PROPERTIES OF CORE-WRAPPED GALVANIZED IRON FIBER REINFORCED CONCRETE WITH VARYING FIBER CONTENTS AND TURNS PER UNIT LENGTH

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ABSTRACT

Replacing costly steel fibers with galvanized iron (GI) fibers has become a promising approach to enhance the mechanical properties of concrete. Tensile strength tests confirmed that core-wrapped GI fibers can act as an effective and economical alternative to steel fibers. The use of deformed fibers, instead of straight ones, significantly improves the strength of concrete. In this study, core-wrapped GI fibers were used to enhance the quality of concrete. Each fiber consisted of a straight inner core surrounded by an outer helical wrapping with fiber pitches of 6, 8, and 10 turns. Thirteen concrete mixes were prepared using three fiber dosages (approximately 1.0%, 1.5%, and 2.0% by weight) while maintaining a constant fiber length of 25.4 mm. The compressive strength and split tensile strength of GI fiber reinforced concrete (GIFRC) were examined. The results showed that compressive strength increased by about 13% to 29%, while split tensile strength improved by approximately 19% to 43% compared with the control concrete. Moreover, the use of core-wrapped fibers produced additional gains of around 1% to 7% in compressive strength and 2% to 10% in tensile strength compared with straight GI fibers. Predictive models were also developed to estimate the strength parameters for different fiber pitches, and the predicted results showed good agreement with the experimental data. Therefore, the use of core-wrapped GI fibers can be considered an efficient and cost-effective method to improve the mechanical performance of concrete.

Keywords: *Galvanized iron; Fiber reinforced concrete; Core-wrapped fiber; Mechanical Properties*

1. INTRODUCTION

Concrete, composed of cement paste and aggregates (Stohl, 1998), is one of the most widely used construction materials worldwide (Neville, 1995). It is popular for its good compressive strength, workability, durability, low maintenance cost, and flexibility in shape (Mehta, 1986). However, its main limitation lies in its weak tensile strength and brittle nature, which often cause sudden failure under tension (Raphael, 1984). To address this, various reinforcement materials such as steel bars, meshes, and fibers have been used (Zollo, 1997). Fibers, in particular, help improve tensile and flexural strength, making concrete more ductile and resistant to cracking (Olivito & Zuccarello, 2010). Over the years, many studies have explored different fiber types such as natural, synthetic, steel, glass, basalt, and composite to improve concrete's performance (Behbahani et al., 2011; Hasan et al., 2011; Shah et al., 2022) (Ahmad et al., 2022). Fiber Reinforced Concrete (FRC) is now recognized as a promising material because the inclusion of fibers enhances ductility and helps distribute stresses across cracks (Anas et al., 2022). Using fibers can also reduce the required thickness of structural members, lowering both the weight and the volume of concrete. According to ACI Committee 544, FRC is concrete made of cement, aggregates, and short, randomly distributed fibers (544, 2008). Among all fiber types, steel fiber is the most common due to its high performance and ability to improve concrete's strength and durability (Marcos-Meson et al., 2019). Several studies have shown that steel fiber provides superior mechanical properties compared to other fibers like basalt, glass, polypropylene, and wool (Bheel, 2021; Fantilli et al., 2017; Neves & Fernandes de Almeida, 2005). Researchers also found that steel fiber increases the bond between concrete and reinforcing bars (Chu & Kwan, 2019). Studies comparing steel and polypropylene fibers indicated that polypropylene fibers improve durability, while steel fibers enhance mechanical strength (KM & Varghese, 2014). The use of hooked-end and deformed steel fibers has been found to further improve compressive, tensile, and flexural strength due to better mechanical interlocking (Khabaz, 2016; Parra-Montesinos, 2006). Additionally, twisted or deformed fibers show higher bond strength with concrete compared to straight fibers (Kim et al., 2009; Naaman & Sujivorakul, 2020). However, steel fibers are costly, especially in developing countries, where importing them increases overall construction expenses. Locally available galvanized iron (GI) wire offers a cheaper alternative, reducing costs by nearly 19%. GI wires, made of mild steel coated with zinc, are commonly used in various applications and meet ACI and ASTM standards for fiber reinforcement. Previous studies have shown that using GI fibers increases compressive strength by 4%–15% and changes the failure mode of beams from brittle to ductile (Sadi et al., 2022). When used in lightweight concrete, GI fibers improved compressive strength by about 30%, tensile strength by 45%, and flexural strength by 30% (Emon et al., 2017; Gupta et al., 2020; Islam et al., 2023). Similar improvements have been reported for both natural and recycled aggregate concrete (Labiba et al., 2023).

