Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol.45 No. 1 (2024)

Mechanical Properties of Polymer Modified High Volume Fly ash Concrete (PMHVFAC) Using Hybrid Textile Fibers

[1]K. P. Thejaswi, [2]Dr. G. S. Manjunatha

[1]*Assistant Professor, Department of Civil Engineering, KLS Gogte Institute of Technology, Affiliated to Visvesvaraya technological University (VTU), Belagavi, Karnataka, India*

[2]*Professor, Department of Civil Engineering, Angadi Institute of Technology, Affiliated to Visvesvaraya technological University (VTU), Belagavi, Karnataka, India*

Abstract:- This paper presents the behavior of polymer modified high volume fly ash concrete (PMHVFAC) using hybrid textile fibers under compressive strength, tensile strength, flexural strength and shear strength. According to the geometrical parameters of textile fibers, the textile fibers can be effective in delaying propagation of micro cracks or macro cracks. In the present paper, the high volume fly ash concrete (HVFAC) is mixed with several single (mono) textile fibers and two-fiber (hybrid) textile fibers. The specimens are cured in water for 28 and 90 days in order to enhance PMHVFAC's mechanical properties. Microstructures of the composites were analyzed by using scanning electron microscope. The findings indicate that it is possible to improve PMHVFAC's mechanical properties in every way by adding hybrid textile fibers. PMHVFAC produced with hybrid textile fibers exhibit higher strength characteristics as compared to PMHVFAC produced with mono textile fibers. Additionally, in comparison to other hybrid fiber combinations, it is evident that PMHVFAC produced with the (CF+PPF) hybrid textile fiber combination has greater strength capabilities.

Keywords: *High volume fly ash, SBR latex Polymer, Mono textile fiber, Hybrid textile fiber*

1. Introduction

Fly ash, a typical type of pozzolan used to create high strength and high performance concrete, is made up of finely separated ashes created by burning pulverized coal in power plants. HVFA concrete, which typically comprises 50–60% fly ash as the total cementitious materials content, is widely employed to achieve the sustainable development of the concrete industry. The use of large quantities of fly ash in concrete has many advantages. Using HVFAC as a construction material will have a large impact on the world's sustainable development and on the economy of producing concrete. Higher volumes of fly ash and less Portland cement are needed for HVFAC. Additionally, workability can be improved and water requirements can be decreased by employing HVFAC. HVFAC shows less heat and drying shrinkage cracks. HVFAC has high durability against reinforcing corrosion, sulphate attack, and alkali-silica expansion. It is estimated that greater usage of fly ash in concrete would help to reduce disposal problem and would also contribute to a cleaner environment. HVFAC with 50% replacement developed higher strength than OPC concrete at 28 days and beyond with water-cementitious material ratios ranging from 0.28 to 0.34 [1]. The mechanical properties of HVFAC are found to have lower rate of initial strength gain [2]. At 90 days and beyond, the concrete containing 40% fly ash and 60% OPC reached its maximal strength. The combination that contained 60% fly ash and had a w/c ratio of 0.30 exhibited the least shrinkage [3]. Applying fine particles like fly ash, modified fly ash or adding exciting agent of fly ash the flexural strength of HVFA-ECC can be increased [4]. The coexistence of C-S-H is observed in the system containing 80% of flyash, confirming that the amount of alumina and silicate phases provided by the flyash is a major factor for the formation of C-S-H(I) and stratlingite in HVFA system [5]. Romualdi J. P and Batson. G. B. [6] has made progressive development in fiber-reinforced cement (FRC) in 1960s. Textile-reinforced concrete (TRC) is a form of reinforced concrete, where conventional reinforcement is replaced with textiles or fibers. The high tenacity of the textile fibers results in flexible and durable concrete structures [7]. By using TRC ultimate load capacity, displacements, bending capacity and shear capacity improved [8]. By using fibers compressive and tensile strength doubled as compared to those of concrete without fly ash [9]. By using PP fiber (0.2%) compressive strength and flexural strength was found to increase as compared to that of plain concrete specimens [10]. For preventing spalling of concrete two different lengths of polypropylene fibres were used and found that 12.5 mm fibres was more efficient than 20 mm fibres [11]. According to few authors when nylon fiber (1% by volume of concrete) is used into the concrete matrix, it has increased significantly the compressive and split tensile characteristics [12] and even the bond within the concrete increases [13]. Some authors found that by 0.25% of nylon fiber there was improvement in the strength characteristics of concrete [14]. By adding SBR latex content compressive strength decreased, but the strength got enhanced with increasing nylon fiber content [15]. The performance of MPC materials improved when polyethylene fibers (PE) were added (1.25%). These improvements included increased in ductility and durability [16]. By 0.4% and 1% addition of polyester fiber in concrete for paver blocks, the concrete attains maximum strength and minimum water absorption at 7, 28 and 56 days [17] [18]. Carbon atoms are joined in a long chain via chemical bonds to create carbon fiber. Due to their stiffness, strength, and light weight, the fibers are employed in a variety of procedures to produce top-notch building materials. Carbon fiber is similar to plastic in weight and steel in terms of its physical characteristics. As a result, carbon fibers have substantially higher strength to weight ratios (as well as stiffness to weight ratios) than either steel or plastic. Carbon fiber is extremely strong [19].

