Indexed in
Scopus Compendex and Geobase Elsevier, Chemical Abstract Services-USA, Geo-Ref Information Services-USA, List B of Scientific Journals, Poland, Directory of Research Journals

www.cafetinnova.org

ISSN 0974-5904, Volume 08, No. 02

International Journal of Earth Sciences and Engineering

April 2015, P.P.372-376

Energy Absorption Characteristics of Steel, Polypropylene and Hybrid Fiber Reinforced Concrete Prisms

M TAMIL SELVI[1] AND T S THANDAVAMOORTHY[2]

[1]Department of Civil Engineering, Dr. M.G.R. Educational and Research Institute University, Chennai 600095, India

[2]Department of Civil Engineering, Adhiparasakthi Engineering College, Melmaruvathur and Past Vice-President, ICI

Email: *tamilselvi_05@yahoo.com, tan_44@yahoo.com*

Abstract: This paper presents a report on the development of a simple model for calculating the energy absorption by steel, polypropylene and hybrid fibers. Three major components were identified as contributing to the energy lost by the projectile during ballistic impact, namely, the energy absorbed in tensile failure of the composite, the energy converted into elastic deformation of the composite and the energy converted into the kinetic energy of the moving portion of the composite. The main requirements of earthquake resistant structures are good ductility and energy absorption capacity. Fiber reinforced concrete possesses high flexural and tensile strength, improved ductility, high energy absorption compared to conventional concrete against dynamic loads. The aim of this paper is to analyze the energy absorption capacity of steel, polypropylene and hybrid fibers. The energy absorption capacity was quantified for axial loading. Based on the results of the experimental program, it can be concluded that the addition of four percentages by volume steel fibres had the best effect on the flexure strength and energy absorption capacity of the prisms. The present study has been taken up for evaluating different types of concrete. Emphasis has been laid on the strength and deformation properties of reinforced concrete beams. This paper presents the results of an experimental investigation carried out on four different type's reinforced concrete prisms of size, 150 mm × 150 mm × 700 mm. The prisms were tested under midspan loading. The results showed that the flexural properties of concrete matrix are significantly improved by the addition of steel, polypropylene and hybrid fibers. Out of the three different types of fibers used in this study, the fibers with steel and hybrid showed better efficiency in improving the flexural response.

Keywords: *Energy absorption, Reinforced concrete, Steel, Polypropylene and Hybrid fiber*

1. Introduction

Concrete is a material weak in tension and fails in a brittle manner when subjected to flexure, tension and impact forces. When, steel fibers are added to concrete, the behavioral efficiency of this composite material is found to be superior to that of plain concrete and many other construction materials of equal cost [1, 2].

Due to this benefit, use of fiber reinforced concrete (FRC) has increased largely in the recent years and this finds its application in airport and highway pavements, earthquake-resistant and explosive-resistant structures, mine and tunnel linings, ridge deck overlays and hydraulic structures [3-5].

Several works have been conducted in exploring the relation between permeability and crack width and have reported that using steel fiber have decreased the permeability of the specimens with reduced crack width upto 100 microns [6]. Steel –fiber reinforced concrete containing up to 1.5% fiber by volume when tested for impact strength has substantially improved resistance to impact and greater energy absorption.

The geometrical size and modulus of elasticity of fibers are the main factors which will affect the performances of fiber reinforced concrete. In order to optimize the benefits of fiber addition in concrete construction, the application of different fiber types into fresh concrete mixtures was introduced and commonly known as hybrid fiber reinforced concrete (HyFRC). It becomes more popular in these recent years and expected to provide better physical and mechanical properties in concrete for structural purposes. The use of different types of fibers in a suitable combination may potentially improve the mechanical properties of concrete and result in synergic performance [7-10]. Addition of steel fiber, generally, provides contribution to the energy absorbing mechanism (bridging action), while nonmetallic fibers offer its ability to delay the formation of microcracks and avoid catastrophic breaking, and also has much lower density [10].

The mixtures were prepared with blended cement containing 23.13% of SiO_2, 8.76% of Al_2O_3, 4.62% of Fe_2O_3, 58.66% of CaO, 0.90% of MgO, 2.18% of SO_3, and 1.69% of loss on ignition which satisfies the requirements in the Indonesian Standards for Pozzolan Portland Cement [11]. Experiments were conducted with different types of concretes with 4% of fibres. The strength, workability and energy absorption characteristics of the composite were studied.

