iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: V Month of publication: May 2026

DOI: https://doi.org/10.22214/ijraset.2026.82436

Experimental Study on Fiber- Reinforced High-Strength Concrete for Airfield Rigid Pavements

Mahammad Ayaan[1], Mohammed Hussain[2], Shrijith Rai[3], Akshaya Krishna N[4], Anusha Jain[5]
[1, 2, 3]U.G, Students, [4, 5]Assistant Professor, Department of Civil Engineering, MITE, Moodabidri, Mangaluru, India 574225

Abstract: Airfield rigid pavements are subjected to extremely heavy aircraft wheel loads, high tire pressures, and repeated dynamic loading conditions. Conventional concrete pavements often suffer from cracking and fatigue failure under such severe loading conditions. This study investigates the performance of fiber reinforced high-strength concrete (FRHSC) for airfield rigid pavement applications. M50 grade high-strength concrete incorporating hooked-end steel fibers at different percentages (0%, 0.5%, 1.0%, and 1.5%) was experimentally evaluated. The mechanical properties such as compressive strength and flexural strength were determined at 7 and 28 days of curing. Results showed that the inclusion of steel fibers significantly improved the strength and ductility characteristics of concrete. The optimum fiber content was found to be 1.0%, which increased compressive strength by approximately 11% and flexural strength by about 16% compared to conventional concrete. The study concludes that fiber reinforced high-strength concrete can effectively improve the performance and durability of airfield rigid pavements
Keywords— Airfield pavement, High-strength concrete, Fiber reinforced concrete, Steel fibers, Flexural strength, Compressive strength

I. INTRODUCTION

Airfield pavements are critical components of aviation infrastructure and are continuously subjected to extremely heavy wheel loads, impact forces during aircraft landing, braking stresses, and repeated aircraft movements. Compared to conventional highway pavements, airfield pavements experience much higher tire pressures, dynamic loading effects, and fatigue stresses due to frequent take-off and landing operations of aircraft. These pavements must provide a smooth, durable, and safe riding surface while maintaining structural stability under severe loading and environmental conditions. Rigid pavements made of Portland cement concrete are widely preferred for airfield applications because of their high stiffness, superior load distribution capability, longer service life, and lower maintenance requirements. In addition, rigid pavements offer better resistance against deformation, rutting, and fuel spillage, which are common in airport operational areas.

With the introduction of heavier and larger aircraft such as the Boeing 777 and Airbus A380, conventional concrete pavements often fail to provide adequate strength, fatigue resistance, and crack control under repeated loading conditions. High-strength concrete (HSC) has emerged as a promising material for airfield pavements because of its superior compressive strength, reduced permeability, improved abrasion resistance, and enhanced durability. However, despite its high compressive strength, HSC generally exhibits brittle behavior under tensile and flexural loading, leading to sudden crack formation and reduced post-cracking performance. To overcome these limitations, steel fibers are incorporated into the concrete matrix to improve ductility, toughness, crack resistance, and energy absorption capacity. The steel fibers act as crack arrestors by bridging micro-cracks and delaying their propagation, thereby enhancing the post-cracking load-carrying capacity of concrete.

Fiber reinforced high-strength concrete (FRHSC) combines the advantages of both high-strength concrete and fiber reinforcement, resulting in a composite material with improved mechanical and durability properties. The inclusion of steel fibers significantly enhances flexural strength, fatigue resistance, impact resistance, and ductility, making FRHSC highly suitable for heavy-duty pavement applications such as runways, taxiways, and aprons. Moreover, the improved crack resistance and toughness of fiber reinforced concrete help reduce maintenance requirements and extend pavement service life. Therefore, the present study focuses on evaluating the effect of hooked-end steel fibers on the compressive and flexural strength characteristics of M50 grade high-strength concrete for airfield rigid pavement applications.

II. LITERATURE REVIEW

Several researchers have investigated the use of high-strength concrete (HSC) and fiber reinforced concrete (FRC) for rigid pavement applications due to their improved strength, durability, and crack resistance characteristics. Željko Kos et al.

