Compression Of Tensile Strength Fiber Reinforced Concrete With Different Types Of Fibers

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ABSTRACT:
Considered superior in mechanical properties and durability when compared to ordinary concrete, fiber-reinforced concrete has always been appealing in the construction business. This paper includes glass fiber and steel fibers to see how compressive strength, a key factor for tensile strength, varies in concrete. Many concrete specimens were cast with varying quantities of glass fiber and steel fiber but maintaining the same mix design of concrete. The compressive strength was tested at days 7, 14, and 28 of curing. It was seen that both fibers enhanced the compressive strength of concrete; however, the improvement brought about by steel fibers was more appreciable because steel fibers can carry loads better and have a better bonding mechanism with the cementitious matrix. Glass fibers are not as efficient when it comes to augmenting compressive strength but do increase ductility and resistance to cracking and corrosion. This finding implies that the role of fiber type selection must be based on the structural requirements and environmental conditions, with steel fibers being suitable for high-strength applications and glass fibers being more useful in more aggressive environments and in cost-limited projects. This study presents practical information for the optimum use of fibers in concrete for improved performance and durability.

Keywords:*Fiber-reinforced concrete, compressive strength, glass fiber, steel fiber, concrete reinforcement.*

1. INTRODUCTION

Concrete has been one of the most widely used construction materials globally due to its high compressive strength and versatility. However, its inherent brittleness, low tensile strength, and susceptibility to cracking under load limit its performance in structural applications [1]. To overcome these limitations, researchers have explored various methods of improving concrete’s mechanical properties, among which fiber reinforcement has emerged as an effective solution [2].

Fiber-reinforced concrete (FRC) involves the incorporation of discrete fibers into the concrete matrix to enhance its structural behavior, particularly under tension and flexure. The addition of fibers such as steel, glass, synthetic polymers, or natural materials can significantly improve crack resistance, ductility, toughness, and impact resistance [3]. Among these, steel and glass fibers are two of the most commonly used types due to their distinct advantages—steel fibers offer high tensile strength and excellent bonding with cementitious materials [4], while glass fibers provide corrosion resistance and cost-effectiveness, making them suitable for aggressive environments [5].

The primary focus of this study is to evaluate the effect of steel and glass fibers on the compressive strength of concrete, which indirectly influences its tensile characteristics. Since compressive strength is a fundamental property that affects overall structural performance, understanding how different fiber types influence it is crucial for practical design and application.Numerous studies have demonstrated the effectiveness of fiber reinforcement in enhancing concrete performance. For instance, Banthia and Sappakittipakorn [6] reported significant improvements in energy absorption and ductility when steel fibers were added to concrete. Similarly, Soroushian et al. [7] observed increased post-cracking strength and reduced spalling in fiber-reinforced concrete systems. Research by Naaman and Homrich [8] further supports the use of synthetic fibers like glass to control shrinkage cracks and improve durability.

In recent years, several researchers have focused on optimizing fiber dosage, type, and orientation to achieve the best mechanical performance. Studies by Nataraja et al. [9] and Ganesan et al. [10] investigated the effects of varying fiber content on compressive and flexural strength, concluding that moderate fiber dosages yield optimal results without compromising workability. Additionally, investigations into hybrid fiber systems [11, 12] have shown promising synergistic benefits, although this study focuses solely on single-fiber systems for clarity and direct comparison.

All these properties are influenced by the composition of the concrete mixture, the material of the fibers used, their shape, processing fiber reinforced concrete and the amount of fibers used. Load displacement diagram of fiber reinforced concrete with different types of fibers and different dosage compared with load displacement diagram ofplain concrete is in the Fig. 1.

