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Effect of Polypropylene Fibers and Rice Husk Ash on High-Performance Concrete: An Experimental Investigation

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ABSTRACT

Extensive experimental investigation on polypropylene fiber reinforced concrete (PFRC) was carried out by researchers. Polypropylene fibre mesh is more effective in resisting bending and punching shear. Test results conducted by various researchers revealed that the use of non-metallic fibre like Nylon, Polythene, Organic fibres, Vegetable fibres etc. are more effective in resisting bending and punching shear. Usually, usage of fibres enhances the properties of concrete structures. The objective of present study is to supply polypropylene fibers with progressed interface bonding with a concrete matrix. The hobby in the use of fibers for the reinforcement of composites has extended during the last numerous years. A mixture of excessive energy, stiffness and thermal resistance favorably characterizes the fibers. At present, studies research is made on numerous properties of polypropylene fiber bolstered concrete by means of the usage of polypropylene fibers in concrete in various chances.

Keywords: PFRC, Interface bonding, RHA, PP, Compressive Strength, Mechanical properties.

1. Introduction

The microstructure of cement paste in the interfacial transition zone (ITZ) can be significantly improved by adding (super) fine materials, such as Fly Ash (FA), Silica Fume (SF), Metakaolin (MK) and Rice Husk Ash (RHA). India is the second largest producer of rice in the world. Rice husk is obtained from the outer covering part of the rice grains which consists of two interlocking halves (Xu et al., 2011). The fiber dispersion into concrete is one of the technique to improve the building properties of concrete. Polypropylene fibers are synthetic fibers obtained as a by-product from textile industry. These are available in different aspect ratios and are cheap in cost. Polypropylene fibers are characterized by low specific gravity and low cost. Its use enables reliable and effective utilization of intrinsic tensile and flexural strength of the material along with significant reduction of plastic shrinkage cracking and minimizing of thermal cracking. It provides reinforcement and protects damage of concrete structure and prevents spalling in case of fire. The fibers are manufactured either by the pulling wire procedure with circular cross section or by extruding the plastic film with rectangular cross-section. They appear either as fibrillated bundles, mono filament. The fibrillated polypropylene fibers are formed by expansion of a plastic film, which is separated into strips and then slit. The fiber bundles are cut into specified lengths and fibrillated. In monofilament fibers, the addition of buttons at the ends of the fiber increases the pull out load.

1.1 OBJECTIVES OF THE PRESENT INVESTIGATION

In the present work, the effect of addition of polypropylene fiber and rice husk ash powder on strength and flexural characteristics of concrete. The precise objectives of the study are follows.

- To carry out the literature review in the area of the study.
- To carry out the study to check the hardened properties of the concrete Containing polypropylene fiber and rice husk ash powder (compressive and split tensile strength).
- To carry out the study to check the flexural properties of concrete containing polypropylene fiber and rice husk ash powder.
- To carry out the study to check the effect of polypropylene fiber and rice husk ash powder in concrete
- To carry out the study to check the fresh properties of the concrete containing polypropylene fiber and rice husk ash powder (Workability).

Literature survey

Balaguru (1988) studies on uniaxial compression test is normally used to evaluate the behaviour of concrete in compression. This produces a combination of shear failure near the ends of the specimen with lateral swelling of the unconfined central section accompanied by cracking parallel to the loading axis when the lateral strain exceeds the matrix cracking strain in tension. Fibers can affect these facets of uniaxial compressive behaviour that involve shear stress and tensile strain. This can be seen from the increased strain capacity and also from the increased toughness (area under the curve) in the post-crack portion of the stress-strain curve.

Khajuria and Balaguru, (1989) .in some instances, if more water is added to fiber concrete to improve its workability, a reduction in compressive strength can occur. This reduction should be attributed to additional water or due to an increase in entrapped air, not fiber addition.

Johnston and Skarendahl, (1992). The addition of fibers up to a volume fraction of 0.1% does not affect the compressive strength. When tested under compression, failure occurs at or soon after the peak load providing very little toughness. It is found that the fibers have very little effect on compressive strength calculated from the peak load, and both slight increase and decrease in strength have been reported with increase in fiber content. The decrease in strength is mostly reasoned due to incomplete consolidation.

