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AN INVESTIGATION ON THE SHRINKAGE CHARACTERISTICS OF HYBRID FIBER REINFORCED CONCRETE PRODUCED BY USING FIBERS OF DIFFERENT ASPECT RATIO

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ABSTRACT

In the present paper, effects of shrinkage in fiber reinforced concrete are studied. Here, in the current research work, an attempt is made to study the effects on shrinkage of concrete when five different fiber materials are used for reinforcing plain concrete. Three configurations of each reinforcing fiber material is studied. Fiber aspect ratios of 40 and 100 and a combination of the fibers of the two aspect ratios in equal proportion (hybrid) make up the three configurations for one individual fiber material reinforcement. Shrinkage values are indicated in terms of total length of crack and the total area of the crack. On-field measurement of crack dimensions at periodic time intervals ranging from 0 minutes to 28 days after casting of concrete has been undertaken to determine the accurate values of shrinkage cracks in the fifteen scenarios i.e. five reinforcing fiber materials with three configurations each using aspect ratio of fibers 40, 100 and the hybrid (40 +100) case. It is seen that, irrespective of the material of fiber used for reinforcing concrete, hybridized concrete consistently shows better results relative to single aspect ratio fiber reinforcement. This research also aims to provide a bench mark for future research works on shrinkage characteristics of hybridized fiber reinforced concrete.

Keywords: Hybrid Fiber, Reinforced Concrete, Shrinkage, Concrete mixture

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1. INTRODUCTION

Concrete mixture in its natural state will shrink when exposed to dry environment [3]. If we restrain this shrinkage, stresses will develop inside the mixture and these stresses will induce cracks inside the concrete. So, shrinkage is time-dependent strain and always this strain will be measured in an unloaded specimen at constant temperature [2]. As we discussed shrinkage, is a natural phenomenon and depends on various factors like relative humidity of the environment, temperature and even on property of material, age when concrete structure is exposed to drying environment. Effects of shrinkage is a major problem in concrete members which are having larger surface area like tunnel linings, bridge decks, slabs and floor slabs etc. Inner surface of tunnels will be subjected to nonstructural cracks due to shrinkage. The concept of shrinkage can be classified into four types based on the effects they produce on the surface areas.

1. Plastic Shrinkage
2. Drying Shrinkage
3. Autogenous Shrinkage
4. Carbonation Shrinkage.

1.1. Plastic Shrinkage

Plastic shrinkage will occur at the early age of setting, at which concrete has not gained sufficient tensile stress (i.e. under plastic state). This type of shrinkage is due to the evaporation of water from the top surface of concrete, the loss of moisture content leads to reduction of volume.

1.2. Drying Shrinkage

Drying shrinkage is an uninterrupted process occurs when concrete structures are exposed to drying conditions. This is very much similar to drying process in timber specimens, drying shrinkage is strain caused due to the evaporation of free water content from the hardened concrete. Factors like humidity, temperature, elastic modulus of material, size and volume of aggregates affects the drying shrinkage. Deflection in beams, loss of prestess in structural members, long deflections in slab structures and shortening of tall structures are examples of structural effects caused by drying shrinkage process.

2. OBJECTIVES OF PROPOSED RESEARCH WORK

The primary objective of this research work is to study the characteristic properties of hybrid fiber reinforced concrete formed by using fiber of different aspect ratios. Five different types of fibers like steel fibers, galvanized fibers, high density polyethylene fibers, waste plastic fibers and polypropylene fibers of different aspect ratio are used in the experimental work to find out the shrinkage characteristics of hybrid fiber reinforced concrete produced by using fibers of different aspect ratios.

3. MATERIALS AND METHODOLOGY

3.1. Materials

3.1.1. Cement

In the current research work, 43 grade ordinary portland cement has been used followed by code IS: 8112 - 1989. The locally available ingredients have been used. Cement from the local distributors is used for casting of concrete specimens.

The standard properties of cement are as shown in Table 1.

Table 1 Properties of cement (OPC 43)

Sl. No.	Material Property	Results obtained
1	Specific gravity	3.15
2	Fineness	4%
3	Normal consistency	34%
4	Initial setting time	30 minutes
5	Final setting time	5 hrs 45 minutes

3.1.2. Fine Aggregates

Locally available river sand is used, confirming to Zone II as mentioned in IS 383-1970. Basic tests are performed on fine aggregate and tabulated below in Table 2.

