

Behaviour of Hybrid Fibre Reinforced Concrete with Partial Replacement of Cement by Fly Ash in Flexure

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ABSTRACT: This paper presents the behaviour of Hybrid Fibre reinforced concrete with partial replacement of cement by fly ash in flexure. Concrete is said to be good in compression and weak in tension. It is often affected by cracking and scaling which are connected to the plastic & hardened states. Low tensile strength, limited ductility and the poor resistance to cracking lead to severe effect in the properties of concrete. Due to increase in coal based thermal power projects there is a rise in the production of fly ash. The improper disposal of fly ash is hazardous. As a solution the fly ash is used in the concrete as a partial replacement of cement. Glass fibre and polypropylene fibres are chemically inorganic. Glass fibres are obtained from molten glass of a specific composition. The replacement of cement with fly ash in hybrid fibre reinforced concrete reduces the environmental pollution and improves the mechanical properties of concrete. In this study different percentages (0%, 0.25%, 0.50%, 0.75% and 1.00%) of glass and polypropylene fibres collectively act as a hybrid fibre with different percentages of fly ash (0%, 10%, 20%, 30%, 40%) are used to know their effect on the mechanical properties like compressive strength, split tensile strength, flexural strength and stress-strain behaviour of the hybrid fibre reinforced concrete. It is found that at 1% (0.50% polypropylene and 0.50% glass fibres) addition of fibres and up to 30% replacement of fly ash in cement can improve the properties of concrete.

KEYWORDS: Hybrid Fibres, Hybrid Fibre reinforced concrete, Glass fibre, Polypropylene fibre, Fly ash, Compressive strength, Split tensile strength, stress strain behaviour, Flexural strength.

I. INTRODUCTION

Concrete is one of the most widely used building materials which can be easily mixed with many materials in order to meet a variety of special needs to form virtually into any shape. The concrete behaves as a stone in strength, hardness and durability. The Concrete is a brittle material which is good in compression but very weak in tension. To increase the properties of the concrete, additional material like pozzolanas and fibres may be used. Concrete generally develops micro cracks and they propagate rapidly under applied stress resulting in low tensile strength of concrete. Hence addition of fibres improves the strength of concrete to overcome the problems. In the present investigation, combination of glass fibre (0%, 0.25% 0.5%, 0.75% and 1%) and polypropylene fibres (0%, 0.25% 0.5%, 0.75% and 1%) with 0%, 10%, 20%, 30% and 40% replacement of cement by fly ash are used to study the variation of compressive strength, split tensile strength, stress strain behaviour and flexural strength of concrete in comparison to the conventional concrete.

II. RELATED WORKS

Vikrant.S(2012) studied the combinations of steel and polypropylene fibres in concrete and found that a combination of steel and polypropylene fibres with 0.8% and 0.2% gave good results compared to conventional concrete. Rooban Chakraborty(2016) worked on hybrid fibre reinforced concrete with steel and polypropylene fibres and suggested that

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Vol. 7, Issue 5, May 2018

the hybrid fibers with fly ash can be proportioned by high volume fraction, i.e. greater than 2% to improve the mechanical properties but may affect the workability of concrete. Shikha Srivastava(2018) suggested hybrid fibre reinforced concrete with 4% of hybrid fibres (polypropylene and steel) and with 5% of fly ash can improve the mechanical properties compared to normal concrete.

III. OBJECTIVES

- To attain the optimum proportion of hybrid fibres (i.e., glass fibre and polypropylene fibre) by studying the compressive and split-tensile strength of the hybrid fibre reinforced concrete.
- To study the compressive and split tensile strengths of hybrid fibre reinforced concrete with fly ash as partial replacement to cement
- To study the stress-strain behaviour of hybrid fibre reinforced concrete with fly ash as partial replacement to cement.
- To study the variation of flexural strength of hybrid fibre reinforced concrete with fly ash as partial replacement to cement.

IV. MATERIALS USED

- **Cement:** Ordinary Portland cement of grade 53, confirming to IS: 12269-2013 is used. The specific gravity of cement obtained was 3.02.
- **Fine aggregate:** Fine aggregate of Zone-II confirming to IS: 383- 1970 is used .The Specific gravity of fine aggregate obtained is found to be 2.29.
- **Coarse Aggregate:** Crushed granite is used as coarse aggregate. The nominal size of coarse aggregate is 20mm with a specific gravity of 2.72.
- **Fly Ash:** Class-F fly ash procured from the Kakatiya thermal power station located at Bhupalpally, Telangana is used. The loss of ignition value is 3.72%. The chemical composition of the fly ash is given in Table1.

