MECHANICAL PROPERTIES OF CONCRETE BY USING NATURAL FIBER (BAMBOO) AND ARTIFICIAL FIBER (NYLON)

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Abstract

The basic objective behind using fibers is to reduce cracking in concrete and to increase its strength. This experimental work was carried out to evaluate mechanical properties of concrete made up of with 0.5%, 1%, 1.5%, 2% bamboo fibers and 0.5%, 1%, 1.5%, 2% nylon fibers for M25 grade concrete. The properties were studied by performing the compression test on concrete cubes and split tensile tests on concrete cylinders. Moreover, manufactured sand is used as a fine aggregate. Tests were carried out after curing 7, 14, and 28 days period. The test results were compared with a nominal mix made up of 0% of fibers. It was found that concrete made up of 1% fibers possess better compressive and split tensile strengths.

Keywords: Concrete; Bamboo fiber; Nylon fiber; Manufactured sand; Compressive strength; Split tensile strength.

1. INTRODUCTION:

Globally, structural material, which is most commonly used, is the concrete, with over seven billion tons of annual production. For multiple reasons, cracks are common in the concrete. The various reasons for cracks in the concrete may be due to structural, environmental, or economic factors. However, the most common reason for cracks the fundamental weakness of the concrete while resisting tensile forces. Especially when restrained the concrete, it shrinks, and cracks may develop. The flaw in tension may be addressed by reinforcing steel bars in the concrete.

Furthermore, by mixing of adequate quantity of specific fibers may resist the cracking through improving its toughness. This experimental investigation intended to discover the effect on mechanical properties like compressive strength and splitting tensile strength by adding natural fiber (bamboo) and artificial fiber (nylon) at proportions of 0.5, 1, 1.5, and 2%. Also, river sand is completely replaced with M-sand.

Objectives:

The main objectives of this study are:

- ✓ To completely replacing river sand by manufactured sand.
- ✓ To investigate the influence of bamboo and nylon fibers on the mechanical properties of M25 grade concrete.
- ✓ To find an optimum quantity that develops the toughness and tensile strength of the concrete.

2. LITERATURE REVIEW

Reza et al. (2020) conducted an experimental study on rubberized concrete-filled FRP tube columns of rubber's incompressibility property. 27 CFFT columns were tested at cement replacement ratios of 0%, 7.5%, and 15%. They found that the strength obtained for the specimens cast in steel molds was higher than that for specimens cast in PVC molds. At a 15% cement replacement ratio, the expansive agent (EA) in concrete increased the rupture strain in FRP by 20% higher than in corresponding specimens with 0% EA.

Ahmad et al. (2019) Kenaf fibers are thermally and alkali-treated to enhance the interfacial bond between the fiber-matrix, the mechanical properties of the fiber itself, the fiber-reinforced thermally activated alum sludge ash (AASA) and the nano-silica (NS) blended cementitious composites. The tensile strength of treated fibers increases by approximately 160% compared to untreated fibers after 72-h immersion in a 6% optimum concentration of mild sodium bicarbonate ($NaHCO_3$). The surface characteristic with refined crystallinity is confirmed by morphology observation from a scanning electron microscope (SEM) and X-ray diffraction (XRD). The treated KF reinforced AASA, and NS blended cementations composite (KFRBCC) blended with 50% AASA, and 4% NS had excellent mechanical properties, with an increase of 42.1% in the compressive strength compared to that of the control. The results suggest that fiber treatment and blended pozzolana addition significantly improve the physical anwd mechanical properties of fiber-reinforced cementitious material.

Jinliang et al. (2019) studied the effect of glass fiber (GF) and polypropylene fiber (PF) on improving the mechanical and durability properties of concrete. Specimens were prepared by adding at proportions of total GF volume fraction of all mixtures was 0.5, 1, and 1.5 %, the total PF fiber volume fraction of all mixtures was 0.5, 1, and 1.5 %, the total GF and PF volume fraction of all mixtures was 0.5, 1, and 1.5 %. Compressive and flexural strength, rapid chloride migration test (RCM) test, rapid chloride penetration test (RCPT), and scanning electron microscopy (SEM) observation were carried on the specimens and compared with plain concrete. It was found that the addition of 1.5% of GF, PF, and GF+PF possess better mechanical and durability properties.