Table 2 Physical properties of fine aggregate

Sl. No.	Material Property	Results obtained
1	Specific gravity	2.58
2	Bulk Density	1752 kg/m^3
3	Water absorption	1%

3.1.3. Coarse Aggregates

Coarse aggregate as per IS 383-1970 are used in this study. The properties of coarse aggregates in Table 3

Table 3 Physical Properties of Coarse Aggregate

Sl. No.	Material Property	Results obtained
1	Specific gravity	2.61
2	Bulk Density	1782 kg/m^3
3	Water absorption	0.6 %

3.1.4. Steel Fibres (SF)

In the present work steel fibres of aspect ratio of 40 and 100 were used. Fibres of crimped shape were found suitable from literature studies. The density and ultimate tensile strength was found to be 7850 kg/m^3 and 395 MPa respectively. Steel fibres were obtained from stewools india (p) ltd. Nagpur.

3.1.5. Galvanized Iron Fibres (GIF)

GI fibres were procured locally. Round galvanized iron wire of 1 mm diameter was cut to the required length of 40 mm and 100 mm giving an aspect ratio of 40 and 100. The ultimate strength and density of fibres was found to be 395 MPa and 7850 kg/m^3 respectively. These GI fibres are commercially available and are generally used for electrical work.

3.1.6. High Density Polyethylene Fibres (HDPEF)

High density polyethylene fibers are acquired by cutting oil cans available in petrol pumps they are cut to a length of 40 mm, 100 mm and width of 1mm obtaining aspect ratio of 40 and 100. Density of HDPE fiber was found to be 900 kg/m^3.

3.1.7. Waste Plastic Fiber (WPF)

The waste plastic fibres were obtained by cutting the waste plastic buckets. Fibres are cut to a length of 40 mm, 100 and width of 1mm obtaining aspect ratio of 40 and 100. Density of WPF fibre was found to be 280 kg/m^3.

3.1.8. Poly Propylene Fiber (PPF)

Poly propylene fibres are readily available in the market in standard dimensions. The fibres used here are of length 6 mm and 12 mm which is prescribed by the manufacturers for the concrete work. The density of PPF is found to be 930 kg/m^3.

3.2. Mix Design for M30 Grade Concrete

Table 4 Mix proportion for M 30 grade concrete

Sl. No	Grade of concrete	Cement	Fine aggregate	Coarse aggregate	W/C
1.	M 30	1.00	1.58	2.71	0.45

4. MIXING

The material required for casting of specimens (15 slabs) are calculated, using the mix proportion by mass and mixing of ingredients have been carried out manually

- Separately mix the cementitious materials and fibers.
- Dry mix the sand and cementitious materials and fibers.
- Add coarse aggregate to it and mix it thoroughly to achieve cement particles on each and every coarse aggregate.
- Add the calculated quantity of water to the dry mix and mix thoroughly to get homogeneous mix.

4.1. Shrinkage Tests

4.1.1. Plastic Shrinkage

The shrinkage behavior of hybrid fibre reinforced concrete is observed with the help of prism specimens whose dimensions are (700 mm length, 500 mm breadth and 70 mm height). The concrete is of M 30 grade Mix design proportions as shown above. Different specimens with varying fibre mix proportion along with differing constituent fiber aspect ratios have been observed individually and changes in certain parameters are noted down. Shrinkage cracks are vigourously monitored during the initial twenty four hours after mixing of water.

4.1.2. Drying Shrinkage

Same specimens are used even for drying shrinkage test, observation is continued even after 28 days of curing. The maximum crack-length and the total crack area are graphically represented below.

Figure 1 Cracks on specimen due to effect of shrinkage

5. TEST RESULTS

For experimental work slabs are of size 700 mm*500 mm *70 mm are used. Shrinkage cracks are observed in different time period like 0 to 5 hours, 8 hours, 12 hours, 24 hours and after 28 days curing are shown tables below.