Bayasi and Zeng (1993) investigated the properties of fiber reinforced concrete with polypropylene fibers. Different length and volume fraction of fibrillated PP fiber were added into the mixtures. The authors concluded that addition of PP fiber tended to increase the water permeability of concrete. Fibers had a relatively small favourable effect on compressive strength and compressive toughness of concrete when ½ inch and ¾ inch fibers were used, respectively. They also concluded that for volumes equal to or less than 0.3 %, ¾ inch long fibers were more favourable for enhancing the post peak resistance, but for 0.5 % volume, ½ inch long fibers were more effective.

Soroushian et al. (1995) evaluated plastic shrinkage cracking of polypropylene fiber reinforced concrete. They summarized that polypropylene fiber reduced the total plastic shrinkage crack area and maximum crack width at 0.1 percent fiber volume fraction. They also concluded that different PP fiber volume fraction (0.05, 0.1, 0.2 percent) had statistically similar effects on the total plastic shrinkage crack area and the maximum crack width. Moreover, longer fibers produced less cracks at 0.1 and 0.2 percent fiber volume fractions and smaller maximum crack width at 0.05 percent fiber volume fractions, when compared with the shorter fibers.

Soroushian et al. (1995) compared the mechanical properties of concrete materials reinforced with polypropylene or polyethylene fiber. They found that PP fibers at 0.1 percent volume fraction as well as PE fibers at 0.025 and 0.025 percent volume fraction had negligible effect on the flexural strength of concrete; only 0.1 percent volume fraction of PE fibers could improve flexural strength. They also concluded that 0.05 percent of PE fiber volume fraction produced impact strengths comparable to those with 0.1 PP fibers volume fraction in concrete.

Alhozaimy et al. (1995) carried out experimental investigations on the effects of adding low volume fractions (<0.3%) of calculated fibrillated polypropylene fibres in concrete on compressive flexural and impact strength with different binder compositions. They observed that polypropylene fibres have no significant effect on compressive (or) flexural strength, while flexural toughness and impact resistance showed increased values. They also observed that positive interactions were also detected between fibres and pozzolans. Bentur, (2007). (Hasan Et Al., 2011 Roesler Et Al. (2006), the addition of polypropylene fibres does not have a significant effect on the direct tensile cracking strength (Bentur, 2007). However, in moderate volume replacements (0.33-0.5%) the addition of macro-synthetic polypropylene fibres showed a 10 to 15% increase in splitting tensile strength.

Toutanji (1999) evaluated the properties of PP fiber reinforced silica fume expansive-cement concrete. The fibrillated PP fibers, ranging between 6 and 51 mm long, were added to the mix at 0.1, 0.3 and 0.5 % volume fraction. The author found that the use of 5 % silica fume resulted in improving the bond strength between the repair materials to the old substrates. The rate of increase in bond strength decreased with increasing SF content from 5 to 10 %. However, the use of PP fiber resulted in an increase in bond strength especially for the mixtures with 10 % silica fume. Moreover, increasing PP fiber volume fraction resulted in an improvement in post peak flexural strength of fiber reinforced silica fume expansive-cement concrete. The author also concluded that the addition of PP fiber caused an adverse effect on the chloride.

Manolis et al. (1997) examined the dynamic properties of polypropylene fiber reinforced concrete slabs. Three different volume fractions (0 %, 0.1 % and 0.5 %) of 19 mm fibrillated polypropylene fiber were added into the mixtures. They concluded that the inclusion of PP fibers significantly improved the impact resistance of concrete slabs without affecting the natural frequency. They also found that the static compression and flexural strength decreased with increasing fiber content. Fracture behaviour of polypropylene fiber reinforced concrete under biaxial loading was investigated by Elser et al. (1996). Concrete mixes consisted of two different length (10 and 20 mm) and two different volume fraction (0.1 % and 0.5 %) of fibrillated polypropylene fiber. They concluded that the peak shape and peak height of the load/displacement curves of FRC.