Mercante et al. (2018) presented a review on the addition of recycled plastic waste to cement composites and influence on their properties. From the most significant scientific peer-reviewed journals, forty-five international journal papers were chosen for the study. The most common things, like plastic features, mix proportion design, and concrete characteristics, were analyzed. The last thing contains fresh and hardened concrete characteristics, the performance of durability, and thermal conductivity. The study on the variables which are negatively influenced by the plastics attenuated some characteristics. The development of insulation properties with plastic is widely examined, but then further research is suggested. Finally, the application of plastic waste may be advantageous on both technical and environmental grounds. The study may be useful for studying and designing cement mortars and concrete mixes with recycled plastic.

Hossein and Jamaludin (2017) this research concentrated on the use of waste carpet fiber and palm oil fuel ash (POFA) to improve the physical, mechanical and microstructural properties of the concrete. 20 mm length carpet fiber and six proportions of 0, 0.25, 0.5, 0.75, 1.0 and 1.25% by volume were used with ordinary Portland cement (OPC). Another six mix proportions were made by replacing OPC with 20% POFA. The combination of carpet fiber and POFA increased the Vee-Bee time and decreased the slump values of fresh concrete. Similarly, there is no improvement in the compressive strength by the addition of carpet fiber into OPC or POFA concrete. A major improvement was also witnessed in the impact resistance of the concrete complex containing carpet fiber when compared to the plain concrete. It is found that carpet fibers act as bridges across the cracks, which improves the load-transfer capacity of the concrete complex.

Kiachehr and Majid (2017) they studied the effect of adding polypropylene (PP) fiber to alkali-activated slag (AAS) concrete on its mechanical properties like compressive, flexural, and tensile strength, and the durability-related properties like total water absorption, water impermeability, rapid chloride permeability, and carbonation depth. Furthermore, changes due to the addition of PP fiber to the microstructure of AAS concrete are studied through scanning electron microscopy (SEM). They found that the optimum quantity of PP fiber to increase the mechanical and permeability properties of AAS concrete is 0.24% by volume. However, the adding of PP fiber increases water absorption and decreases chloride penetration resistance of AAS concrete.

3. MATERIALS AND METHODS

The materials used in this study are:

3.1 Cement

Ordinary Portland Cement (OPC) of 53 grade UltraTech brand pertaining as per IS 12269: 2013 was considered in the current study. Some physical properties of the cement were tested, ensuing IS 4031, and the results were presented in table1.

Table 1: Physical properties of the cement

S.No.	Property	Test value	Standard value (IS 12269: 2013)	Method of a test, Ref. to
1	Specific gravity	3.13	---	IS 4031 (Part 11): 1988
2	Fineness, m^2/kg	370	Min. 225	IS 4031 (Part 2): 1999
3	Soundness, mm (By Le-Chatelier method)	6	Max. 10	IS 4031 (Part 3): 1988
4	Initial setting time, min	42	Min. 30	IS 4031 (Part 5): 1988
	Final setting time, min	350	Max. 600	
5	Compressive strength, MPa (After 28 days curing)	53	Min. 53	IS 4031 (Part 6): 1988

3.2 Coarse Aggregate

The locally available coarse aggregates, which are granite origin, free from clayey matter, silt, and organic impurities, were used. It is tested for their properties, as per IS: 2386-1963, and the results were presented in table 2. The maximum size of 20 mm is used as a coarse aggregate in concrete,

Table 2: Physical properties of coarse aggregate

S.No.	Property	Test value	Standard value (IS 383: 2016)	Method of a test, Ref. to
1	Specific gravity	2.66	Max. 3.2	IS 2386 (Part III): 1963
2	Water absorption, %	0.25	Max. 5	IS 2386 (Part III): 1963
3	Unit weight, kg/m^3	1593	---	IS 2386 (Part III): 1963

3.3 Manufactured sand (M –Sand)

M-sand is one of the substitutes for river sand. Due to the fast-growing construction industry, the demand for sand has increased tremendously, causing a deficiency of suitable river sand in most of the world. Since M-sand, which is obtained by crushing of hard granite rocks, is readily available at the nearby place of the study area, hence transportation costs reduce than from the far-off river sand beds so that the construction cost can be reduced. The physical properties are shown in table 3.

Table 3: Physical properties of M-Sand

S.No.	Property	Test value	Standard value (IS 383: 2016)	Method of a test, Ref. to
1	Specific gravity	2.58	Max. 3.2	IS: 2386 (Part III) – 1963
2	Water absorption, %	2.2	Max. 5	IS: 2386 (Part III) – 1963
3	Bulk density, kg/m^3	1659	---	IS: 2386 (Part III) – 1963
4	Grading Zone	Zone II	Zone I to IV	IS: 2386 (Part I) – 1963

3.4 Water

One of the essential ingredients of concrete is water, and it actively participates in the chemical reaction with cement. Since it helps to form the strength-giving cement gel, the quantity and quality of water must be looked into very carefully. The locally available potable water, free from the concentration of acid and organic substances, is used to mix the concrete.

