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Performance of Hybrid Fiber Reinforced Concrete Beams under Static Flexural Load

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Abstract

This study investigatesthe behavior of reinforced concrete beams under static flexural load developed with mono fiber and hybrid fibers reinforced concrete. Hybridization is to improve the flexural performance of simply supportedreinforced concrete beams. In this investigation, five different mixes are investigated under flexure. Two mono fiber reinforced concrete beam with Steel fiber and Polyethylene Terephthalate (PET) fiber fiber of 2.0% volume fraction mixes. Hybrid fiber reinforced concrete mix with recycled PET bottle fiber of 0.5% hybrid with 1.5% of steel fiber, PET fiber of 1.0% and steel fiber of 1.0% and PET fiber of 1.5% and steel fiber of 0.5% are the other threemixes under investigation. The flexural properties of concrete beam without fiber reinforcementisused as the base mix for comparison. From the results, it has been studied that hybrid fiber reinforced concrete beams performed better than the all the other mixes.

Keywords:Flexural Strength, Load vs Deflection, Steel Fiber,PET Fiber,Fiber reinforced concrete

1. Introduction

Concrete is a man made materials commercialized since being of nineteenth century. Day by day performance of concrete is increasing based on the application and the site conditions. It is versatile and possesses desirable engineering properties which can be molded into any shape and produced using cost-effective materials.This variation is achieved by adding different ingredients or chemical/mineral admixtures in the concrete mix depends upon the various structural application. Similarly, fibers are induced in the concrete to improve the tensile strength,flexural strength, shrinkage crack, ductility, energy absorption, ultimate load, crack resistance, etc.,(1-5)

The exponential growth of multifarious industries catering to the basic needs of human life in turn is liable to produce huge annual turnovers of waste by-product dumps. It is time that a paradigm shift as regards the partial or complete replacement of these conventional ingredients as a techno-economical viable alternative, ushered without detrimental to the environment.In other hand, Polyethylene Terephthalate bottle wastes are dumped as a solid waste which create pollution to environment create land and water pollution. In this investigation an attempt is made to recycle the Polyethylene Terephthalate bottle and convert it to fiber and same was used as a fiber reinforcement in the concrete(6).

A recent improvement in the fiber reinforced concrete is hybridization of fiber by adding two or more fiber with different modulus, which optimize the performance of material for different structural application. This modification in the fiber reinforced concrete is achieved by mechanical properties of used fibers which reduce the crack, increase the deflection behaviourundervarious loading conditions, which comprise using fibers with different sizes and modulus of elasticity(5, 7-9). In this investigation steel fiber used as a high modulus fiber which perform better in tensile strength, high flexural load carrying capacity, energy absorption.Polyethylene Terephthalate (PET) fiber is low modulus fiber which is capable to deform than the steel fiber which may increase the toughness of concrete. In this experimental study, 2.0% volume fraction kept as constant for all the fibers. PET fiber hybrid 0.5% volume fraction to the 1.5% volume fraction of steel fiber, PET and steel fiber with 1.0% volume fraction and finally 1.5% volume fraction of PET fiber hybrid with 0.5% volume fraction of steel fiber.

2. Materials and Experimental Test Setup

In this experimental investigation, Ordinary Portland Cement 53 Grade used as binding materials as per IS 12269-2013(10). Natural river sand of Zone III has used as fine aggregate as per IS 383-1970(11), Coarse aggregates of size less

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than 12 mm used as per IS:2386 (Part- III)(12), potable water takento mixall the ingredients in the concrete and conplast SP430 is used as a super plasticizer. PET and Steel fiber used as fiber in the concrete, Table.1 shows the properties of PET and Steel fibers

Table.1 Properties of PET and Steel fibers

Test particulars	PET Fibers	Steel Fibers
Length (mm)	50	50
Direct Tensile (MPa)	550	2000
Modulus of Elasticity (GPa)	2.8	175
Melting Point (ºC)	250	1370
Elongation (%)	11.5	4.5
Diameter (μm)	1000	300
Aspect Ratio	50	167
Density (kg/m^3)	1380	7900

Wooden mouldsare used to cast the specimen for a beam size of 100 mm x 200 mm x 1700 mm. Reinforced concrete beams were designed as a under reinforced section.Designed beam is reinforcement with 2 numbers of longitudinal reinforcement with 10mm diameter bars at the bottom and 2 numbers of 8mm diameter bars at the top of the beamas a hanger bar. Clear cover of 25mm maintained in all the direction. 6mm diameter of reinforcement placed at 125mm center to center spacing as a stirrups used a shear resistant reinforcement. Table 2 and Table 3 shows concrete mix proportion and Mix I.D for this investigation. Figure 1 shows the Casting of Concrete Beams in the wooden mould.

