Behavior of Polymer Modified High Volume Fly Ash Concrete (PMHVFAC)Produced with Hybrid Textile Fibers

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Abstract: High volume fly ash concrete (HVFAC) is a concrete in which the cement is replaced by fly ash by 50% or more than 50%. Textile reinforced concrete (TRC) is a form of concrete, where conventional reinforcement is replaced with textile fibers. Because of the high tenacity ofthe concrete prepared by textile fibers will result in flexible and durability of structures.The characteristics of workability and compressive strength of polymer modified high volume fly ash concrete (PMHVFAC) with different mono textile fibers and hybrid textile fibers are investigated in this paper. In the present study the textile fibers such as carbon fiber, polypropylene fiber, nylon fiber, polyster fiber and polyethelene fiber are used. The results depicts that,there is adrastic reduction of workability in PMHVFAC produced from hybrid textile fibers and mono textile fibers. In addition, the compressive strength of PMHVFAC produced with different hybrid textile fibers are more as compared to HVFAC and their respective mono textile fibers.

Keywords: High volume fly ash concrete, hybrid fibers, mono fibers, SBR latex polymer

1. Introduction:

Concrete is the second-most-used material in the world after water, and is the most comprehensively used construction material.The researchers considered the use of extra cementatious materials where cement could be substituted by what are known as pozzolanas because it is known fact during the manufacture of one ton of cement it emits the same amount of carbon dioxide.Many researchers have proved that upto 30% cement can be substituted by fly ash without compromising the good qualities of concrete, even later researchers revealed that the cement can be substituted by fly ash upto 50%. Such concretes in which 50% or more cement is substituted by fly ash is called high volume fly ash concrete (HVFAC).Since 1930fly ash has been used in USA; The first research work on the use of fly ash in concrete was published by Davis et al. in 1937.[1].Fly ash blended concrete has a lower early age compressive strength than control concrete.[2]. After 180 days of curing with 40% replacement of cement with fly ash the strength increased [3].The HVFA concrete material was formed in 1986 for structural applications by the Canadian Center for Mineral and Energy Technology (CAN-MET).In their investigations they have revealed that HVFA concrete has outstanding mechanical properties,permeability, lower shrinkage and superior durability compared with conventional concrete[4-7].HVFA concrete has advantages over Portland cement concrete such as 28-day strength, higher long-term strength, modulus of elasticity, lower drying shrinkage and creep, and excellent durability[8].When fly ash is used in concrete it improves the penetration rate of CO_2 or chloride ions [9].

Fibers are secondary reinforcing material and act as crack arresters. Fiber reinforced cement and concrete materials (FRC) have been progressively developed during the early work by Romualdi. J.P. et al,[10]in the 1960s.Due to the occurrence of high tenacity in textile fibers, the concrete prepared by textile fibers will result in flexible and durable concrete[11].Carbon fibers are used in many processes to create excellent building materials due to its stiffness, strength and light weight[12]. By using 1% of polypropylene fiberand nylon fiber by volume of the concretein HVFAcompressive strength doubled as compared to those of concrete without fly ash[13].By increasing SBR latex contentcompressive strength decreased, but increased with increasing nylon fiber content [14].Workability of polyster fiber reinforced concrete decreases, when the percentage of polyster fibers by volume fraction increases [15]. According to some authorsthe mechanical properties of concrete with polyster fibre did not improve[16].The addition of different percentages of hybrid fibers (steel and polypropylene fraction of 0.25% or 0.50%) to the concrete mixtures gained strength at all testing ages[17].

Flexible butadiene and rigid styrene chains are both present in styrene butadin rubber (SBR) latex. SBR provides concrete and mortars with outstanding mechanical qualities, watertightness, and abrasion resistance because of its molecular structure. [18,19]. With the additions of SBR latex and polyester fiber, there was slight reduction in compressive strength, the optimal polymer to cement ratio tends to be 15% [20]. By increasing the latex contentandnylon fiber by volume fraction the impact resistance, permeability resistance, abrasion resistanceand flexural strength of the latex modified nylon fiber reinforced concretecan be increased [14]. According to Feldman et al., found that when HVFAC pastes, reacts with calcium hydroxide [$Ca(OH)_2$] between 3 and 7 days, significant amount of $Ca(OH)_2$ and fly ash still remain unreacted after 90 days of hydration [21]. Berry et al., claims that fly ash particles are still active in chemical processes that produce ettringite after 7 days[22,23]. The amount of calcium hydroxide (CH) can be reduced within 10-15 hours [24]. Some researchers connected the mechanical qualities of concrete to the alteration in the microstructure and evolution of CH into dense C-S-H products, which is how the pozzolonic reaction of fly ash is manifested by the reduction in the content of crystalline CH and production of dense C-S-H [25].