Table 5 Shrinkage characteristics of steel fiber reinforced concrete

Fibers	Time	Length (mm)	Breadth (mm)	Area (mm^2)	Total crack area
Steel 40	0 to 5 hours	0	0	0	32
	8 hours	15	0.5	7.5	
	12 hours	23	0.5	11.5	
	24 hours	26	0.5	13	
	28 days	0	0	0	
Steel 100	0 to 5 hours	5	0.5	2.5	47
	8 hours	18	0.5	9	
	12 hours	32	0.5	16	
	24 hours	35	0.5	17.5	
	28 days	4	0.5	2	
Steel 40+100	0 to 5 hours	0	0	0	25
	8 hours	10	0.5	5	
	12 hours	18	0.5	9	
	24 hours	22	0.5	11	
	28 days	0	0	0	

Table 6 Shrinkage characteristics of galvanized fiber reinforced concrete

Fibers	Time	Length (mm)	Breadth (mm)	Area (mm^2)	Total crack area
GI 40	0 to 5 hours	0	0	0	39.5
	8 hours	18	0.5	9	
	12 hours	28	0.5	14	
	24 hours	33	0.5	16.5	
	28 days	0	0	0	
GI 100	0 to 5 hours	10	0.5	5	58
	8 hours	21	0.5	10.5	
	12 hours	36	0.5	18	
	24 hours	41	0.5	20.5	
	28 days	8	0.5	4	
GI 40+100	0 to 5 hours	0	0	0	29
	8 hours	12	0.5	6	
	12 hours	20	0.5	10	
	24 hours	26	0.5	13	
	28 days	0	0	0	

Table 7 Shrinkage characteristics of high-density polyethylene fibers reinforced concrete

Fibers	Time	Length (mm)	Breadth (mm)	Area (mm^2)	Total crack area
HDPE 40	0 to 5 hours	0	0	0	49
	8 hours	22	0.5	11	
	12 hours	32	0.5	16	
	24 hours	38	0.5	19	

	28 days	6	0.5	3	
HDPE 100	0 to 5 hours	14	0.5	7	66.5
	8 hours	26	0.5	13	
	12 hours	39	0.5	19.5	
	24 hours	44	0.5	22	
	28 days	10	0.5	5	
HDPE 40+100	0 to 5 hours	0	0	0	34.5
	8 hours	15	0.5	7.5	
	12 hours	23	0.5	11.5	
	24 hours	28	0.5	14	
	28 days	3	0.5	1.5	

Table 8 Shrinkage characteristics of waste plastic fiber reinforced concrete

Fibers	**Time**	**Length (mm)**	**Breadth (mm)**	**Area (mm^2)**	**Total crack area**
WPF 40	0 to 5 hours	7	0.5	3.5	59.5
	8 hours	25	0.5	12.5	
	12 hours	36	0.5	18	
	24 hours	42	0.5	21	
	28 days	9	0.5	4.5	
WPF 100	0 to 5 hours	18	0.5	9	78
	8 hours	30	0.5	15	
	12 hours	44	0.5	22	
	24 hours	50	0.5	25	
	28 days	14	0.5	7	
WPF 40+100	0 to 5 hours	5	0.5	2.5	47
	8 hours	18	0.5	9	
	12 hours	28	0.5	14	
	24 hours	35	0.5	17.5	
	28 days	8	0.5	4	

Table 9 Shrinkage characteristics of polypropylene fiber reinforced concrete

Fibers	**Time**	**Length (mm)**	**Breadth (mm)**	**Area (mm^2)**	**Total crack area**
PPF 300	0 to 5 hours	18	0.5	9	83.5
	8 hours	32	0.5	16	
	12 hours	44	0.5	22	
	24 hours	51	0.5	25.5	
	28 days	12	0.5	6	
PPF 600	0 to 5 hours	22	0.5	11	102.5
	8 hours	40	0.5	20	
	12 hours	52	0.5	26	
	24 hours	59	0.5	29.5	
	28 days	17	0.5	8.5	
PPF 300+600	0 to 5 hours	10	0.5	5	65.5
	8 hours	25	0.5	12.5	
	12 hours	36	0.5	18	
	24 hours	41	0.5	20.5	
	28 days	11	0.5	5.5	