The characteristics of concrete at each volume fraction were enhanced by employing hybrid fiber (polypropylene and polyester) with varying fractions by weight of cement and micro silica as cement replacement. 10% of micro silica and 0.1% fiber content gives the best performance by increasing in compressive strength and tensile strength [20]. Some authors investigated on single, two-fiber and three-fiber hybrid composites using different fiber types such as macro and micro-fibers of steel, polypropylene and carbon. The modulus of rupture was increased by adding the micro-fiber. It was discovered that the crimped microfiber outperformed the macro-fibers made of polypropylene. Maximum synergy is demonstrated by hybridizing crimped polypropylene macrofiber with carbon and polypropylene microfibers [21].

Styrene butadin rubber latex SBR's molecular structure gives concrete and mortars excellent mechanical qualities, water tightness, and abrasion resistance [22] [23]. With the additions of SBR latex and polyester fiber, there was decrease in the compressive strength slightly, but the flexural strength and toughness were remarkably improved. The optimal polymer to cement ratio tends to be 15% [24]. By the incorporation of PP fiber and SBR polymer latex, the abrasion resistance, flexural strength and brittleness index can be improved considerably. After seven days of curing, the microscopic examination indicates that SBR polymer latex has little or no impact on the cement hydration. The creation of the transition layer improved the bonding characteristics between the cement hydrates and

PP fibers [25]. Researchers have done research on polymer compound modified concrete and found that at 0.14 vol. % of polyester fiber and at 90kg/m3 of SBR latex, there was improvement in the properties of concrete. Continuous SBR latex films formation made the concrete to raise toughness and compact degree of interface transition zone (ITZ) [26].

2. Materials used and tests performed

2.1 Materials

In the study, OPC of grade 53 with specific gravity (SG) of 3.15 and fineness of 4% was used. Fly ash with SG of 2.12, fine aggregate (zone II) and coarse aggregate with SG of 2.3, 7.3 and fineness of 2.7 and 3.02 respectively are used. Superplasticizer and polymer are used to design M30 grade concrete. Tables 1 and 2 indicate the characteristics of the Conplast SP 430 superplasticizer and SBR latex polymer.

Table1: Properties of Conplast SP 430 and Superplasticizer

Appearance	Specific Gravity	Chloride content	Air entrainment	Alkali content
Brown liquid	Typically 1.20 at 20°C	Nil to BS 5075	Less than 2%	Less than 72.0 g. Na_2O

Table 2: Properties of SBR Latex

Appearance	Density	Solid content	pH	Viscosity at 25 °C	Surface tension
White milky liquid	1.02 kg/L at +27 °C	50%	8.3	40 mPa s	45 mN/m

Various textile fibers like carbon, polypropylene, polyethylene, nylon, and polyester with a length of 12 mm, were employed in the investigation. Table 3 depicts the parameters of these fiber types.

Table 3: Properties of textile fibers

Fibers	Density (kg/m3)	Ultimate tensile strength (MPa)	Young's modulus of elasticity (MPa)
Carbon fiber (CF)	2000	2500 -7000	5,00,000
Polypropylene fiber (PPF)	895-945	520	1325
Polyethylene fiber (PEF)	950-960	600	1070-1090
Nylon fiber (NF)	1140	558-607	2700
Polyester fiber (PF)	1360	600	920

Different combinations of hybrid textile fibers used in the study are (CF+PPF), (CF+PEF), (CF+NF) and (CF+PF). Hybrid textile fibers are added (0.5+0.5) % by volume fraction and mono fibers are added 1% by volume fraction. SBR latex polymer and superplasticizer are added at the rate of 3% and 1.4% by weight of cementitious material. M30 grade mix design for HVFAC yielded a proportion of 1:1.34:3.29 with a water to cementitious material ratio of 0.35. All the ingredients of concrete are dry mixed first and then water, superplasticizer and polymer are added to get homogenous mix. The strength characteristics are found after 28 days and 90 days of water curing.

2.2 Tests Performed

The compression strength test is conducted on cube specimens of size (150x150x150) mm in accordance with IS:516-1959 [27] as shown in Figure 1. The split tensile strength test is conducted on cylindrical specimens of size 150 mm diameter and 300 mm length in accordance with IS:5816-1999 [28] as shown in Figure 2. Flexural strength test is conducted on beam specimens of size (100x100x500) mm in accordance with IS:516-1959 [27] by applying two point load loading as shown in Figure 3. Shear strength test is conducted on L-shape specimens prepared by using cube mould of size 150 X 150 X 150 mm and inserting a wooden block of size 150 X 90 X 60 mm. The arrangement of application of load for shear strength is shown in Figure 4. The maximum load at the failure of the specimen is noted and shear strength is calculated using Eqn 1 and Eqn 2.

