

EFFECT OF NATURAL RAW FIBERS ON MECHANICAL PROPERTIES OF FIBER REINFORCED CONCRETE: A STEP TOWARDS SUSTAINABILITY

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ABSTRACT:

Concrete is the mostly used constructional material in industry and have versatile quality in nature. Fibrous concrete has significant factor that improve the scale and value to concrete for humid environments. Day by day abundant demand and use of concrete is increasing in construction industry. It is considered as a 2nd largest building material due to the major productivity. By the use of fibrous concrete, some bonding issues have been addressed and mitigate the environmental problems. Keeping in this view, an experimental based study is conducted to evaluate the strength of fiber reinforced concrete at different percentages 0%, 0.5%, 1.0%, 1.5% and 2.0%. All percentages are added by the weight of concrete with all fibers. In this connection, forty-five cylinders of five mixes are prepared. Workability checked of fresh concrete during the pouring of concrete cylinders. Poured cylinders' samples are left for different curing ages at 7 and 28 days. Thirty cylinders for compression at 7 and 28days but fifteen cylinders for split tensile test at 28days with all fibers i.e. glass fiber, steel fiber, coconut fiber and polypropylene fiber. After curing, compression and split tensile tests are performed to check the strength of hardened concrete. Workability of five mixes lies between 40-90mm and compression strength is increased at 1% replacement with all fibers which is suitable for sustainable construction. Also, fibrous concrete is suitable for humid environment where high strength and voids less concrete are required like plaster in external walls and all structural components. Addition of fibers in concrete may improves the strength parameters as well as to increase the bonding and tensile properties of concrete. It reduces the quantity of water to be used in concrete. Also, the use of different types of fibers has been proved to be economical and is considered as environmentally friendly construction material.

1. INTRODUCTION

Concrete is the most demanding building construction material in construction industry. Utilization of concrete is now increasing day by day (Ahmad, J., et al., 2023). Several environmental problems are produced by the usage of ordinary concrete which can never be neglected and needed to be taken under consideration. Many natural resources are produced to use in concrete by the partial replacement of coarse and fine aggregates in concrete (Bittner, C. M., et al., 2022). One ton cement produces around one ton CO₂ into the atmosphere which is around 7% of the world's annual production. Now it is our responsibility to protect the environment and preserve natural resources for future generations (Amin, K. F., et al., 2021). This is right time for Pakistan to identify residue in order to protect the environment and meet construction needs without depleting natural resources (Ban, Y., et al., 2020).

Mostly cementitious concrete faces so many defects due to improper mixing, poor tensile strength and bonding issues (Farhan, S. A., et al., 2023). There are so many waste products which can be utilized in many productive ways after recycling. By the addition of recycled waste materials in concrete, that may improve the bonding behavior and mechanical properties (Hou, S., et al., 2024, Li H., et al., 2024). After utilizing waste fibrous materials from our surroundings, such as steel fiber, Sugarcane fiber, Bamboo fiber and Jute Fiber etc., cost of construction projects will have to be reduced which is the great impact on our economic factor (Tai, Y., et al., 2024). Better compatibility, good thermosetting, and binding material due to low density, good mechanical qualities, good thermal insulation, low cost, unavailability, ease of approach, and free disposal are the attributes which present the versatile and prior properties of natural fibers (Iqbal, M. A., et al., 2024), (Kiamahalleh, M. V., et al., 2024). Though natural fibers have broadly been explored in consideration of their thermal, mechanical and morphological

behavior like tensile, water absorption and compressive properties. Raw materials can be used after proper recycling and adequate treatment as per the requirement (Tiwari, S., et al., 2020). Waste materials like steel fiber, sugarcane fiber, bamboo fiber and jute fiber are used in different forms as construction materials after recycling for beneficial purposes (Ubayi, S. S., et al., 2024), (Veerappan, P., et al., 2024).