2. Experimental Work

In this experimental investigation concrete prisms of size 150 mm × 150 mm × 700 mm with steel, polypropylene, and hybrid fibers of 2% by (4% by weight) volume of cement were cast individually and tested. The materials used, details of prisms, etc., are elaborated below.

3. Materials Used

Ordinary Portland Cement (OPC – 53 grade) conforming to the requirements of [12], graded river sand and crushed aggregate of size varying from 10 to 20 mm conforming to [13] were used. Ordinary potable water which is free from organic impurities and turbidity for was used for preparing concrete.

3.1. Design Details of the Prisms

The details are furnished below. Cross- sectional dimension of the prism: 150 mm ×150 mm and length of the prism: 700 mm. Prisms were cast with and without longitudinal reinforcement and with fiber reinforcement in all cases.

1) Without Reinforcement: Here, no longitudinal reinforcement bar was provided
2) Singly reinforced: Main reinforcement bars: 2 Nos.12 mm dia with Fe415 steel on the tension side.
3) Doubly reinforced: Main reinforcement bars: 2 Nos.12 mm dia with Fe415 steel on the tension side; 2 Nos. 8 mm dia with Fe 250 steel hanger bars on the compression side. Stirrups of 6 mm dia at 75 mm centers at supports and at mid span section.

4. Testing of R.C.C. Prisms

The prism is supported over a span of 500 mm and a single point load at midspan was applied. The experimental setup is shown in Fig. 1. The specimen was tested to failure and the central deflections of the beam at load increments were recorded for gradually applied load till the ultimate load was reached.

(a)Testsetup

(b) Strain gauge instrumentation

(c) Shear crack

(d) Crushing at load support

Fig. 1*Testing of beam*

4.1. Energy Absorption Calculations

The load-deflection curve was drawn and the area enclosed under load-deflection curve was found out. The work done in a particular type of concrete was calculated. The unit of energy absorption is kN-mm. The energy absorption characteristic of the steel, polypropylene and hybrid fiber reinforced concrete prisms are presented in Tables 1, 2, and 3) and in Figs 2,3,and 4.

Table: 1*Results of tested prisms without reinforcements*

Type of concrete	Specimen	Energy absorption kN-mm
Conventional concrete	A_1	40.0
Steel FRC	B_1	47.0
Polypropylene FRC	C_1	97.0
Hybrid FRC	D_1	36.0

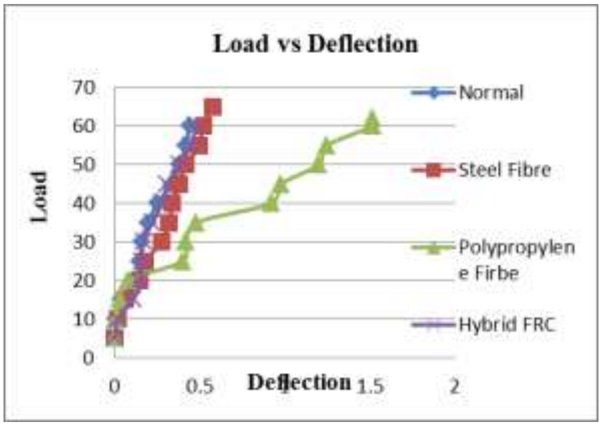

Fig.2 *Tested prisms without reinforcements*

Table 2 *Results of singly reinforced R.C.C. tested prisms*

Type of Concrete	Specimen	Energy absorption kN-mm
Conventional concrete	A_{1-1}	132
Steel FRC	B_{1-1}	140
Polypropylene FRC	C_{1-1}	133
Hybrid FRC	D_{1-1}	90