However, extensive research has been done on HVFAC and hybrid fiber reinforced concrete separately. Due to less tensile strength and weaker bonding property of HVFAC, polymer modified high volume fly ash concrete produced by using hybrid textile fibers has been studied.

2. Materials used and their properties

2.1 Materials:

In the study OPC of grade 43, fly ash, fine aggregate, coarse aggregate, superplasticizer and polymer are used to design M30 grade concrete. Theproperties of the OPC, aggregates and fly ash are shown in table 1a and 1b. The properties of Conplast SP 430 superplasticizer and SBR latex polymer is as shown in table 2 and 3.

Table 1a: Properties of materials

Materials	Fineness	Specific gravity
OPC	4%	3.15
Fine aggregate (Zone II)	2.7	2.3
Coarse aggregate	3.02	7.3

Table 1b: Properties of fly ash

Specific gravity	2.12
pH	8.9
EC (µs/cm)	200
TDS (mg/L)	128
SiO_2 +Al_2O_3+Fe_2O_3 % by mass	83.32
Silicon dioxide(SiO_2) % by mass	48.42
Magnesium oxide(MgO) % by mass	1.36
Total Sulphur as sulphur trioxide(SO_3) % by mass	0.26
Loss of ignition % by mass	5.96
Sodium oxide(Na_2O) % by mass	0.64
Total Chlorides % by mass	0.088

Table 2: Properties of Conplast SP 430 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 3: Properties of SBR latex

Appearance / Colour	**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

Different type of textile fibers such as carbon fiber, polypropylene fiber, nylon fiber, polyster fiber and polyethelene fiberwith 12 mm length are procured and their physical properties are shown in table 4.

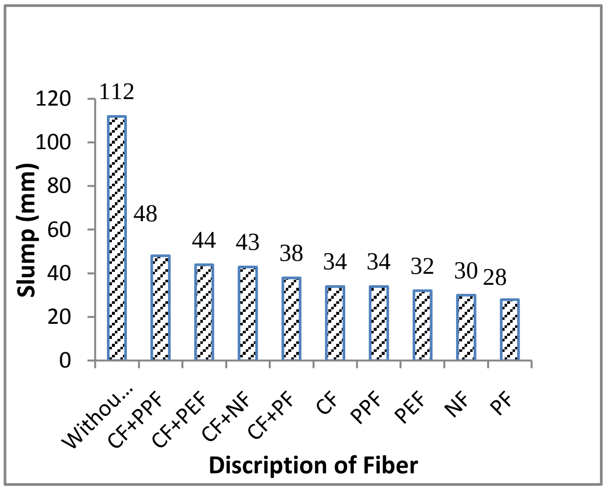
Table 4: Properties of textile fibers

Fibers	**Density**	**Ultimate tensile strength**	**Young's modulus of elasticity**
Carbon fiber (CF)	2000 kg/m^3	2500 MPa -7000 MPa	5,00,000 MPa
Polypropylene fiber (PPF)	895-945 kg/m^3	520 MPa	1325 MPa
Polyethelene fiber (PEF)	950-960 kg/m^3	600 MPa	1070-1090 MPa
Nylon fiber (NF)	1140 kg/m^3	558-607 MPa	2700 MPa
Polyster fiber (PF)	1360 kg/m^3	600 MPa	920 MPa

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. By weight of cementitious material 3% and 1.4% of SBR latex polymer and superplasticizer is added. Mix design for M30 grade HVFAC yielded a proportion of 1:1.34:3.29. All the ingredients of concrete are dry mixed first and then water, superplasticizer and polymer are added to get homogenous mix.

3. Experimental results:

3.1 Workability results: The workability test results for PMHVFAC with different hybrid textile fibers and mono fibers are graphically represented in fig 1 to fig 4 for slump, compaction factor, Vee Bee degree and percentage flow.



