PERFORMANCE OF HIGH-STRENGTH CONCRETE USING ALUMINUM FIBER

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Abstract-*High-strength concrete (HSC) has become one of the most important construction materials in modern civil engineering due to its superior compressive strength, durability, and long-term performance. However, the brittle nature of HSC and its lower tensile capacity restrict its use in structures subjected to impact, vibration, and dynamic loading. The incorporation of fibers into concrete is an effective technique to improve ductility, crack resistance, toughness, and post-cracking behavior. The present research investigates the performance of high-strength concrete reinforced with aluminum fibers. Concrete grades M60 and M80 were prepared with varying aluminum fiber volume fractions of 0.5%, 1.0%, and 1.5%. Experimental investigations were carried out to evaluate workability, compressive strength, split tensile strength, and flexural strength. Results indicated that the addition of aluminum fibers significantly enhanced the mechanical performance of concrete. Compressive strength increased by approximately 13%, while split tensile and flexural strengths also showed considerable improvement due to crack-bridging action and improved stress transfer mechanisms. Although workability decreased with increasing fiber dosage, the use of superplasticizer maintained workable mixes. The optimum performance was achieved at 1.5% fiber content. The study concludes that aluminum fiber-reinforced high-strength concrete can be effectively utilized in structural applications requiring improved strength, durability, and crack resistance.*

Keywords: High-strength concrete, Aluminum fibers, Fiber reinforced concrete, Compressive strength, Flexural strength, Split tensile strength, Workability, M60 concrete, M80 concrete

1. INTRODUCTION

1.1 Background

Concrete is the most widely used construction material in the world due to its versatility, durability, economy, and ease of production. In recent decades, the rapid development of infrastructure and the increasing demand for high-rise buildings, bridges, marine structures, and industrial facilities have accelerated the use of high-strength concrete (HSC). High-strength concrete generally refers to concrete having compressive strength greater than 55 MPa. Compared to normal concrete, HSC offers superior load-carrying capacity, reduced member size, improved durability, and enhanced resistance to aggressive environmental conditions.

Despite these advantages, high-strength concrete possesses certain limitations. One of the major drawbacks of HSC is its brittle behavior under tensile and flexural loading conditions. The concrete tends to fail suddenly without providing adequate warning, which may compromise structural safety. Moreover, HSC exhibits lower energy absorption capacity and poor crack resistance compared to conventional concrete. These deficiencies restrict its application in structures subjected to dynamic, cyclic, and impact loading.

To overcome the brittle nature of concrete, fibers are introduced into the concrete matrix. Fiber-reinforced concrete (FRC) is a composite material consisting of cement, aggregates, water, admixtures, and discrete fibers uniformly distributed throughout the mix. The addition of fibers improves ductility, toughness, impact resistance, and crack control properties. Various types of fibers such as steel fibers, glass fibers, polypropylene fibers, carbon fibers, and aluminum fibers are commonly used in concrete technology.

Among these fibers, aluminum fibers have gained increasing attention due to their lightweight nature, corrosion resistance, thermal conductivity, and adequate tensile strength. Aluminum fibers improve the post-cracking behavior of concrete and help in bridging micro-cracks that develop during loading. Additionally, aluminum fibers contribute to improved toughness and energy absorption while reducing structural self-weight. The present study focuses on evaluating the influence of aluminum fibers on the mechanical and fresh properties of high-strength concrete grades M60 and M80. The research investigates compressive strength, split tensile strength, flexural strength, and workability characteristics with varying aluminum fiber contents

1.2 Objective of study

1. To prepare high-strength concrete mixes of grades M60 and M80.
2. To investigate the influence of aluminum fibers on concrete properties.
3. To evaluate compressive strength, split tensile strength, and flexural strength.
4. To study the effect of aluminum fibers on workability.
5. To determine the optimum fiber dosage for improved performance.
6. To assess the suitability of aluminum fiber-reinforced concrete for structural applications

2. LITERATURE REVIEW

Several researchers have investigated the behavior of fiber-reinforced concrete to improve the deficiencies of conventional concrete.

Review 1.