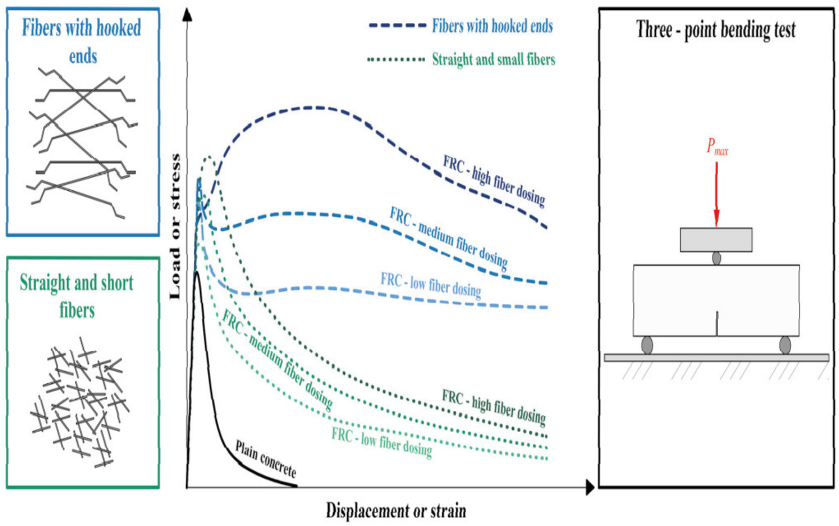

Fig. 1. Load displacement diagram of fiber reinforced concrete with fibers with hooked ends and straight fibers according to Marcalikova et al., 2020.

This research aims to contribute to the existing body of knowledge by experimentally analyzing the compressive strength development of concrete reinforced with glass and steel fibers at different percentages. The findings will assist engineers and researchers in selecting appropriate fiber types based on structural needs and environmental conditions, ultimately promoting more durable and efficient concrete structures.

2. MATERIALS & METHODOLOGY

2.1 MATERIALS

a) Cement

Cement is a binding material and chemical substance used for construction which sets, hardens, and adheres other materials to bind them together. Depending on the requirements, several types of cement are available today. Generally, in construction, we use OPC (Ordinary Portland Cement) and PPC (Portland Pozzoloan Cement). PPC usually exceeds and in some cases tends to surpass the strength of OPC over time. While OPC provides good strength, its durability might be slightly lower in certain conditions. PPC is used in construction works such as dykes, marine works, and sewage pipe works while OPC is used in other structures such as residential and commercial buildings, bridges, and other large structures.

We used OPC with Grade 53

Table1: Properties of cement

S. No	Description	Values
1	Normal Consistency of cement	29.8%
2	Specific Gravity	3.28
3	Fineness	6.4%
4	Initial Setting Time	30 min

Fig. 2. Cement

5	Final Setting Time	250 min

b) Fine Aggregate (F.A)

Fine aggregate is a material which passes through an IS sieve 4.75mm. The river sand is used Fine aggregate cubical or rounded shape with a smooth surface texture. Being cubical, rounded, and smooth texture, it gives good workability. The Fine aggregate also helps the cement paste to hold the Coarse aggregate.

Fig. 3.Fine Aggregate (F.A)

Table 2: Properties of Fine Aggregate

S. No	Description	Values
1	Specific Gravity	2.7
2	Sieve Analysis of sand	ZONE -II
3	Bulking of Sand	7.6
4	Water Absorption	3.36%

c) Coarse Aggregate (C.A)

Coarse aggregate is a material which retained through an IS sieve 4.75mm to 80mm sieve. Coarse aggregate shall consist of naturally occurring materials (Silica, Quartz,etc.,) such as gravel or resulting from the crushing of parent rock, to include natural rock, slag, expanded clays and shales, and other approved inert materials with similar characteristics, having hard, strong, durable particles, conforming to the specific requirements of this Materials. It is in angular shape should not possess high flakiness dues to flakiness the aggregate may break easy and the strength decreases. It is available in the ocean and river bed. Mainly granite, marble and beasalt stones are used in coarse aggregate.