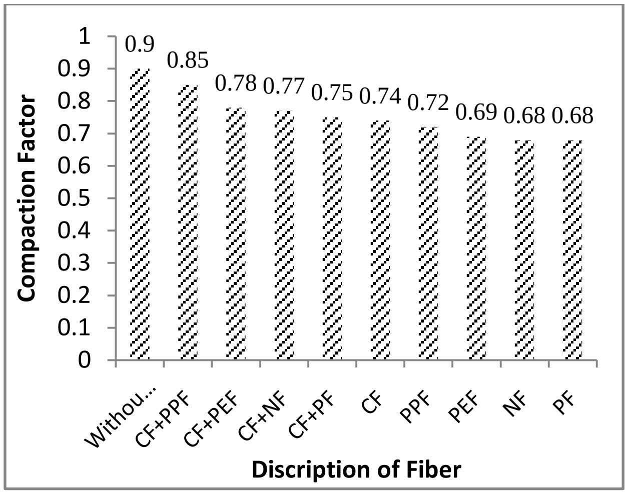
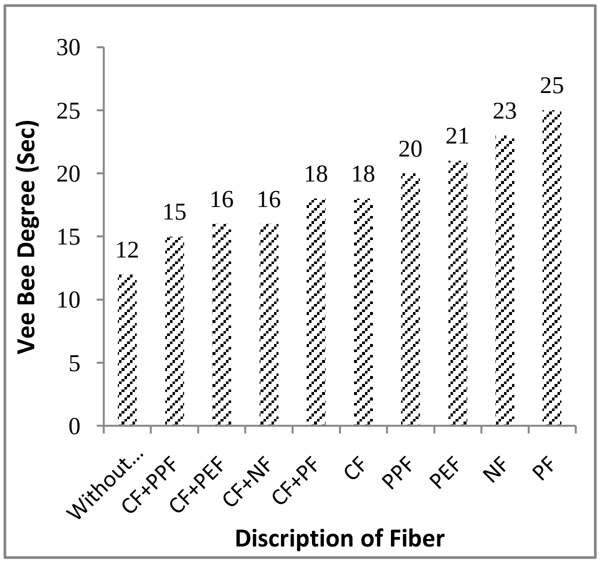


Fig 1 Variation of slump

Fig 2 Variation of compaction factor



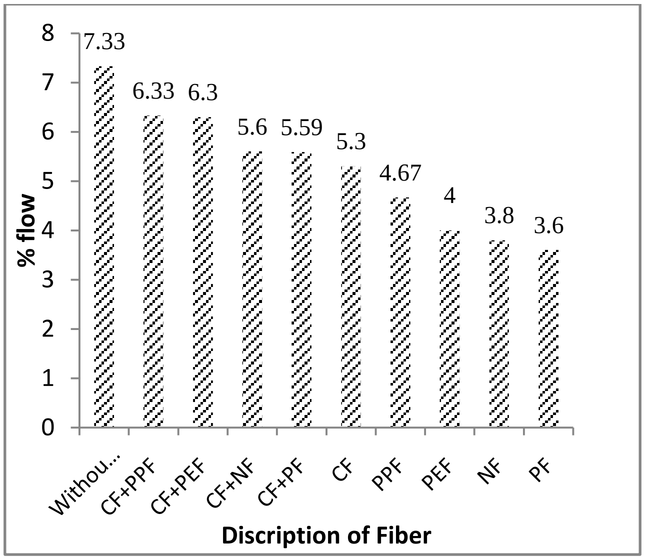


Fig 3 Variation of Vee Bee degree

Fig 4 Variation of percentage flow

3.2 Water absorption and soroptivity test results

The variation in water absorption and soroptivity for PMHVFAC are graphically represented in fig 5. The percentage of water absorption and soroptivity can be calculated using Equation (1) and Equation (2);

% water absorption: $[(W2 - W1) / W1] \times 100$ Eqn (1)

Soroptivity: $S = i/\sqrt{t}$ Eqn (2)

Where, W1 = dry weight;

W2 =wet weight;

S = sorptivity in mm/√min,

i = rise of water level (mm),

t = time taken for this rise (min)