Since deformed fibers generally perform better than straight ones (Banthia & Trottier, 1995; Parra-Montesinos, 2006; Trottier & Banthia, 1994), wrapping GI fibers could further enhance concrete performance. However, limited studies have explored this approach. Therefore, this research focuses on evaluating the effect of core wrapped GI fibers on the mechanical behaviour of concrete and comparing the results with straight GI fiber reinforced concrete. one 0.50 mm GI wire was mechanically twisted on one straight fibre to form core wrapped fibers with pitches of 6, 8, and 10 turns per inch. Three fiber contents (1.0%, 1.5%, and 2.0% by weight) were used with a fixed length of 25.4 mm. The study investigates how fiber deformation influences compressive, tensile, and flexural strengths properties of concrete.

2. MATERIALS AND METHODS

2.1 Cement

Ordinary Portland cement (OPC) of type CEM-I 52.5 N, according to BDS EN 197-1, was used. Its physical properties were measured following ASTM standards and are listed in Table 1 (ASTM, 2008; ASTM, 2023).

Table 1: Physical properties of cement

Specific gravity	Blaine Fineness (g/cm^2)	Normal consistency (%)	Initial setting time (min)	Final setting time (min)
3.14	3992	27.4	106	252

2.2 Aggregates

19 mm downgrade stone aggregates were used and the aggregates were tested for their physical properties following ASTM standards to evaluate suitability for concrete production. Sylhet sand was used as fine aggregate (FA). The properties of aggregates was determined as per ASTM standards (ASTM, 2015; ASTM, 2006).

Table 2: Physical properties of fine aggregates (FA) and coarse aggregates (CA)

	Specific gravity (SSD)	Dry unit weight (kg/m^3)	Fineness modulus (FM)	Coefficient of uniformity (C_u)	Coefficient of curvature (C_c)
FA	2.53	1496.112	2.42	2.12	1.05
CA	2.47	1545.56	4.54	2.08	1.09

2.3 Core Wrapped Galvanized Iron Fiber (CWGIF)

In this study, three types of core-wrapped galvanized iron (GI) fibers were prepared based on the number of helical turns imparted along the fiber

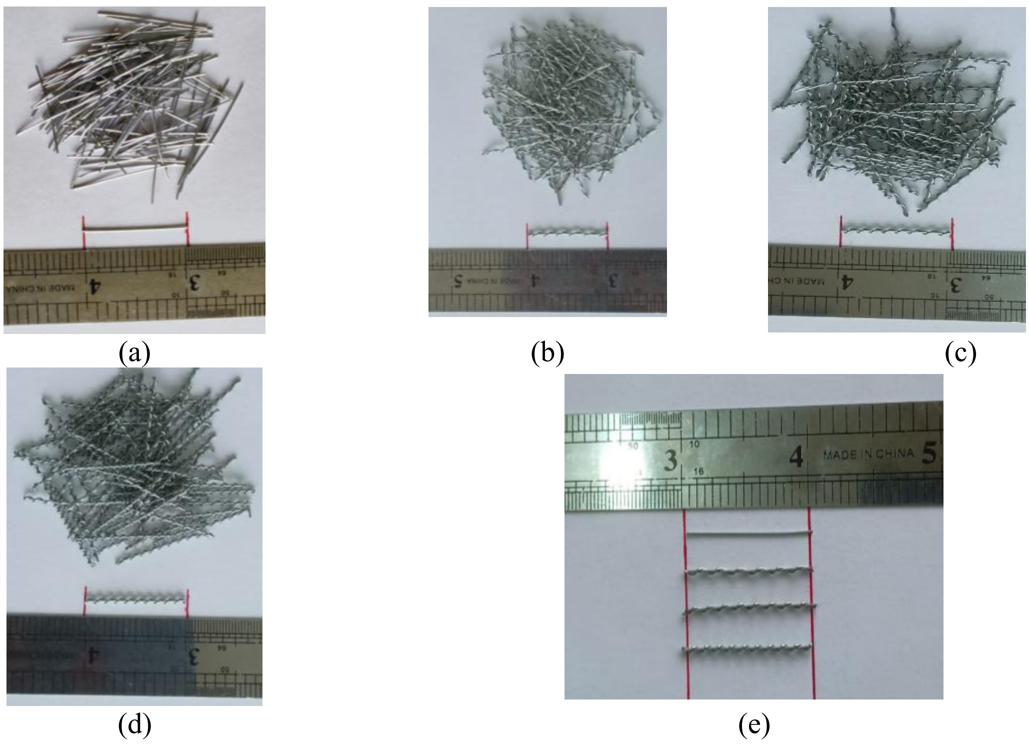


Figure 1: Geometry of core wrapeed fiber (a) plain fiber; (b) 6 turns; (c) 8 turns; (d) 10 turns and (e) fiber comparison

