MECHANICAL PROPERTIES OF HYBRID FIBER REINFORCED CONCRETE FOR PAVEMENTS

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Abstract

The effect of addition of mono fibers and hybrid fibers on the mechanical properties of concrete mixture is studied in the present investigation. Steel fibers of 1% and polypropylene fibers 0.036% were added individually to the concrete mixture as mono fibers and then they were added together to form a hybrid fiber reinforced concrete. Mechanical properties such as compressive, split tensile and flexural strength were determined. The results show that hybrid fibers improve the compressive strength marginally as compared to mono fibers. Whereas, hybridization improves split tensile strength and flexural strength noticeably.

Keywords:-*Hybridization, mono fibers, steel fiber, polypropylene fiber, Improvement in mechanical properties.*

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1. INTRODUCTION

Concrete is the most popular material used in construction in general and rigid pavements in particular. Pavements made of concrete provide durable service life and has remarkable application under heavy traffic loading [1].Though the rigid pavements have several advantages; it suffers from a major disadvantages. Concrete is weak in resisting tensile forces. Hence, it cracks easily under low level tensile stresses. The demand for repair is growing every day because of cracking in the normal concrete (NC) pavement. Adequate repair of this pavement is harder, in case of degradation or damage. Another main concern about concrete pavement is its brittleness. The higher the strength of concrete, the lower is its ductility. This inverse relation between strength and ductility is a serious drawback when using concrete as a pavement material. This emphasized the urgency to secure technologies for increase in compression, flexural strength, tensile strength and to improve the modulus of elasticity of concrete.

In view of the above, the use of fiber reinforcement in concrete pavements is enduring to see more contemplation in recent years. Various fiber types are currently being specified in bridge decks, ultra-thin white topping pavements, thin unbounded overlays, and concrete bus pads. Studies [2-8] have reported that flexural strength, fatigue strength, tensile strength and the ability to resist cracking and spalling are also enhanced with the addition of fibers to the concrete. Parviz [2] concluded that cellulose fibers had statistically comparable effects on the plastic shrinkage cracking of conventional and high performance concrete. Soutsos [4] proved that flexural toughness of concrete was found to increase considerably when steel and synthetic fibres were used. Prahallada and Prakash [5] studied the effect of strength and workability characteristics of waste plastic fiber reinforced concrete and found that the waste plastic fibers are very effective in controlling the cracks in concrete. Experiments conducted by Cengiz et.al [7] to study the influence of using fly-ash, polypropylene fibers, and steel fibers in concrete showed that strong relation existed between abrasion and flexural tensile strength, than between abrasion and compressive strength of the concrete containing either fly-ash or fibers or both.

Fibers used in concrete pavements are typically made from steel or plastic and are available in a variety of lengths, shapes, sizes, and thicknesses. They are added to fresh concrete during the batching and mixing process.

In the last decade, an innovative type of fiber reinforced concrete is developed, which improves both the tensile strength and the ductility [9-14] titled as “The Hybrid Fiber reinforced Concrete (HFRC)”. Hybridization refers to combination of different types of fibers. The purpose of combining the fibers is to improve the multiple properties of concrete mixture. The behavioral efficacy of this composite material is far superior to that of plain and mono fiber reinforced concrete. Da and Wang [9] indicate that the addition of fiber is helpful to improve the fracture properties of concrete. A study by Shuling et al [10] reported that the mechanical properties, impermeability, freeze-thaw resistance of fiber reinforced concrete have improved greatly compared with ordinary concrete. As concluded by Ramadevi and Babu [11], the workability of hybrid fiber reinforced concrete mix was increased by addition of a super plasticizer. The test results of the research shows that use of Hybrid Fiber reinforced concrete improves flexural performance of the beams during loading. Ethar Thanon Dawood and Mahiyuddin Ramli [12] conducted studies on hybridization of different percentages of steel fibers and palm fibers and reported that the use of hybrid fiber in specimens increases notably the toughness indices and thus increases their flexural toughness and rigidity and enhance the overall performances of concrete. Ravi and Prakash [14] studied that the resistance of hybrid fiber reinforced self compacting concrete to elevated temperature is better than that of mono fiber reinforced self compacting concrete.

The hybrid fibers are comprehensively being used in rigid pavements, airfield pavements, flexible pavements, earthquake-resistant and explosive-resistant structures, mine and tunnel linings, bridge deck overlays, hydraulic structures, rock-slope stabilization, etc.