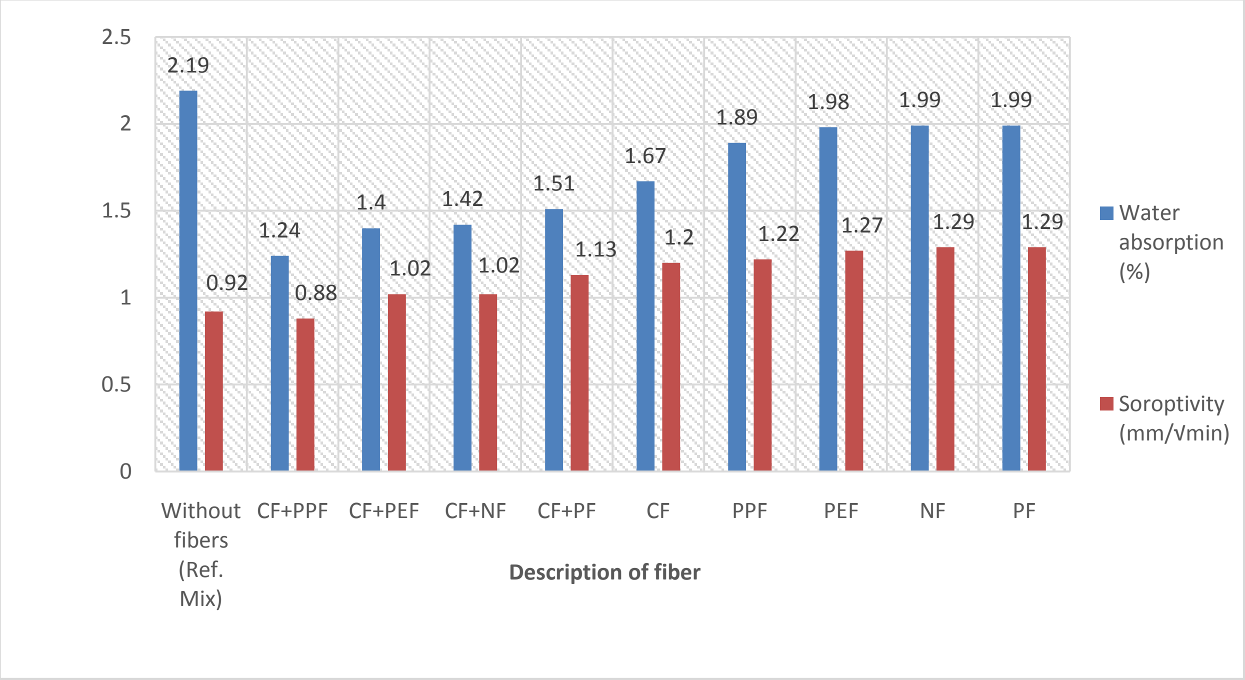


Fig 5: Variation of water absorption and soroptivity

3.3 Compressive strength test results: The compressive strength test results for PMHVFAC using various hybrid textile fibers and mono fibers are presented in table 6 for 28 days and 90 days. Figure 7 illustrates variation of compressive strength graphically. The compressive strength for PMHVFAC can be calculated by Equation (3);

$$\text{Compressive strength} = \frac{\text{Load (P)}}{\text{Area (A)}} \qquad \text{Eqn (3)}$$

Table 6: Compressive strength results for 28 and 90 days

Description of PMHVFAC with different textile fibers	**Average compressive strength (MPa) 28 days**	**Average compressive strength (MPa) 90 days**	**Percentage increase of compressive strength w.r.t ref. mix for 28 days**	**Percentage increase of compressive strength w.r.t ref. mix for 90 days**	**Percentage increase of compressive strength for hybrid fiber combinations w.r.t respective mono fibers for 28 days**	**Percentage increase of compressive strength for hybrid fiber combinations w.r.t respective mono fibers for 90 days**
Without Fibers (Ref. Mix)	28.30	32.15				
CF+PPF	36.59	46.52	29.30	44.69	14.88	26.10
CF+PEF	35.85	40.44	26.68	25.80	15.24	12.81
CF+NF	33.33	39.56	17.79	23.03	7.66	13.62
CF+PF	32.59	34.52	15.17	7.37	12.82	0.43
CF	32.00	38.52	13.07	19.81		
PPF	31.85	36.89	12.55	14.74		
PEF	31.11	35.85	9.93	11.51		
NF	30.96	34.81	9.41	8.29		
PF	28.89	34.37	2.08	6.91		

