EFFECTS OF POLYVINYL ALCOHOL FIBER ON THE TOUGHNESS OF CONCRETE

Anshul Jain and A.Sanjay Jain

VIT University, Vellore-632014, Tamil Nadu, India.

ABSTRACT

The main objective of this research is to study the effect of fibers on the mechanical properties of the concrete which includes impact, abrasion resistance, shatter, toughness, compressive strength and flexural strength of the various concrete mixture proportions. The inclusion of polyvinyl alcohol fiber impart the toughness to the concrete matrix. The high gain in strength was observed due to less shrinkage and cracks, the gain in strength also depends upon the compaction effort on the concrete. The percentage of polyvinyl alcohol fiber varies from 0% to 0.3% . The test results proved the increase in compressive strength with respect to the reference mix, the maximum strength was found by the addition of 0.20% polyvinyl alcohol fiber. The maximum compressive strengths were 40.9 MPa at 3 days, 45.8 MPa at 7 days and 56.2 MPa at 28 days. The flexural strength also increases by increasing fiber content and the maximum flexural strength of 6.39 MPa at 7 days and 8.12 MPa at 28 days with 0.30% polyvinyl alcohol fiber.

Keywords:- Polyvinyl alcohol fiber, Compressive strength, Flexural strength, Concrete, Fiber reinforced concrete.

Corresponding Author: Anshul Jain

INTRODUCTION

The normal concrete made with the portland cement is generally strong in compression but weak in the tension which leads to the shrinkage cracks and distortion in tension zone. The tension zone is weak so it can be improved by incorporating the polyvinyl alcohol fiber. The addition of fiber also improves the behaviour of the concrete matrix composite after it has cracked, so improving the toughness property of the concrete. The use of different types of

fibers improves the mechanical properties as well as improve the performance of conventional concrete. Polyvinyl alcohol fibers do not behave as the primary reinforcement in the concrete because of its relatively low modulus of elasticity. Polyvinyl alcohol fibers increases the flexural behaviour by arresting the cracks in the concrete matrix this property of fibers make it useful for fiber reinforced concrete. [1] showed that the addition of glass fiber improves the mechanical properties if the concrete, the addition of 0.1% glass fiber shows marginal increase in compressive strength at 28 days and the flexural strength, toughness of the concrete also increases.[2] investigated the permeability of chloride was less on the addition of glass fiber to the concrete and the voids also decreased which means the cracks could be arrested at failure.[3] concluded that the inclusion of glass fiber increases the compressive strength upto 20-25 %, flexural strength and split tensile strength increases upto 15-20%.[4] found that the inclusion of polypropylene fiber significantly improved the fracture properties of concrete composite containing 15% fly ash and 6% silica fume, like toughness, fracture energy etc.[5] demonstrated that incorporation of the polypropylene fiber leads to reduction in the workability and mix slump.[6] in their research they showed that the increasing dosages of PP fibers in the concrete causes small but consistent increases of the overall total shrinkage strain of concrete..[7-8] concluded in their research studies that there has been marginal improvement in the compressive strength and flexural strength at first crack of fiber reinforced concrete cubes and deep beams respectively.[9]they found that no workability problem was encountered for the use of hooked fibers up to 1.5 percent in the concrete mix. [10] concluded that the ultimate residual strengths of RC beams containing polypropylene fibers are higher than the conventional concrete beams[11] studied the behaviour of concrete by the addition of steel and polypropylene fibers and concluded that the addition of fibers improves the mechanical behaviour of the concrete.

EXPERIMENTAL METHODOLOGY

The list of materials used in this experimental investigation are as follows.

A. Cement

The Ordinary Portland cement of 53 grade having 28 days compressive strength of 49.72 MPa, satisfying the requirements of IS: 12269–1987. Some of the physical properties of cement value are presented in Table 1.