This research study evaluates the use of waste fibers in concrete and to establish a sustainable environment for green construction (Li, L., et al., 2024, Vivas K. A., et al 2024). Also, it explores the bonding and strength properties of concrete. Fibrous material may improve the durability properties as well (Liu S.,et al, 2024; Wang Y. 2024).

Now a days, different geopolymers with different behavior have been used as a building material in many structural applications like foundations, beams and minor structural applications (Ahmed et al., 2022). Raw fibers are added in concrete to improve the bonding, durability and mechanical properties. Similarly, the key benefit is to reduce the environmental problems and cost factor which may leads to Green and sustainable construction (Zhao, X., et al., 2024), (Zafeer, M. K., et al., 2023).

Strength of fibrous concrete of all mixes are not significantly changed at replacement of cement with different percentages. All fibers can be used at 0.5% and 1.0% for mixing of concrete without any loss of strength. The use of fibers is recommended for normal FRC for structural and aesthetic purposes. Also, FRC is safe for human to be used in the construction industry.

2. MATERIALS AND METHODS

Main ingredients of concrete consist of cement, fine aggregates and coarse aggregates. Some waste natural fibers are used in concrete with addition as a replacement of cement. Detail of fibers are described in Fig. 1. Chemical reaction starts when water added in cement then as a result heat produced. It directly affects the strength property of concrete.

- Cement (OPC grade 43) is used to prepare a normal concrete. Chemical and physical properties of cement are described in Table 2 and Table 5 respectively.
- Chenab sand and Margalla crush are collected from a single source to prepare concrete samples. Physical properties of sand and crush are shown in Table 3 & Table 4 respectively.
- Tap water is used to prepare a concrete for proper workability, strength and durability.

Waste fibers like steel fibers, sugarcane fiber, bamboo fiber and jute fiber are collected from different sources and treat it properly for making a workable concrete. Jute fiber is collected from local source and wash with normal water. After drying, cut the fibers manually of approximately 20mm in length. Steel fiber, sugarcane fiber and bamboo fiber are taken from locally available market and treat it properly. Table 1 describes the physical properties of fibers and pictorial representation of different fibers are shown in Fig. 1.

Sr. No	Description	Length	Dia.	Color
1	Steel Fiber	20mm-40mm	0.4 microns	Black
2	Sugarcane Fiber	16mm	16 microns	White
3	Bamboo Fiber	12mm	18 microns	White
4	Jute Fiber	20mm	17 microns	Brown

Table 1. Physical properties of different types of fibers

All fibers are in dry condition with proper cutting to achieve the optimum results.



Figure 1. Different types of Fibers: a) Sugarcane Fiber, b) Steel Fiber c) Bamboo fiber, d) Jute fiber

Durability and mechanical properties may improve by the addition of waste fibers in concrete which is a great step towards sustainability.

Sr. No.	Property	Value
1	Specific Gravity	3.15
2	Consistency	28%
3	Initial Setting Time	45 mins
4	Final Setting Time	230 mins
5	Fineness	7%

Table 2. Physical Properties of Cement

Sr. No.	Property	Value
1	Specific Gravity	2.46
2	Fineness Modulus	2.48
3	Loose Bulk Density	1330 Kg/m ³
4	Compacted Bulk Density	1330 Kg/m ³

Table 3. Physical Properties of Fine Aggregates

Sr. No.	Property	Value
1	Specific Gravity	2.68
2	Fineness Modulus	2.44
3	Loose Bulk Density	1330 Kg/m ³
4	Compacted Bulk Density	1330 Kg/m ³

Table 4. Physical Properties of Coarse Aggregates

Sr. No	Materials	Cements %
1	SiO ₂	21.82
2	Al ₂ O ₃	6.49
3	Fe ₂ O ₃	1.93
4	CaO	60.74
5	Mgo	1.08
6	SO ₃	2.62
7	Na ₂ O	0.14
8	Free Cao	0.84

Table 5. Chemical properties of cement

2.1 Mix Design

M20 ordinary concrete is prepared having mix ratio is 1:2:4 and water cement ratio is 0.5. All fibers are added in concrete with different percentages 0%, 0.5%, 1%, 1.5% and 2% by the weight of concrete. The purpose of this research is to explore the fresh and mechanical properties of concrete by the use of fibers at different curing ages 7 and 28days.