Bentur and Mindess (2019) reported that fibers improve toughness, crack resistance, and impact strength of concrete. Their study concluded that fibers delay crack propagation and improve post-cracking behavior.

Review 2.

Rao and Patil (2023) investigated aluminum fiber-reinforced high-strength concrete and observed that compressive strength increased by nearly 15% at optimum fiber content. The researchers also noted significant enhancement in tensile and flexural strengths.

Review 3.

Kumar and Prasad (2022) studied the durability characteristics of aluminum fiber-reinforced concrete and reported improved resistance against chloride attack, acid attack, and sulfate attack.

Review 4.

Zhao et al. (2023) investigated hybrid fiber systems in high-performance concrete and concluded that fibers enhance energy absorption and structural ductility. Previous studies indicate that fiber reinforcement improves concrete performance; however, limited research is available regarding the use of aluminum fibers in M60 and M80 grade high-strength concrete. Therefore, this study aims to address this research gap.

3. MATERIALS USED

3.1 Cement

Ordinary Portland Cement (OPC) 53 Grade conforming to IS 12269 was used throughout the investigation. The cement possessed high early strength and good consistency properties suitable for high-strength concrete production.

3.2 Fine Aggregate

Natural river sand conforming to Zone II of IS 383 was used as fine aggregate. The sand was clean, free from organic impurities, and possessed suitable grading characteristics.

3.3 Coarse Aggregate

Crushed angular aggregates of 10 mm and 20 mm size were used. The aggregates exhibited high strength and proper interlocking characteristics.

3.4 Water

Potable water free from harmful impurities was used for mixing and curing.

3.5 Super plasticizer

A Polycarboxylate Ether (PCE)-based superplasticizer was used to improve workability without increasing the water-cement ratio.

3.6 Aluminum Fibers

Hooked-end aluminum fibers with an average length of 25 mm and diameter of 0.5 mm were used. The fibers possessed excellent corrosion resistance and lightweight properties.

4. METHODOLOGY

The experimental methodology included batching, mixing, casting, curing, and testing of concrete specimens.

4.1. Mix Design

Concrete mixes were designed according to IS 10262:2019 guidelines

Table 1: Mix Design Parameters

Parameter	M60	M80
Water-Cement Ratio	0.30	0.28
Cement Content (kg/m^3)	480	580
Slump Range (mm)	75–100	75–100
Superplasticizer Dosage (%)	0.9–1.2	1.0–1.3
Aluminum Fiber Content (%)	0.5, 1.0, 1.5	0.5, 1.0, 1.5

The lower water-cement ratio was adopted to achieve higher compressive strength and durability.

4.2 Mixing Procedure

All materials were dry mixed in a mechanical mixer. Aluminum fibers were added gradually to ensure uniform distribution and avoid clustering.

4.3 Casting of Specimens

Concrete specimens were cast in standard molds:

- Cubes: 150 × 150 × 150 mm
- Cylinders: 150 × 300 mm
- Beams: 100 × 100 × 500 mm

The molds were compacted using a table vibrator to eliminate entrapped air.