2. MATERIALS AND MIX PROPORTIONS

2.1 Materials

The cement used in concrete mixtures was ordinary Portland cement of 53 grade , fine aggregate was natural river sand confirming to Zone II of IS 383:1970 with maximum size of less than 4.75. Coarse aggregate satisfies gradation in Table 2 of IS 383:1970. The properties of super plasticizer are given in table 1. Two types of fibers were used for present investigation as shown in figure 1 (i) Hooked steel fibers-60mm long and (ii) Polypropylene fibers. The properties of hooked steel fiber and polypropylene fibers are given in Table 2 and Table 3 respectively:

Fig 1: Polypropylene fibers & Hooked Steel fibers used for present study

Table 1: Properties of Super plasticizer

Property		Value
Appearance		Brown liquid
Specific gravity		1.15@24°C
pH		9.25

Table 2: Properties of Hooked Steel Fibers

Property	:	Value
Average fiber length, mm	:	60
Average fiber width, mm	:	0.8
Aspect Ratio (L/d)	:	75
Yield Strength (MPa)	:	1100-1380
Tensile Strength (MPa)	:	1.16

Table 3: Properties of Polypropylene fibers

Property	:	Value
Average fiber length, mm	:	12 mm
Shape of fiber	:	special for improved holding of cement aggregates
Tensile strength, MPa	:	392-588 kg/cm2
Melting point, ºC	:	> 250
Dosage rate as specified by the supplier	:	900g per cubic meter of concrete mix

2.2 Mix Proportions

Four types of concrete mixes were prepared using water-cement ratio of 0.4. (i)Plain concrete (PC) (ii) Concrete reinforced with 0.036% (900g per cum of concrete) of Polypropylene (PFRC) (iii) Concrete reinforced with 1% of Steel fibres (SFRC) and (iv) Concrete reinforced with combination of 0.036% Polypropylene + 1% of Steel fibres (HFRC). Concrete composition design is given in Table 4. The percentages of fibers are decided based on the literature review [1, 11].

The amount of super plasticizer was decided by marsh cone test which was 1.4% by weight of binder to maintain the workability and the uniformity of the mixes.

The mix design of the conventional plain concrete mix (PC) is carried out according to IS 10262:2009.

Table 4: Concrete composition design

Index	Cement kg/m³	Water kg/m³	Super Plasticizer %	Sand kg/m³	Coarse Aggregate kg/m³	Steel fiber (SF)%	PP Fibers %
PC	450	180	1.4	761.8	1035	0	0

PFRC	450	180	1.4	761.8	1035	0	0.036
SFRC	450	180	1.4	761.8	1035	1	0
HFRC	450	180	1.4	761.8	1035	1	0.036

3. SCOPE OF PRESENT INVESTIGATION

The purpose of our study was to compare the mechanical properties of plain concrete (PC), polypropylene fiber reinforced concrete (PFRC), steel fiber reinforced concrete (SFRC) and hybrid fiber reinforced concrete (HFRC)concrete. The studied parameters include compressive strength, flexural strength and split tensile strength.

4. TEST METHODS

The slump test for 4 types of concrete mixes was performed with a targeted slump flow of 100 mm±10mm. Following mechanical properties were determined for the 4 types of concrete mixes at the ages of 14 and 28 days of curing:

1. Compressive strength test by casting 150x150x150mm cubes,
2. Split tensile strength test by casting 150mm dia x 300mm height cylinders and
3. Flexural strength test by casting 100x100x500mm beam for of PC and PFRC & 150x150x700mm beam for SFRC and HFRC.

5. RESULTS AND DISCUSSION

The test results of PFRC, SFRC and HFRC are compared with PC at 14 and 28days of curing. The comparison of mechanical properties of concrete specimens given in Table 5 is discussed below:

5.1 Compressive Strength

From Table 5, at 14 and 28days of curing, the compressive strength of concrete mixture increases by 7.29% & 10.85% for PFRC, 11.75% & 13.58% for SFRC and 14.30% & 17.11% for HFRC respectively. Result shows that the % increase in the compressive strength higher with the addition of 1% steel fiber as compared to 0.36% of PP fibers. However, hybridisation improves the compressive strength marginally as compared to mono fibers.

Table 5: Comparison of mechanical properties of concrete specimens

Concrete Composition	Days of curing	Compression strength MPa		Split Tensile Strength, MPa		Flexural Strength, MPa	
		Obtained	% increase	Obtained	% increase	Obtained	% increase
PC	14	40.08	0.00	3.40	0.00	3.95	0.00
	28	43.60	0.00	3.48	0.00	4.35	0.00
PFRC	14	43.00	7.29	3.70	8.82	4.20	6.33
	28	48.33	10.85	3.82	9.77	4.76	9.43
SFRC	14	44.79	11.75	4.48	31.76	4.35	10.13
	28	49.52	13.58	5.11	46.84	5.13	17.93
HFRC	14	45.81	14.30	4.69	37.94	4.80	21.52
	28	51.06	17.11	5.32	52.87	5.84	34.25

5.2 Split Tensile Strength

From Table 5, at 14 and 28days of curing, the split tensile strength of concrete mixture increases by 8.82% & 9.77% for PFRC, 31.76% & 46.84% for SFRC and 37.94% & 52.87% for HFRC respectively. There is substantial increase in the split tensile strength with the addition of fibers to the concrete mix. Hybrid fibers improve the split tensile strength noticeably as compared to mono fibers.