Table.2Concrete mix proportion in Kg/cum

Cement	Fly ash	Fine aggregate	Coarse aggregate	Water Cement ratio	Super Plasticizer
386	43	835	1024	172	4.3

Table.3Mix I.D based Fiber Volume Fraction

Mix	PET Fibers	Steel Fibers
CC	--	--
PET$_{2.0}$	2.0	--
STEEL$_{2.0}$	--	2.0
(PET$_{1/4}$+Steel$_{3/4}$)$_{2.0}$	0.5	1.5
(PET$_{1/2}$+Steel$_{1/2}$)$_{2.0}$	1.0	1.0
(PET$_{3/4}$+Steel$_{1/4}$)$_{2.0}$	1.5	0.5

Figure 1 Casting of Concrete Beams in the wooden mould

Figure 2 shows the flexural test setup of reinforced concrete beams. Flexural tests were conducted using 100 tonne capacity loading frame. Four point loading flexural test was carried out on the reinforced concrete beams, load is acting at every 0.5m interval. 100 kN capacity servo controlled hydraulic jack was used to apply the load on the reinforced concrete beam, spanderal beam is used to distribute the load at 0.5m interval. Linear Variable Differential Transformer (LVDT) placed at three locations, mid span and two loading acting location are the three places. LVDT and hydraulic jack connected with the data acquisition system, deflection of concrete beams with respecting to the load are stored in the system interface. First crack load, ultimate load and failure load are noted at the time of testing.

Figure 2 Flexural Test Setup of Reinforced Concrete Beams

3. Results and Discussion

Following results were made after the experimental study. The conventional concrete beam has its visible first crack load, yield crack load and ultimate crack load on 3.75kN, 16.50kN and 19.05kN and its corresponding deflections are 2.92mm, 13.80mm and 13.94mm. The conventional concrete beam has the 1.891 ductility and the total section energy absorption is 352kN-mm. The load versus deflection curve of CC beam is displayed in Figure.3.Table.4shows the salient features of all the specimen subject to flexural load and Table.5 shows the ductility and energy absorption of different reinforced concrete beams.

The PET fiber of 2.0% volume fraction concrete beam has its visible first crack load, yield crack load and ultimate crack load on 6.60kN, 17.60kN and 27.35kN and its corresponding deflections are 4.48mm, 12.80mm and 19.00mm. The PET fiber concretebeam has the 1.977ductility and the total section energy absorption is 416.80 kN-mm. The ultimate flexural load absorbingability of the PET fiber concrete beam is 44% more than conventional concrete beam. Similarly ductility and energy absorption has improved 5% and 18% from the CC beam. The load deflection curve of the PET fiber is displayed in Figure.4.

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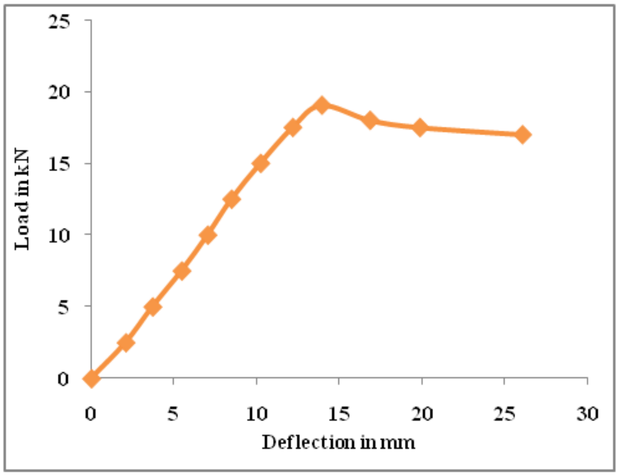
The steel fiber of 2.0% volume fraction concrete beam has its visible first crack load, yield crack load and ultimate crack load on 6.35kN, 17.80kN and 24.80kN and its corresponding deflections are 3.68mm, 10.30mm and 15.10mm. The steel fiber concrete beam has the 2.883ductility and the total section energy absorption is 540.20 kN-mm. The ultimate flexural load absorbing ability of thesteel fiber concrete beam is 30% more than conventional concrete beam. Similarly ductility and energy absorption has improved 52% and 53% from the CC beam. The load deflection curve of the Steel fiber is displayed in Figure.5.