4.4 Curing

Specimens were demolded after 24 hours and cured in water at 27±2°C for 28 days

5. EXPERIMENTAL RESULTS

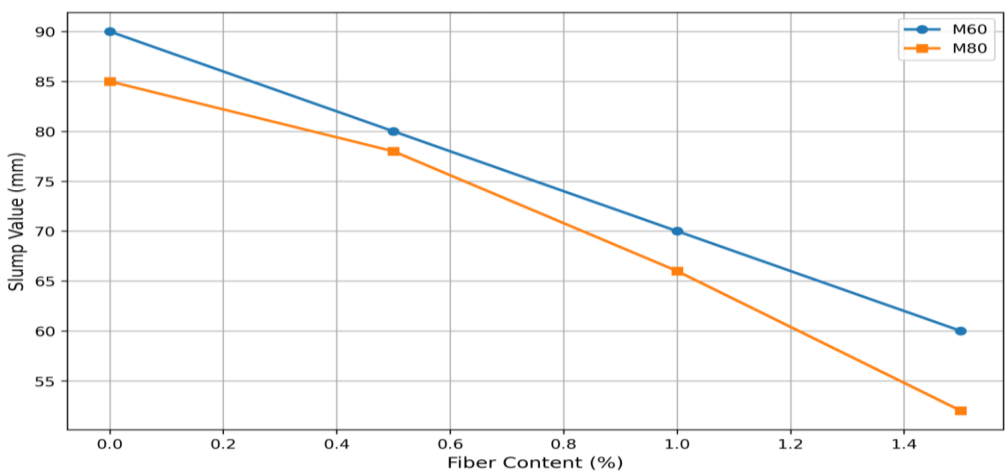
5.1 Workability

Table 2: Slump Test Results

Fiber Content (%)	M60 Slump (mm)	M80 Slump (mm)
0.0	90	85
0.5	80	78
1.0	70	66
1.5	60	52

The slump values decreased with increasing fiber dosage due to internal friction and obstruction caused by fibers. M80 mixes showed lower slump because of the lower water-cement ratio.

Graph 1: Slump Value vs Fiber Content



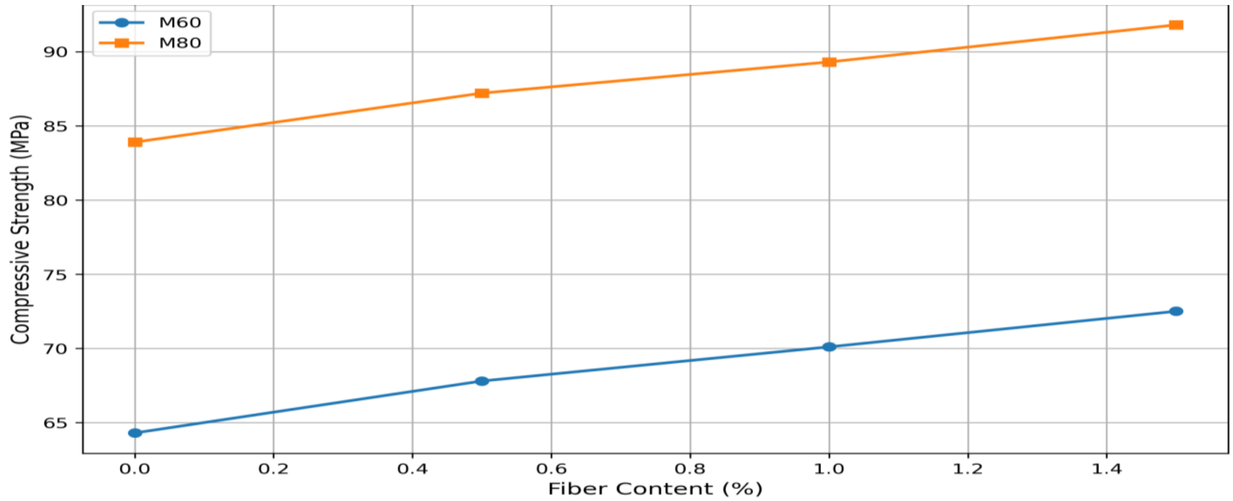
5.2 Compressive Strength

Table 3: Compressive Strength Results

Fiber Content (%)	M60 (MPa)	M80 (MPa)
0.0	64.3	83.9
0.5	67.8	87.2
1.0	70.1	89.3
1.5	72.5	91.8

The addition of aluminum fibers increased compressive strength due to crack-bridging mechanisms and improved stress transfer.

