INFLUENCE OF FIBERS ON FRESH AND MECHANICAL PROPERTIES OF (FRC) FIBER REINFORCED CONCRETE, A STEP TOWARDS SUSTAINABILITY

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ABSTRACT:

Mostly used material is concrete which has versatile quality for construction works. Fibrous concrete have significant factor that improve the scale and value to concrete for humid environments with significant role. Day by day abundant demand and use of concrete is increasing. It is considered as a 2nd largest building material due to the major productivity. By the use of fibrous concrete, some bonding and environmental issues have been addressed. 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, one hundred and fifty-three 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. One hundred and two cylinders for compression at 7 and 28days but fifty-one 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.Fibrous concrete is suitable for humid environment where high strength and voids less concrete are required. 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 environmental friendly construction material.

1. INTRODUCTION

Concrete is composite building construction material which is used in construction industry abundantly. Consumption of concrete is now increasing day by day (Afroughsabet & Ozbakkaloglu, 2015). It is the 2nd largest building material which is mostly used in construction industry. Many environmental issues are produced by the use of ordinary concrete which can never be neglected and needed to be taken under consideration. A lot more natural resources are used for the production of concrete as fine and coarse aggregates (Farnam et al., 2010).

Approximately one ton of carbon dioxide is discharged into the atmosphere by production of one ton of cement. It is 7% of the world's total annually production of CO_2. Now It is our duty to save the natural resources for next generation and relieve the burden from the environment for ecological balance (M. B. Ali et al., 2011). In Pakistan it is the right time to find out the residue to save the environment and fulfill the construction needs without disturbing the natural resources. Also concrete deteriorates due to a poor performance of bonding and tensile behavior. After recycling many waste products are used in beneficial way to improve the mechanical properties (Ghani et al., 2020). Better performance in low cost can only be achieved by using waste fibrous material in our surrounding like waste coconut fiber, glass fiber, steel fiber, polypropylene fiber etc. The use of waste materials in concrete will reduce the economic factor in major construction projects (Ahmad et al., 2022; Aslam et al., 2022; Das et al., 2020; Shah et al., 2022).

The versatile quality of natural fibers are better compatibility, good thermosetting, and binding material due to its low density, good thermal insulation properties, improved mechanical properties, low prices, unavailability, easy to approaches, and free disposals, among several features (Baghban et al., 2022; Feng et al., 2022; Latifi et al., 2022; Marcalikova et al., 2020; Ruslan et al., 2022; Su et al., 2022). Although, the fact is that natural fibers have been broadly

investigated in terms of their mechanical, thermal and morphological characteristics, like compressive and tensile qualities. Waste materials can be used after recycling and treatment as per the requirement. Waste materials like coconut fiber, steel fiber, polypropylene fiber and glass fiber are used in different forms as construction materials after recycling for beneficial purposes (M. Ali et al., 2012; Farooq & Yokota, 2022; Rath et al., 2022).

This study explores the utilization of waste fibers in concrete which may lead to a sustainable environment. Also, it evaluates the strength and bonding properties of concrete by the usage of waste fibers. Fibrous material may improve the durability properties as well (Blazy et al., 2022; Devi et al., 2022; Sivakrishna et al., 2020). Recently, some geopolymers have been used as a building material in different structural applications like beams, foundations and minor structural applications (Ahmed et al., 2022; Aisheh et al., 2022; Zhang et al., 2022). Some waste fibers are added in concrete to improve the mechanical properties and durability. Also the major benefit is to reduce the environmental problems and cost factor which may leads to sustainable construction (Khan & Ali, 2016; Lalinde et al., 2022; Maraveas, 2020).

2. MATERIALS& METHODS

Ingredients of concrete consist of cement, sand and crush in addition with different types of fibers. Different fibers details are shown in Figure 1. When water mixed with cement then chemical reaction starts as a result heat produced. This heat directly affects the strength property of concrete.