$$\text{Failure load (P2)} = \frac{PL1}{(L1 + L2)} \qquad (1)$$

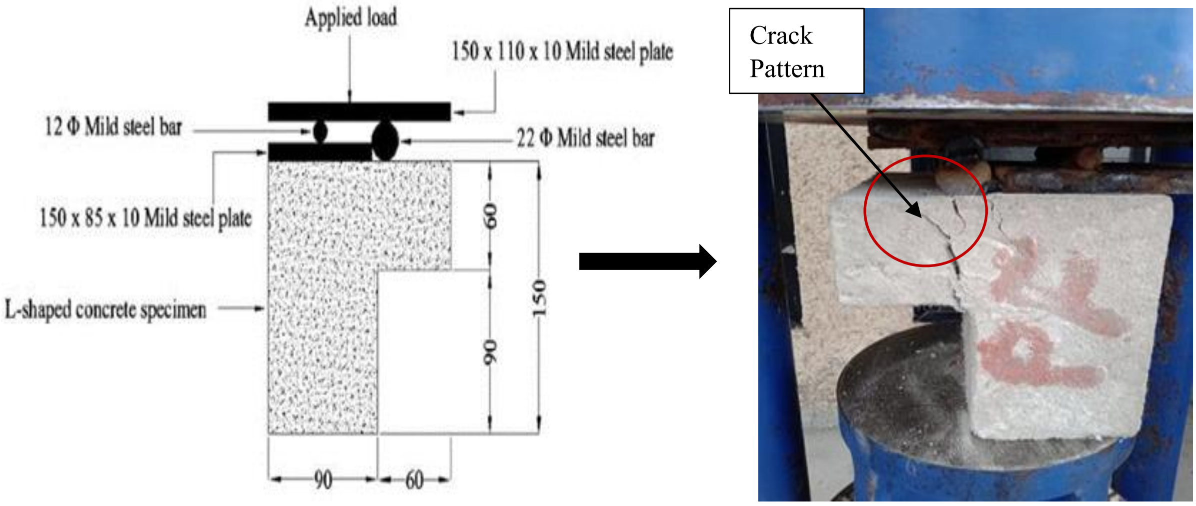
$$\text{Shear strength} = \frac{P2 \text{ X } 1000}{A} \qquad (2)$$

Where; P= Applied load (kN); L1 and L2 = Length of applied load between the rods; A= Area of shear surface.

Figure 1: Compressive strength test and crack and crack pattern

Figure 2: Split tensile strength test pattern

Figure 3: Flexural strength test and crack pattern



(a) (b)

Figure 4: Shear strength test (a) [29] and crack pattern (b)

3. Experimental results

3.1 Polymer modified high volume fly ash concrete strength test results

For 28 and 90 days of curing, Table 4 shows the percentage increase in compressive strength relative to the reference mix and the percentage increase in compressive strength for hybrid fiber combinations with respect to the mono textile fibers. Figure 5 displays the test results for PMHVFAC's compressive strength after 28 and 90 days of curing using various hybrid textile fibers and mono textile fibers. Similarly, table 5, table 6 and table 7 shows the percentage increase in split tensile strength, flexural strength and shear strength relative to the reference mix and the percentage increase in split tensile strength, flexural strength and shear strength for hybrid fiber combinations relative to the mono textile

Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol.45 No. 1 (2024)

fibers. Figure 6, figure 7 and figure 8 shows the test results for PMHVFAC's split tensile strength, flexural strength and shear strength after 28 and 90 days of curing using various hybrid textile fibers and mono textile fibers.

Table 4: Compressive strength test results of PMHVFAC with different hybrid textile fibers

Description of PMHVFAC with different textile fiber	**% increase of compressive strength w.r.t ref. mix for 28 days**		**% increase of compressive strength w.r.t ref. mix for 90 days**	**% increase of compressive strength for hybrid fiber combinations w.r.t respective mono fibers for 28 days**	**% increas compressive str hybrid combinations respective mon for 90 days**
Without fibers (Ref. mix)	-		-	-	-
CF+PPF	29.30		44.69	14.88	26.10
CF+PEF	15.17		25.80	12.82	12.81
CF+NF	17.79		23.03	7.66	13.62
CF+PF	26.68		7.37	15.24	0.43
CF	11.50		19.81	-	-
PPF	9.41		14.74	-	-
PEF	9.93		11.51	-	-
NF	12.55		8.29	-	-
PF	2.08		6.91	-	-