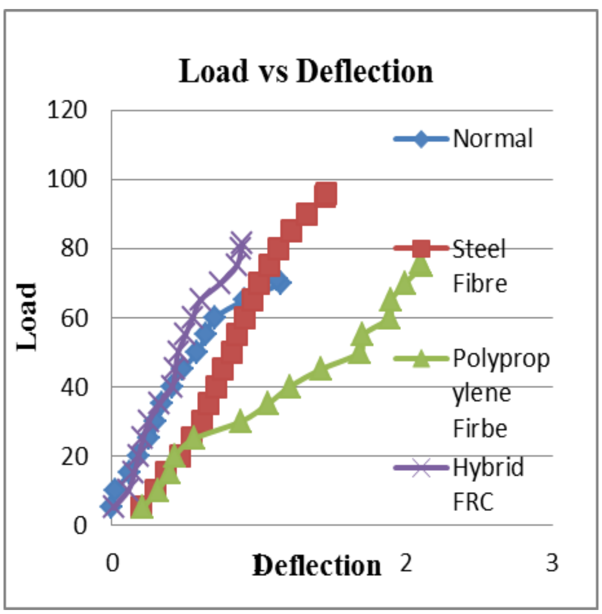

Fig.3 *Tested singly reinforced prisms*

Table 3 *Results of doubly reinforced R.C.C. prisms*

Type of Concrete	Specimen	Energy absorption kN-mm
Conventional concrete	A_{1-2}	144
Steel FRC	B_{1-2}	222
Polypropylene FRC	C_{1-2}	176
HYBRID FRC	D_{1-2}	93

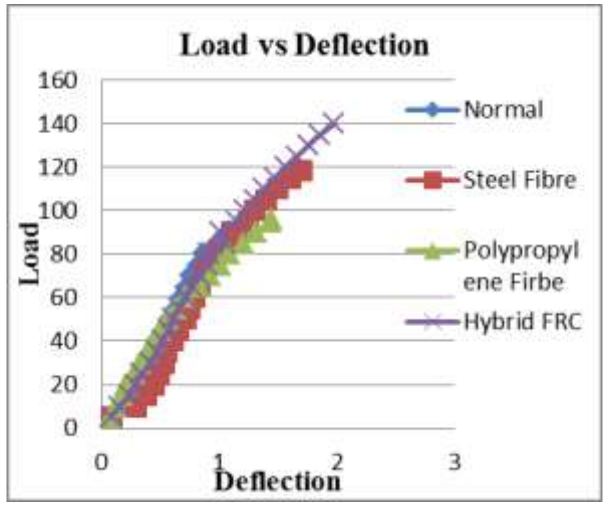

Fig. 4 *Tested doubly reinforced prisms*

5. Comparison of Test Results and Discussion

The test results of the steel, polypropylene and Hybrid fibre reinforced concrete are compared with the conventional concrete. Further to evaluate the effectiveness of the process carried out discussion is presented below.

5.1. Comparison of Energy Absorption

The energy absorption of all three types of concrete made using steel, polypropylene and Hybrid fiber reinforced concrete are compared in Table 4.

Table 4 *Comparison of energy absorption*

Type of concrete	Energy absorption experimental value (kN-mm)		
	Without reinforcement	Singly reinforced	Doubly reinforced
Conventional concrete	40.0	132	144
SFRC	47.0	140	222
PPFRC	97.0	133	176
Hy. FRC	36.0	90	93

Experimental value the following points are presented. The experimental value of SFRC without reinforcement is higher by 17.5%, singly reinforced is 6% higher and doubly reinforced is 54% higher than the conventional concrete. The corresponding value of PPFRC without reinforcement is higher by 142%, singly reinforced is equal and doubly reinforced is 23% higher than the conventional concrete. The experimental value of Hybrid FRC without reinforcement is lower by 10%, singly reinforced is 32% higher and doubly reinforced is 36% higher than the conventional concrete.

6. Conclusion

In the fresh state addition of steel, polypropylene and Hybrid fibre reinforced concrete caused lower workability. The energy absorption based experimental value of SFRC without reinforcement was higher by 17.5%, singly reinforced was 6% higher and doubly reinforcement was 54% higher than the conventional concrete. The value of PPFRC without reinforcement was higher by 142%, singly reinforced was equal and doubly reinforcement was 23% higher than the conventional concrete. The experimental value of Hybrid FRC without reinforcement was lower by 10%, singly reinforced was 32% higher and doubly reinforcement was 36% higher than the conventional concrete.

Based on the comparison between steel, polypropylene and Hybrid fibre reinforced concrete it is shown that the Hybrid fibre reinforced concrete results in the concrete with less energy absorption among all type of specimens.

7. Appendix-1

Mix Design Details Mix Design for M30 Grade of concrete Based on I.S. Method [14]

1) Design stipulations

a) Characteristic compressive strength at the end of 28 days = 30 N/mm^2
b) Maximum size of aggregate = 20 mm
c) Degree of workability = 0.9 CF (medium)
d) Type of exposure = Mild
e) Degree of quality control = Good

2) Test Data for Materials

a) Specific gravity of cement = 3.15
b) Specific gravity of coarse aggregate (Natural) = 2.64
c) Specific gravity of fine aggregate (Sand)=2.60

3) Target Mean Strength of Concrete

Target mean strength of concrete at the end of 28 day = 30 + (1.65 × 5) = 38.25 N/mm^2

4) Selection of Water/Cement Ratio (w/c)

Water / Cement ratio required to attain target mean Strength 37.60 N/mm^2 = 0.45

5) Selection of Water and Sand Content

Water content per cubic meter of concrete = 186 kg

Sand as percent of total aggregate by absolute volume = 35%

For change in value of water/cement ratio, compacting factor and sand belonging to Zone III, the adjustment in water and sand content is required.