3.5 Bamboo Fibers

Bamboo is a multipurpose reserve categorized by a large ratio of strength to weight and its ease of work with simple tools. Bamboo may be used in several ways for constructing the structures because of its availability and high strength to weight ratio. Locally available bamboo fiber is used for the study, and its physical properties are shown in table 4.

Table 4: Physical properties of bamboo fiber

Type of fiber	Bamboo
Length (L), mm	50
Diameter (D), mm	0.80
Aspect ratio (L/D)	60

3.5 Nylon Fiber

For strengthening the bond between the fiber and matrix, the fibers, circular in cross-section are used. Fibers made from nylon were drawn wire conforming to IS: 667 with the diameter of wire 0.2 mm have been used, and its physical properties are shown in table 5.

Table 5: Physical properties of nylon fiber

Type of fiber	Nylon
Length (L), mm	25
Diameter (D), mm	0.2
Aspect ratio (L/D)	125

3.6 Methodology

Concrete specimens are cast using complete replacement of fine aggregate with M-sand. Cubes of standard size 150mm were cast and tested for 7, 14, and 28 days compressive strength. Standard cylinders of size 150mm x 300mm (diameter x height) were cast and tested for 7,14, and 28 days for splitting tensile strength and observed the strengths of the concrete specimens, both the natural fibers and artificial fiber by adding at proportions of 0.5%, 1%, 1.5%, and 2% for M25 grade concrete.

4. RESULTS AND DISCUSSIONS

This part presents and discusses the results of the investigation on the effectiveness of natural fiber and artificial fiber as an enhancer on the mechanical properties. The results found are used to study the effect on the above properties of using bamboo fiber and nylon fiber. Based on the various tests that are conducted in the laboratory are to analyze the strength characteristics, and their results correlate with the study and derive positive results and improvement. The results of the present investigation are presented both in tabular and graphical forms to facilitate the analysis; interpretation of the results is carried on each phase of the experimental work. The significance of the results is assessed as per the standards specified by the relevant IS codes.

4.1 Compressive strength

The compressive strength is tested for the fiber mixed and nominal concrete specimens on different curing periods. The test, as per IS 516-1959, was conducted after a curing period of 7, 14, and 28 days. The cubes were tested using the Compression Testing Machine (CTM) of capacity 2000 kN. It is tested for four different proportions of bamboo fiber and nylon fiber.

4.1.1 Compressive strength of concrete containing bamboo fiber for 7, 14, and 28 days

The compressive strength values of the fiber mixed and nominal concrete specimens containing various percentages of bamboo fiber for 7, 14, and 28 days are shown in table 6 and figure 1.

Table 6: Compressive strength of concrete at various percentages of bamboo fiber

Testing after curing	Compressive strength of concrete containing bamboo fiber (N/mm^2)				
	0%	**0.5%**	**1.0%**	**1.5%**	**2%**
7 days	20.46	21.29	22.92	21.61	19.54
14 days	27.53	28.23	31.29	28.96	26.45
28 days	30.78	31.46	34.76	32.24	29.54

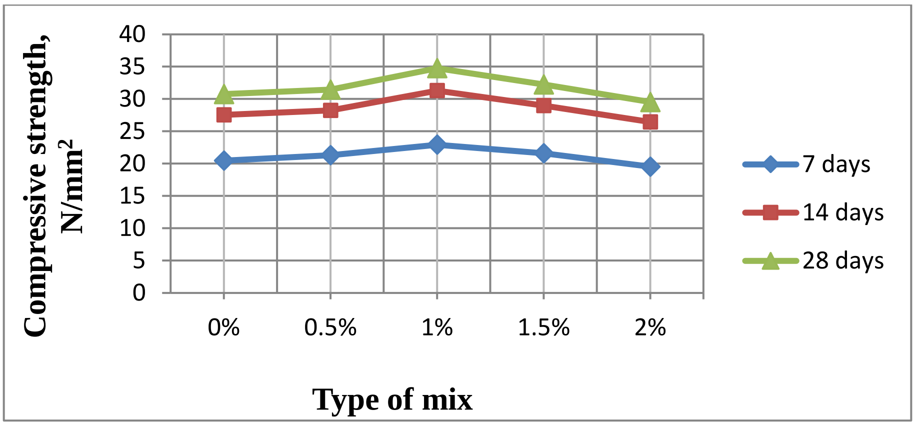

Figure 1: Compressive strength of concrete at various percentages of bamboo fiber

4.1.2 Compressive strength of concrete containing nylon fiber for 7, 14, and 28 days

The compressive strength values of the fiber-mixed and nominal concrete specimens at various percentages of nylon fiber for 7, 14, and 28 days are shown in table 7 and figure 2.