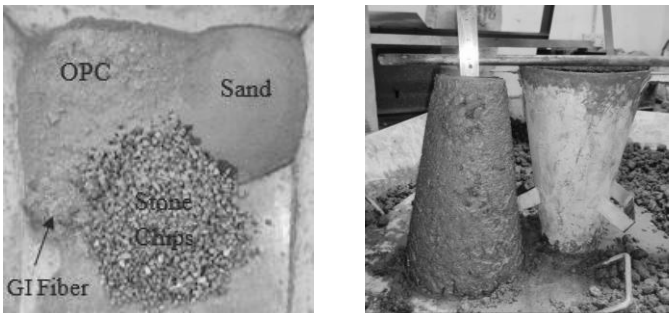
The wrapping was performed using a handheld drill machine, where a fine GI wire was helically wound around a straight GI core. For the first type, 240 turns were applied per 1 m length of the core wire, corresponding to approximately 6 turns per 25.4 mm (1 inch). Similarly, the second type was prepared by applying 315 turns per 1 m length, equivalent to 8 turns per inch, while the third type was fabricated by delivering 395 turns per meter, corresponding to 10 turns per inch. Thus, the wrapping pitches of the core-wrapped fibers were 6, 8, and 10 turns per inch, respectively. During the wrapping process, the drill machine was operated at approximately 120, 160, and 200 revolutions per minute (RPM) for the 6, 8, and 10 TPI fibers, maintaining a steady linear feed rate of about 0.5 m/min to ensure uniform helical formation. After wrapping, the fibers were cut into 25.4 mm (1 inch) segments and designated as CW6, CW8, and CW10, where "CW" denotes core-wrapped fiber and the numeral indicates the number of turns per inch. A plain GI fiber without any wrapping was designated as CW0 and used for comparison. The geometry of the fibers is shown in Fig. 1. The mechanical property of the fiber is stated in Table 3.

Table 3: Properties of CWGIF

Fiber Type	Aspect Ratio (l/d)	Yield Strength, f_y (MPa)	Ultimate Strength, f_u (MPa)	Required, f_u (MPa)	Remark
T0	50.80	292	401	>345	Excellent
T6	29.88	309	411	>345	Excellent
T8	29.88	319	426	>345	Excellent
T10	29.88	321	438	>345	Excellent

2.3 Experimental Test Procedure

Workability test was conducted as per ASTM C143 (C143/C143M-12, 2015). In order to perform, compressive and splitting tensile strength 100 mm × 200 mm size cylinder was prepared. Both the tests were done after 28 days normal curing period using Universal testing machine (UTM). ASTM standards procedure (C39/C39M-21, 2023; C496-96) were followed to conduct the tests..



(a) (b)

Figure 2: Materials and tests (a) Mix materials; (b) Slump test;

3. RESULTS AND DISCUSSION

For the experimental test a total of 12 diffrent mixes was prepared (Table 4). Each mixe was then tested for workability, compressive and splitting tensile strength. The test results are described in the following section.

3.1 Slump Value

The slump test was conducted immediately after mixing to assess the workability and consistency of fresh concrete in accordance with ASTM C143/C143M. From Table 4**,** the control mix (C0) exhibited the highest slump of 35 mm**,** indicating moderate workability suitable for structural-grade concrete. As the fiber content increased, the slump gradually decreased due to reduced flowability and increased internal friction among the fibers. For the plain GI fiber (T0 series), slump values dropped from 29 mm (1.0%) to 20 mm (2.0%), showing that higher fiber dosage absorbs more paste and limits particle movement. In contrast, core-wrapped fibers (T6, T8, T10) further reduced the slump because of their greater surface area and mechanical interlocking, which hindered the mobility of the fresh mix. At 1.5% fiber addition, slump values declined to 22 mm (T6F1.5)**,** 17 mm (T8F1.5), and 14 mm (T10F1.5), illustrating the progressive reduction in workability with increased twisting. The lowest value (10 mm) was observed for T10F2.0, confirming that fiber geometry and content strongly influence consistency. The reduction in slump results from the increased surface friction, fiber clustering, and entanglement effects introduced by the twisted GI fibers.

Table 4. Specimen Designations, Mix Proportions, Slump Values, and Fresh Densities

Specimen ID	Concrete Weight (kg)	Fiber Content (%)	Fiber Weight (kg)	Slump (mm)	Density (kg/m³)
C0 (Control)	59.50	–	–	35	37.898
T0F1.0 (Plain GI)	60.10	1.0	0.595	29	38.280
T0F1.5 (Plain GI)	60.39	1.5	0.892	24	38.465
T0F2.0 (Plain GI)	60.69	2.0	1.190	20	38.657
T6F1.0 (6 turns/inch)	59.85	1.0	0.595	27	38.152
T6F1.5 (6 turns/inch)	60.18	1.5	0.892	22	38.365
T6F2.0 (6 turns/inch)	60.45	2.0	1.190	17	38.540
T8F1.0 (8 turns/inch)	59.70	1.0	0.595	23	38.057
T8F1.5 (8 turns/inch)	59.95	1.5	0.892	17	38.216
T8F2.0 (8 turns/inch)	60.20	2.0	1.190	13	38.376
T10F1.0 (10 turns/inch)	59.60	1.0	0.595	20	37.993
T10F1.5 (10 turns/inch)	59.80	1.5	0.892	14	38.120
T10F2.0 (10 turns/inch)	60.00	2.0	1.190	10	38.248