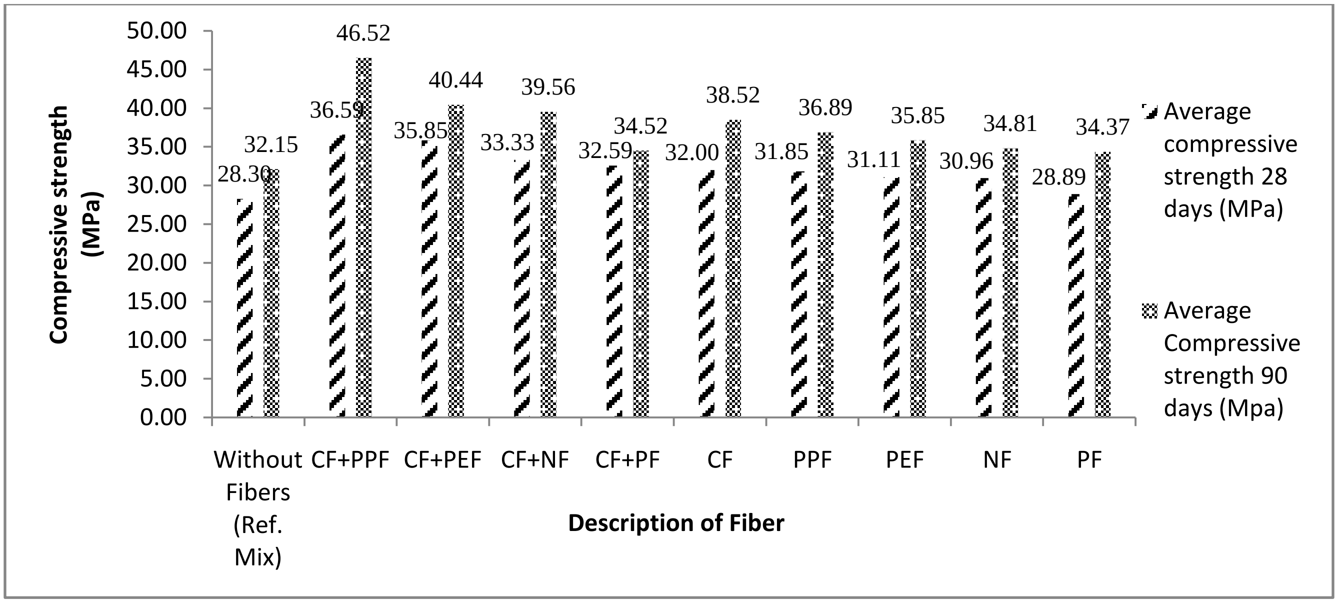


Fig 7 Variation of compressive strength

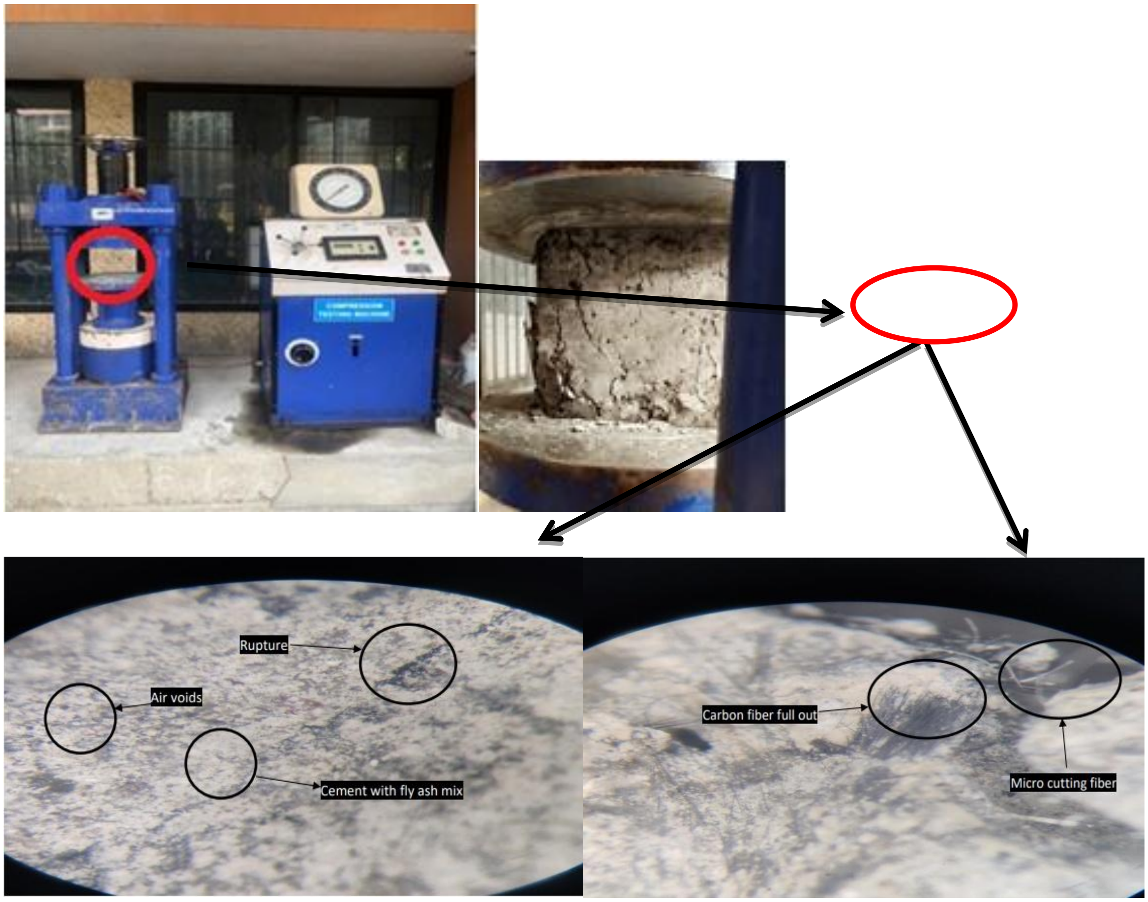


Fig 8Microstructural behavior of fibers under compressive loads

4. Observations and discussions: From theexperimentalresults, the following observations are made:

1) It can be observed that the workability of PMHVFAC produced by using hybrid textile fibers and mono textile fibers is seriously affected as compared to PMHVFAC without fibers. The different workability tests conductedshows that the values have drastically reduced for PMHVFAC produced from hybrid textile fibers and mono textile fibers.This is obviously because of the fact that,combination of either hybrid textile fibers or mono textile fibers will check the flow of concrete. The fibers offer lot of friction in the concrete mass for the flow.
2) From the workability tests results of PMHVFAC produced by using hybrid textile fibers are slightly higher as compared to PMHVFAC produced by using mono textile fibers.This could be as a result of the fact that when hybrid textile fibers are added, one of the fiber among them may offer less friction to the flow as compared to the other.
3) Table 6 exhibits the 28 and 90 days compressive strength test results for PMHVFAC with different hybrid textile fibers and mono textile fibers. Also fig 7 shows the graphical representation of variation of compressive strength. The 28 days compressive strength of PMHVFAC produced with different hybrid textile fibers are more as compared to ref. mix (without fibers) and PMHVFAC produced by using respective mono textile fibers. Similar trend is observed for 90 days compressive strength.This may be because the addition of hybrid textile fibers to the concrete has a synergistic impact. At various levels of loading, the hybrid textile fibers have the ability to arrest cracks. One fiber will arrest the cracks in the initial stage of loading and another fiber will arrest the cracks in the later stage of loading.