Toutanji et al. (1998) investigated the chloride permeability and impact resistance of PP fiber reinforced silica fume concrete. Different length and volume fraction of the fibrillated PP fiber were added into separate mixtures containing different contents by weight of silica fume. They concluded that the incorporation of PP fibers increased the permeability of concrete specimens containing no silica fume. Reducing fiber length from 19 to 12.5 mm, with an equivalent volume fraction, resulted in a decrease in the permeability of plain and silica fume concrete. They also found that the addition of silica fume enhanced the impact resistance of PP fiber concrete, but had no effect on the unreinforced concrete.

Methodology and flow chart

Mix Design

Table 1 Mix proportion per m^3

MIX	CEMENT	W/B	RHA	WATER	FA.	CA	PP	SP
	(Kg/m^3)		(Kg/m3)	(Kg/m^3)	(Kg/m^3)	(Kg/m^3)	FIBER	(%)
M1	360	0.4	40	160	694	1141	0%	1
M2	360	0.4	40	160	694	1141	0.50%	1
M3	360	0.4	40	160	694	1141	0.75%	1
M4	360	0.4	40	160	694	1141	1.00%	1
M5	360	0.4	40	160	694	1141	1.50%	1
M6	360	0.4	40	160	694	1141	2.00%	1.25

Table 2 Mix details

MIX	OPC (%)	RHA (%)	FIBRE (%)
M1	90%	10%	0.0%
M2	90%	10%	0.5%
M3	90%	10%	0.75%
M4	90%	10%	1%
M5	90%	10%	1.5%
M6	90%	10%	2.0%

Tests Performed

Tests on Fresh Concrete – Workability

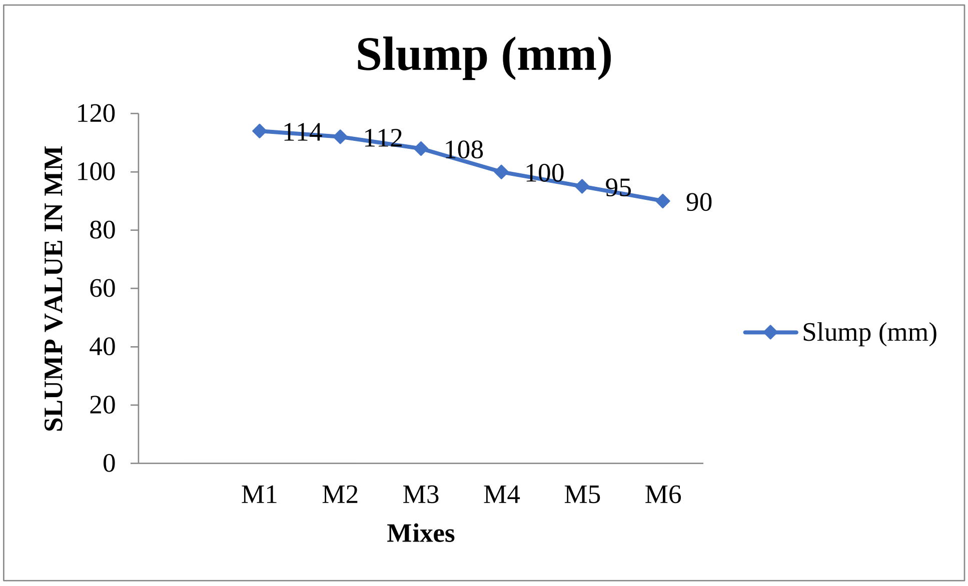
Workability is considered to be that property of plastic concrete which indicates its ability to be mixed, handled, transported and most importantly, placed with a minimum loss of homogeneity. More precisely, it defines that it can be fully compacted with minimum energy input. There should be no sign of any segregation or bleeding in a workable concrete. The workability of all the mixes of concrete used in this work was controlled by conducting slump test, test apparatus was shown in Fig 3.1. It was observed that the slump value for all the mixes was maintained in the range of 90-110 mm, which is acceptable. A super plasticizer, SP-430 was used in the concrete mix varying from 1.0% -1.25% by weight of binder.