[1] reported that the addition of steel fibers improved the flexural strength and crack resistance of rigid pavement concrete by approximately 15–25% compared to conventional concrete. The study concluded that steel fiber reinforcement enhanced pavement durability and service life under repeated traffic loading conditions. Mehta and Monteiro [2] stated that high-strength concrete generally achieves compressive strengths greater than 60 MPa due to improved microstructure and stronger bonding between cement paste and aggregates. Neville [3] emphasized that high-strength concrete provides superior resistance against sulfate attack, chloride penetration, and freeze–thaw cycles, making it suitable for aggressive environments such as airfield pavements. Siddique and Khan [4] observed that the incorporation of silica fume increased the compressive strength of concrete by nearly 15–20%; however, the concrete still exhibited brittle behavior under flexural loading, indicating the need for fiber reinforcement to improve ductility and toughness. Wang et al. [5] studied the behavior of steel fiber reinforced concrete under dynamic loading and reported significant improvements in fatigue resistance, impact strength, and energy absorption capacity. Similarly, Vamshi Krishna and Venkateswara Rao [6] concluded that steel fibers increased the flexural strength and load-carrying capacity of rigid pavement concrete by about 20–30% compared to plain concrete. Previous studies indicate that the combination of high-strength concrete and steel fiber reinforcement significantly improves compressive strength, flexural strength, crack resistance, ductility, and fatigue performance, making fiber reinforced high-strength concrete highly suitable for airfield rigid pavement applications subjected to heavy aircraft wheel loads and repeated dynamic loading conditions.

III. OBJECTIVES OF THE STUDY

The main objectives of the study are:

1) To develop M50 grade high-strength concrete suitable for airfield rigid pavements.
2) To investigate the effect of steel fibers on compressive and flexural strength.
3) To determine the optimum percentage of steel fiber addition.
4) To compare the performance of conventional and fiber reinforced concrete.
5) To evaluate the suitability of fiber reinforced concrete for airfield pavement applications.

IV. MATERIALS & METHODOLOGY

A. *Materials Used*

The materials used in this investigation include:

- Ordinary Portland Cement (OPC 43 Grade)
- River sand conforming to Zone II
- Crushed granite coarse aggregate of 20 mm size
- Potable water
- Hooked-end steel fibres

TABLE I
PHYSICAL AND MECHANICAL PROPERTIES OF MATERIALS WITH CODAL LIMITS

SL NO	Material	Property	Obtained Values	Permissible Limits as per IS code	IS Code Reference
1	Cement	Specific Gravity	3.15	3.10-3.15	IS 4031
2	Fine Aggregate	Specific Gravity	2.65	2.60-2.80	IS 2386 (Part III)
3	Coarse Aggregate	Specific Gravity	2.70	2.60-2.90	IS 2386 (Part III)
4	Steel Fiber	Length	30 mm	ASTM A820	As per design requirement
		Diameter	0.5 mm	ASTM A820	-
		Aspect Ratio	60	ASTM A820	40-100

		Tensile Strength	1100MPa	ASTM A820	>1000 MPa
		Density	7.85g/cm^3	Manufacturer Specification	7.80-7.90g/cm^3

Table 1 shows the physical and mechanical properties of the materials used in the present study. The obtained values were compared with the relevant IS codal provisions and ASTM standards and were found to be within the permissible limits.

B. Mix Design

M50 grade concrete mix was designed according to IS 10262:2019 and IS 456:2000. Steel fibers were added at different percentages: 0%, 0.5%, 1.0%,1.5%. The water-cement ratio was maintained between 0.30 and 0.35.

C. Specimen Preparation

Concrete cubes of size 150 × 150 × 150 mm were cast for compressive strength testing, while beam specimens of size 500 × 100 × 100 mm were prepared for flexural strength testing. The specimens were cured for 7 and 28 days before testing.

D. Experimental Procedure

The methodology adopted in this study includes:

1) Selection and testing of materials
2) Design of M50 grade high-strength concrete mix as per IS 10262:2019 and IS 456:2000
3) Preparation of concrete mix with a mix proportion of 1: 1.13: 1.96 and water–cement ratio of 0.35
4) Addition of hooked-end steel fibers at varying percentages of 0%, 0.5%, 1.0%, and 1.5% by weight of cement
5) Mixing, preparation, casting, and compaction of concrete specimens
6) Preparation of cube specimens of size 150 × 150 × 150 mm for compressive strength testing
7) Preparation of beam specimens of size 500 × 100 × 100 mm for flexural strength testing
8) Curing of concrete specimens for 7 and 28 days under water curing conditions
9) Compressive strength testing of concrete cube specimens using Compression Testing Machine (CTM)
10) Flexural strength testing of concrete beam specimens under two-point loading conditions
11) Analysis and interpretation of experimental results.