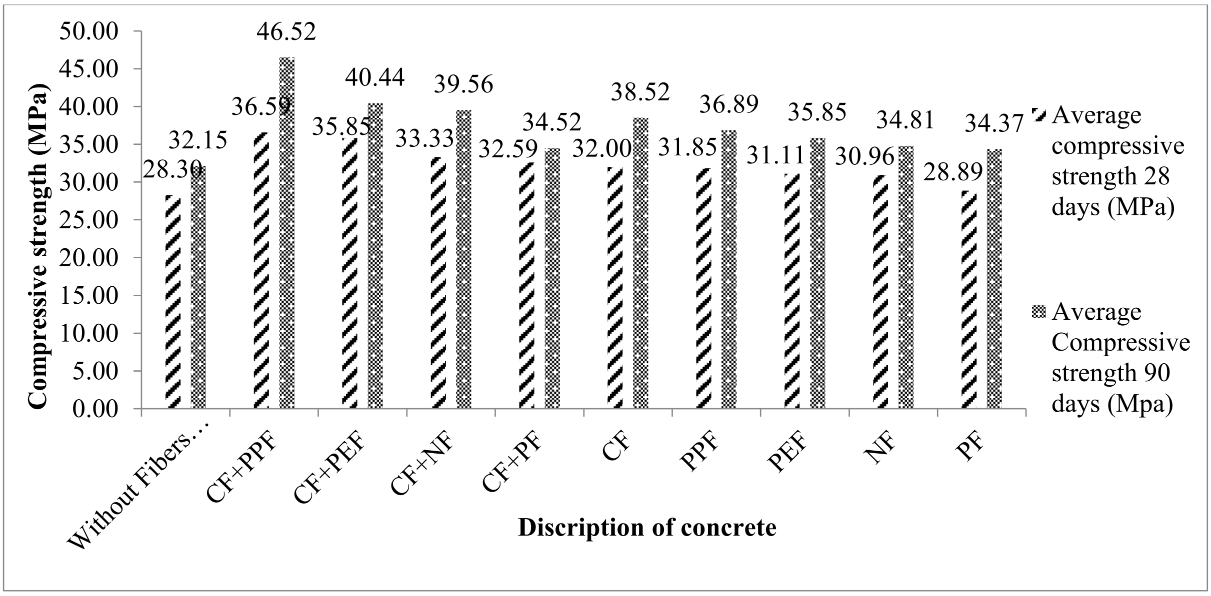


Figure 5: Variation of compressive strength for 28 and 90 days of PMHVFAC with different hybrid and mono textile fibers

Table 5: Split tensile strength test results of PMHVFAC with different hybrid textile fibers

Description of PMHVFAC with different textile fiber	**% increase of split tensile strength w.r.t ref. mix for 28 days**	**% increase of split tensile strength w.r.t ref. mix for 90 days**	**% increase of split tensile strength for hybrid fiber combinations w.r.t respective mono fibers for 28 days**	**% increase of split tensile strength for hybrid fiber combinations w.r.t respective mono fibers for 90 days**
Without fibers (Ref. mix)	-	-	-	-
CF+PPF	65.03	48.58	42.37	36.11
CF+PEF	33.59	30.39	21.43	17.81
CF+NF	29.66	24.32	20.00	9.33
CF+PF	21.81	21.29	16.98	17.65
CF	17.88	16.74	-	-
PPF	15.91	13.71	-	-
PEF	10.02	10.68	-	-
NF	8.05	9.16	-	-
PF	4.12	3.10	-	-

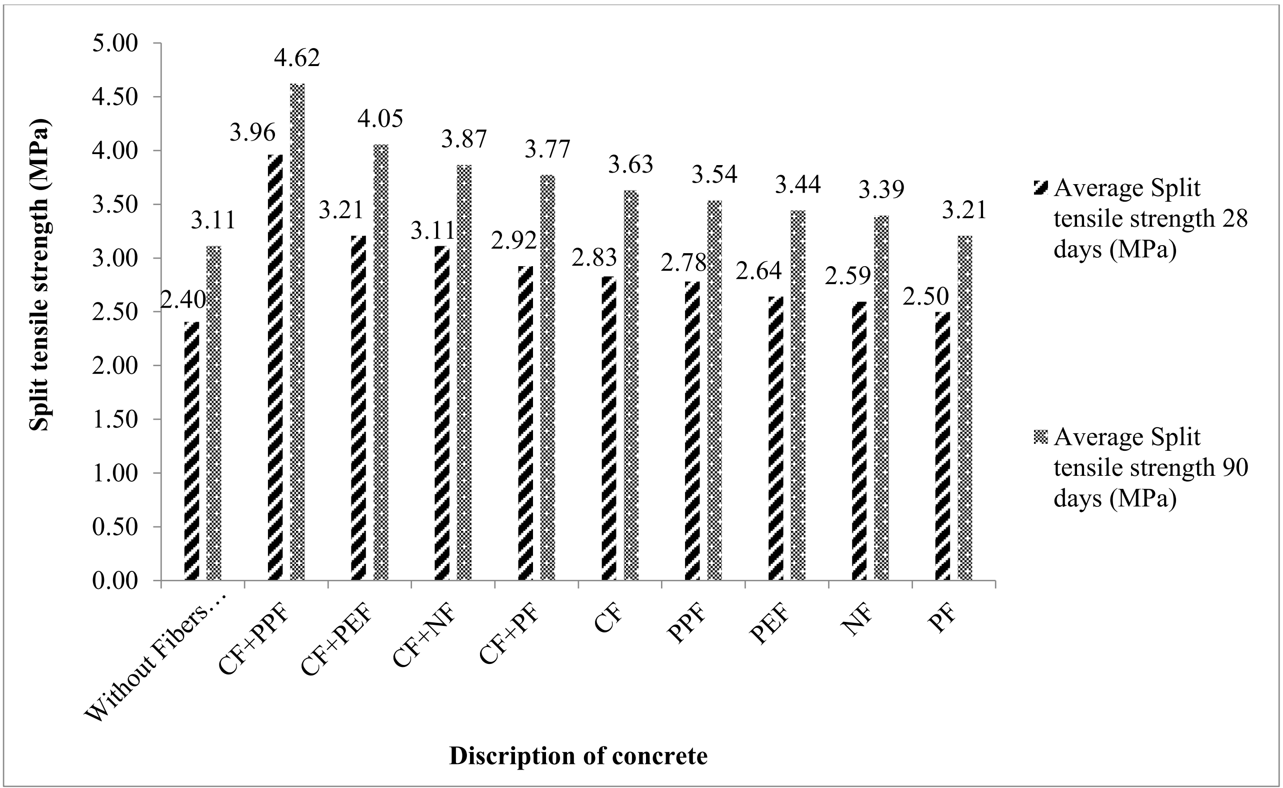


Figure 6: Variation of split tensile strength for 28 and 90 days of PMHVFAC with different hybrid and mono textile fibers