Table 1. (Properties of Cement)

S.NO	Name of the test	Value
1	Consistency	32%
2	Initial Setting Time	148 minutes
3	Final Setting Time	474 minutes
4	Specific Gravity	3.27
5	Fineness of cement	3%
6	Soundness	3 mm
7	Compressive Strength 7 days 28 days	28.64 N/mm2 49.72 N/mm2

B. Fine aggregates

The sand obtained from locally available in the river bed, fine aggregate passing through IS sieve, satisfying to the grading zone-II as per the IS: 383-1970. The fineness modulus value is 2.97, specific gravity of 2.70 and water absorption of 0.69 % at 24 hours.

C. Coarse aggregates

Mechanically crushed angular blue granite stone of size 20 mm and 12.5 mm were used, for different size of sieve used as per standard , which is maintained with different proportion of coarse aggregate and conforming to IS: 383-1970. The specific gravity was found to be 2.74, fineness modulus is 7.21 and water absorption is 0.63 % at 24 hours.

D. Chemical admixtures

Polycarboxylate ether based super-plasticizer condensate as high range water reducing admixture (HRWR) to maintain a satisfactory of workability for different mixes with constant w/b ratio throughout the experimental works. It has a specific gravity value of 1.19; pH value of 5.6 and solids content of 39%.

E. Polyvinyl Alcohol Fibers

The raw material of polypropylene is derived from the monomeric unit of C3H6 which is pure a hydrocarbon. Its process of polymerization and high molecular weight makes it suitable for processed into fibers combine to give polypropylene fibers. The general properties are shown in Table 2.

Table 2. (Properties of PVA fiber)

Material	Polyvinyl Alcohol
Appearance	Crimped white fiber
Density (g/cc^3)	1.26
Length	45 mm
l/d ratio	80
Width	1.1 mm
Tensile strength	880MPa-1600MPa
Failure strain	23%

F. Concrete Mixture Proportions and Casting of specimens

The concrete mixture proportions used in the study are provided in the Table 3. A total of 7 different concrete mixtures were proportioned based on the water to binder ratio (w/b) 0.35 and fine to coarse aggregate ratio (F/C) 0.6. The concrete mixtures were mixed using a 30 liters capacity of container with tilting drum type mixer and specimens were casted by using the steel mould of standard cube 100 X 100 X 100 mm and size of beam mould 100 X 100 X 500.The experimental test set up for flexural strength is shown in Figure 1. The fresh concrete mixtures in moulds were compacted using table vibrator and the sspecimens were demoulded after 24 hours after casting and water cured at 27 ± 3^oC until the age of testing at 7 and 28 days as shown in Figure 2.

Table 3. (Mix Proportions)

Mix Id	Cement	Fine Aggregate	Coarse Aggregate	Water	F/C	w/b	Polyvinyl alcohol fiber (%)
	Kg/m3						
M1	472	644	1073	165	0.6	0.35	0
M2	465	644	1073	165	0.6	0.35	0.05
M3	465	644	1073	165	0.6	0.35	0.1
M4	465	644	1073	165	0.6	0.35	0.15
M5	465	644	1073	165	0.6	0.35	0.2
M6	465	644	1073	165	0.6	0.35	0.25
M7	465	644	1073	165	0.6	0.35	0.3

Figure 1 . (Experimental setup for flexural test)

Figure 2. (Experimental Setup for compressive test)

EXPERIMENTAL TEST RESULTS AND DISCUSSION

The test results include the compressive strength and the flexural strength of various mixture proportions with different dosages of polyvinyl alcohol fibers. The mechanical behaviour of various mixture proportions can be easily studied.

A. Compressive Strength

The increase in the percentage of polyvinyl alcohol fiber addition showed a marginal improvement in the compressive strength as compared to reference concrete (as shown in Table 4). The strength of various concrete mixes containing different dosage level of fibers for different curing days as shown in Figures 3 and 4. It can be concluded that addition of 0.2% V_f of PVA fibers showed an increase in compressive strength upto good level at 3 days,7 days and 28 days, the compressive strength was found to be 40.9 MPa, 45.8 MPa and 56.2 MPa respectively. With the further increase in polyvinyl alcohol fiber dosage the strength was found to be decreased compared to reference concrete due to defects arising internally as a result of loss in workability. This can be concluded that optimum fiber addition upto 0.2% V_f of PVA fibers can result in good fiber dispersion as well as improving the fiber reinforcement index.