E. Results and discussion

1) Compressive Strength

Table 2 shows the 28-day compressive strength results of conventional and fiber reinforced M50 grade high-strength concrete mixes. It was observed that the compressive strength increased with the addition of steel fibers up to an optimum dosage of 1.0%. The conventional M50 concrete achieved a compressive strength of 50.78 MPa, whereas the concrete containing 1.0% steel fibers attained the maximum strength of 56.58 MPa, representing an increase of approximately 11%. The improvement in compressive strength is mainly attributed to the crack arresting and stress redistribution capability of steel fibers within the concrete matrix. The fibers effectively controlled the initiation and propagation of micro-cracks, thereby improving the load-carrying capacity of the M50 concrete.

TABLE 2
28-DAY COMPRESSIVE STRENGTH RESULTS

Concrete Mix	28-Day Compressive Strength (MPa)
Conventional Concrete	50.78
0.5% Steel Fiber	54.28
1.0% Steel Fiber	56.58
1.5% Steel Fiber	55.53

Table 2 presents the 28-day compressive strength results of conventional and steel fiber reinforced M50 grade concrete mixes, showing that the compressive strength increased with fiber addition up to an optimum dosage of 1.0% steel fibers.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue V May 2026- Available at www.ijraset.com

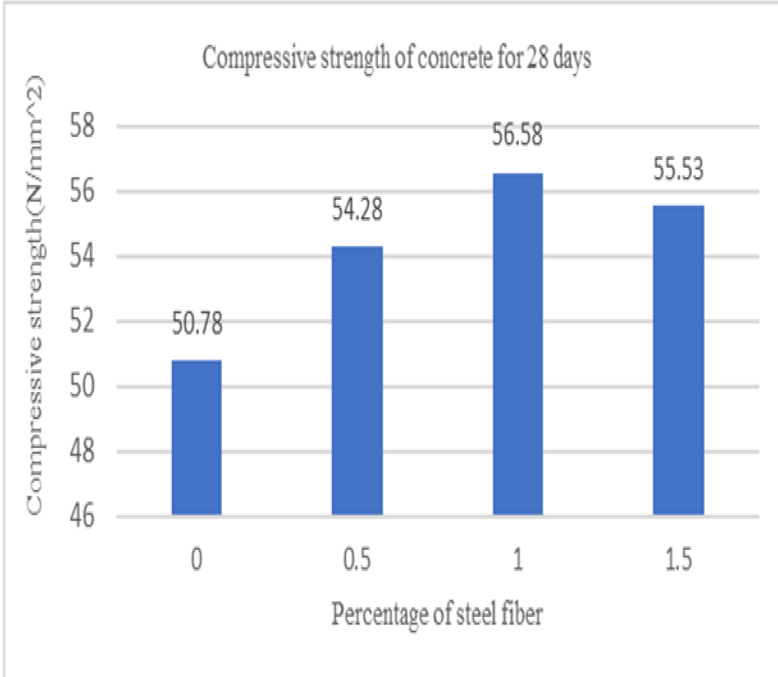

Fig. 1 Variation of compressive strength with steel fiber content

Figure 1 shows that the compressive strength of concrete cubes gradually increased with the increase in steel fiber content up to 1.0%. The maximum compressive strength of 56.58 MPa was achieved at 1.0% steel fiber addition, indicating improved load-carrying capacity and crack resistance of concrete cubes. However, beyond 1.0% fiber content, a slight reduction in strength was observed due to reduced workability, improper compaction, and non-uniform fiber distribution within the concrete matrix.

Fig. 2 Compressive and Flexural Strength Test Setup for Concrete Specimens

2) Flexural Strength

The flexural strength results of fiber reinforced M50 grade high-strength concrete are presented in Table 3. The inclusion of steel fibers significantly enhanced the flexural behavior of concrete. The conventional M50 concrete achieved a 28-day flexural strength of 7.25 MPa, whereas the concrete containing 1.0% steel fibers attained the maximum flexural strength of 8.45 MPa, indicating an improvement of approximately 16%.

The enhancement in flexural strength is mainly attributed to the crack bridging action of steel fibers, which delayed crack initiation and propagation under bending loads. The steel fibers improved the post-cracking load-carrying capacity, toughness, and ductility of the M50 concrete beams. However, at 1.5% fiber content, a slight reduction in flexural strength was observed due to poor workability, fiber agglomeration, and non-uniform distribution of fibers within the concrete matrix.

