Experimental Investigation of Macro Synthetic Fiber Reinforced Concrete

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***Abstract*— The Structural Polypropylene fibre reinforced concrete (SPFRC) contains randomly distributed short discrete Polypropylene fibres which act as internal reinforcement so as to enhance the properties of the cementitious composite (concrete). The principal reason for incorporating short discrete fibres into a cement matrix is to increase the flexural tensile strength and increase the toughness and ductility and effect on properties of the fresh concrete and fracture properties of the resultant composite. These properties of SPFRC primarily depend upon length and volume of fibres used in the concrete mixture.**

To determine these properties experimental work was carried out. For the study, Structural polypropylene fibres of two different lengths (lf) of 48 mm and 60 mm with dosage 3kg/m3, 4kg/m3 and 6kg/m3 (0.33%, 0.44% and 0.66% by volume) volume fractions (Vf) were used. The research reported in this study includes an experimental investigation to characterize selected mechanical properties of SPFRC and to study the effect of volume fraction of SPF and length of SPF on the mechanical properties.

To determine properties of concrete specimens (cubes and beams) were casted to determine the mechanical behaviour such as compressive strength, flexural tensile strength. Test results showed that Structural polypropylene fibre enhanced the compressive strength and increase the toughness insignificantly. The failure of plain concrete specimens was sudden (brittle) for the flexural test. However, the concrete reinforced with Structural Polypropylene fibres showed more ductile behaviour compared to the plain concrete. And also provide an interpretation for the observed tension response of fibre reinforced concrete in flexure in terms of crack propagation and toughening mechanisms in the composite.

***Keywords*— SPFRC,SPF**

I. Introduction

The addition of the fibres to concrete has been shown to enhance the toughness of concrete. The ability of fibre-reinforced concrete composites to absorb energy has long been recognized as one of the most important benefits of the incorporation of fibres in plain concrete. Fibbers bridge a crack and provide resistance to crack opening which imparts post- cracking ductility to the cementitious composite which would otherwise fail in a brittle manner.

A concrete beam containing fibres suffers damage by gradual development of single or multiple cracks with increasing deflection, but retains some degree of structural integrity and post-crack resistance even under considerable deflection. A similar beam without fibres fails suddenly at a small deflection by separation into two pieces. The toughening effect is the result of several types of fibre/matrix interactions, which leads to energy absorption in the fibre-bridging zone of a fibre-reinforced concrete (FRC). These processes include fibre bridging, fibre debonding, fibre pull-out (sliding) and fibre rupture as a crack propagates across a fibre through the matrix [1]

There are many kinds of fibres, both metallic and polymeric, which have been used in concrete to improve specific engineering properties of the material. Steel fibres are used in a wide range of structural applications, in general, when the control of concrete cracking is important such as industrial pavements [2,3], precast structural elements [4] and tunnel linings [5]. Steel fibres have high elastic modulus and stiffness and produce improvements in compressive strength and toughness of concrete [6]. Improvements in flexural strength of the material are also obtained by the use of steel fibres in concrete. Increase in flexural strength is achieved with increasing fibre aspect ratio (length to diameter ratio) and fibre volume fraction; significant improvements are obtained at high volume fractions [7]. In general, addition of steel fibres influences the compressive strain at ultimate load and ductility in flexure more significantly than the improvements in strength [8]. Steel fibres, however, increase structure weight of concrete and exhibit balling effect during mixing, which lowers the workability of the mix. In addition, steel fibres easily basset and rust, and it also has the problem of conductive electric and magnetic fields.

Synthetic fibres are usually smaller than steel fibres and are most typically used in industrial pavements to reduce the cracking induced by shrinkage. Polypropylene fibres have good ductility, fineness, and dispersion so they can restrain the plastic cracks [9]. Synthetic fibres are mainly effective in reducing crack formation, particularly at an early stage of the cast and in severe weather conditions (e.g. in dry climatic zones), when hygrometric shrinkage brings along some weak tensile stress which is yet too high for the fresh mixture to withstand.