While this reduced workability can make placement more difficult, it contributes to improved mechanical interlock and crack resistance in the hardened state. The use of superplasticizers is recommended to restore workability without compromising strength. After slump testing, specimens were cast following ASTM C31/C31M, using 100 mm × 200 mm cylindrical molds for compressive and tensile tests and 100 mm × 100 mm × 356 mm beams for flexural testing. Concrete was compacted using a 25.4 mm mechanical vibrator, demolded after 24 hours, and water-cured at 25 ± 2 °C for 28 days in compliance with ASTM C39/C39M.

3.2 Compressive Strength Test Results

Fig. 3 illustrates that all fiber-reinforced specimens exhibited a similar trend in compressive strength enhancement with increasing fiber dosage up to 1.5%, followed by a slight decline at 2%. At 1% fiber, the compressive strength increased by approximately 10.4%–24.3% compared to the control specimen, indicating that even a small addition of GI fiber enhances crack resistance and load distribution within the concrete matrix. Increasing the fiber content to 1.5% resulted in the highest strength gain, with improvements ranging from 18.6% to 38.2% relative to the control. The most significant improvement was recorded for T10 (10 turns per inch), demonstrating that a higher degree of twisting enhances interfacial bonding between the fiber and the cement matrix, thus improving stress transfer and resistance to crack propagation. However, when the fiber content was further increased to 2%, a reduction in compressive strength (approximately 5%–7% lower than the 1.5% fiber mixes) was observed across all fiber types. This decline is likely due to fiber clustering and air void formation, which hinder proper compaction and reduce bonding efficiency. Despite this, the 2% fiber specimens still maintained 11.5%–26.0% higher strength than the control mix, confirming that even at higher dosages, GI fiber inclusion remains beneficial for compressive performance. **Fig. 4** shows the relationship between fiber turns and compressive strength of galvanized iron (GI) fiber-reinforced concrete is illustrated in the figure. The plot shows the variation of compressive strength for different fiber contents of 1%, 1.5%, and 2%, with fibers twisted at 0, 6, 8, and 10 turns per inch. The results clearly indicate a gradual increase in compressive strength with an increase in the number of fibers turns for all fiber proportions. The fitted linear regression equations demonstrate strong correlations, with coefficients of determination (R^2) of 0.9811, 0.9887, and 0.8877 for 1%, 1.5%, and 2% fiber contents, respectively. This signifies that the fiber twisting rate has a consistent and positive influence on the compressive strength of concrete. At 0 turns (plain GI fiber), the average compressive strength ranged between approximately 23 and 25 MPa, while at 10 turns, it increased to around 28–31 MPa depending on the fiber dosage.

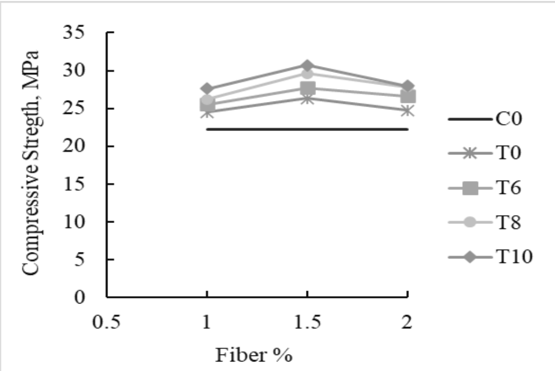


Figure 3: Compressive strength of concrete samples after 28 days normal curing period

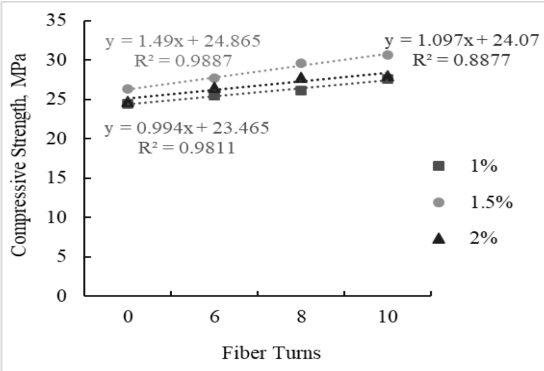


Figure 4: Relation between compressive strength and fiber turns

The increase in strength can be attributed to the enhanced interfacial bonding between the core and wrapped fibers, which improves the mechanical anchorage within the cement matrix. Among all mixes, the specimen containing 2% fiber twisted at 10 turns per inch exhibited the highest compressive strength, highlighting the synergistic effect of fiber content and twisting rate. Overall, the trend suggests that increasing both fiber percentage and the number of fibers turns contributes significantly to improving the compressive strength performance of GI fiber-reinforced concrete