Table 6: Flexural strength test results of PMHVFAC with different hybrid textile fibers

Description of PMHVFAC with different textile fiber	**% increase of flexural strength w.r.t ref. mix for 28 days**	**% increase of flexural strength w.r.t ref. mix for 90 days**	**% increase of flexural strength for hybrid fiber combinations w.r.t respective mono fibers for 28 days**	**% increase of flexural strength for hybrid fiber combinations w.r.t respective mono fibers for 90 days**
Without fibers (Ref. mix)	-	-	-	-
CF+PPF	90.35	73.80	79.03	53.18
CF+PEF	69.35	52.12	50.76	35.81
CF+NF	38.91	38.39	27.56	24.35
CF+PF	16.18	30.08	15.81	26.32
CF	12.75	22.13	-	-
PPF	12.33	13.46	-	-
PEF	12.33	12.01	-	-
NF	8.90	11.29	-	-

PF	0.32	2.98	-	-

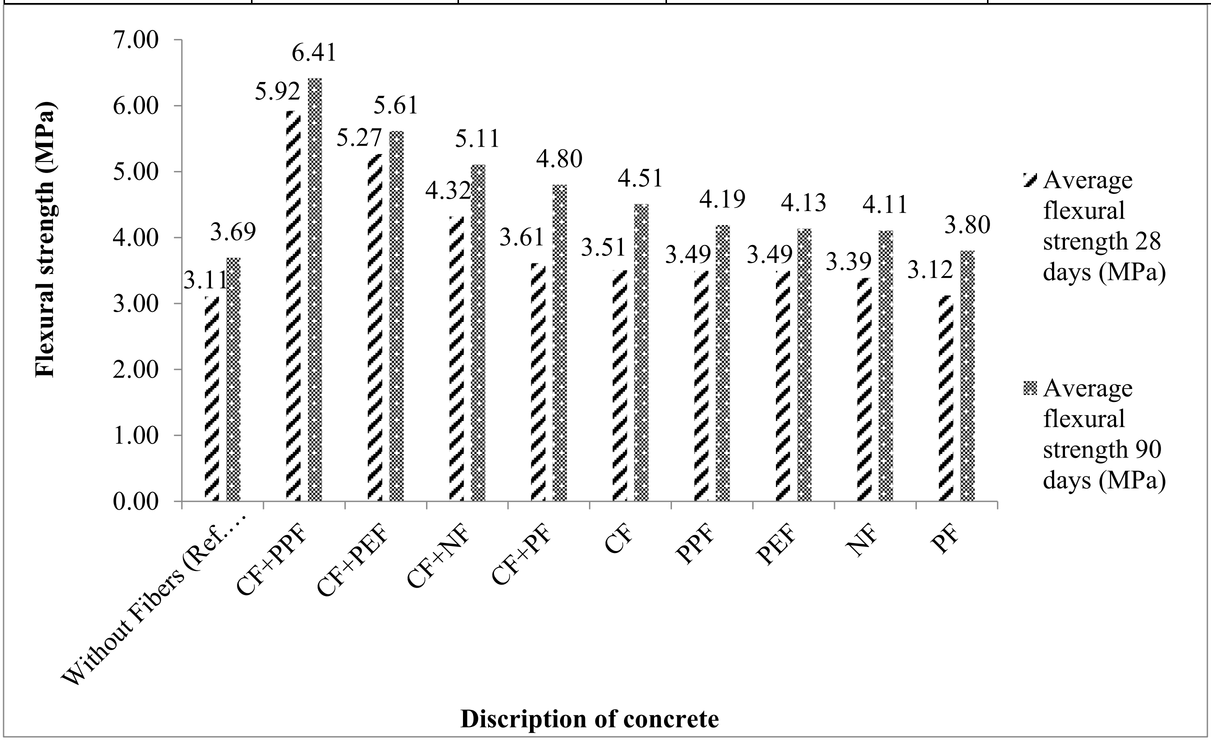


Figure 7: Variation of flexural strength for 28 and 90 days of PMHVFAC with different hybrid and mono textile fibers

Table 7: Shear strength test results of PMHVFAC with different hybrid textile fibers

Description of PMHVFAC with different textile fiber	**% increase of flexural strength w.r.t ref. mix for 28 days**	**% increase of flexural strength w.r.t ref. mix for 90 days**	**% increase of flexural strength for hybrid fiber combinations w.r.t respective mono fibers for 28 days**	**% increase of flexural strength for hybrid fiber combinations w.r.t respective mono fibers for 90 days**
Without fibers (Ref. mix)	-	-	-	-
CF+PPF	86.22	82.44	38.46	62.22
CF+PEF	68.98	54.95	32.43	51.22
CF+NF	55.18	49.95	25.00	39.53
CF+PF	51.73	29.95	41.94	36.84
CF	44.84	27.46	-	-
PPF	34.49	12.46	-	-
PEF	27.60	7.46	-	-
NF	24.15	2.46	-	-