TABLE 3
28-DAY FLEXURAL STRENGTH RESULTS

Concrete Mix	28-Day Flexural Strength (MPa)
Conventional Concrete	7.25
0.5% Steel Fiber	7.86
1.0% Steel Fiber	8.45
1.5% Steel Fiber	8.10

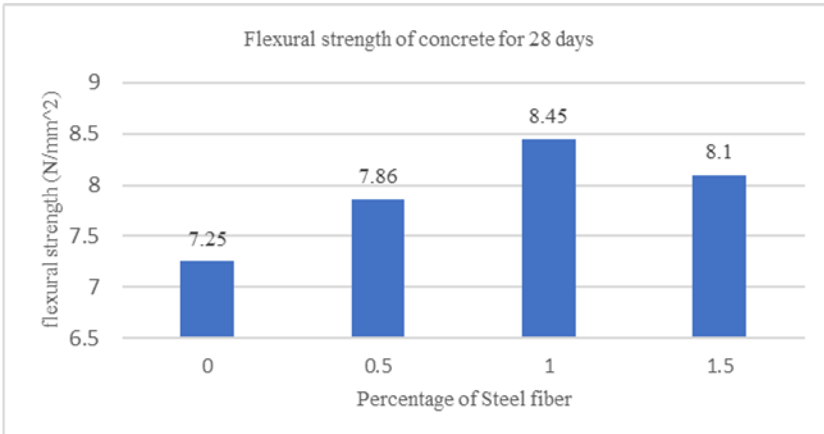

Fig. 3 Variation of flexural strength with steel fiber content

Table 3 presents the 28-day flexural strength results of conventional and steel fiber reinforced M50 grade concrete mixes, indicating that the flexural strength improved significantly with the addition of steel fibers up to an optimum dosage of 1.0%.

Figure 3 illustrates that the flexural strength of concrete beam specimens increased progressively with the addition of steel fibers. The highest flexural strength of 8.45 MPa was recorded at 1.0% steel fiber content, demonstrating the effectiveness of fibers in improving crack bridging and post-cracking behavior of concrete beams. At 1.5% fiber content, a marginal decrease in flexural strength was noticed due to poor workability and fiber clustering in the concrete mix.

Fig. 4 Casting of concrete in Moulds and Curing of concrete cubes

F. Discussions

The experimental investigation demonstrated that the incorporation of steel fibers significantly enhanced the mechanical properties and overall performance of M50 grade high-strength concrete. The presence of steel fibers improved crack resistance, ductility, toughness, and post-cracking load-carrying capacity of the concrete specimens.

Conventional concrete specimens exhibited sudden and brittle failure upon reaching the ultimate load, whereas fiber reinforced concrete specimens showed a more gradual and ductile failure pattern due to the crack bridging action of steel fibers. Among the different fiber dosages investigated, the concrete mix containing 1.0% steel fibers exhibited the highest compressive and flexural strength values. The improvement in strength is primarily attributed to the ability of steel fibers to arrest micro-crack propagation and redistribute stresses within the concrete matrix. However, beyond 1.0% fiber content, a slight reduction in mechanical performance was observed due to reduced workability, fiber agglomeration, and difficulties in achieving proper compaction and uniform fiber dispersion. The enhanced compressive strength, flexural strength, ductility, and crack resistance confirm that fiber reinforced M50 grade high-strength concrete is highly suitable for airfield rigid pavement applications subjected to heavy aircraft wheel loads, repeated impact loading, and fatigue stresses.

G. Data analysis and Interpretation

The experimental results obtained from the compressive and flexural strength tests were evaluated by comparing the average strength values of conventional and fiber reinforced M50 grade concrete mixes containing different percentages of steel fibers. The graphical and tabular results showed that the compressive and flexural strengths gradually increased with the addition of steel fibers up to an optimum dosage of 1.0%. The enhancement in strength is mainly due to the ability of steel fibers to control crack initiation and propagation, improve stress distribution, and increase the load-carrying capacity of the concrete matrix. The inclusion of fibers also improved the ductility and post-cracking behavior of the concrete specimens. However, at 1.5% steel fiber content, a marginal reduction in strength was observed due to decreased workability, difficulty in compaction, and uneven distribution of fibers within the concrete mix. Based on the overall test results, the concrete mix containing 1.0% steel fibers was found to be the optimum mix for improving the mechanical performance of concrete suitable for airfield rigid pavement applications.