Table 7: Compressive strength of concrete at various percentages of nylon fiber

Testing after curing	Compressive strength of concrete containing nylon fiber (N/mm^2)				
	0%	**0.5%**	**1.0%**	**1.5%**	**2%**
7 days	20.46	22.27	24.62	22.41	19.97
14 days	27.53	29.24	33.74	30.65	27.49
28 days	30.78	33.53	37.65	34.21	30.35

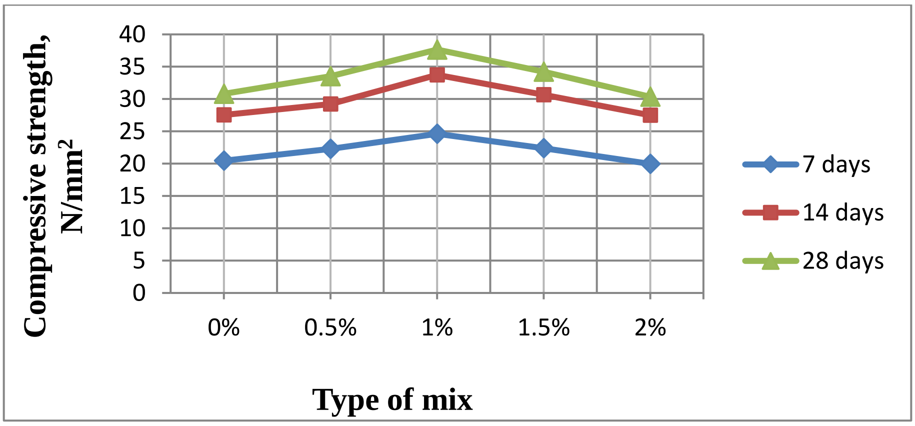

Figure 2: Compressive strength of concrete at various percentages of nylon fiber

4.2 SPLITTING TENSILE TEST

The test was conducted as per the IS 516-1959 to obtain splitting tensile strength of concrete after a curing period of 7, 14 & 28 days. The cylinders were tested using the Compression Testing Machine (CTM) of capacity 2000kN. Then it is tested for four different proportions of bamboo fiber and nylon fiber.

4.2.1 Splitting tensile strength of concrete containing bamboo fiber

The values of the splitting tensile strength of the fiber-mixed and nominal concrete specimens containing various percentages of bamboo fiber are shown in table 8 and figure 3.

Table 8: Splitting tensile strength of concrete at various percentages of bamboo fiber

Testing after curing	Splitting tensile strength of concrete containing bamboo fiber (N/mm^2)				
	0%	0.5%	1.0%	1.5%	2%
7 days	2.62	2.73	2.94	2.77	2.50
14 days	3.14	3.22	3.57	3.30	3.09
28 days	3.46	3.54	3.91	3.62	3.42

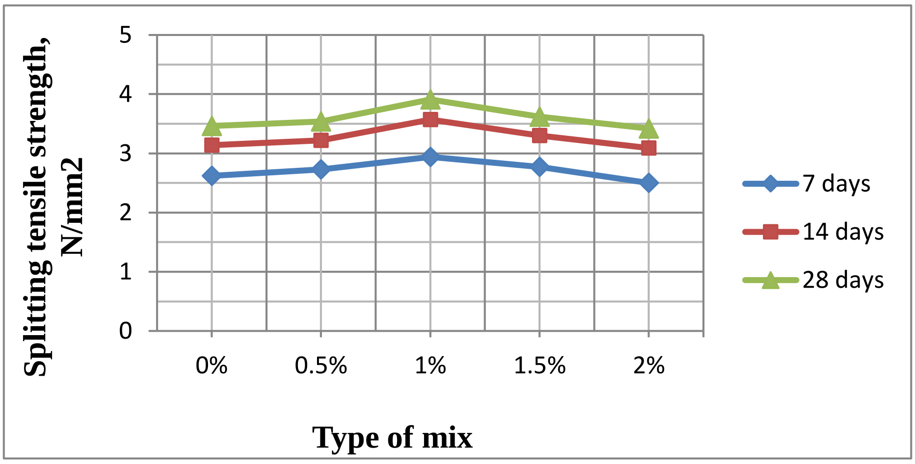

Figure 3: Splitting tensile strength of concrete at various percentages of bamboo fiber

4.2.2 Splitting tensile strength of concrete containing nylon fiber

The values of the splitting tensile strength of the fiber-mixed and nominal concrete specimens at various percentages of nylon fiber are shown in table 9 and figure 4.