PF	6.90	-5.03	-	-

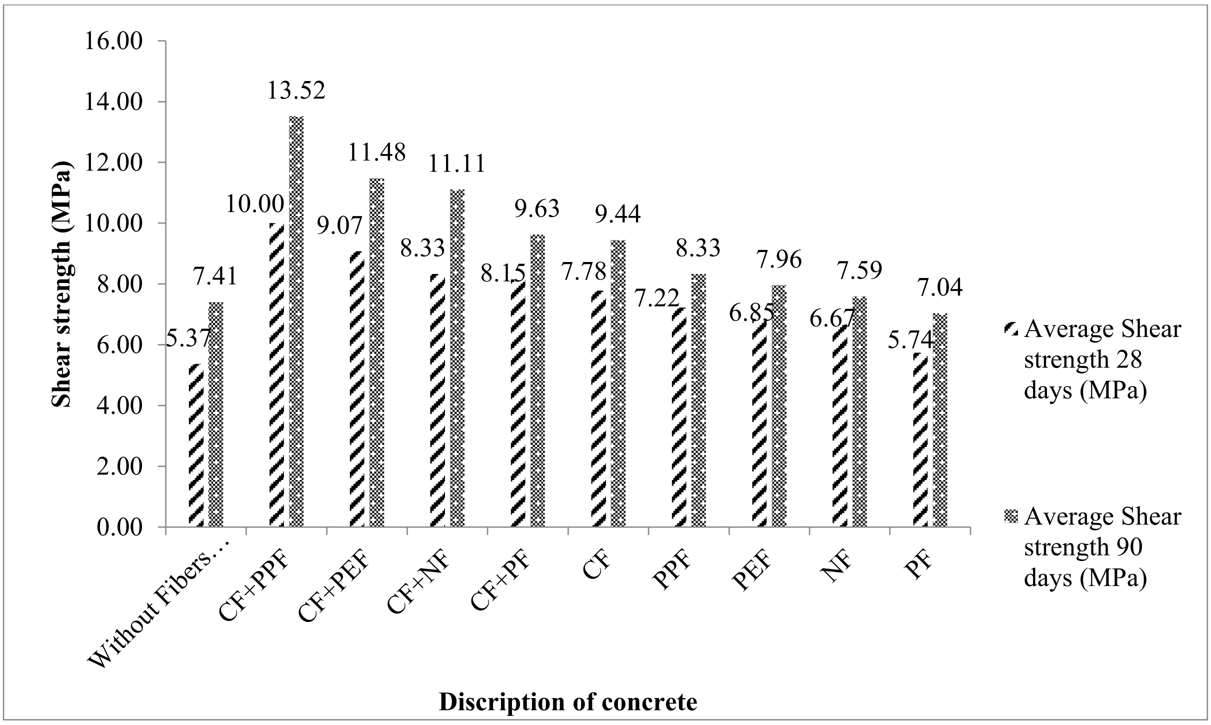
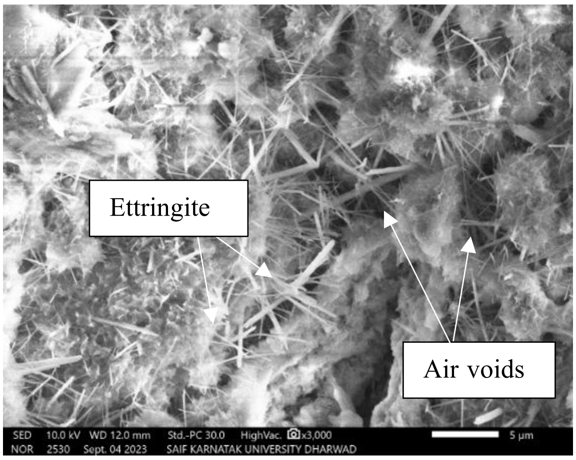


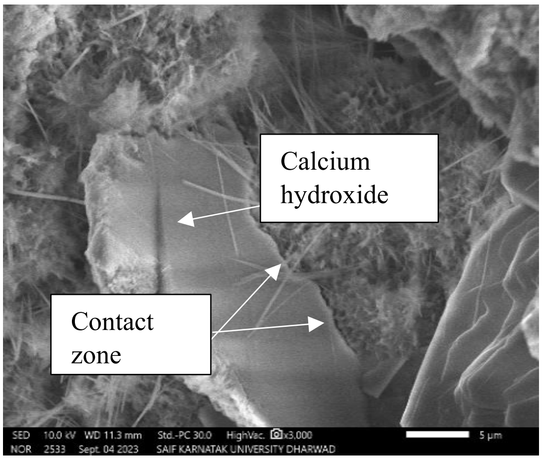
Figure 8: Variation of shear strength for 28 and 90 days of PMHVFAC with different hybrid and mono textile fibers

3.2 Micro structural analysis

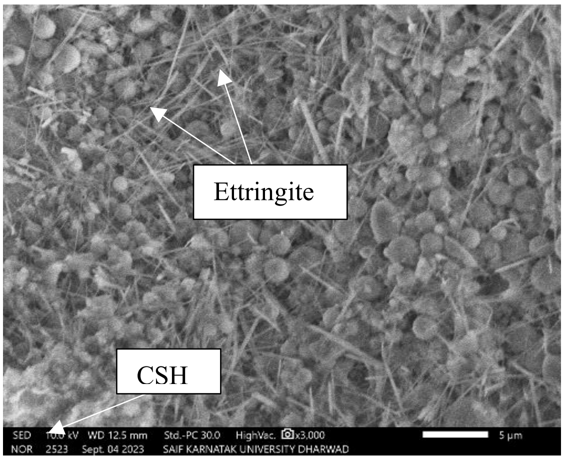
The samples of PMHVFAC, PMHVFAC with CF fiber, PMHVFAC with PPF fiber and PMHVFAC with hybrid fiber combination (CF+PPF) are analyzed for scanning electron microscope images. The microstructure of PMHVFAC produced with hybrid textile fiber combination (CF+PPF) shows a dense microstructure as compared that of respective individual mono fibers and without any fibers. The SEM images are shown in figure 9 (a), (b), (c) and (d) for PMHVFAC, PPF, CF and (CF+PPF).