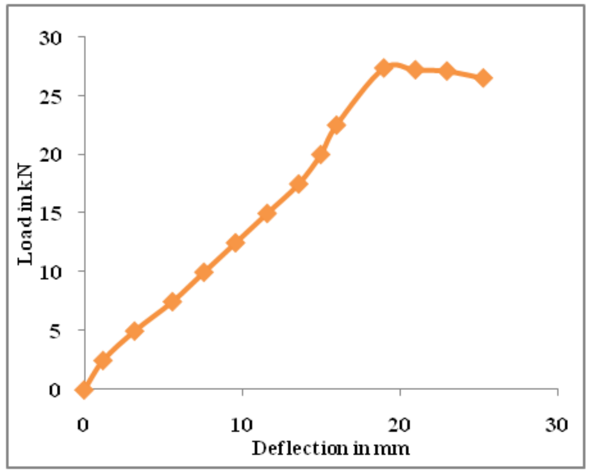
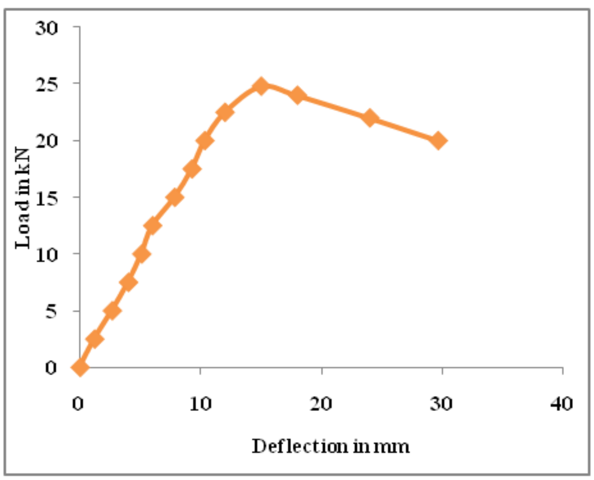


Figure.3 Load-Deflection curve of CC beamFigure.4 Load-Deflection curve of PET fiber (2.0%) beam



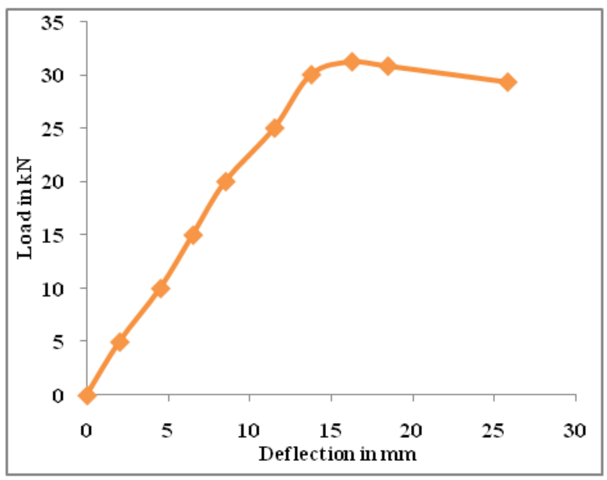


Figure.5Load-Deflection curve of Steel fiber(2.0%) beamFigure.6Load-Deflection curve of (PET$_{1/4}$+Steel$_{3/4}$)2.0 fiberbeam

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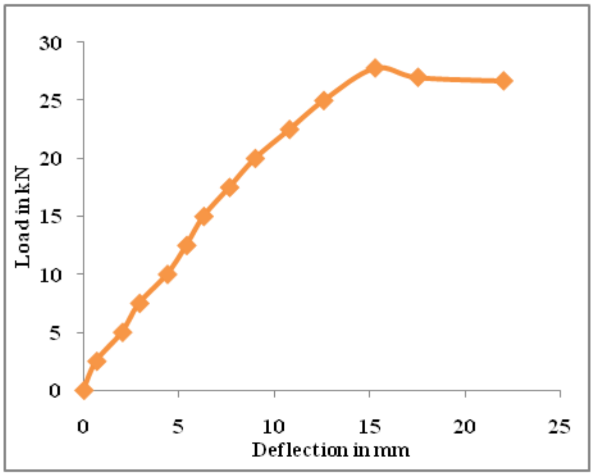