4) The 28 days compressive strength of PMHVFAC produced with hybrid textile fibers (CF+PPF) is higher than that of (CF+PEF), (CF+NF) and (CF+PF). PMHVFAC produced with (CF+PPF) exhibits a compressive strength of 36.59 MPa which is 29.3% higher as compared to ref. mix and 14.88% more as compared to respective mono textile fiber concrete produced with PPF. Similar trends are observed for 90 days compressive strength. This is because of the fact that (CF+PPF) hybridization may results in a better microstructure and may exhibit a better synergistic effect as compared to other combinations of hybrid textile fibers.

5. Conclusions:

Following conclusions may be drawn from the study conducted.

1)The workability characteristics of PMHVFAC produced using hybrid textile fibers or mono textile fibers are less as compared to PMHVFAC without fibers. High dosage of superplasticizers are required to induce the required workability in PMHVFAC produced with hybrid textile fibers or with mono textile fibers.

2) The workability of PMHVFAC produced by using hybrid textile fibers are slightly higher as compared to the PMHVFAC produced by using mono textile fibers.

3) PMHVFAC produced by different hybrid textile fibers exhibits better compressive strength as compared to reference mix (without fiber) and PMHVFAC produced by respective mono textile fiber concrete.

4) PMHVFAC produced with (CF+PPF) exhibitsbetter compressive strength as compared to the other hybrid fibers combinations. Also it may be concluded that, the higher compressive strength for PMHVFAC is achieved by the hybrid combination (CF+PPF) followed by (CF+PEF), (CF+NF) and (CF+PF).

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