3. SAMPLE PREPARATION

Concrete cylinders are used to prepare for split tensile and compression tests. Dimension of cylindrical concrete specimen is 6" × 6" × 12" (150mmx150mmx300mm) for all hardened concrete testing. In order to evaluate the mechanical properties, forty-five concrete cylinders are prepared confirming to ASTM C-192. Three cylinders are prepared of each mix of four types of fibers for compression test and tensile test. Slump test is performed on fresh concrete to check the workability of concrete. And hardened properties are evaluated by performing compression test at 7 and 28 curing days. And split tensile test is at 28 curing days. Mixing and casting of cylinders are shown in Fig. 2 and Fig. 3 respectively.



Figure 2. Mixing of concrete



Figure 3. Preparation and casting of sample

4. MECHANICAL PROPERTIES

Following tests are performed on fresh and hardened concrete to check the mechanical properties of concrete.

4.1 Fresh Concrete

4.1.1 Slump Test

Slump Test is performed on fresh concrete confirming to ASTM C-143 to measure the workability of four types of fibers as shown in Fig. 4 in order to check the water cement ratio and optimum quantity of fiber in concrete to make it workable.



Figure 4. Performing Slump Test

4.2 Hardened Concrete

Following tests are used to check the hardened properties of concrete.

4.2.1 Compression Test: After the slump test, pour the fresh concrete in well-oiled and cleaned concrete cylinders. Also poured in three layers by 25 hammering stocks in each layer for proper compaction according to ASTM C 39 and left for 24 hours to set. Hardened concrete cylinders are remolded and left for 7 and 28 days for curing.

Compressive strength of fibrous concrete is evaluated to explore the bearing capacity against medium rate of loading. Compression test is performed on fibrous concrete by adding different percentages 0.5, 1, 1.5 and 2% of all types of fibers at different curing ages 7 and 28 days which is shown in Fig. 5 and Fig. 6 where samples are shown before and after testing. Type of failure is shown in Fig. 7.



Figure 5. Compression Testing Machine



Figure 6. Sample before testing



Figure 7. Sample after testing

4.2.2 Split Tensile Test: Concrete has little tensile ability but considered as weak in tension. Different fibers are added in concrete to check the tensile behavior against loading. Improved tensile behavior of FRC is better for ordinary concrete to reduce the cracks. Split tensile test is performed on fibrous concrete cylinders conforming to ASTM C 496 by adding different percentages 0.5, 1, 1.5 and 2% of all types of fibers at 28 curing days which is shown in Fig. 8.

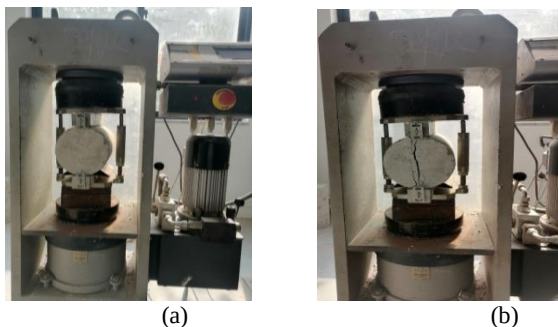


Figure 8. Split Tensile test (a) before testing (b) after testing

5. RESULTS AND DISCUSSIONS

Results of fresh and hardened properties of fibrous concrete have been discussed.

5.1 Slump Test Results

Concrete workability varies by adding different fibers at different percentage level. Workability trend shows that it decreases significantly by the addition of different fibers in concrete but it varies at different replacement level with different fibers. Maximum workability is achieved at the addition of 0.5% and 1% after that it decreases with all fibers.