Table 3: Properties of Coarse Aggregate

S. No	Description	Values
1	Specific Gravity of Coarse Aggregates	2.7
2	Water Absorption of Coarse Aggregates	0.43%
3	Impact Test	23.48%
4	Los Angeles Test	32.5%
5	Aggregate Crushing test	28.64%
6	Flakiness index	22%
7	Elongation index	17%

Fig. 4.Coarse Aggregate

Water plays a crucial role in concrete mix design by ensuring proper cement hydration and optimizing strength development. In this study, local tap water was used for all mixes. The water-cement ratio was maintained between 0.42 and 0.45.

d) Steel Fiber

Steel fiber Crimped steel fibers improve concrete by raising the interacting bond strength, crack resistance, and flexural performance. A deformed shape strengthens the concrete's resilience by increasing toughness and energy absorption against impact and fatigue loadings.

Table 4: Properties of Steel fiber

Properties	Value
Length (L)	50mm
Diameter (d)	0.2mm
Aspect Ratio(L/d)	25
Specific gravity	7.85


Fig. 5. Steel fiber

e) Glass fiber

Glass fibers are short strands of chopped fibers generally in lengths varying from a few millimeters to a couple of centimeters. They have extensive use in composite materials to increase strength, toughness, and crack resistance. These fibers could be added to concrete, polymer, or resin to improve mechanical properties such as tensile strength, flexural strength, and impact resistance.

Table 5: Properties of glass fiber

Property	Values
Tensile strength	2000-4000 MPa
Melting Point	1200 to 1500 0c
Density	2.7 g/cm^3
Youngs Modulus	70-80MPa
Fabric diameter	5-30 microns
Fabric GSM	200


Fig. 6. Glass fiber

Admixture The study utilized the superplasticizer SNP (Sulphonated Naphthalene Polymers) of specific gravity 1.20, having a brand name of TEC® MIX 550 which has enhanced water reduction properties, to improve workability and reduce water demand in the concrete mix.

2.2 METHODOLGY

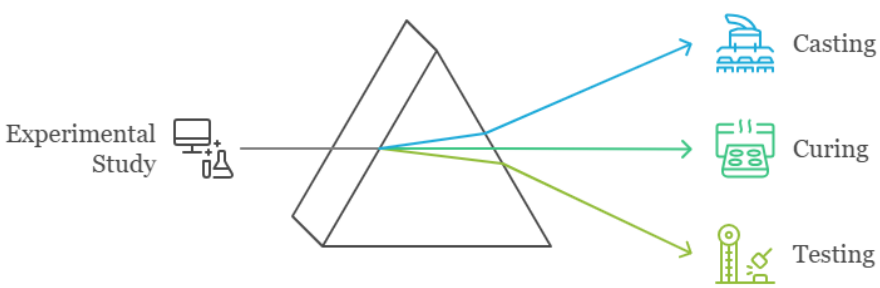

Fig. 7. Flow Chart for Methodology

A well-arranged experimental consideration was carried on the mechanical property testing of fiber-reinforced concrete. Concrete test specimens were prepared with varying fiber content under set curing conditions and were subjected to compressive and flexural strength tests afterward. Cubic specimens were used for compression testing, whereas beam specimens were used for flexural testing. The test results were capable of laying a field of study on the strengthening, ductility, and crack resistance imparted by fibers and thus the possibility of high-performance construction materials.

2.3 MIX DESIGN

The research sought to assess the effectiveness of Steel Fibre Reinforced Concrete (SFRC) and Glass Fibre Reinforced Concrete (GFRC). The concrete was formulated for M30 grade in accordance with IS 10262:2009, ensuring a harmonious balance among workability, strength, and durability while integrating fibres in varying proportions. A control mix of plain cement concrete (PCC-M30) was initially prepared. This was succeeded by fibre-reinforced variants containing different percentages of steel and glass fibres. The mix proportions for PCC are detailed in the accompanying table 6.

Table 6: Mix proportion of M30 grade concrete

Component	Cement	Fine aggregate	Coarse aggregate	Water	W/C Ratio
Content kg/m^3)	440.96	819.46	946.52	185.20	0.42

The mix proportions are 1:1.8:2.1

The fibre reinforced concrete mixes were modified based on the fibre dosage levels (0.5 %, 1.0%, 1.5 % by volume of concrete) requiring adjustments in the volume fractions of other materials to maintain mix consistency.