Therefore required Water content per cubic meter of concrete = 191.58 kg

Sand content on % of total aggregate by absolute volume =32.5%

6) Determination of Cement Content

Water/ Cement Ratio = 0.45
Water content = 191.58 kg /m^3
Cement content= 420 kg /m^3

7) Determination of Coarse Aggregate and Fine Aggregate Contents

For the specified maximum size of aggregate of 20mm, the amount of entrapped air in the wet concrete is 2%.

$$1\ m^3 = 0.02 + (191.58/1000) + 420/(3.15x1000) + V_{ca} + V_{fa}$$

$$(V_{ca} + V_{fa}) = 0.477\ m^3$$

Weight of fine aggregate = 403 kg /m^3
Weight of coarse aggregate = 850 kg /m^3

8) Typical Test results of trial mixes.(Table A-1)

Table A-1 *Details of Mix*

Sl.No	Material	Quantity per m^3 in Kg.			
		Conventional concrete	Steel fibre reinforced concrete	Polypropylene fibre reinforced Concrete	Hybrid fibre reinforced
1	Cement	420	420	420	420
2	Fine aggregate	420	420	420	420
3	Coarse aggregate	840	840	840	840
4	W/C ratio (%)	0.45	0.45	0.45	0.45
5	Steel fibre		16.8		
6	Polypropylene fibre			16.8	
7	Hybrid fibre		8.4	8.4	16.8

9) Mix Proportion by Weight for M30 Grade of Concrete is

1:1:2/0.45

References

[1] Ganesan N, Indira P V and Santosh Kumar P T (2006), "Ultimate Strength of Steel Fiber Reinforced Self Compacting Concrete Flexural Elements", Indian Concrete Journal.

[2] Niranjana G, Samson Mathew and Jayabalan P (2007), "Structural Strength Enhancement of Rigid Pavement Using Scrap Steel Fibre Reinforcement", Department of Civil Engineering, National Institute of Technology, Tiruchirappalli.

[3] Barros J A O (1995), "Behavior of Fiber Reinforced Concrete-Numerical and Experimental Research".

[4] Sekar M (2004), "Fibre Reinforced Concrete from Industrial Waste – A Feasibility Study", Institution of India Journal, Vol. 84.

[5] Anette Jansson (2008), "Fibres in Reinforced Concrete Structures – Analysis, Experiments and Design".

[6] Gupta S M, Segal V K and Kaushik S K (2009), "Shrinkage of High Strength Concrete

[7] S. F. U. Ahmed, M. Maalej, and P. Paramasivam, "Flexural responses of hybrid steel-polyethylene fiber reinforced cement composites containing high volume fly ash," Construction and Building Materials, vol. 21, pp. 1088–1097, 2007.

[8] F. Altun, T. Haktanir, and K. Ari, "Effects of steel fiber addition on mechanical properties of concrete and RC beams," Construction and Building Materials, vol. 21, no. 3, pp. 654–661, 2007.

[9] N. Banthia and N. Nandakumar, "Crack growth resistance of hybrid fiber reinforced cement composites," Cement and Concrete Composites, vol. 25, no. 1, pp. 3–9, 2003.

[10] A. Sivakumar and M. Santhanam, "Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibres," Cement and Concrete Composites, vol. 29, no. 8, pp. 603–608, 2007.

[11] National Standardization Body of Indonesia, SNI: 15-0302-2004: Pozzolan Portland Cement, the National Standardization Body, Bandung, Indonesia, 2004, (In Indonesian).

[12] Indian Standard Code of Practice for Specification for 53 grade ordinary Portland cement IS 12269: (1987), Bureau of Indian Standards, New Delhi.

[13] Indian Standard Code of Practice for Specification for Coarse and Fine Aggregates from Natural Sources for Concrete IS 383: (1970), Bureau of Indian Standards, New Delhi.

[14] Indian Standard Code of Practice for Recommended Guidelines for Concrete Mix Design IS 10262: (1982), Bureau of Indian Standards, New Delhi.