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Table 4. Compressive Strength in MPa.

MIX ID	3 DAYS	7 DAYS	28 DAYS
M1	28.3	35.1	41.9
M2	34.1	38.5	43.2
M3	37.9	39.2	46.5
M4	39.4	41.7	49.3
M5	40.9	45.8	56.2
M6	38.6	43.3	48.4
M7	37.3	42.4	46.7

Figure 3. Variation of compressive strength of M1, M2,M3,M4

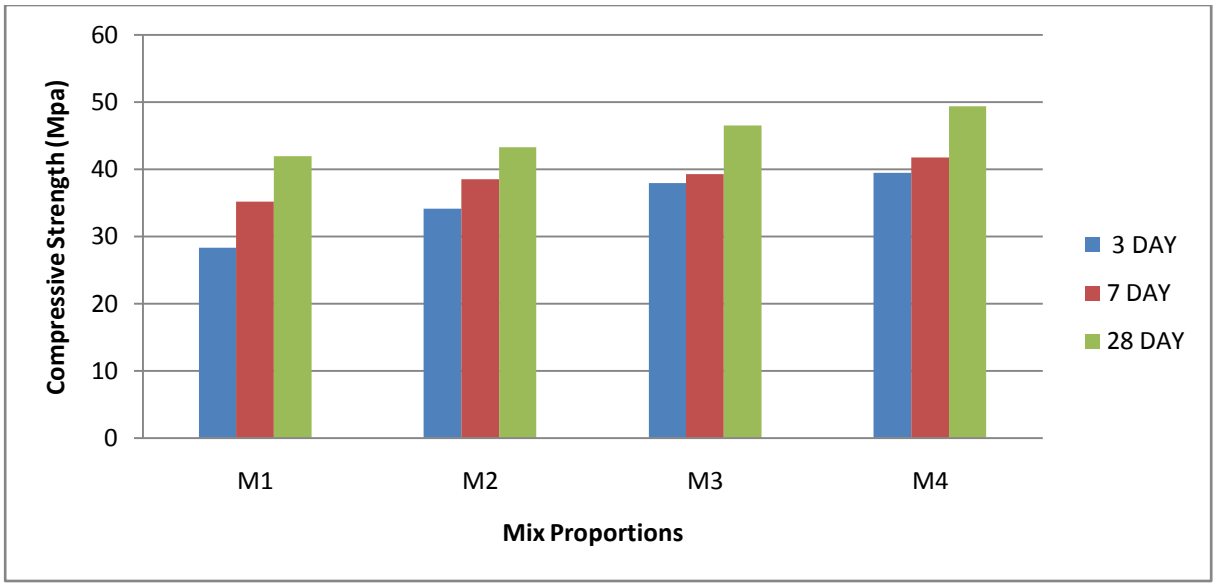
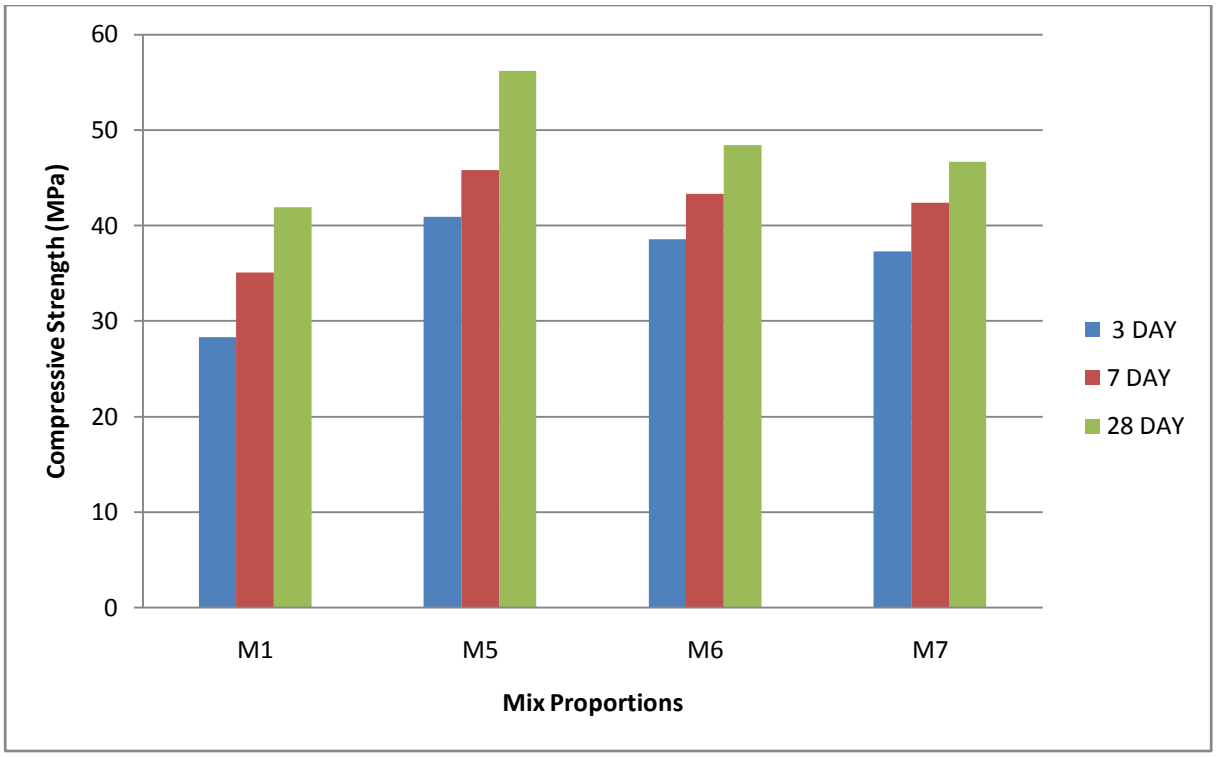