Table 9: Splitting tensile strength of concrete at various percentages of nylon fiber

Testing after curing	Splitting tensile strength of concrete containing nylon fiber (N/mm^2)				
	0%	0.5%	1.0%	1.5%	2%
7 days	2.62	2.75	3.13	2.86	2.68
14 days	3.14	3.36	3.79	3.49	3.34
28 days	3.46	3.67	4.12	3.78	3.62

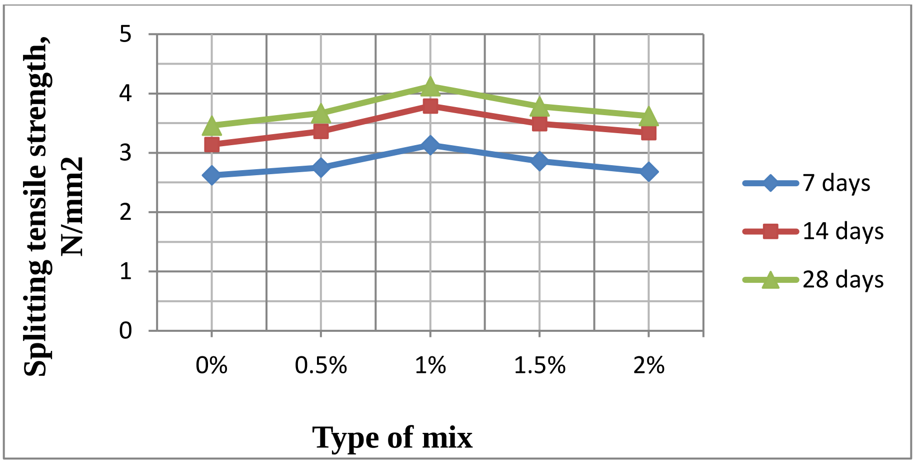

Figure 4: Splitting tensile strength of concrete at various percentages of nylon fiber

5. CONCLUSIONS

The overall significant findings regarding their mechanical properties for the M25 design mix concrete and the addition of bamboo fiber and nylon fiber can be extracted from the test results presented in this paper and may be summarized as follows.

- The higher compressive strength was obtained at 1%, adding bamboo fiber. Its 7 days, 14 days, and 28 days the strength enhancement compare to the nominal mix are 20.46 to 22.92 N/mm^2 (12.02%), 27.53 to 31.29 N/mm^2 (13.66%), and 30.78 to 34.76 N/mm^2 (12.93%) respectively.
- The higher compressive strength was obtained at 1%, adding nylon fiber. Its 7 days, 14 days, and 28 days the strength enhancement compare to the nominal mix are 20.46 to 24.62 N/mm^2 (20.33%), 27.53 to 33.74 N/mm^2 (22.56%), and 30.78 to 37.65 N/mm^2 (22.32%) respectively.
- The higher splitting tensile strength was obtained at 1%, adding bamboo fiber. Its 7 days, 14 days, and 28 days the strength enhancement compare to the nominal mix are 2.62 to 2.94 N/mm^2 (12.21%), 3.14 to 3.57 N/mm^2 (13.69%), and 3.46 to 3.91 N/mm^2 (13.01%) respectively.
- The higher splitting tensile strength was obtained at 1%, adding nylon fiber. Its 7 days, 14 days, and 28 days the strength enhancement compare to the nominal mix are 2.62 to 3.13 N/mm^2 (19.46%), 3.14 to 3.79 N/mm^2 (20.70%), and 3.46 to 4.12 N/mm^2 (19.08%) respectively.
- Finally, it can be concluded that 1%, adding bamboo fiber and nylon fiber, gives better compressive and splitting tensile strength than the nominal mix. Furthermore, nylon fiber gives better strength than the bamboo fiber and is recommended for use in M25 grade concrete.

Scope for further study:

- An analogous study may be carried out for other design mixes.
- Fibers, along with other admixtures, may be carried out.
- Flexural strength, modulus of elasticity, and durability tests may be carried out.

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