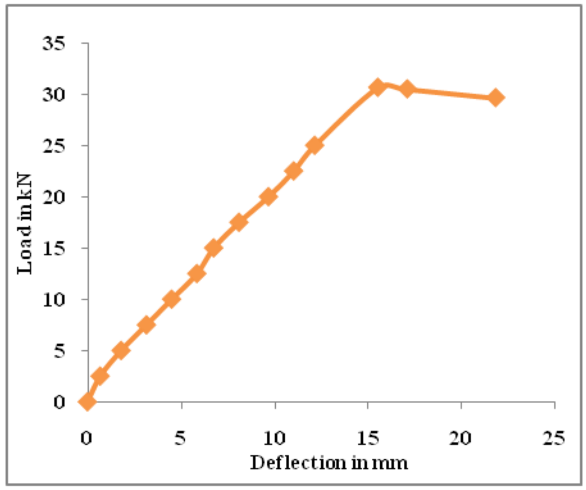

Figure.7Load-Deflection curve of $(PET_{1/2}+Steel_{1/2})2.0$ fiber beamFigure.8Load-Deflection curve of $(PET_{3/4}+Steel_{1/4})2.0$ fiberbeam

Table.4Salient features of beams at different stages

Mix	First Flexural crack load in kN (Pcr)	Deflection at FlexuralFirst crack load in mm (δ_{cr})	Load at yield crack in kN (Py)	Deflection at yield crack load in mm (δ_y)	UltimateFlexural load in kN (Pu)	Deflection at ultimate crack load in mm (δ_u)
CC	3.75	2.92	16.50	13.80	19.05	13.94
$PET_{2.0}$	6.60	4.48	17.60	12.80	27.35	19.00
$STEEL_{2.0}$	6.35	3.68	17.80	10.30	24.80	15.10
$(PET_{1/4}+Steel_{3/4})_{2.0}$	5.40	2.53	22.05	9.65	31.20	16.25
$(PET_{1/2}+Steel_{1/2})_{2.0}$	5.30	4.35	17.80	17.10	27.80	34.00
$(PET_{3/4}+Steel_{1/4})_{2.0}$	5.45	4.50	17.10	17.30	30.65	34.50

Table.5Ductility and Energy Absorption of Reinforced Concrete Beams

Mix	Ductility	Energy Absorption Capacity (kN-mm)
CC	1.891	352
$PET_{2.0}$	1.977	416.8
$STEEL_{2.0}$	2.883	540.2
$(PET_{1/4}+Steel_{3/4})_{2.0}$	3.117	609.3
$(PET_{1/2}+Steel_{1/2})_{2.0}$	3.395	626.3
$(PET_{3/4}+Steel_{1/4})_{2.0}$	4.306	617.7

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The (PET1/4+Steel3/4) fiber of 2.0% volume fraction concrete beam has its visible first crack load, yield crack load and ultimate crack load on 5.40kN, 22.05kN and 31.20kN and its corresponding deflections are 2.53mm, 9.65mm and 16.25mm. The (PET1/4+Steel3/4) fiber concrete beam has the 2.674ductility and the total section energy absorption is 578.70 kN-mm. The ultimate load carrying capability of the (PET1/4+Steel3/4) fiber concrete beam is 64% more than conventional concrete beam. Similarly ductility and energy absorption has improved 41% and 64% from the CC beam.The load deflection curve of the PET + steelfiber hybrid beamis shown from Figure.6 to Figure.8.

4. Conclusion

From the elaborated experimental study, the following conclusions were derived. The hybrid fibers have acceptable increment in their strength when adding the fibers by 2% of volume fraction.

- From the structural behaviour of beam of conventional, mono fiber and hybrid fiber concrete performed well. The ultimate flexural load carrying capacity of the concreteimproved much when adding the fibers. The fibers have good bonding with the concrete and the performance of fiber presence in the bottom of the beam has given the restriction against the applied load, so that the deflection of the beams are very less and in controlled manner.
- In this structural behaviour of beam, the hybrid fiber with PET and steel combination have good ductility nature, better energy absorption also good performance in load deflection criteria.

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