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SYNTHESIS AND CHARACTERIZATION OF POLYPROPYLENE FIBER REINFORCED CONCRETE

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ABSTRACT

The capability of durable structure to resist weathering action, chemical attack, abrasion and other degradation processes during its service life with the minimal maintenance is equally important as the capacity of a structure to resist the loads applied on it. Although concrete offers many advantages regarding mechanical characteristics and economic aspects of the construction, the brittle behavior of the material remains a larger handicap for the seismic and other applications where flexible behavior is essentially required. Recently, however the development of polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. Here we study the synthesis and characterization of polypropylene fiber reinforced concrete.

I INTRODUCTION

Ceramics were the first engineering materials known to mankind and they still constitute the most used materials in terms of weight [1, 2]. Hydraulic cements and cement-based composites including concretes are the main ceramic-based materials. Concrete offers many advantages in the application due to its improved mechanical characteristics, low permeability and higher resistance against chemical and mechanical attacks. Although concrete behavior is governed significantly by its compressive strength, the tensile strength is important with respect to the appearance and durability of concrete. The tensile strength of concrete is relatively much lower. Therefore, fibers are generally introduced to enhance its flexural tensile strength, crack arresting system and post cracking ductile behavior of basic matrix. Concrete modification by using polymeric materials has been studied for the past four decades [3]. In general, the reinforcement of brittle building materials with fibers has been known from ancient period such as putting straw into the mud for housing walls or reinforcing mortar using animal hair etc. Many materials like jute, bamboo, coconut, rice husk, cane bagasse, and sawdust as well as synthetic materials such as polyvinyl alcohol, polypropylene (PP), polyethylene, polyamides etc. have also been used for reinforcing the concrete. Research and development into new fiber reinforced concrete is going on today as well.

Polypropylene fibers were first suggested as an admixture to concrete in 1965 for the construction of blast resistant buildings for the US Corps of Engineers. The fiber has subsequently been improved further and at present it is used either as short discontinuous fibrillated material for production of fiber reinforced concrete or a continuous mat for production of thin sheet components. Since then the use of these fibers has increased tremendously in construction of structures because addition of fibers in concrete improves the toughness, flexural strength, tensile strength and impact strength as well as failure mode of concrete. Polypropylene twine is cheap, abundantly available, and like all manmade fibers of a consistent quality.

II PROPERTIES OF POLYPROPYLENE FIBERS

The raw material of polypropylene is derived from monomeric C3H6 which is purely hydrocarbon. Its mode of polymerization, its high molecular weight and the way it is processed into fibers combine to give polypropylene fibers very useful properties as explained below

- There is a sterically regular atomic arrangement in the polymer molecule and high crystallinity. Due to regular structure, it is known as isotactic polypropylene.
- Chemical inertness makes the fibers resistant to most chemicals. Any chemical that will not attack the concrete constituents will have no effect on the fiber either. On contact with more aggressive chemicals, the concrete will always deteriorate first.
- The hydrophobic surface not being wet by cement paste helps to prevent chopped fibers from balling effect during mixing like other fibers.
- The water demand is nil for polypropylene fibers.
- The orientation leaves the film weak in the lateral direction which facilitates fibrillations. The cement matrix can therefore penetrate in the mesh structure between the individual fibrils and create a mechanical bond between matrix and fiber.

The fibers are manufactured either by the pulling wire procedure with circular cross section or by extruding the plastic film with rectangular cross-section.

III PROPERTIES OF POLYPROPYLENE FIBER REINFORCED CONCRETE

Before mixing the concrete, the fiber length, amount and design mix variables are adjusted to prevent the fibers from balling. Good FRC mixes usually contain a high mortar volume as compared to conventional concrete mixes. The aspect ratio for the fibers are usually restricted between 100 and 200 since fibers which are too long tend to "ball" in the mix and create workability problems. As a rule, fibers are generally randomly distributed in the concrete; however, placing of concrete should be in such a manner that the fibers become aligned in the direction of applied stress which will result in even greater tensile and flexural strengths. There should be sufficient compaction so that the fresh concrete flows satisfactorily and the PP fibers are uniformly dispersed in the mixture. The fibers should not float to the surface nor sink to the bottom in the fresh concrete. Chemical admixtures are added to fiber-reinforced concrete mixes primarily to increase the workability of the mix. Air-entraining agents and water-reducing admixtures are usually added to mixes with a fine aggregate content of 50% or more. Superplasticizers, when added to fiber-reinforced concrete, can lower water: cement ratios, and improve the strength, volumetric stability and handling characteristics of the wet mix. The properties of PFRC with various fiber volume % are shown in Table 1.