Improvements are being made to optimize fibres to suit applications. Recently, macro- synthetic fibres have been produced with the aim of substituting steel fibres in structural applications. There has been a growing interest on synthetic fibres, owing to some substantial advantages over metallic ones, such as strong chemical stability in alkaline and generally aggressive environments, exemption from oxidation, lightness and, in turn, convenient stocking and handling, a-toxicity and electromagnetic transparency. This latter aspect is relevant, for instance, when either dealing with special equipment (ranging from mobile phones to CT diagnostics) or in industrial buildings wherein, say, automated toll collection booths employing electromagnetic vehicle detectors are planned. The availability of a structural synthetic fibre, capable of contributing to the load carrying capacity of an element while increasing its toughness and durability at a reasonable cost, is an important asset for an improved building technology. The knowledge on the mechanical behaviour of concretes reinforced with these fibres is still limited.

The broad objective of the work reported in this paper is to investigate the influence of macro synthetic fibers on the mechanical behavior of concrete. Specific objectives of the paper include

1. To evaluate the influence of macro-synthetic polypropylene fibers on the workability and compressive strength of concrete.
2. To evaluate the influence of macro-synthetic polypropylene fibers on the toughness and ductility of concrete.

II. POLYPROPYLENE FIBBERS

Most commercial applications of polypropylene fibres have used low volume percentage (0.1 percent), monofilament or fibrillated fibres (in the case of polypropylene). Typical properties of monofilament and fibrillated polypropylene fibres is given in Table 2.2.

Table 2.2: Properties of various types of polypropylene fibre

Fiber type	Length	Diameter	Tensile strength	Modulus of elasticity	Specific Surface	Density
	(mm)	(mm)	(MPa)	(MPa)	(m2/kg)	(kg/cm3)
Monofilament	30-50	0.30-0.50	547-658	3.50-7.50	91	0.9
Microfilament	12-20	0.05-0.20	330-414	3.70-5.50	225	0.91
Fibrillated	19-40	0.20-0.30	500-750	5.00-10.00	58	0.95

These uses of these fibres have been restricted to non-structural and non-primary load bearing members. At typical dosages usually employed in the construction industry there is a marginal improvement in the mechanical properties of concrete.
At dosages considered by the industry, of 1.2 kg/m3, PP fibres have been shown to influence the fracture behaviour; the influence of the fibres was especially felt in the tail of the P-d curve, showing a wider softening branch in the case of the FRC mixes, which corresponds to a more ductile behaviour of the concrete. The effect of the fibre is more remarkable in the case of the low strength concrete, where the stresses in the cohesive zone are lower, and the bridge effect of the fibre has a greater effect due to the higher level of deformation. It was shown that the fibres with the highest elongation and lowest strength (i.e. the most ductile fibres) presented the highest values of fracture energy. In the case of high strength concrete the higher level of the cohesive stresses mitigates the bridge effect of the fibres. In low- and normal-strength concrete the main mechanism of failure of the fibres was by pull-out while in high strength concrete it was due to fibre breakage [21].

III. METHODOLOGY

Experimental program and Mix Proportions

Concrete mix design for the mix design procedure given in IS: 10262 was followed with minor modification for M35 grade. For a target mean strength of 43 MPa, two different water/cement ratios equal to 0.47 was considered (from IS 10262-1982 for 53G). Taking into considerations, the minimum requirements for cement content in kg/m3 of concrete for M35 as per IS 456-2000 as 300 kg/m3, cement content was fixed at 340 kg/m3. Using this, the water content was determined. In the concrete mixture fine aggregate were taken as 45% of the total aggregate volume fraction. The weights of fine and coarse aggregate were then calculated considering the specific gravities of coarse and fine aggregate. The Concrete mixtures were produced at a constant water/Cement ratio of 0.47 and one control mixture and three different mixtures with different dosage of fibre were prepared. The control mixture contained no fibre. Concrete mixtures labelled PF3, PF4 and PF6 were produced with different dosage of fibre 3kg/m3, 4 kg/m3and 6 kg/m3 by volume. The design mixtures are presented in Table 3 and the final batch weights of the different mixes for one cubic meter of concrete are presented in Table 3.1.