Graph 2: Compressive Strength vs Fiber Content



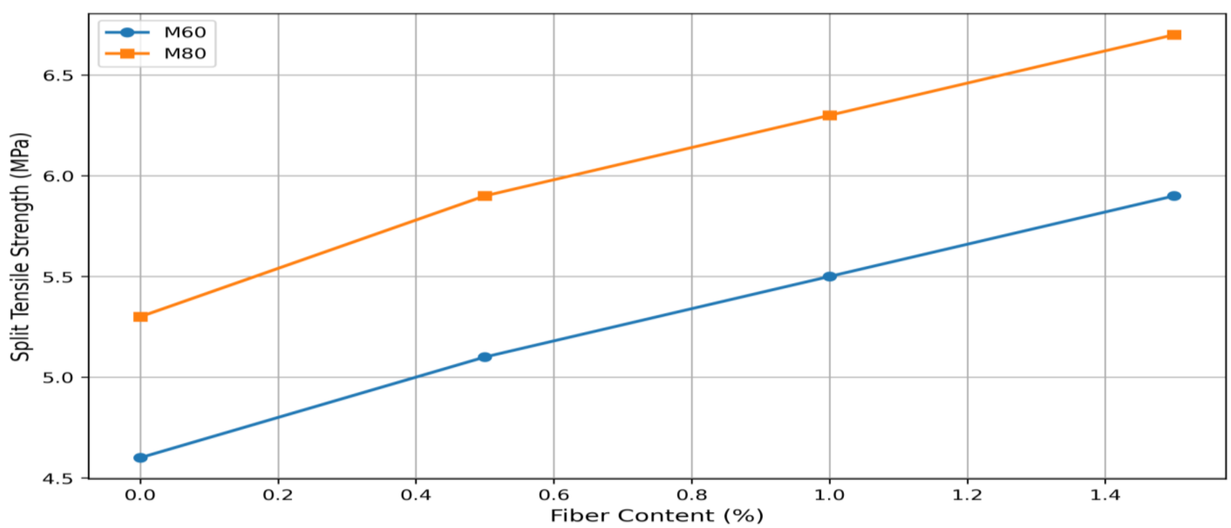
5.3 Split Tensile Strength

Table 4: Split Tensile Strength Results

Fiber Content (%)	M60 (MPa)	M80 (MPa)
0.0	4.6	5.3
0.5	5.1	5.9
1.0	5.5	6.3
1.5	5.9	6.7

The fibers effectively bridged micro-cracks and delayed crack propagation, resulting in improved tensile behavior.

Graph 3: Split Tensile Strength vs Fiber Content



6. RESULTS AND DISCUSSION

The experimental investigation clearly demonstrates that aluminum fibers significantly improve the mechanical performance of high-strength concrete. The improvement in compressive strength is attributed to better crack resistance and stress redistribution within the concrete matrix.

The increase in tensile and flexural strengths confirms the effectiveness of aluminum fibers in controlling crack propagation. The fibers act as micro-reinforcements that bridge cracks and improve ductility.

Although workability decreases with increasing fiber content, the use of superplasticizer compensates for this reduction and ensures proper placement and compaction.

The optimum fiber dosage was found to be 1.5%, which provided maximum strength enhancement without severe workability issues.

7. MAJOR ADVANTAGES

- Improved compressive strength.
- Increased split tensile and flexural strength.
- Enhanced crack resistance and crack-bridging capability.
- Better toughness and ductility
- Lightweight compared to steel fibers.

8. LIMITATIONS

- Reduced workability with increasing fiber content.
- Requirement of chemical admixtures for proper mixing.
- Difficulty in achieving uniform fiber distribution.
- Higher material cost compared to conventional concrete

9. APPLICATIONS

- High-rise buildings.
- Bridges and flyovers.
- Industrial floors and warehouses.
- Airport pavements and runways.
- Highway pavements.

10. CONCLUSION

Based on the experimental investigation, the following conclusions are drawn:

1. Aluminum fibers significantly improve compressive, tensile, and flexural strengths.
2. Maximum strength enhancement was observed at 1.5% fiber dosage.
3. Flexural strength showed the greatest improvement due to enhanced crack resistance.
4. Workability decreased with increasing fiber content but remained within acceptable limits.
5. Aluminum fibers improved toughness and ductility of high-strength concrete.
6. Aluminum fiber-reinforced concrete can be effectively used in high-rise buildings, pavements, industrial floors, and bridge structures.

11. FUTURE SCOPE

- Investigation on durability properties under aggressive environmental conditions.
- Study on hybrid fiber combinations
- Evaluation of long-term creep and shrinkage behavior.
- Application of aluminum fiber-reinforced concrete in precast elements.
- Microstructural analysis using SEM and XRD techniques.

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