Polypropylene fibers are used in two different ways to reinforce cementitious matrices. One application is in thin sheet components in which polypropylene provides the primary reinforcement. Its volume content is relatively high exceeding 5%, in order to obtain both strengthening and toughening. In other application the volume content of the polypropylene is low, less than 0.3% by volume, and it is intended to act mainly as secondary reinforcement for crack control, but not for structural load bearing applications [11]. The performance and influence of the polypropylene fibers in the fresh and hardened concrete is different and therefore these two topics are treated separately.

Mechanical Properties of Polypropylene Fiber Reinforced Concrete														
No	Concrete mix						Fibers		Vf%	fcu (MPa)	ft (MPa)	fs (MPa)	Slump (mm)	Ref.
	w/c	Cement (kg/m3)	CA (kg/m3)	FA (kg/m3)	Admixture	Specimen shape	Type	l/d						
1.	0.49	390 (OPC)	1000 (10mm)	640	Super plasticizer (Fosroc 430)	Cylinder, Cubes & Prism	Fibrillated (20mm long & 0.29mm dia)	69	0 0.10 0.30	17.2 14.1 12.6	1.08 1.72 1.34	4.5 2.5 3.0	100 – 120	[15]
2.	0.45	360 (OPC)	1100 (20mm)	647	-	Prism	Micro filament (19mm long & 0.048mm dia)	396	0 0.045 0.082 0.128	- - - -	2.24 2.33 2.40 2.43	4.01 3.76 4.01 4.22	- - - -	[10]
3.	0.45	360 (OPC)	1100 (20mm)	647	-	Prism	Mono filament (30mm long & 0.55 mm dia)	55	1.0 1.2 1.4	- - -	2.50 2.68 2.70	5.36 5.47 5.51	- - -	[10]
4.	0.48	418 (OPC)	724 (25mm)	998	-	Cylinder	Mono filament	56	0 1.0 1.5	35.03 35.42 30.74	2.23 3.21 3.21	- - -	102 38 7	[16]
5.	0.40	372 OPC + 28 SF	1140 (20mm)	750	Super-plasticizer	Prism	Mono filament	200	0 0.5	56.10 56.10	4.10 4.40	5.21 5.61	100 80	[29]
6.	0.50	383 (PPC)	1162 (20mm)	572	-	Cylinder, Cubes & Prism	Graded Fibrillated (12mm ~ 24mm)	NR	0 0.1 0.2 0.3	35.23 39.50 41.00 48.00	3.54 4.42 4.88 4.95	5.23 5.47 5.65 6.35	- - - -	[25]
7.	0.44	430 (PPC)	1154 (20mm)	540	-	Cylinder, Cubes & Prism	Graded Fibrillated 12mm ~ 24mm)	NR	0 0.1 0.2 0.3	41.22 49.78 50.22 52.00	3.72 4.53 4.67 4.75	5.35 5.99 6.12 6.29	- - - -	[25]
8.	0.39	498 (PPC)	1136 (20mm)	503	NIL	Cylinder, Cubes & Prism	Graded Fibrillated 12mm ~ 24mm)	NR	0 0.1 0.2 0.3	46.15 50.67 55.33 57.11	3.89 4.88 5.09 5.52	5.56 5.70 6. 40 6.84	- - - -	[25]

3.1 Effects on Fresh Concrete

The main parameter, which is often used to determine the workability of fresh concrete, is the slump test. The slump value depends mainly on the water absorption and porosity of the aggregates, water content in the mixture, amount of the aggregate and fine material in the mixture, shape of the aggregates and surface characteristics of the constituents in the mixture. The slump values decrease significantly with the addition of polypropylene fibers as shown in Table 2. The concrete mixture becomes rather clingy resulting in increasing of the adhesion and cohesiveness of fresh concrete. During mixing the movement of aggregates shears the fibrillated fibers apart, so that they open into a network of linked fiber filaments and individual fibers. These fibers anchor mechanically to the