Figure 4. Variation of compressive strength of M1, M5,M6,M7



B. Flexural Strength

The flexural strength results are given in the Table 5 and shown graphically in Figure 5 and 6. It has been observed that the maximum strength of 3.21 MPa at 7 days and 4.13 MPa at 28 days was seen for reference concrete; whereas with the fiber addition at 0.30% V_f of PVA,the strength was around 6.39 MPa at 7 days and 8.12 MPa at 28 days. The addition of fibers beyond the required reinforcement index may reduce the contribution of interfacial bond strength provided by matrix and can result in poor stress redistribution. A matrix reinforced with optimum fibers can envisage efficient stress transfer mechanism upon reaching maximum fiber stress and this result in composite energy absorbing capacity. Also, the failure strain of PVA fibers (23%) had shown a good improvement in the post peak straining of concrete and results in high toughness. In this investigation, optimum percentage of fiber addition contributed for the strength enhancement of concrete which leads to the improvement on the hardened properties of concrete.

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Table 5. Flexural Strength in MPa

MIX ID	7 DAYS	28 DAYS
M1	3.21	4.13
M2	3.52	4.77
M3	4.34	5.48
M4	4.86	5.97
M5	5.38	6.54
M6	6.17	7.36
M7	6.39	8.12

Figure 5. Variation of Flexural Strength of M1,M2,M3,M4

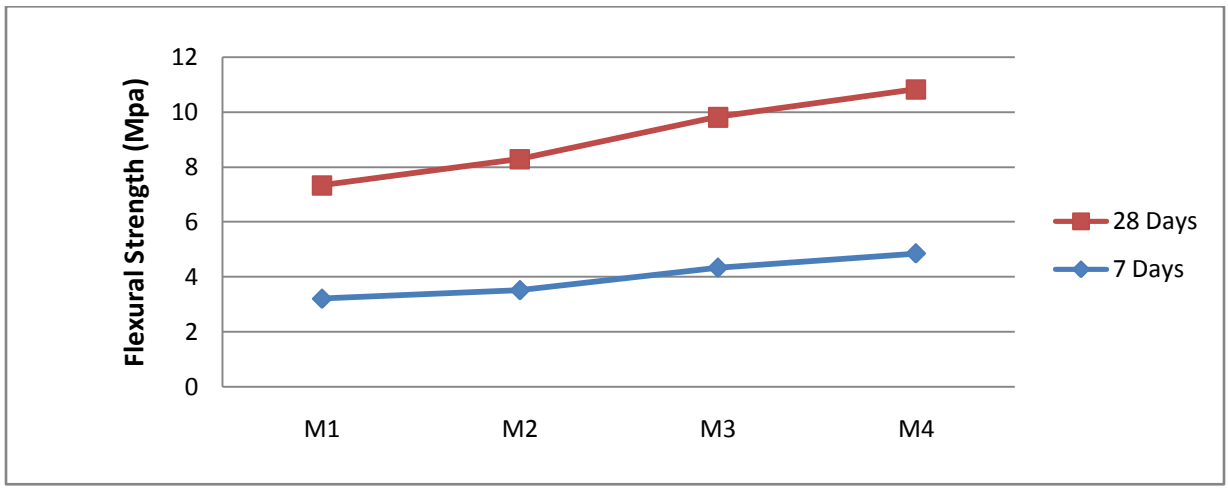
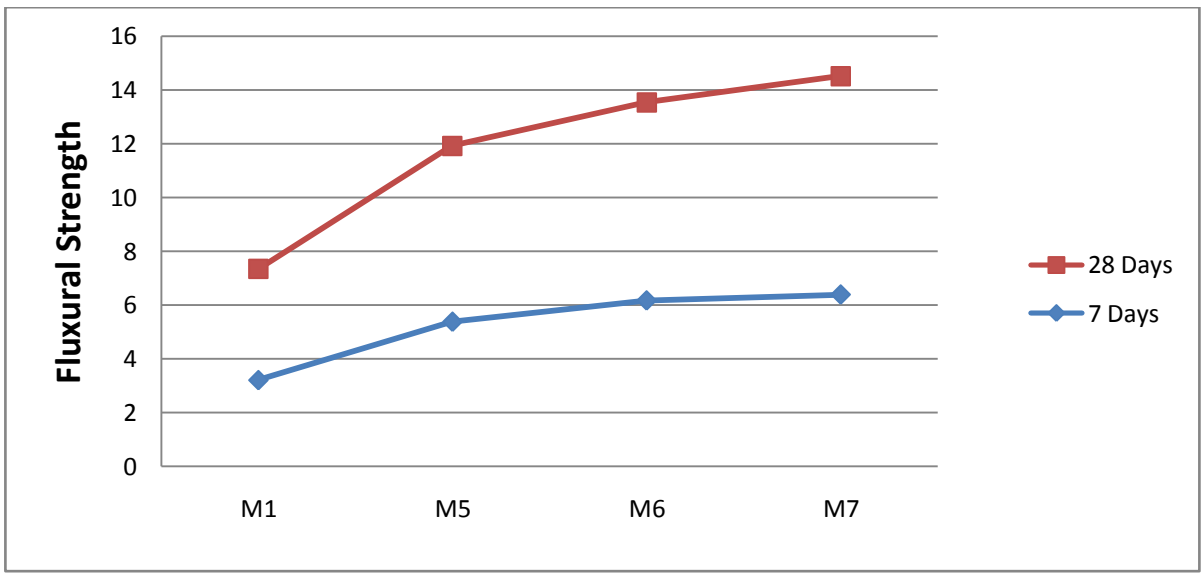


Figure 6. Variation of Flexural Strength of M1,M4,M5,M6,M7



CONCLUSIONS

Based on the research study the following conclusions are drawn from the test results:-

- The performance behaviour of polyvinyl alcohol fiber were dependent on the optimum fiber dosage upto 0.2% since fiber addition resulted in loss in workability.
- The maximum increase in compressive strength was found to be around 44% with the use of polyvinyl alcohol fibers as compared to the reference concrete.
- The maximum increase in flexural strength was observed to be around 96 % with the use of polyvinyl alcohol fibers as compared to the reference concrete.
- The role of polyvinyl alcohol fibers in delaying the crack formation were realized.

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