5.3 Flexural Strength

From Table 5, at 14 and 28days of curing, the flexural strength concrete mixture increases by 6.33% & 9.43% for PFRC, 10.13% & 17.93% for SFRC and 21.52% & 34.25% for HFRC respectively. Similar trend as shown in split tensile strength is observed in case of flexural strength. Hybridization keeps improving the flexural strength as compared to mono fibers.

CONCLUSIONS

Following conclusions are drawn from the present investigation:

1) It is evident from the present investigation that the hybridization of fibres proves to be better as compared to mono fibers.
2) There was 17% increase in the compressive strength as a result of hybridization.
3) Hybridization boosted the split tensile strength and flexural strength by 52.87% and 34.25% .
4) The improved mechanical properties of HFRC would result in reduction of warping stresses, short and long term cracking and reduction of slab thickness.

REFERENCES

[1] Hui Li, Mao-hua Zhang, Jin-ping Ou" Abrasion resistance of concrete containing nano- particles for pavements" science direct, wear 260, (2006) ,page 1262-11266.

[2] Parviz soroushian & Siavosh Ravanbakhsh,"Control of plastic cracking with specialty cellulose fiber", ACI Materials Journal, V.95, No.4 (2012), page 429-435.

[3] Jacek Katzer, Jacek Domski," Quality and mechanical properties of engineered steel fibres used as reinforcement for concrete", Construction and Building Materials, vol.34 (2012), page 243–248.

[4] M.N. Soutsos, T.T. Le, A.P. Lampropoulos," Flexural performance of fibre reinforced concrete made with steel and synthetic fibres", Construction and Building Materials 36 (2012) 704–710.

[5] M.C, Prahallada and K.B, Prakash (2011) Strength and Workability Characteristics of Waste Plastic Fibre Reinforced Concrete Produced From Recycled Aggregates. International Journal of Engineering Research and, 1 (4). pp. 1791-1802. ISSN 2248-9622.

[6] YI Xianren, FAN Xiaochun "Flexural-tensile properties of layered steel fiber reinforced rubber concrete" Journal of Wuhan University of Technology-Mater, Vol.24, No.5 (Oct.2009) page 846-848.

[7] Cengiz Duran Atis and Okan Karahan.,(2009) "Relation Between Strength Properties (Flexural And Compressive) And Abrasion Resistance Of Fiber (Steel And Polypropylene) Reinforced Fly-ash concrete", ASCE , Journal Of Materials In Civil Engineering, Vol.21, Issue-8, pp 402-408.

[8] M.C. Nataraja, T.S. Nagaraj and S.B. Basavaraja. (2005) Reproportioning of steel fibre reinforced concrete mixes and their impact resistance, Cement and Concrete Research, Volume 35, Issue 12, December 2005, Pages 2350-2359Elsevier Science Ltd.

[9] Yun Da Shao, Wen Feng Wang, (2012) "Experimental Study on Fracture Properties of Hybrid Fiber Reinforced Concrete", Advanced Materials Research (Volumes 450 - 451), pp518-522.

[10] Shuling Gao, Wenling Tian, Ling Wang, Pei Chen, (2012)Comparison of the Mechanics and Durability of Hybrid Fiber Reinforced Concrete and Frost Resistant Concrete in Bridge Deck Pavement, Transportation Infrastructure Construction and Emerging Technology, pp. 2927-2935.

[11] Ramadevi K., Venkatesh Babu D. L. (2012), "Flexural Behaviour of Hybrid (Steel-Polypropylene) Fibre Reinforced Concrete Beams", European Journal of Scientific Research, ISSN 1450-216X Vol.70 No.1, pp. 81-87.

[12] Eethar Thanon Dawood and Mahyuddin Ramli (2011) "Contribution of Hybrid Fibers on The Hybrid Fibers on the Properties of High Strength Concrete Having High Workability" proceedings of Twelfth East Asia-Pacific Conference on Structural Engineering and Construction. Procedia Engineering 14 (2011) 814–820.

[13] Joshua D. Blunt and Claudia P. Ostertag, "Deflection Hardening and Workability of Hybrid Fiber Composites", ACI Materials Journal, V.106, No.3 (2009), page 265-272.

[14] Ravi K and K B Prakash,(2008) "Strength Characteristics of Hybrid Fiber Reinforced Self Compacting Concrete Subjected to Sustained Elevated Temperature", Proceedings of 33rd Conference on Our World In Concrete & Structures: 25 – 27 August 2008, Singapore.