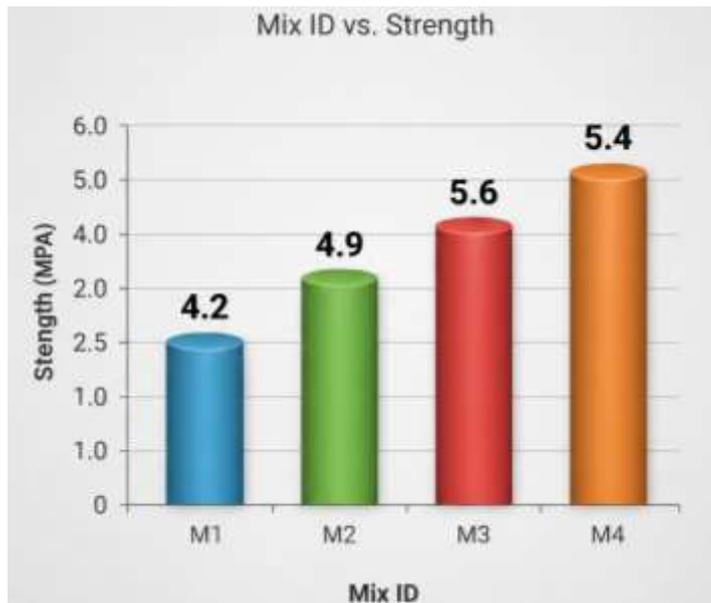


Figure 4.7 Test setup for flexural strength of concrete

Table 9: Flexural Strength Results

Mix ID	Strength (MPa)
M1	4.2
M2	4.9
M3	5.6
M4	5.4

Graph-3 Split Tensile Strength



4. CRACK PATTERN ANALYSIS

Plain lightweight concrete exhibited sudden brittle failure. Fibre-reinforced specimens showed gradual crack propagation and multiple microcracks instead of single dominant crack.

This indicates improved toughness and structural reliability.

5. STATISTICAL INTERPRETATION

The strength results show consistent improvement trends with increasing fibre content up to 1.0%. Beyond optimum fibre dosage, clustering may reduce efficiency.

Regression analysis suggests a strong correlation between fibre percentage and tensile strength improvement.

6. CONCLUSIONS

- Density reduced by approximately 20% compared to conventional concrete.
- Compressive strength maintained structural grade performance.
- Split tensile strength improved up to 35%.
- Flexural strength improved up to 30%.
- Crack propagation effectively controlled.
- Optimum fibre content observed around 1.0%.
- GFRLWC is suitable for structural and sustainable construction applications.

7. FUTURE SCOPE

- Long-term durability studies (chloride attack, sulphate attack)
- Shrinkage and creep analysis
- Hybrid fibre combinations
- Microstructural analysis using SEM
- Large-scale structural behavior under seismic loading

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