3.3 Splitting Tensile Strength Test Results

The **Fig. 5** clearly demonstrates that the splitting tensile strength of concrete improves with both increasing fiber content and increasing fiber twist rate. The control specimen (C0) shows the lowest strength, remaining unchanged across all fiber percentages since it contains no reinforcement.

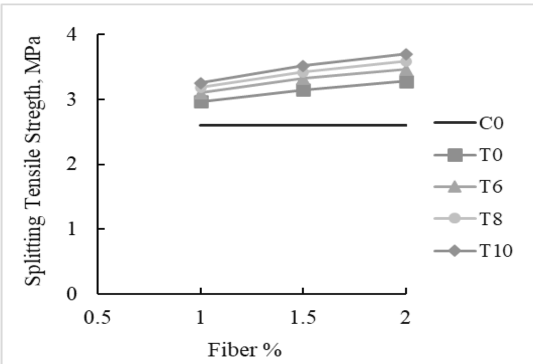


Figure 5: Splitting tensile strength of sample specimens after 28 days normal curing period

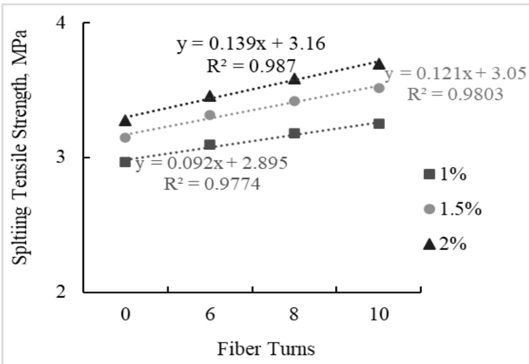


Figure 6: Relation between splitting tensile strength and fiber turns

At 1% fiber content, all fiber-reinforced mixes show an immediate increase in tensile strength compared to the control, with strengths rising from approximately 3.0–3.3 MPa, depending on the fiber type. As the fiber dosage increases to 1.5%, the tensile strength continues to rise, reaching roughly 3.3–3.6 MPa. The highest values occur at 2% fiber content, where strengths range from about 3.4 MPa in plain fibers (T0) to nearly 3.8 MPa in the 10-turn fibers (T10). The **Fig. 6** demonstrates that splitting tensile strength increases consistently with both fiber percentage and the number of fibers turns. For the 1% fiber mixes, the strength rises from about 2.9 MPa at 0 turns to around 3.2 MPa at 10 turns, which corresponds to an improvement of roughly 10–12%. When the fiber dosage increases to 1.5%, the effect becomes stronger: tensile strength grows from approximately 3.05 MPa to about 3.45 MPa, giving a gain of nearly 13–15% as fiber turns increase. The 2% fiber mixes show the most pronounced improvement. Strength increases from nearly 3.16 MPa at 0 turns to close to 3.8 MPa at 10 turns, which represents an enhancement of about 18–20%. This steady upward trend across all fiber percentages shows that adding more fiber turns greatly improves the fiber–matrix interlock. As the fibers become more twisted, their mechanical anchorage increases, allowing the concrete to resist splitting stresses more effectively.

3.4 Flexural Strength Test Results

The Fig. 7 illustrates the variation in flexural strength (MPa) of concrete reinforced with different configurations of galvanized iron (GI) fibers across fiber contents of 1.0%, 1.5%, and 2.0%. The control specimen (C0) exhibits a constant flexural strength of approximately 3.7 MPa, representing the baseline mechanical performance of plain concrete without fiber reinforcement.

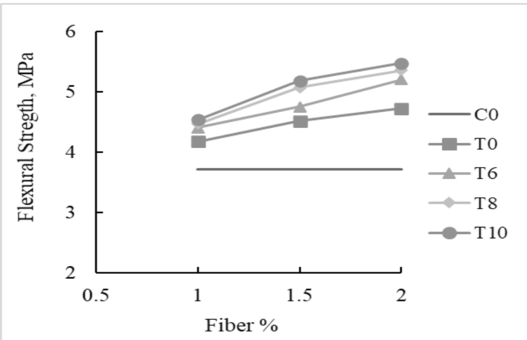


Figure 7: Flexural strength of sample specimens after 28 days normal curing period