Table 1 Chemical Composition of fly ash in percentages

Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	TiO ₂	P ₂ O ₅	V ₂ O ₅	ZnO
19.24	63.41	4.46	2.28	1.18	0.20	1.92	0.04	1.06	0.08	0.03	0.02

- **Glass fibre:** In this investigation alkali resistant glass fibres are used as shown in Figure 1(a). The properties of glass-fibres are shown in Table 2.

Table 2 Properties of Glass fibre

Properties	Values
Tensile strength (MPa)	4028 to 4650
Elongation of break (%)	5.81
Diameter (μ)	10
Melting temperature bond	1558
Length of the fibre (mm)	12-13mm

- **Polypropylene fibre:** In this study, soft polypropylene fibres are used as shown in Figure 1(b). The properties of polypropylene fibre are given in Table 3.

Table 3 Properties of Polypropylene fibre

Properties	Values
Tensile strength (kg/cm ²)	6000
Elongation of break (%)	45-55
Diameter (μ)	33-35
Length of the fibre (mm)	12-13mm

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Vol. 7, Issue 5, May 2018



Fig 1 (a) Glass Fibre



Fig 1 (b) Polypropylene Fibre

- **Water** : Potable water without any dissolved salts is used for mixing and curing.

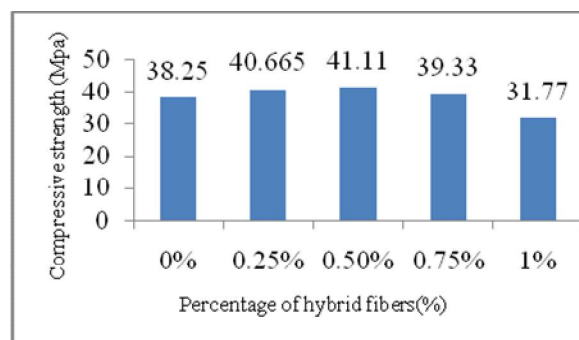
V. EXPERIMENTAL RESULTS AND DISCUSSION

Mix design for M30 grade of concrete was done as per IS: 10262(2009) with mix proportions 1:1.55:3.19 with a water cement ratio of 0.45. Test specimens of standard size 150 mm x 150 mm x 150mm cubes for compressive strength and cylinders of diameter 150mm and height 300 mm for split tensile strength with combination of Glass and polypropylene fibres of varying percentages (0%, 0.25%, 0.50%, 0.75% and 1.00%) were cast and cured for 28 days. The specimens were tested to obtain the optimum dosage of combination of fibres in the concrete. Cubes and cylinders with optimum dosage of hybrid fibres and varying percentages of fly ash (0%, 10%, 20%, 30% and 40%) were cast and cured for 28 days. The specimens were tested under compression testing machine to obtain the dosage of fly ash to be used with hybrid fibres in concrete. Beam specimens of size 600 mm x 150mm x 100 mm with optimum dosage of the hybrid fibres and different percentages of fly ash (0%, 10%, 20%, 30% and 40%) were cast and cured for 28 days. The specimens were tested under Universal Testing Machine according to IS: 516-1979 to study the flexural behaviour of hybrid fibre reinforced concrete.

a. Compressive and Split Tensile Strength of the Hybrid Fibre Reinforced Concrete:

Table 4 compressive and split tensile strength of Hybrid Fibre reinforced concrete

Percentage of Fibres		Compressive Strength For 28 Days (Mpa)	Split Tensile Strength For 28 Days (Mpa)
Polypropylene Fibre(P.F)	Glass Fibre (G.F)		
0%	0%	38.25	2.15
0.25%	0.25%	40.66	2.44
0.50%	0.50%	41.11	2.84
0.75%	0.75%	39.33	2.71
1.00%	1.00%	31.77	2.08



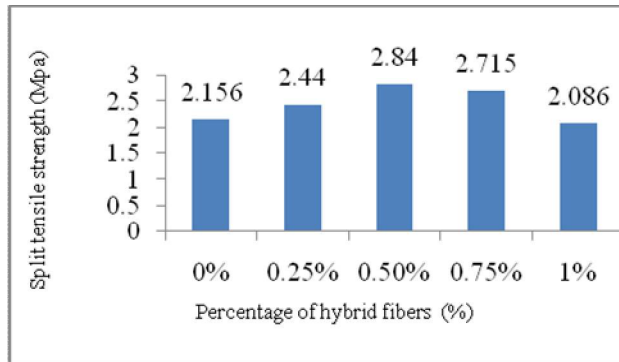
Graph 1 Average Compressive Strength of cubes with hybrid fibres

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(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 5, May 2018