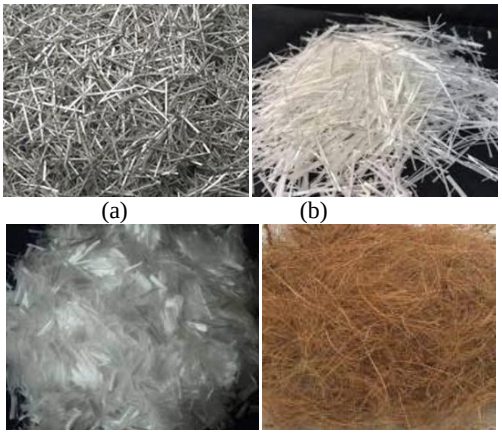
- OPC grade 43 cement is used for this study to prepare an ordinary concrete. Physical and chemical properties of cement are given in Table 2 and Table 5 respectively.
- Chenab sand and margala crush are collected from a single vendor for the preparation of concrete. Physical properties of fine aggregates and coarse aggregates are shown in Table 3 and Table 4 respectively.
- Water is essential part of concrete for proper strength, durability and workability.

Different fibers like polypropylene fibers, glass fibers, coconut fiber and steel fibers are collected from different sources. Coconut fiber is collected from local source and wash with normal water. After drying, cut the fibers manually of approximately 25mm in length. Polypropylene fiber, steel fiber, coconut fiber is taken from sika Pakistan which is the local vendors. Detail properties are shown in Table 1 and visual representation of all fibers are shown in Figure 1.

Sr. No	Description	Length	Dia.	Color
1	Steel Fiber	20mm-40mm	0.4 micron	Black
2	Glass Fiber	16mm	16 micron	White
3	Polypropylene Fiber	12mm	18 micron	White
4	Coconut Fiber	25mm		Brown

Table 1. Physical properties of different types of fibers

Polypropylene fibers are 100% alkali resistance. Glass fiber should not be handled by naked hand as because itching problem and sharp edges. Steel fiber length to depth ratio is 35- 65.



(a) (b)

(b) (d)

Figure 1. Different types of Fibers: a) Steel Fiber, b) Glass Fiber, c) Polypropylene fiber, d) Coconut fiber

Addition of all fibers in concrete may improve the mechanical and durability properties of fiber reinforced concrete (FRC).

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	2.61
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	2.77
2	Fineness Modulus	2.48
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_2O_3	6.49
3	Fe_2O_3	1.93
4	CaO	60.74
5	Mgo	1.08
6	SO_3	2.62
7	Na_2O	0.14
8	Free Cao	0.84

Table 5**.** Chemical properties of cement

2.1 Mix Design

Mix ratio (1:2:4)is used to prepare ordinary concrete of M20, 20 Mpa for all fibers 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. PREPARATION

Concrete cylinders are used to prepare for compression and split tensile tests. Dimension of cylindrical concrete specimen is 6" ×6" ×12" (150mmx150mmx300mm) for all hardened concrete testing. Total one fifty three cylinders are prepared confirming to (ASTM C-192). One hundred and two cylinders of four types of fibers for compression test and fifty one for tensile test. Slump test is performed on fresh properties of concrete to check the workable capacity of concrete. And hardened properties are evaluated by performing compression test at 7 and 28 curing days. And split tensile test is at 28 days. Mixing and casting of cylinders are shown in Figure 2 and Figure 3.



Figure 2. Mixing of concrete



Figure 3. Preparation of sample after casting

Following tests are performed on fresh and hardened concrete in this research. Different types of fibers i.e. glass fiber; steel fiber, coconut fiber and polypropylene fiber are added in concrete with different percentages.

3.1 Slump Test

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



Figure 4. Slump test

3.2 Compression Test

Maximum reliability of concrete is compression test which is performed on hardened concrete samples according to ASTM C-39. 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, 14 and 28 days as shown in Figure 5 and Figure 6 where samples are shown before and after testing. Also the type of failure is shown in Figure 6(b).