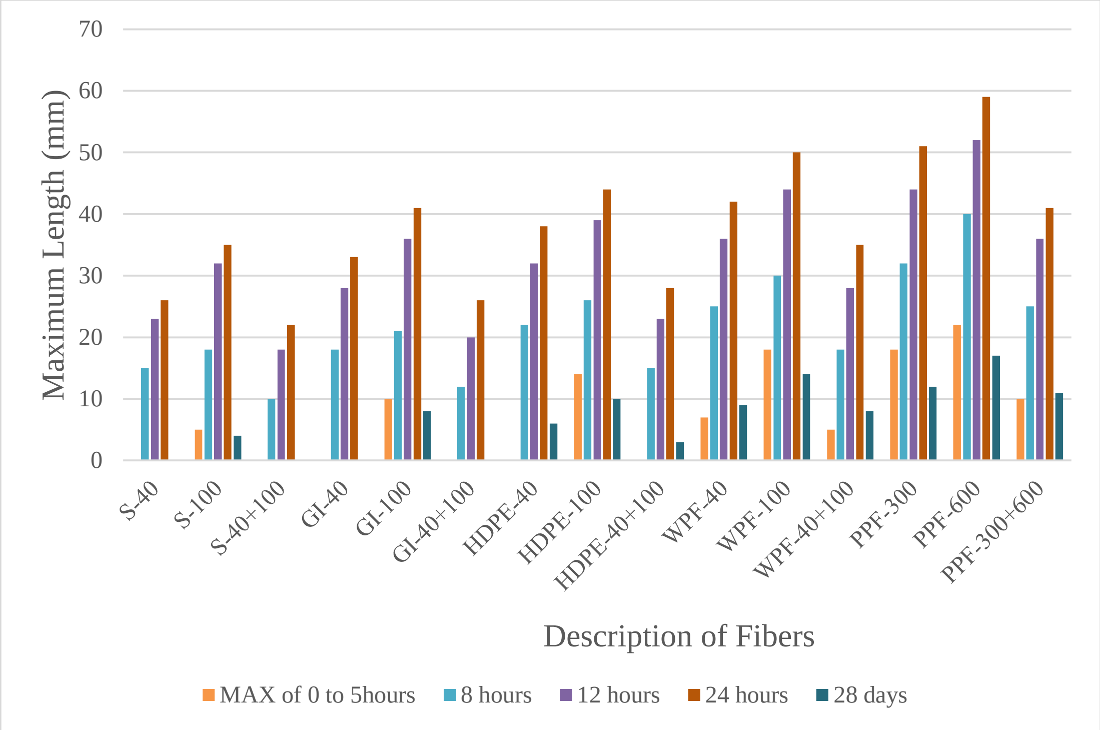

Figure 2 Variation of crack length (mm)

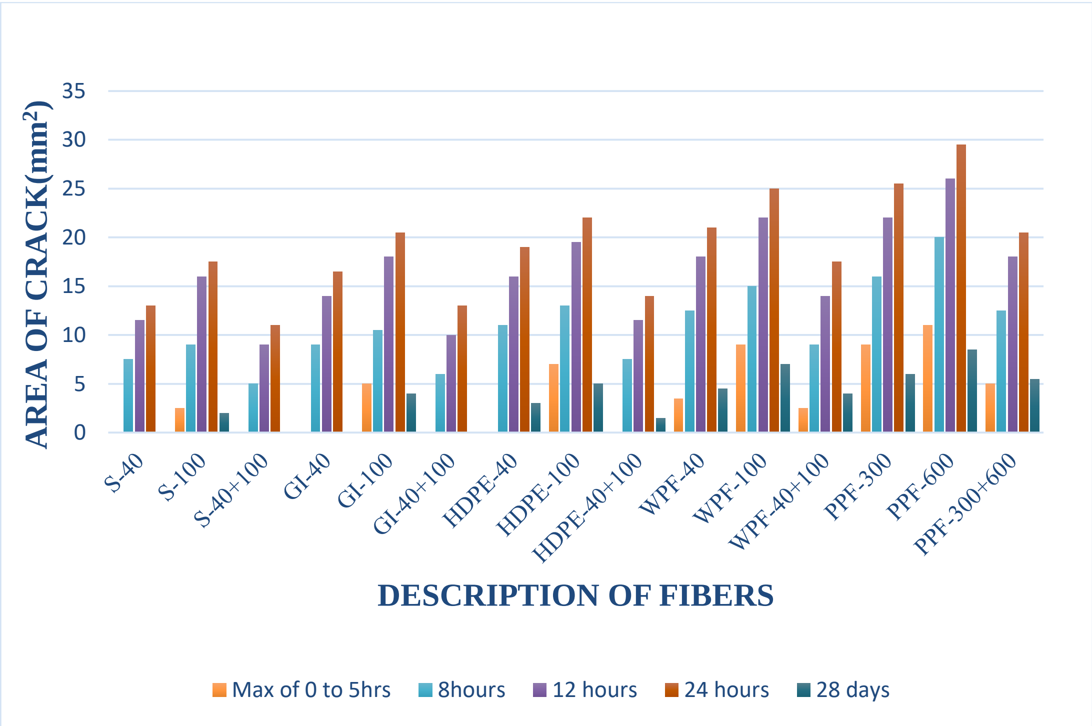

Figure 3 Variation of crack area (mm^2)