Graph 2 Average split tensile strength of cylinders with hybrid fibres

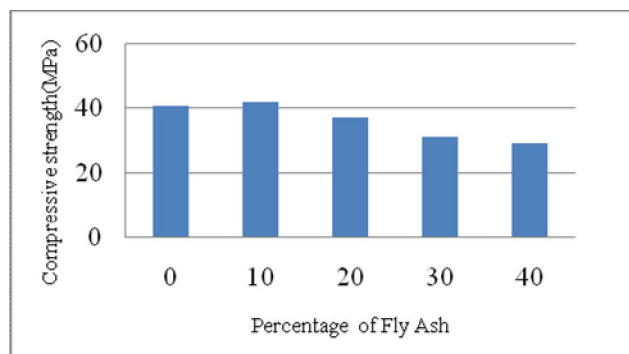
From the above results it was observed that cubes and cylinders cast with a combination of 0.50% of glass fibre and 0.50% of polypropylene fibres gave a good compressive strength of 41.11 MPa and split tensile strength of 2.11 MPa which were relatively higher than the compressive and split tensile strengths of conventional concrete.

b. Compressive and Split Tensile Strengths of Hybrid Fibre Reinforced Concrete with Partial Replacement of Cement by Fly Ash

Compressive and Split Tensile strengths of Hybrid fibre reinforced concrete with varying percentages of fly ash are shown in Table 5.

Table 5 compressive and split tensile strength for replacement of fly ash in cement along with the hybrid fibre

Hybrid Fibre Percentage		Percentage of Fly Ash (%)	Compressive Strength (Mpa)	Split Tensile Strength (Mpa)
Polypropylene Fibre (P.F)	Glass Fibre (G.F)			
0.50	0.50	0	41.11	2.84
0.50	0.50	10	41.99	3.12
0.50	0.50	20	37.32	2.61
0.50	0.50	30	31.33	1.98
0.50	0.50	40	29.55	1.83



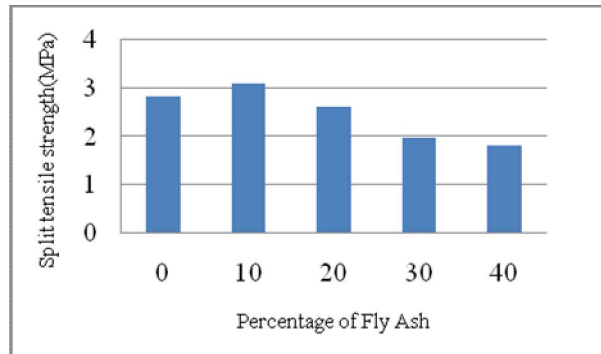
Graph 3 Average compressive strengths of hybrid fibre reinforced concrete with fly ash

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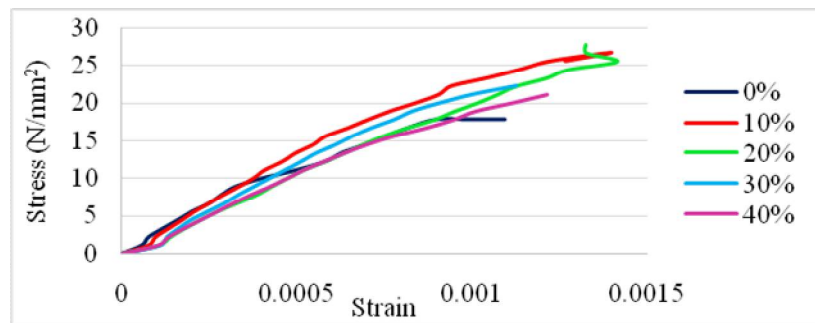
Vol. 7, Issue 5, May 2018



Graph 4 Average split tensile strength of hybrid fibre reinforced concrete with fly ash.

From the above results it was observed that cubes and cylinders cast with a combination of 0.50% of glass fibre and 0.50% of polypropylene fibres with 10 % replacement of cement by fly ash gave a compressive strength of 41.99 MPa and Split tensile strength of 3.12 MPa which were higher than the compressive and split tensile strengths of conventional concrete and hybrid fibre reinforced concrete cast with optimum dosage of hybrid fibres.