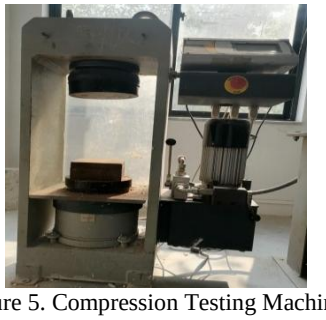


Figure 5. Compression Testing Machine

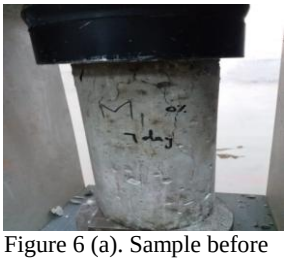


Figure 6 (a). Sample before testing

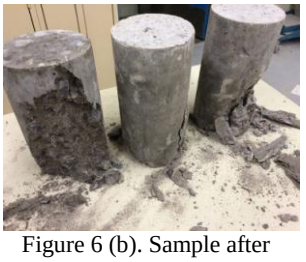


Figure 6 (b). Sample after testing

3.3 Split Tensile Test

Concrete is 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 confirming to ASTM C 496 by adding different percentages 0.5, 1, 1.5 and 2% of fibers at 28 curing days as shown in figure 7.



(a) (b)

Figure 7. Split Tensile test (a) before testing (b) after testing

4. RESULTS AND DISCUSSIONS

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

4.1 Slump Test Results

Workability works in a different way by the addition of different types of fibers at different percentages level. Workability trend shows that it increases with 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 as shown in figure 8.

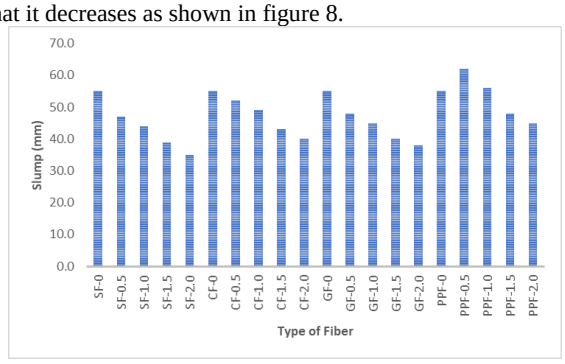


Figure 8. Slump test results at Different Percentage of different types of fibers

Figure 8 shows the result of slump at different percentage level. This graph shows that workability of fresh concrete decreases by adding different types of fibers i.e. glass fiber, steel fiber, coconut fiber and polypropylene fiber with different replacement level.

4.2 Compression Test Results

After the slump test, fresh concrete have been poured into cleaned and well-oiled concrete cylinders in three layers according to ASTM C 39 and left for 24 hours to set. The hardened concrete remolded off the cylinder and cured for 7 and 28 days inside a curing tank by complete immersion in water.

4.2.1 Compression Test Results of Steel Fiber: This is 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 1.5% and 2.0% which is 5% and 9% higher than the unmodified sample which is shown in Figure 9.

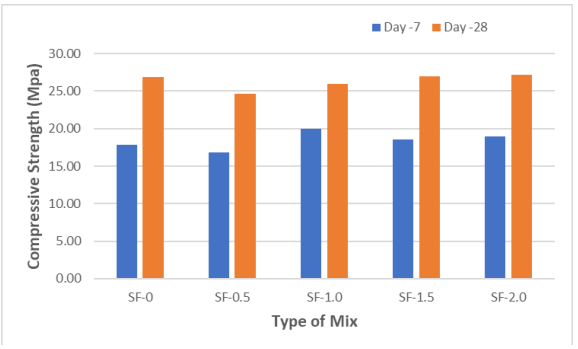


Figure 9. Results of compressive Strength at different replacement level of steel fiber

4.2.2 Compression Test Results of Coconut Fiber: By the addition of coconut fiber, compressive strength is increased. Maximum strength is achieved 1.0% addition which is 12%. Strength going to reduced after increasing the percentages of coconut fiber because for proper mixing of concrete more water is required. Figure 10 represents the trend between compressive strength and type of mix at different addition level of coconut fiber.

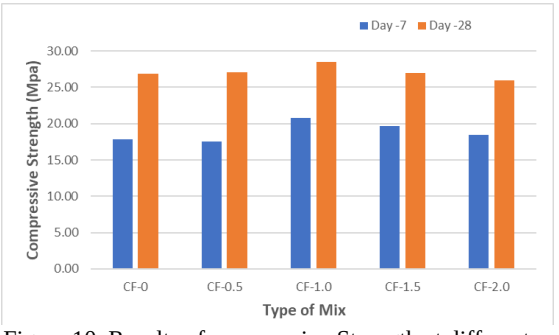


Figure 10. Results of compressive Strength at different replacement level of coconut fiber

4.2.3 Compression Test Results of Glass Fiber: Figure 11 shows the relation between compressive strength and glass fiber at different replacement level. Graph shows the increasing trend at 7 and 28 days. Maximum strength is achieved at 1.0% which is 5%. After the addition of glass powder increases, strength decreases slightly.