Figure 9 shows the slump test results at different percentage level of fibers. This graph shows that workability of fresh concrete first increases and then decreases by adding different types of fibers i.e. steel fiber, sugarcane fiber, bamboo fiber and jute fiber with different replacement level.

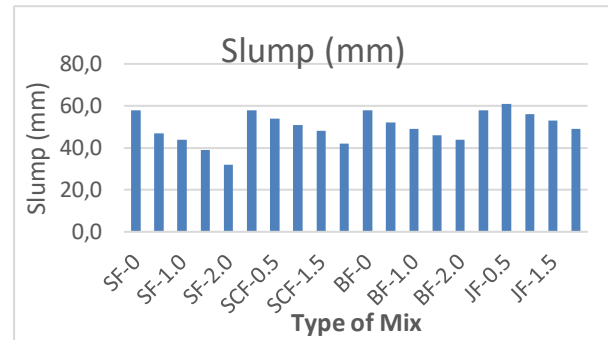


Figure 9. Slump test results at Different Percentage of different types of fibers

5.2 Compression Test Results

After the slump test, Compression test is performed on different fibers to explore the bonding and loading behavior.

5.2.1 Compression Test Results of Steel Fiber: Figure 10 represents the graphical representation of steel fiber which is added in concrete with different percentages 0.5%, 1.0%, 1.5% and 2.0%. Maximum compressive strength is obtained at 1.0% and 1.5% which is 10% and 6% higher than the unmodified sample.

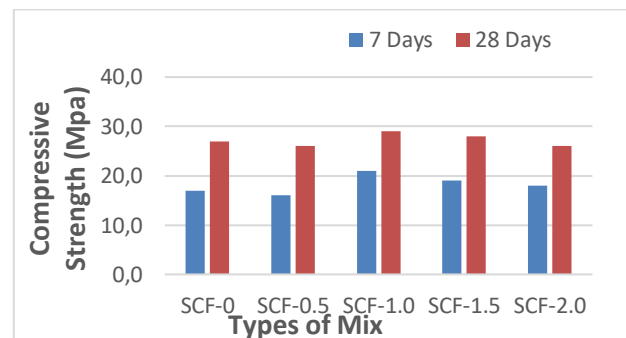


Figure 10. Results of compressive Strength at different replacement level of steel fiber at 7 and 28 curing days

5.2.2 Compression Test Results of Sugarcane Fiber: Compressive strength is increased by the addition of sugarcane fiber. Maximum strength is achieved at 1.0% addition which is 14%. Strength is going to reduce after increasing the percentages of sugarcane fiber because more mixing of concrete is required with more water. Figure 11 represents the trend between compressive strength and type of mix at different addition level of Sugarcane fiber.

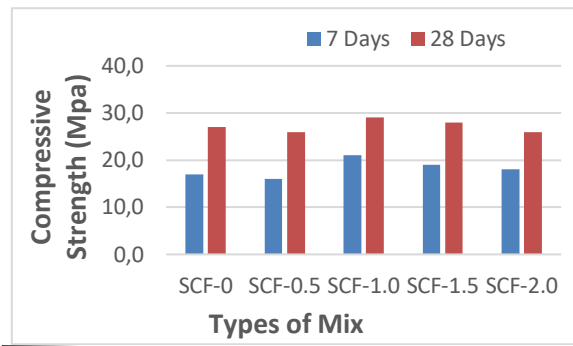


Figure 11. Results of compressive Strength at different replacement level of Sugar cane fiber at 7 and 28 curing days

5.2.3 Compression Test Results of Bamboo Fiber: Figure 12 shows the relation between compressive strength and bamboo fiber at different replacement level. Graph shows the increasing trend at 7 and 28 days. Maximum strength is achieved at 1.0% which is 6%. After the addition of bamboo fiber, strength decreases slightly.