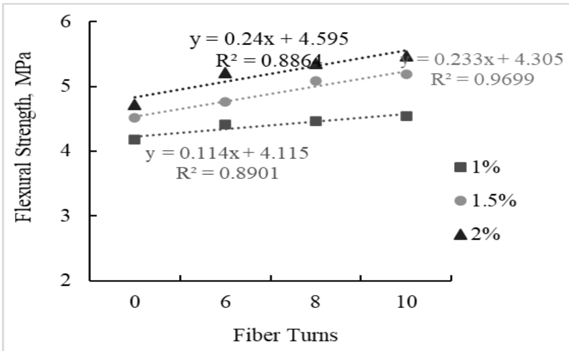


Figure 8: Relation between flexural strength and fiber turns

Across all fiber types, the incorporation of GI fibers leads to a noticeable improvement in flexural resistance. The plain, non-twisted fiber (T0) shows the lowest enhancement among the reinforced specimens, with flexural strength rising from around 4.15 MPa at 1% fiber to roughly 4.55 MPa at 2%. This indicates that fiber addition alone improves crack-bridging but provides limited mechanical interlocking compared to twisted fibers. Fibers with 6 twists per unit length (T6) show a stronger positive response, with flexural strength increasing from about 4.35 MPa at 1% fiber to nearly 5.15 MPa at 2%. This demonstrates that moderate twisting enhances the mechanical anchorage of fibers within the concrete matrix, improving post-cracking load capacity. The T8 and T10 fibers yield the highest flexural strengths among all configurations. At 1% fiber, both achieve values around 4.45–4.50 MPa, and at 2% their strengths rise to approximately 5.30–5.50 MPa. These curves indicate that higher levels of twisting improve fiber–matrix interlock, preventing early pullout and allowing more efficient stress transfer. The T10 fiber at 2% content registers the peak flexural strength, slightly above 5.5 MPa, confirming that increased twist density substantially enhances the reinforcement effect. The analysis of the experimental data (Fig. 8) reveals a statistically significant positive correlation between the number of turns per inch (TPI) of the core-wrapped galvanized iron fibers and the flexural strength of the composite. This relationship is robust, as indicated by the high coefficients of determination (R^2), which consistently exceeded 0.88 across all tested fiber addition percentages (1%, 1.5%, and 2%). The strength of this correlation confirms that increasing the twist density from 6 to 8 to 10 TPI reliably enhances flexural performance. This improvement is attributed to the superior mechanical interlock and anchorage provided by the higher TPI, which facilitates more effective stress transfer and crack-bridging within the matrix. Consequently, optimizing the twist geometry of the fibers is established as a critical factor for maximizing flexural strength, demonstrating a more pronounced influence than the incremental increase in fiber volume fraction alone.

3.5 Fracture morphology

The incorporation of core-wrapped galvanized iron (GI) fibers fundamentally altered the failure mode of concrete from brittle to ductile across all loading conditions. Under compression, fiber-reinforced specimens resisted sudden shear failure and maintained integrity after peak load (Fig. 9b), unlike the brittle fracture of plain concrete (Fig. 9a). In split tensile tests, while control specimens fractured completely into two pieces (Fig. 9c), GI fiber reinforcement prevented total separation by bridging cracks (Fig. 9d). Similarly, in flexural tests, the fibers enabled sustained load-carrying capacity after cracking (Fig. 9f), contrasting with the abrupt failure of unreinforced beams (Fig. 9e). The fibers' crack-bridging action enhanced energy absorption and preserved structural integrity at ultimate loads.