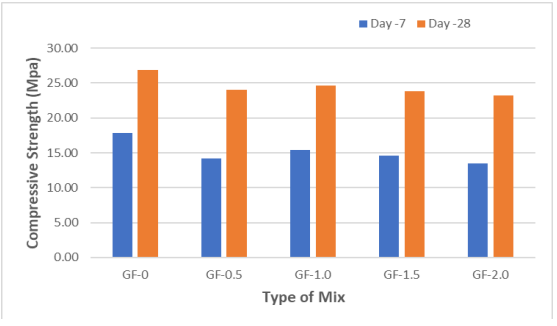


Figure 11. Results of compressive Strength at different replacement level of glass fiber

4.2.4 Compression Test Results of Polypropylene Fiber: Figure 12 indicates that the graphical representation between compressive strength and polypropylene at different replacement level. Strength increases slightly but also improve the tensile properties of concrete due to the elongated fiber.

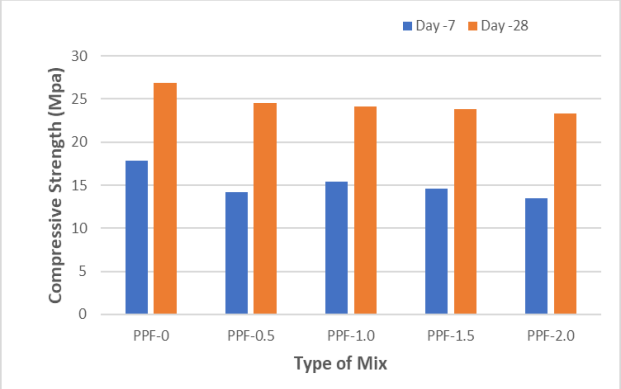


Figure12. Results of compressive Strength at different replacement level of polypropylene fiber

4.3 Split Tensile Test Results

Figure 13 shows the relation between the tensile strength and different types of fiber at different addition level at 28 days. It is the Summary of Split Tensile Test Results of glass fiber, steel fiber, coconut fiber and polypropylene fiber at 28 days.

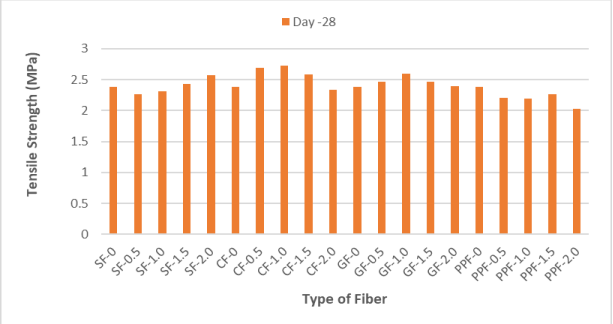


Figure 13. Summary of Split Tensile Strength of different types of fibers at 28 days

5. CONCLUSIONS

- Following conclusions have been drawn from the experimental results:
- All mixes have achieved the required workability between 50 mm to 80 mm which is suitable for normal concrete.
- Compressive strength of concrete increases with the increase of different types of fibers. Max. Strength have achieved at different percent addition of different fibers. Strength of coconut fiber is achieved at 1.0% addition which is 12% 28days. Strength of steel fiber is obtained at 1.0% which is 5%. And maximum compressive strength is achieved at 1.5% and 2.0% which is 5% and 9% higher than the unmodified mix. Addition of fiber improves the bonding and durability properties of concrete.
- Coconut fiber and polypropylene fiber improves the tensile behavior of concrete in minor structural applications which stabilize the strength property.
- By using different types of fibers, environmental pollution can also be controlled.

6. ACKNOWLEGEMENT

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7. SUMMARY

Strength of fibrous concrete of all mixes are not significantly changed at addition level of different percentages; therefore, the steel fiber at 1.5% to 2%, glass fiber & coconut fiber at 1% and polypropylene at 0.5%-1% can be used 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.

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