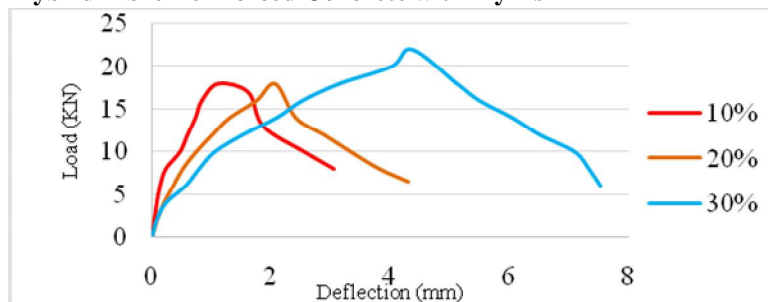
c. Stress –Strain Curves of Hybrid Fibre Reinforced Concrete with Fly Ash:



Graph 5 Stress –Strain Curves for Hybrid Fibre Reinforced Concrete with different percentages of Fly Ash

From the above graph it was observed that hybrid fibre reinforced concrete cast with 0.50% of glass and 0.50% of polypropylene fibres with 10% of fly ash resulted a maximum stress which was greater than 25 MPa within the allowable range of strain.

d. Load Vs Deflection of Hybrid Fibre Reinforced Concrete with Fly Ash



Graph 6 Load Vs deflection curves of Hybrid Fibre reinforced concrete with different percentages of Fly Ash

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 7, Issue 5, May 2018

From the above test results it was observed that hybrid fibre reinforced concrete cast with optimum dosage of fibres with 30% replacement of cement by fly ash carried an ultimate load of 22 KN compared to the beam specimens cast with the same percentage of hybrid fibres with 10% an 20% of fly ash replacement with cement.

e. Flexural Strength

Flexural strength specimens were tested under two point loading over an effective span of 500mm. The details of the test set up with loaded specimen are shown in figure 2. The test specimens were simply supported on rollers and two point loads were applied at equidistance from both the supports between them. Loading was applied through a hydraulic jack arrangement to cause downward deflection. The load was given through the jack in small increments, to measure the deflection, a dial gauge was arranged. The loading was continued till the ultimate failure of the specimens was reached.

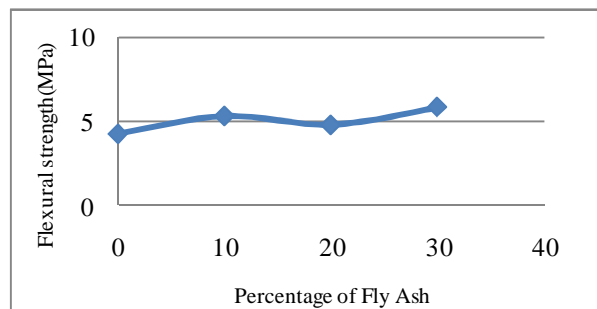
Modulus of rupture is the ultimate strength determined in a flexure test which is determined using the following equation.

$$R = PL/bd^2$$

Here, R= Modulus of Rupture, P = Ultimate Load, L= Length of specimen, b = width of specimen, d = depth of specimen.

Table 6 Flexural strength for replacement of fly ash in cement along with the hybrid fibre

Hybrid Fibre Percentage		Percentage of Fly Ash (%)	Flexural Strength (Mpa)
Polypropylene Fibre (P.F)	Glass Fibre (G.F)		
0.50	0.50	0	4.26
0.50	0.50	10	5.33
0.50	0.50	20	4.80
0.50	0.50	30	5.86



Graph 7 Average Flexural strength of Hybrid Fibre reinforced concrete.



Fig 2 Beam specimen arranged for flexure test on 100T Universal Testing Machine

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 5, May 2018

From the above test results it was observed that hybrid fibre reinforced concrete cast with optimum dosage of hybrid fibres and 30 % replacement of cement by fly ash resulted a flexural strength of 5.86 MPa which was found to be greater than the remaining specimens.

VI. CONCLUSION

- The optimum dosage of the hybrid fibres in hybrid fibre reinforced concrete achieved at 1% of fibres i.e., combination of 0.50% of polypropylene fibre and 0.50% of Glass fibre.
- The compressive and split tensile strength of the hybrid fibre reinforced concrete cast with 1% hybrid Fibres(0.50% of polypropylene fibre and 0.50% of Glass fibre) with 10 % replacement of cement by fly ash resulted a Compressive strength of 41.99 MPa and a Split tensile strength of 3.12 MPa which were higher than the compressive and split tensile strengths of conventional concrete and hybrid fibre reinforced concrete cast with optimum dosage of hybrid fibres.
- It was observed that hybrid fibre reinforced concrete cast with 0.50% of glass fibre and 0.50% of poly propylene fibres with 10% of fly ash showed a maximum stress which was greater than 25 MPa within the allowable range of strain.
- It was observed that hybrid fibre reinforced concrete cast with 1% hybrid Fibres(0.50% of polypropylene fibre and 0.50% of Glass fibre) with 30 % replacement of cement by fly ash resulted a maximum flexural strength of 5.86 MPa.
- Hence hybrid fibre reinforced concrete (0.50% of polypropylene fibre and 0.50% of Glass fibre) with usage of fly ash upto 30% as partial replacement of cement not only improves the mechanical properties of concrete but also protects the environment from the hazards of fly ash.

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