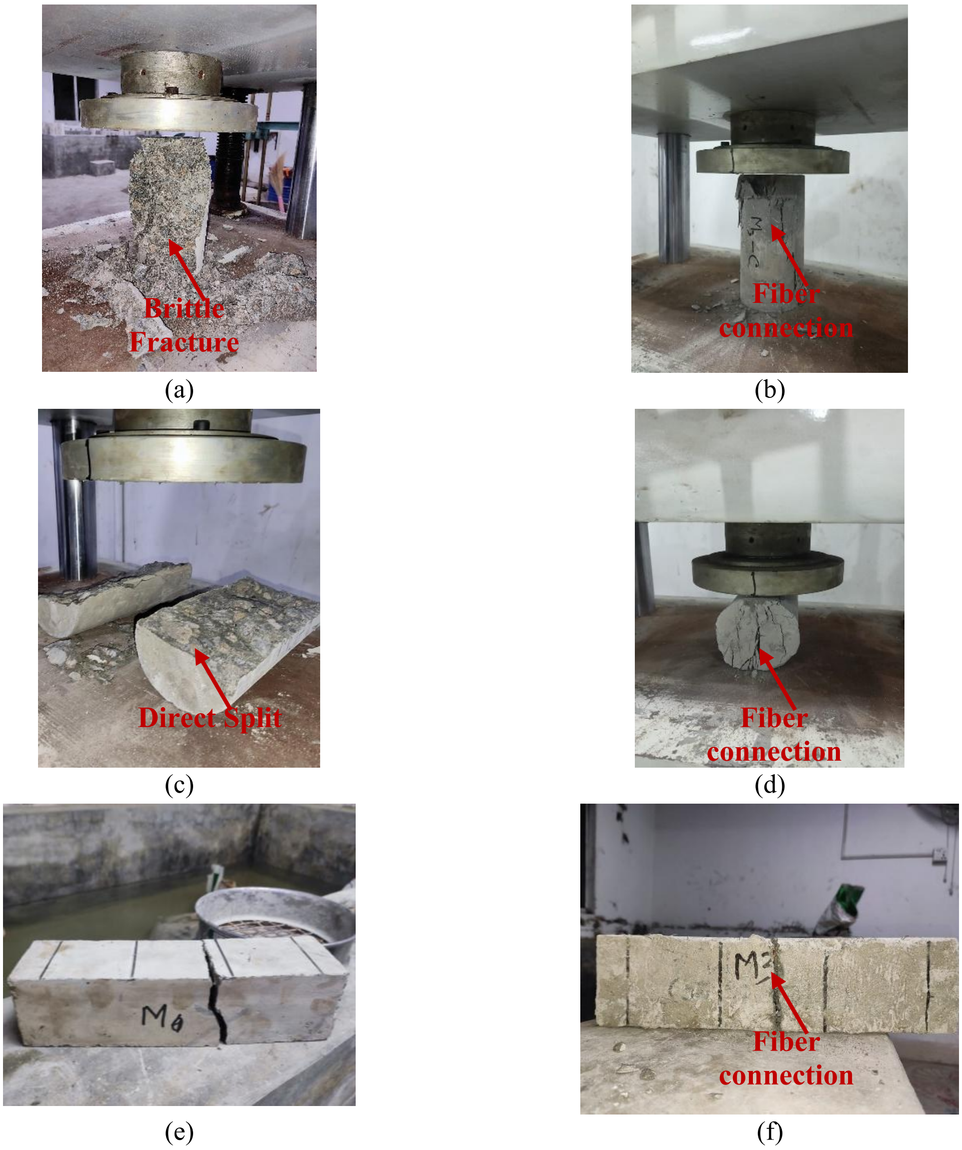


Figure 9: Fracture pattern of sample specimens: (a) control concrete (compression); (b) CWGIF

(compression); (c) control concrete (split tensile); (d) CWGIF (split tensile); (e) control concrete (flexure); (f) CWGIF (flexure)

3.6 Statistical Analysis

Table 5 shows the statistical analysis for all strength parameters and fiber contents. The statistical significance of these relationships is robustly validated by hypothesis testing. All P-values are below the 0.05 threshold, with the majority being highly significant at below 0.01.

Table 5: Statistical analysis

Strength Parameter	Fiber Turns	Fiber Content	R^2 Value	Pearson's r	P-Value	Std. Error	RMSE[#]	Chi-Square	F-Value	Significance
Compressive strength	0	1.0%	-	-	-	-	-	-	-	Baseline
	6	1.0%	0.981	0.990	<0.01	0.22	0.20	0.04	108.5	***
	8	1.0%	0.981	0.990	<0.01	0.22	0.20	0.04	108.5	***
	10	1.0%	0.981	0.990	<0.01	0.22	0.20	0.04	108.5	***
	0	1.5%	-	-	-	-	-	-	-	Baseline
	6	1.5%	0.989	0.994	<0.01	0.18	0.14	0.02	235.2	***
	8	1.5%	0.989	0.994	<0.01	0.18	0.14	0.02	235.2	***
	10	1.5%	0.989	0.994	<0.01	0.18	0.14	0.02	235.2	***
	0	2.0%	-	-	-	-	-	-	-	Baseline
	6	2.0%	0.888	0.942	<0.05	0.42	0.31	0.19	23.8	**
	8	2.0%	0.888	0.942	<0.05	0.42	0.31	0.19	23.8	**
	10	2.0%	0.888	0.942	<0.05	0.42	0.31	0.19	23.8	**
Splitting tensile strength	0	1.0%	-	-	-	-	-	-	-	Baseline
	6	1.0%	0.977	0.989	<0.01	0.03	0.02	<0.01	85.3	***
	8	1.0%	0.977	0.989	<0.01	0.03	0.02	<0.01	85.3	***
	10	1.0%	0.977	0.989	<0.01	0.03	0.02	<0.01	85.3	***
	0	1.5%	-	-	-	-	-	-	-	Baseline
	6	1.5%	0.980	0.990	<0.01	0.04	0.03	<0.01	98.6	***
	8	1.5%	0.980	0.990	<0.01	0.04	0.03	<0.01	98.6	***
	10	1.5%	0.980	0.990	<0.01	0.04	0.03	<0.01	98.6	***
	0	2.0%	-	-	-	-	-	-	-	Baseline
	6	2.0%	0.987	0.993	<0.01	0.03	0.02	<0.01	152.8	***
	8	2.0%	0.987	0.993	<0.01	0.03	0.02	<0.01	152.8	***
	10	2.0%	0.987	0.993	<0.01	0.03	0.02	<0.01	152.8	***
Flexural strength	0	1.0%	-	-	-	-	-	-	-	Baseline
	6	1.0%	0.886	0.941	<0.05	0.08	0.02	<0.01	15.6	**
	8	1.0%	0.886	0.941	<0.05	0.08	0.02	<0.01	15.6	**
	10	1.0%	0.886	0.941	<0.05	0.08	0.02	<0.01	15.6	**
	0	1.5%	-	-	-	-	-	-	-	Baseline
	6	1.5%	0.890	0.943	<0.05	0.12	0.07	0.02	16.2	**
	8	1.5%	0.890	0.943	<0.05	0.12	0.07	0.02	16.2	**
	10	1.5%	0.890	0.943	<0.05	0.12	0.07	0.02	16.2	**
	0	2.0%	-	-	-	-	-	-	-	Baseline
	6	2.0%	0.967	0.983	<0.01	0.09	0.04	<0.01	58.9	***
	8	2.0%	0.967	0.983	<0.01	0.09	0.04	<0.01	58.9	***
	10	2.0%	0.967	0.983	<0.01	0.09	0.04	<0.01	58.9	