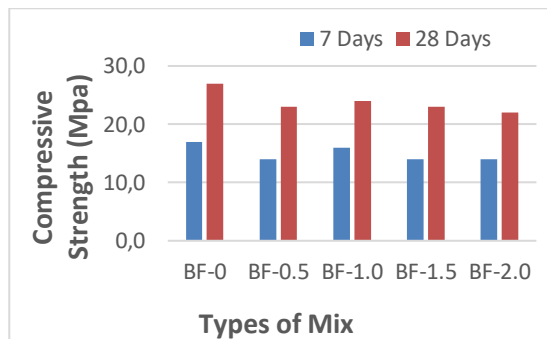


Figure 12. Results of compressive Strength at different replacement level of bamboo fiber at 7 and 28 curing days

5.2.4 Compression Test Results of Jute Fiber: Figure 13 indicates that the graphical representation between compressive strength and jute fiber at different replacement level. Strength increases slightly but also improve the tensile properties of concrete due to the elongated fiber. And maximum compressive strength of jute fiber is achieved at 1.0% which is 9% higher than the control mix.

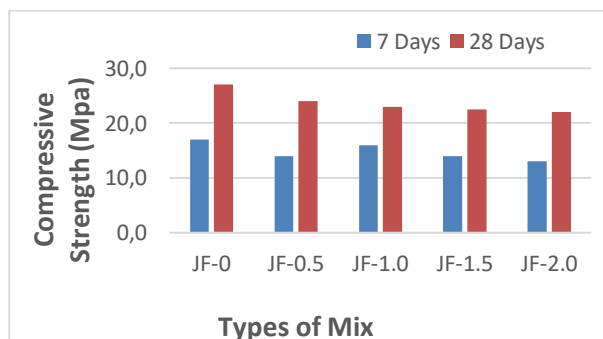


Figure 13. Results of compressive Strength at different replacement level of jute fiber at 7 and 28 curing days

5.3 Split Tensile Test Results

Figure 14 shows the graphical representation between the tensile strength and different types of fibers i.e. steel fiber, sugar cane fiber, bamboo fiber and jute fiber with different addition level at 28 curing days.

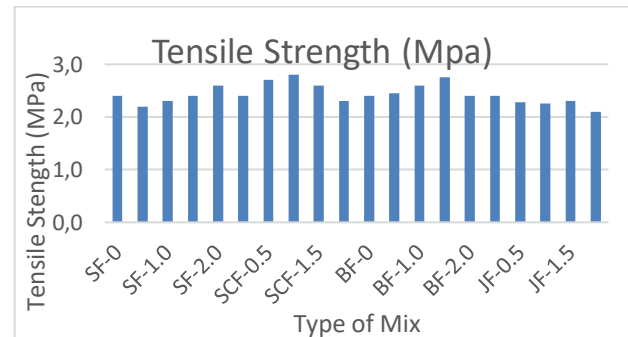


Figure 14. Summary of Split Tensile Strength of different types of fibers at 28 days

6. CONCLUSION

Following conclusions have been drawn from the experimental results.

All mixes have achieved the required workability between 50mm to 80mm which is suitable for ordinary concrete.

Compressive strength of concrete increases with the increase of different types of fibers. Maximum strength of steel fiber is obtained at 2% replacement which is 10%, maximum strength of sugarcane fiber is obtained at 1% replacement which is 14%, maximum strength of bamboo fiber is obtained at 1% replacement which is 6%. And maximum compressive strength of jute fiber is achieved at 2.0% which is 9% higher than the unmodified mix. Addition of fiber improves the bonding and durability properties of concrete.

Steel fiber, sugarcane fiber, bamboo fiber and jute fiber improve the tensile behavior of concrete in different structural applications which stabilize the strength property.

Environmental pollution can also be controlled by using different types of raw fibers, a step towards sustainability.

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