Table 3.1: Summary of weight proportion of the various mixes

Materials(kg/m3)	C1	PF3	PF4	PF6
Polypropylene fibre	-	3	4	6
OPC 53 grade cement	280	280	280	280
Fly ash (Manuguru)	60	60	60	60
Water/Cement Ratio	0.47	0.47	0.47	0.47
Admixture (%)	0.65	0.65	0.65	0.65
20 mm aggregates	520	520	520	520
10mm aggregates	520	520	520	520
Fine aggregates (river sand)	819	819	819	819
Water	165	165	165	165

Casting and Curing of Specimens

IS standard 150mm Cubes, 150mm X 300mm cylinder and 150 X 150 X 500 beams were cast from each mixture to evaluate compressive strength and toughness and ductility gain. Concrete was prepared using a drum mixer with a capacity of 0.25 m3. The ingredients were put into the mixer in the decreasing order of their sizes staring from 20mm aggregate to cement. Dry mixing of the aggregates and cement was done for two minutes and then water was added gradually in the rotating mixer and allowed to mix for 15 minutes. During the mixing process, the walls and bottom of mixer were scraped well to avoid sticking of mortar. After mixing, the slump was checked and noted down to ascertain the effects of differently proportioned blends on workability of concrete. Finally, the fresh concrete was placed in oiled moulds and compacted properly in three layers, each layer being tamped 35 times using a tamping rod. After the initial setting of concrete, the surface of the specimen was finished smooth using a trowel. Immediately after casting, all specimens were covered with plastic covers to minimize moisture loss. The specimens were stored at room temperature about 25oC. Specimens were demoulded 24 hours after casting and kept in curing water tank.

Slump

Slump was used to find the workability of fresh concrete where the nominal maximum size of aggregate does not exceed 38 mm. slump cone was used to find the slump of the concrete as per the requirements of IS 1199-1959.

Procedure

Oil is applied on the base plate and interior surface of the slump cone. The slump cone is kept on a levelled surface and filled with fresh concrete in three layers, approximately one- third of height of the cone. Each layer is tamped 25 times with a tamping rod. After compacting the top layer, the concrete surface is struck off. The slump cone is removed by raising it slowly in a vertical direction. The slump is recorded as the height to which concrete settles from the height at the highest point of the concrete.

Compression Strength Testing

A digital compressive testing machine is used for determine the compressive strength of hardened concrete as per the requirements of IS 516-1959 using standard 150mm cubes.

IV. PROCEDURE

For cubes, before starting the test the weight of the sample is recorded. The plates of the machine are cleaned and the specimen is kept centrally between the two plates. Load is applied gradually on the specimen at a load rate of 5.15kN/s up to failure. Once the sample is failed, the failure pattern is recorded and the compressive strength is calculated from the maximum load recorded in the test.

Table 4.2: Compressive strength for cube

	Compressive strength (MPa)	Average compressive strength (MPa)	Standard deviation (MPa)
Control -1	60.1	63.74	3.28
Control -2	66.5		
Control -3	60.2		
Control -4	66.5		
Control -5	65.4		
3kg/m^3-1	58.4	57.54	3.40
3kg/m^3-2	60.1		
3kg/m^3-3	59.2		
3kg/m^3-4	51.5		
3kg/m^3-5	58.5		
4kg/m^3-1	69.4	70.6	0.54
4kg/m^3-2	68.9		
4kg/m^3-3	70.6		
4kg/m^3-4	71.4		
4kg/m^3-5	72.7		
6kg/m^3-1	63	64.66	1.78
6kg/m^3-2	65.6		
6kg/m^3-3	62.7		
6kg/m^3-4	65.1		
6kg/m^3-5	66.9		

IV.RESULT AND DISCUSSION

The results indicate that the addition of macro synthetic polypropylene fibres at quantities up to 6 kg/m3 has no effect on the compressive strength. The minor differences noticed are expected variation in sample preparation, and to variations in the actual air contents of the hardened concrete and the differences in their unit weights. These results are in agreement with the observation from fibrillated polypropylene fibres [7]. The addition of polypropylene fibres had a significant effect on the mode and mechanism of failure of concrete cylinders in compression test. The fibre reinforced concrete failed in a more ductile mode, whereas plain control concrete cylinders typically shatter due to an inability to absorb the energy release imposed by the test machine at failure.

V. REFERENCES

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