Workability of Concrete Mixes

The workability of concrete mixes was found out by slump test as per procedure given in chapter 3. w/b ratio was kept constant 0.4 for all the concrete mixes. Super-plasticizer SP 430 was used to maintain the required slump. The workability results of different concrete mixes were shown in Table 4.1

Table 3. Workability values for different concrete mixes

Mix no.	Description	Super plasticizer (%) by weight of binder	Slump (mm)
1	90%OPC+10%RHA+0%PP	1.00	114
2	90%OPC+10%RHA+0.5%PP	1.00	112
3	90%OPC+10%RHA+0.75%PP	1.00	108
4	90%OPC+10%RHA+1%PP	1.00	100
5	90%OPC+10%RHA+1.5%PP	1.00	95
6	90%OPC+10%RHA+2%PP	1.25	90



Graph 1 Mix v/s slump value

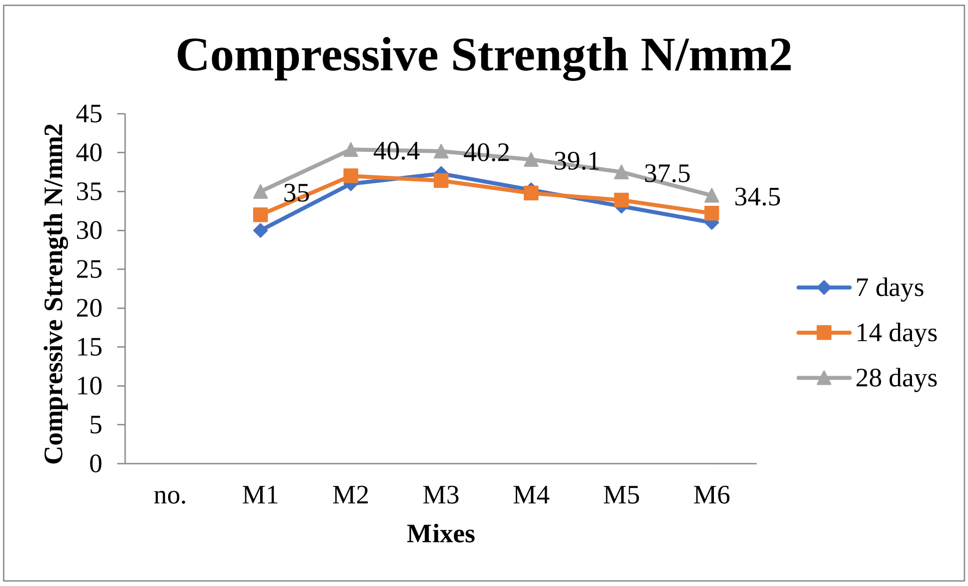
Slump : Results shows that as the addition of fibres to concrete mix increases, the workability of concrete mix has found to decrease as compared to control mix.

Compressive Strength Test Results

The results of the compressive strength tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. The compressive strength test was conducted at curing ages of 7, 14, and 28 days. The compressive strength test results of all the mixes at different curing ages are shown in Table 4.2. Variation of compressive strength of all the mixes cured at 7, 14, and 28 days are also shown in graph 4.2.

Table 4. Compressive strength (MPa) results of all mixes at different curing ages.

Mix no.	Description	7 days	14 days	28 days
1	90%OPC+10%RHA+0%PP	30.00	32.00	35.00
2	90%OPC+10%RHA+0.5%PP	36.00	37.00	40.40
3	90%OPC+10%RHA+0.75%PP	37.30	36.40	40.20
4	90%OPC+10%RHA+1%PP	35.20	34.80	39.10
5	90%OPC+10%RHA+1.5%PP	33.10	33.90	37.50
6	90%OPC+10%RHA+2%PP	31.00	32.20	34.50



Graph 2 Variation of compressive strength of concrete with age

Results show that mix M2 has 28 days compressive strength more in compare to control concrete when 90%OPC+10%RHA+0.5%PP used.

CONCLUSION AND SCOPE FOR FURTHER STUDY

1. Based on the scope of work carried out in this investigation, following conclusions are drawn.
2. It was observed that as the addition of PP fibres to concrete mix increases, the workability of concrete mix was found to decrease as compared to control mix.
3. At optimum dosage of PP fibres the increase in compressive strength of PP fibre concrete mixes compared with control mix of concrete at 28 days.
4. It was observed that tensile strength of concrete decreasing with increasing percentage of PP fiber.

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