V. CONCLUSIONS

Based on the experimental investigation conducted on M50 grade fiber reinforced high-strength concrete for airfield rigid pavement applications, the following conclusions were drawn in accordance with the objectives of the study:

1) M50 grade high-strength concrete suitable for airfield rigid pavement applications was successfully developed and tested under laboratory conditions.
2) The addition of hooked-end steel fibers significantly improved the compressive and flexural strength of high-strength concrete compared to conventional concrete.
3) The compressive strength increased from 50.78 MPa for conventional concrete to 56.58 MPa for concrete containing 1.0% steel fibers, showing an improvement of approximately 11%.
4) The flexural strength increased from 7.25 MPa for conventional concrete to 8.45 MPa at 1.0% steel fiber content, indicating an improvement of approximately 16%.
5) The optimum percentage of steel fiber addition was found to be 1.0%, which provided maximum improvement in strength and ductility characteristics.
6) Fiber reinforced concrete specimens exhibited better crack resistance, ductility, and post-cracking behavior compared to conventional concrete specimens, which showed brittle failure.
7) Beyond 1.0% steel fiber addition, workability and compaction difficulties increased due to fiber clustering, resulting in a slight reduction in strength.
8) The improved compressive strength, flexural strength, crack resistance, and ductility demonstrate that fiber reinforced high-strength concrete is suitable for airfield rigid pavement applications subjected to heavy wheel loads and repeated dynamic loading conditions.

REFERENCES

[1] Ž. Kos, S. Kroviakov, A. Mishutin, and A. Poltorapavlov, "An experimental study on the properties of concrete and fiber-reinforced concrete in rigid pavements," Materials, vol. 16, no. 17, p. 5886, Aug. 2023, doi: 10.3390/ma16175886.
[2] P. K. Mehta and P. J. M. Monteiro, Concrete: Microstructure, Properties, and Materials, 4th ed. New York, NY, USA: McGraw-Hill Education, 2014.
[3] A. M. Neville, Properties of Concrete, 4th ed. London, U.K.: Pearson Education, 2005.

[4] R. Siddique and M. I. Khan, Supplementary Cementing Materials. Berlin, Germany: Springer, 2011.

[5] Z. L. Wang, Y. S. Liu, and R. F. Shen, “Stress–strain relationship of steel fiber-reinforced concrete under dynamic compression,” Construction and Building Materials, vol. 22, no. 5, pp. 811–819, 2008.

[6] K. Vamshi Krishna and J. Venkateswara Rao, “Experimental study on behaviour of fiber reinforced concrete for rigid pavements,” IOSR Journal of Mechanical and Civil Engineering, vol. 11, no. 4, 2014.

[7] A. Bentur and S. Mindess, Fiber Reinforced Cementitious Composites, 2nd ed. London, U.K.: Taylor & Francis, 2007.

[8] N. Banthia and R. Gupta, “Hybrid fiber reinforced concrete (HyFRC): Fiber synergy in high strength matrices,” Materials and Structures, vol. 37, no. 10, pp. 707–716, 2004.

[9] P. S. Song and S. Hwang, “Mechanical properties of high-strength steel fiber-reinforced concrete,” Construction and Building Materials, vol. 18, no. 9, pp. 669–673, 2004.

[10] M. Nili and V. Afroughsabet, “Combined effect of silica fume and steel fibers on the impact resistance and mechanical properties of concrete,” International Journal of Impact Engineering, vol. 37, no. 8, pp. 879–886, 2010.

[11] IS 456:2000, Plain and Reinforced Concrete – Code of Practice. New Delhi, India: Bureau of Indian Standards, 2000.

[12] IS 10262:2019, Concrete Mix Proportioning – Guidelines. New Delhi, India: Bureau of Indian Standards, 2019.

[13] ACI Committee 544, State-of-the-Art Report on Fiber Reinforced Concrete, ACI 544.1R-96. Farmington Hills, MI, USA: American Concrete Institute, 1996.

[14] S. P. Shah and V. C. Li, “High performance fiber reinforced cementitious composites,” Concrete International, vol. 21, no. 12, pp. 27–34, 1999.

[15] P. Balaguru and S. P. Shah, Fiber-Reinforced Cement Composites. New York, NY, USA: McGraw-Hill, 1992.