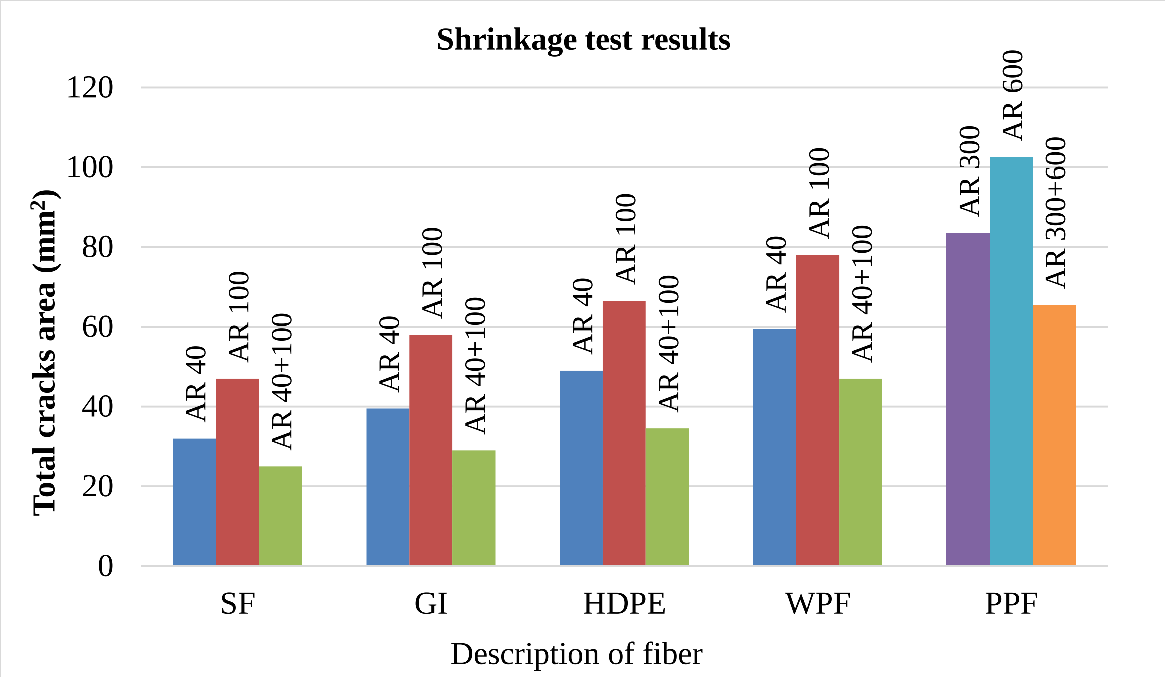

Figure 4 Total area of cracks

6. RESULTS DISCUSSIONS AND CONCLUSIONS

- From the test results of steel fibers (SF) and galvanized iron fibers (GIF), as seen in fig. 5.1, it is concluded that steel fibers are the most efficient crack arresting fibers that can be used for reinforcing concrete. This can be primarily attributed to the high density and high modulus of elasticity of the material of steel.
- From the aggregate of all the test results i.e. fig. 5.1, fig. 5.2 and fig. 5.3, it is clear that hybridized reinforcing fibers, irrespective of the fiber material used, helps in decreasing the amount of both, plastic and drying shrinkage cracks in concrete. A combination of different fiber aspect ratios in the reinforcement imparts versatility to the concrete matrix to bridge cracks of different lengths more efficiently in the microstructure of concrete.
- Comparing the test results of steel fiber reinforced concrete and galvanized iron fiber reinforced concrete, the lower crack dimensions witnessed in steel fiber reinforced concrete can be attributed to the crimped shape of steel fibers. It is also to be noted that the addition of crimped shape steel fibers also imparts a certain amount of tensile strength to the concrete mix.

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