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cement paste because of their large specific surface area. The concrete mixture with polypropylene fibers results in the fewer rate of bleeding and segregation as compared to plain concrete. This is because the fibers hold the concrete together and thus slow down the settlement of aggregates. Due to its high tensile and pull-out strength, the PP fibers even reduce the early plastic shrinkage cracking by enhancing the tensile capacity of fresh concrete to resist the tensile stresses caused by the typical volume changes. The fibers also distribute these tensile stresses more evenly throughout the concrete. As the plastic shrinkage cracking decreases, the number of cracks in the concrete under loading is reduced, due to decrease in cracks from the existing shrinkage cracks. If shrinkage cracks are still formed, the fibers bridge these cracks, reducing at the same time their length and width.

Initial slump (mm)	Final slump (mm)	Fiber length (mm)
90	76	51
130	70	51
170	120	30
127	48	51
1245	53	51
114	64	19

Table 2 Effect of polypropylene fibers

3.2 Effects on Hardened Concrete

The addition of polypropylene fibres in the concrete did not significantly affect the compressive strength and the modulus of elasticity but they do increase the tensile strength. Splitting tensile strength of PFRC approx ranges from 9% to 13% of its compressive strength. Addition of PP fibers in concrete increases the splitting tensile strength by approx 20% to 50%**.**

3.3 Flexural Tensile Strength

The flexural tensile strength increases with increase in volume fraction of fiber. It is also observed that there was increase in strength for with the increase in aspect ratio of fibre.

3.4 Bond strength

It is necessary that there should be a good bond between the fiber and the matrix. If the critical fiber volume for strengthening has been reached then it is possible to achieve multiple cracking. This is a desirable situation because it changes a basically brittle material with a single fracture surface to fracture into a pseudo ductile material which can absorb transient minor overload and shocks with little visible damage. So the aim is to produce large number of

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multiple cracks at as close spacing as possible so that the crack widths are very small, almost invisible to naked eye so that the rate at which aggressive materials can penetrate the matrix is reduced. High bond strength helps to give close crack spacing but it is also essential that the fibers should give sufficient ductility to absorb impacts. But in terms of physiochemical adhesion there is no bond between the fiber and the cement gel. The use of chopped and twisted fibrillated polypropylene fibers with their open structure has partially remedied the lack of interfacial adhesion by making use of wedge action at the slightly open fiber ends and also by mechanical bonding through fibrillation. The general pull out loads of twisted fibrillated fibers may range from 300-500N for commonly used staples but the accurate calculation of bond strength is complicated by a lack of knowledge of the surface area of fiber in contact with the paste.

3.5 Flexural Impact Properties

The number of blows required to develop the first visible crack on the beam's lower surface is defined as the initial-crack impact number (N_{cr}). Failure impact number N_f is defined as the number at which one main macro-crack develops from bottom to top of the beam. Impact ductility index is defined as the ratio of failure impact number to initial crack impact number, which can be used to present the flexural impact ductility.

$$J=N_f / N_{cr}$$

where J is impact ductility index, which for plain concrete is 1. The flexural impact test results are shown in table 3 by researcher [10]. The results indicate that significant improvement in impact resistance of concrete can be achieved with relatively low volume fraction of polypropylene fibers.

Type of mix	*Vf* %	Average Impact number	Average failure Impact number	Impact ductility index
Control	0	25.8	26.8	1.04
Microfilament	0.05	34.7	46.5	1.34
	0.095	28.6	30.4	1.06
	0.14	38.1	40.1	1.05
Monofilament	1	68.9	224.2	3.26
	1.2	70.7	712.7	10.08
	1.4	62.8	831	13.23

Table 3 impact properties of fiber reinforced concrete

IV CONCLUSION

Innovations in engineering design and construction, which often call for new building materials, have made polypropylene fiber-reinforced concrete applications. In the past several years, an increasing number of constructions have been taken place with concrete containing polypropylene fibres such as foundation piles, prestressed piles, piers, highways, industrial floors, bridge decks, facing panels, flotation units for walkways, heavyweight coatings for underwater pipe etc. This has also been used for controlling shrinkage & temperature cracking. Due to enhance performances and effective cost-benefit ratio, the use of polypropylene fibers is often recommended for concrete structures recently. PFRC is easy to place, compact, finish, pump and it reduces the rebound effect in sprayed concrete applications by increasing cohesiveness of wet concrete. Being wholly synthetic there is no corrosion risk. PFRC shows improved impact resistance as compared to conventionally reinforced brittle concrete.