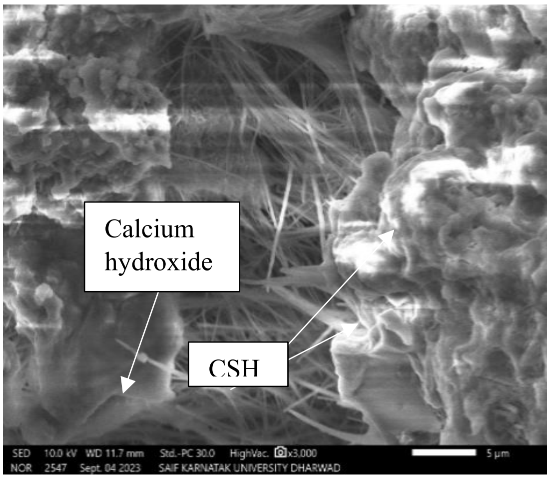
(a)



(b)



(c)



(d)

Figure 9: (a) SEM images of PMHVFAC, (b) PMHVFAC with CF, (c) PMHVFAC with PPF, (d) PMHVFAC with (CF+PPF)

4. Observations and discussions

According to results of experiments conducted, the 28 days compressive strength, split tensile strength, flexural strength and shear strength of PMHVFAC produced with different hybrid textile fibers are more as compared to reference mix (without fibers) and PMHVFAC produced by using respective mono textile fibers. Even at 90 days, different strength tests showed a similar trend.

This could be as a result of the fact that synergistic effect of adding of hybrid textile fibers into the concrete. At various loading stages, the hybrid textile fibers have the ability to arrest cracking. In the early phase of loading, one fiber will arrest the cracks, and in the latter stages of loading, another fiber will arrest the cracks.

The results show that PMHVFAC made using hybrid textile fibers (CF+PPF) has a greater 28-day compressive strength (36.59 MPa), split tensile strength (3.96 MPa), flexural strength (5.92MPa), and shear strength (10.00 MPa) than (CF+PEF), (CF+NF), and (CF+PF).

The hybrid textile fiber combination (CF+PPF) for PMHVFAC has a compressive strength of 14.88% stronger than the corresponding mono textile fiber concrete made with PPF and 29.30% higher than the reference mix (without fibers). The split tensile strength for hybrid textile fiber combination (CF+PPF) was found to be 42.37% stronger than the corresponding mono textile fiber concrete made with PPF and 65.03% higher than the reference mix. Similarly for flexural strength the combination of (CF+PPF) was found to be approximately 79.03% greater than the corresponding mono textile fiber concrete made with PPF and 90.35% higher than the reference mix. Additionally, it was observed that the shear strength was 38.46% greater than that of the corresponding mono textile fiber concrete made with PPF and 86.22% higher than that of the reference mix. A comparable pattern was noticed for 90 days compressive strength, split tensile strength, flexural strength and shear strength.

This could be because, in comparison to other hybrid textile fiber combinations, (CF+PPF) hybridization may produce a superior microstructure and may exhibit a better synergistic effect.

5. Conclusions

1. PMHVFAC produced by different hybrid textile fibers exhibits higher strength characteristics in all aspects as compared to reference mix (without fiber) and PMHVFAC produced by respective mono textile fiber concrete.
2. PMHVFAC produced with (CF+PPF) exhibits higher strength characteristics as compared to the other hybrid fibers combinations. Higher compressive strength, split tensile strength, flexural strength and shear strength for PMHVFAC is achieved by the hybrid combination (CF+PPF) followed by (CF+PEF), (CF+NF) and (CF+PF).
3. Since the microstructure of PMHVFAC produced with hybrid fiber combination (CF+PPF) shows a denser structure, the strength characteristics such as compressive strength, tensile strength, flexural strength and shear strength are high for PMHVFAC produced with hybrid textile fibers (CF+PPF).
4. In comparison to PMHVFAC with hybrid textile fibers and PMHVFAC with mono textile fibers, a greater number of pores were discovered during the microstructural study of reference mix (without fibers). Because of the addition of fibers into the cement matrix, the fibers have the capacity to grip the cement paste intact in position creating less pores, this might be one of the reason for getting higher mechanical strengths for PMHVFAC with hybrid textile fibers and PMHVFAC with mono textile fibers when compared with reference mix (without fibers).