Fiber incorporation and placement

1. Steel fibre reinforced concrete (SFRC)

Crimped steel fibers were incorporated at volumes of 0.5%, 1%, and 1.5% of the concrete mix. These fibers were evenly dispersed throughout the mixture to enhance tensile strength, toughness, and crack resistance. The inclusion of fibers diminished workability, necessitating the use of a superplasticizer.

2. Glass fibre reinforced concrete (GFRC)

Alkali-resistant air glass fibers were incorporated into concrete at concentrations of 0.5%, 1.0%, and 1.5%. The glass fibers were evenly distributed, improving both exhaust and impact resistance. However, a higher fiber content resulted in greater challenges during mixing and placement, as it diminished workability.

3. RESULTS AND DISCUSSION

Samples composed of standard concrete and two varieties of fiber-reinforced concrete were cast in the laboratory of VŠB-TU Ostrava. In total, 7 series of samples were produced, each varying in fiber dosage and type. For each series of samples, tests were conducted to measure density, cube compressive strength, splitting tensile strength, and bending tensile strength. The average mechanical properties of both plain concrete and fiber-reinforced concrete are presented in Table 7, along with information regarding the standard deviation. Compressive strength and splitting tensile strength were evaluated using cubes measuring 150 x 150 x 150 mm. Bending tensile strength was assessed using beams measuring 150 x 150 x 600 mm, which were notched 25 mm at the midpoint of the span. Density was determined based on 12 test specimens for each series. Compressive strength and splitting tensile strength were evaluated on 6 specimens from each series, while bending tensile strength was assessed on 3 specimens from each series. A diagram illustrating all tests conducted is displayed in Figure 8.

Table 7: Basic mechanical properties plain concrete and fiber reinforced concrete.

Type concrete	Dosage [kg/m^3]	Density [kg/m^3]	Standard deviation [kg/m^3]	Compressive strength - cube [MPa]	Standard deviation [MPa]	Splitting tensile strength [MPa]	Standard deviation [MPa]	Bending tensile strength [MPa]	Standard deviation [MPa]
Plain concrete	0	2205	49.13	55.87	1.02	2.99	0.37	3.14	0.23
	40	2248	19.26	57.10	3.53	4.18	0.27	4.58	0.38
FRC –Steel Fiber	75	2273	25.59	64.01	2.73	5.01	0.55	4.78	0.16
	110	2294	23.39	59.32	2.44	5.88	0.35	5.45	0.29
	40	2267	34.46	56.59	2.61	5.18	0.49	5.96	0.71
FRC –Glass Fiber	75	2289	20.01	60.39	2.31	7.35	0.30	9.65	1.54
	110	2305	27.30	57.55	3.06	7.63	0.35	12.11	1.41