REFERENCES

1. Saenz, A., Rivera, E., Brostow, W. and Castan˜o, V.M., "J. Mater," (Ed.), Vol..21, No.267 (1999).
2. Castan˜o, V. M. and Rodriguez, J. R., "Performance of Plastics" Ch 24, Brostow, W., ed., Hanser, Munich-Cincinnati (2000).
3. Dodson, V., "Concrete and Mixtures" Van Nostrand Reinhold: Structural Engineering Series, New York (1989).
4. Sheldon, R. R.,"Composite Polymer Materials" Applied Science Publishers, London (1982).
5. Ramaswamy, H. S., Ahuja, B. M. and Krishnamoorthy, S., "J. Mex. Inst. Cement Concrete" Vol. 22,No. 161 (1984).
6. Jindal, C. V., " J. Composite Materials," Vol.20, No.265 (1986).
7. Beaudoin, J. J., "Handbook of Fibre Reinforced Concrete" Noyes Publications, New Jersey (1990).
8. Colling, J., " J. Mex. Inst. Cement Concrete" Vol. 19, No. 127 (1981).
9. Hananth, D. J., "Fiber Cements and Fiber Concretes" A Wiley-Inter science Publication, John Wiley and Sons, Ltd pp 81-98.
10. Deng, Z., and Li, J., "Tension and Impact Behaviours of New Type Fibre Reinforced Concrete." Computers and Concrete, Vol. 4, No. 1 (2007) pp. 19-32.
11. Bentur, A. and Mindess, S., "Fiber Reinforced Cementitious Composites," Elsevier Science Publishers Ltd. Ch 10, pp 310-330.
12. "High performance concrete" A state of art report (1989-1994).
13. Bruce, P., "Effective Use of Polypropylene Fibers in Concrete," SCI Seminar 2004.

14. Aulia, T. B., "Effects of Polypropylene Fibers on the Properties of High-Strength Concretes." LACER No. 7 (2002), pp.43-59.
15. Waheeb, A. L. K., "Mechanical Properties and Time Dependent Defor- mations of Polypropylene Fibre Reinfor- ced Concrete," J King Saud Univ., Vol. 7, Eng.Sci. (1) (1993),pp. 67-76.
16. Choi, Y., Yuan, R.L., "Experimental Relationship between Splitting Tensile Strength and Compressive Strength of GFRC and PFRC", Cement and Concrete Research, Vol. 35 (2005) pp.1587-1591.
17. Antoni, Honguchi T. and Saeki N."Influence of Stress on Chloride Penetration into Fiber Reinforced Concrete ", JCI,Vol.25 (2003), pp.779-784.
18. Malisch,W. R., "Polypropylene fibers in concrete."
19. Sukontasukkul, P., "Toughness Valuation of Steel and Polypropylene Fibre Reinforced Concrete Beams under Bending" Thammasat Int. J. Sc. Tech., Vol. 9, No. 3, (2004),pp.35-41.
20. Ritchie, A.G.B. and Mackintosh, D.M., "Selection and Rheological Characteristics of PP fibers," Concrete, pp 36-39 (1972).
21. Hughes, B.P. and Fattuhi, N.I., "Fibrer Reinforced Concrete in Direct Tension," Fiber Reinforced Materials, paper 16, conference at Institution of Civil Engineers, London. 1977, pp 127-133.
22. Hadi, M. N. S., "An Investigation of the Behaviour of Steel and Polypropylene Fibre Reinforced Concrete Slabs," 7th International Conference. Concrete: Construction's Sustainable Option - Harnessing Fibres for Concrete Construction, Dundee, Scotland, 8-10 July 2008.