References

[1] Atis C D. High-Volume Fly Ash Concrete with High Strength and Low Drying *Shrinkage, J. Mater. Civ. Eng*., 2003;15:153–156.
[2] Arezoumandi M, Volz J S. A comparative study of the mechanical properties, fracture behavior, creep and shrinkage of high- volume fly ash concrete, *Journal of Sustainable Cement-Based Materials.,* 2013;2:173-185.
[3] Karahan O. Transport properties of high volume fly ash or slag concrete exposed to high temperature, *Constr. Build. Mater.,* 2017;152:898–906.
[4] Wu Y, Sun Q, Guo Y, Li W, Xu C. The improvement of setting time and early strength of fiber-reinforced concrete with high- volume fly ash, *Composite Interfaces.,* 2013;20 (3):201-209.
[5] Bae S, Meral C, Oh J, Moon J, Kunz M, Monteiro P J M. Cement and Concrete Research Characterization of morphology and hydration products of highvolume fly ash paste by monochromatic scanning x-ray micro-diffraction (μ -SXRD), *Cem. Concr. Res.,* 2014;59:155–164.
[6] Batson G B, Roumaldi J, P. Mechanics of crack arrest in concrete, *J. Eng. Mech.,* 1963;89 (3):147–168.
[7] Venigalla S G, Nabilah A B, Nasir N A M, Safiee N A, Aziz F N A. Textile-Reinforced Concrete as a Structural Member: A Review, *MDPI, Build*.,2022;12.
[8] Bruckner A, Ortlepp R, Curbach M. Textile reinforced concrete for strengthening in bending and shear, *Mater. Struct. Constr.,*2006;39 (8):741–748.
[9] Kayali O. Effect of high volume fly ash on mechanical properties of fiber Reinforced concrete, *Materials and Structures*.,2004;37:318–327.
[10] Suji D, Natesan S C, Murugesan R. Experimental study on behaviors of polypropylene fibrous concrete beams," *J. Zhejiang Univ. Sci. A.,*2007;8 (7):1101–1109.
[11] Bilodeau A, Kodur V K R, Hoff G C. Optimization of the type and Amount of polypropylene fibres for preventing the spalling of lightweight concrete subjected to hydrocarbon fire, *Cem. Concr. Compos.,* 2004;26 (2):163–174.

[12] Siva Subramanian E, Vaishnave V R, Vignesh V T S. (2016), Experimental Investigation of Concrete Composite Using Nylon Fibre, *International Journal of Engineering Sciences & Research Technology.,* 2016;5 (12):998-1002.

[13] Gadgihalli V, Shankar S, Havanje R P. Analysis of Properties Of Concrete Using Nylon Fiber As Fiber Reignforcement Admixture, *International Journal Research Granthaalayah.,* 2017;5 (4):63-66.

[14] Saxena J, Saxena P A. Enhancement the Strength of Conventional Concrete by using Nylon Fibre, *International Journal of Engineering and Science*, 2015;5 (2):56–59.

[15] Oh R, Kim D, Park C. Durability performance of latex modified nylon fiber reinforced concrete for precast concrete pavement applications, *Indian Journal of Engineering & Materials Sciences.,* 2014;21:49–56.

[16] Tang Z, Chen D, Wang X, Han Z, Tao R, Zhang G, Hou D, Wu D, Ding Q. Impact of polyethylene fiber on the ductility and durability of magnesium phosphate cement, *Journal of Building Engineering*., 2023;68.

[17] Navya G, Rao J V. Influences of polyester fiber on concrete paver blocks, *IOSR J. Mech. Civ. Eng*., 2014;11(4):70–75.

[18] Kirubakaran P, Nivetha S, Bari J A. Study on Strength Properties of Polyester Fibre Reinforced Concrete," *Int. J. Adv. Sci. Eng. Res.,* 2018;3(1):207–213.

[19] Bhatt P, Goe A. Carbon Fibres: Production, Properties and Potential Use, *Mater. Sci. Res. India.*,2017

[20] Venkata Ramana N, Raghu Babu U, Aruna Kanthi E. Performance of Polyester and polypropylene fibres in concrete, *Int. J. Sci. Eng. Res.,* 2016;7(4):156–160.

[21] Banthia N, Gupta R. Hybrid fiber reinforced concrete (HyFRC): Fiber Synergy in high strength matrices, *Mater. Struct. Constr.,* 2004;37:707–716.

[22] Ohama Y, Demura K, Nagao H, Ogi T. Adhesion of Polymer-Modified Mortars to Ordinary Cement Mortar By Different Test Methods, Sci. *Media Dordr.,*1986;719–729.

[23] Bentur A. Properties of polymer latex-cement composites," *Int. J. Cem. Compos. Light. Concr.,* 1982;4 (1):57–65.

[24] Wei Deng xin Y, Xinping Z, Hanlin C, and Dingpeng W. Mechanical Properties of Polyester Fiber and SBR Latex Compound-Modified Mortar for Tunnel Grouting, Electron. *J. e-government*., 2016;21:1365–1374.

[25] Xu F, Zhou M, Li B, Shen W. Influences of polypropylene fiber and SBR polymer latex on abrasion resistance of cement mortar, *J. Wuhan Univ. Technol. Sci. Ed.,* 2010;25(4):624–627.

[26] Xu F, Zhou M, Chen J, Ruan S. Mechanical performance evaluation of polyester fiber and SBR latex compound-modified cement concrete road overlay material, *Constr. Build. Mater.,*2014;63:142–149.

[27] *Bureau of Indian Standards IS 516: (1959),* Methods of tests for Strength of Concrete, New Delhi, India.

[28] *Bureau of Indian Standards IS 5816: (1999),* Spliting Tensile Strength of Concrete- Method of test, New Delhi, India.

[29] Arjun Ramakrishna Kurup A, Senthil Kumar K. Effect of Recycled PVC Fibers from electronic Waste and Silica Powder on Shear Strength of Concrete, *J. Hazard. Toxic Radioact. Waste.,*2017:21 (3).