Fig. 8. a) Compressive strength cube

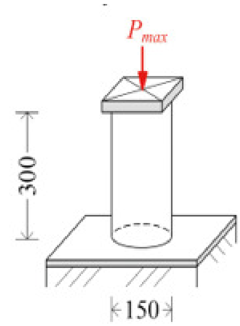

Fig. 8. b) Compressive strength static modulus of elasticity cylindrical

Fig. 8. c) Splitting tension strength

Fig. 8. d) Bending tensile strength two-point test

One of the key properties monitored in fiber reinforced concrete is the splitting tensile strength. The relationship between the splitting tensile strength and the quantity of fibers in the concrete is illustrated in Fig. 9. There is a significant increase in splitting tensile strength when compared to plain concrete. For fiber reinforced concrete containing Steelfibers at a dosage of 40 kg/m3, the tensile strength increased by 40%. In contrast, for fiber reinforced concrete with Glassfibers at the same dosage of 40 kg/m3, the increase was as much as 73%. According to the functional relationship depicted in Fig. 9, a strong correlation between the increase in splitting tensile strength and the dosage can be observed, which can be quantified by the R2 value. In both instances of fiber reinforced concrete, the R2 value approaches 1.0. Another critical property of fiber reinforced concrete is the bending tensile strength. The relationship between bending tensile strength and fiber quantity is presented in Fig. 10. For fiber reinforced concrete with Steelfibers at a dosage of 40 kg/m3, an average bending tensile strength of 4.58 MPa was recorded. In the case of fiber reinforced concrete with Glassfibers at the same dosage, the average bending tensile strength reached 5.96 MPa. The increase in bending tensile strength compared to plain concrete was 46% for fiber reinforced concrete with Steelfibers, and 89% for fiber reinforced concrete with Glassfibers. This also demonstrated a strong correlation between the model of bending tensile strength dependence and the fiber quantity. The R2 value was determined to be 88.8% for fiber reinforced concrete with Steel fibers, and 99.3% for fiber reinforced concrete with Glassfibers.

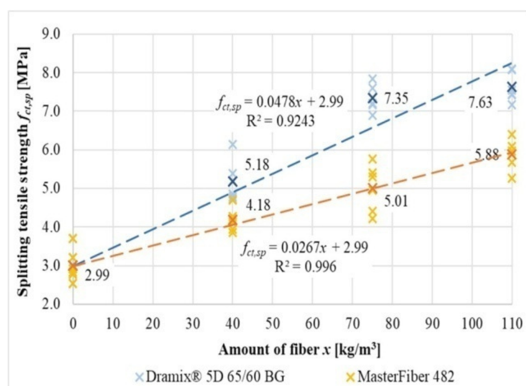

Fig. 9. Functional dependence of splitting tensile strength on the amount of fibers.

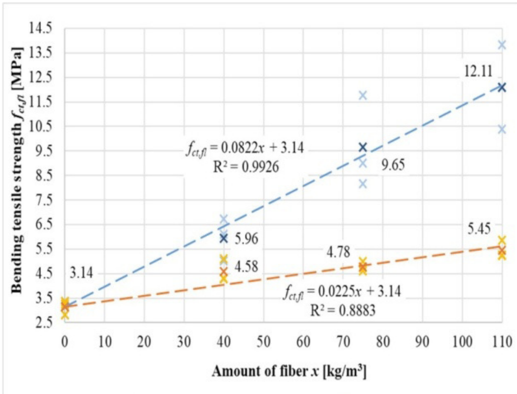

Fig. 10. Functional dependence of bending tensile strength on the amount of fibers.

Further evaluations of plain concrete were conducted, during which the cylindrical compressive strength and modulus of elasticity were also assessed. Tests for cylindrical compressive strength and modulus of elasticity were carried out on cylinders measuring 150 mm in diameter and 300 mm in height. From 6 test specimens, the mean cylindrical compressive strength was found to be 48.85 MPa, while the average modulus of elasticity, based on 3 test specimens, was determined to be 27.13 GPa.

4. CONCLUSION

The paper deals with the determination of mechanical properties of fiber reinforced concrete. A total of seven series of samples were evaluated, varying in the type of fibers utilized and the quantity of dispersed reinforcement incorporated into the concrete mixture.

Two types of fibers were selected, specifically straight and short fibers and fibers with double hooked ends. Dosing was chosen with respect to previous research at 0, 40, 75 and 110 kg/m^3. Comparison of the effect on compressive strength, splitting tensile strength and bending tensile strength was performed.

The conclusions drawn from the article are outlined as follows:

- Both types of fiber reinforced concrete exhibited a modest increase in compressive strength, reaching up to 15% with a dosage of 75 kg/m3.
- However, at a higher dosage of 110 kg/m3, a detrimental reduction in compressive strength was noted.
- Even at the lowest dosage of 40 kg/m3, there was a notable enhancement in both splitting tensile strength and bending tensile strength, with a more pronounced increase observed in fiber reinforced concrete utilizing fibers with double hooked ends.

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