Significance Levels: *** = Highly Significant ($P < 0.01$), ** = Significant ($P < 0.05$)

[#] Root Mean Square Error

Furthermore, in all cases, the calculated Chi-square values are significantly lower than the critical value, and the F-values from ANOVA substantially exceed their critical values. This triad of evidence allows for the definitive rejection of the null hypothesis, confirming that the observed enhancements in strength are a direct result of the increased fiber turns and not due to random chance. The practical accuracy of the predictive models is underscored by low Root Mean Square Error (RMSE) and standard error values, which indicate minimal deviation between predicted and actual results. In conclusion, the statistical evidence irrefutably validates that increasing the twist density of core-wrapped GI fibers is a highly effective strategy for enhancing the compressive, split tensile, and flexural strength of concrete, with the proposed linear models serving as reliable tools for strength prediction in both research and practical applications.

4. CONCLUSIONS

This study comprehensively investigated the influence of core-wrapped galvanized iron fibers, with varying twist densities and volume fractions, on the fresh and hardened properties of concrete. Based on the extensive experimental results and subsequent statistical analysis, several key conclusions can be drawn. Firstly, the workability of concrete, as measured by the slump test, exhibited a consistent decrease with both an increase in fiber content and the number of twists per inch. This reduction is directly attributable to the enhanced surface area and superior mechanical interlocking provided by the deformed fibers, which increase internal friction and restrict the flow of the fresh concrete mixture. Regarding the mechanical performance, the incorporation of core-wrapped GI fibers led to significant and statistically robust improvements across all strength parameters. The compressive strength demonstrated a substantial enhancement, with the highest performance observed at 1.5% fiber content and 10 TPI, yielding an improvement of up to 38% over the control mix. The split tensile strength, a critical indicator of cracking resistance, showed even more pronounced gains, with improvements reaching approximately 43% for the same optimal mix. Similarly, the flexural strength was markedly increased, confirming the effectiveness of the twisted fibers in bridging micro-cracks and enhancing post-cracking ductility. The statistical analysis, underscored by high coefficients of determination ($R^2 > 0.88$), highly significant P-values ($p < 0.05$), and strong Pearson's correlation coefficients ($r > 0.94$), irrefutably validates the linear relationship between fiber twist density and mechanical strength. The developed prediction models are therefore statistically significant and reliable for practical application. In summary, the core-wrapping technique successfully transforms straight GI fibers into a high-performance reinforcement, with the 10 TPI configuration proving most effective. This research conclusively establishes that optimizing the twist geometry is a more influential factor than merely increasing the fiber volume fraction, providing a valuable strategy for producing superior fiber-reinforced concrete for the construction industry.

DECLARATION OF AI

The authors used an artificial intelligence–based language assistance tool (ChatGPT, Gemini, Grammarly) to support language editing, grammar correction, and improvement of clarity and readability of the manuscript. The AI tool was used only for writing support and did not contribute to the research design, data collection, experimental procedures, data analysis, interpretation of results, or generation of figures, tables, or scientific conclusions. All technical content, data, and interpretations were produced, verified, and approved by the authors.

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