Available online at www.elixirpublishers.com (Elixir International Journal)

Cement and Concrete Composites

Elixir Cement & Con. Com. 41 (2011) 6005-6008

ISSN: 2229-712X

Performance of concrete beams under shear and torsion with fly ash and steel fibers

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ARTICLE INFO

Article history:

Received: 9 September 2011;

Received in revised form:

15 December 2011;

Accepted: 28 December 2011;

Keywords

Bond strength,

By-products,

Spalling.

ABSTRACT

Tensile stresses on concrete leading to the formation of cracks which further leads to the spalling of concrete. To overcome this shortcoming, due to its high tensile strength, ductility, ability to arrest propagation of cracks, improved bond strength, etc. This paper investigates the different strengths of Steel Fiber Reinforced Concrete (SFRC) using Fly ash as cement replacement. Silica fume and fly ash are the by-products and so has the uncontrolled engineering properties which sometimes don't give the required results. The objective of this paper is to study the behavior of fly ash concrete with steel fibers under shear and torsion.

Introduction

As we know, brittle failure is the inherent property of the plain concrete, i.e. it has very low tensile strength and low strain capacity at fractures. These shortcomings of plain concrete are overcome by adding reinforcing bars or prestressing steel. The main drawback of the reinforcing steel is corrosion due to the ingress of chloride ions in the concrete. This problem becomes severe in coastal areas. Corrosion of steel bars forms rust with time. This rust is bigger in volume than iron which results in expansion. This expansion exerts large tensile stresses on concrete leading to the formation of cracks and thus propagation of these cracks leads to the spalling of concrete. To overcome this shortcoming, fibers are incorporated in cement concrete. There are different types of fibers available but here steel fibers are used because of their high tensile strength, ductility, ability to arrest propagation of cracks, improved bond strength, etc.

Extensive research has been done on Steel Fiber Reinforced Concrete (SFRC) using fly ash and silica fume as cement replacement but very little research has been conducted on SFRC using Fly ash. The present experimental work is mainly done to investigate the different strengths of SFRC using Fly ash as cement replacement. Silica fume and fly ash are the by-products and so has the uncontrolled engineering properties which sometimes don't give the required results. Instead, Fly ash is the manufactured product, produced by calsining fly ash at a temperature of 700^0c – 800^0c. Thus its controlled engineering properties yield good results regarding workability and durability of concrete. Silica fume or fly ash when blended with cement darkens the colour of concrete but Fly ash being white in colour doesn't alter the colour of concrete, thus enhancing aesthetic look.

The objectives of this paper is to study the behavior of fly ash concrete with steel fibers under shear and torsion.

Methodology

The properties of ingredient material are checked. ACC 43 grade conforming to IS 12269 – 1987 is used. Natural river sand conforms to zone II as a fine aggregate and locally available crushed stone with size 5 mm to 12.5 mm as a coarse aggregate are used. The dose of fly ash conforms to IS 3812:1981, is 15% and that of silica fume is 6 %. The cement is replaced by the fly ash hence the water cement ratio is varies from 3 % to 4 %. The water binder ratio is kept constant as 0.3. The reduction in water cement ratio is possible due to addition of super plasticizer. Sodium Sulphonate based EB – 821/R conforms to the BS 5075 and ASTM C 494 Type A and F, is used. The dose of super plasticizer is 8% of volume of cement.

Dramix steel fibers conforming to ASTM A 820 type-I are used for experimental work. Dramix RC - 80/60 - BN are high tensile steel cold drawn wire with hooked ends, glued in bundles & specially engineered for use in concrete. The dose of steel fiber is varying from 0.0 % to 5.0% of volume of cement at the interval of 0.5 %.

Total 66 beams are tested for shear and torsion, out of this 33 casted with longitudinal reinforcement, with 4 no. of bars of 8 mm diameter, 2 at top and 2 at bottom and 33 without reinforcement. The size of each beam is 1000 mm x 100 mm x 100 mm. The proportioning of concrete is maintained constant throughout the investigation. A concrete mix targeting a compressive strength of 30 MPa is used.

The cured beams are white washed before testing to facilitate the crack identification. One end of the beam is supported on rollers, while the other end is supported on rigid support. This type of test setup facilitates free rotation of roller end and provides stability to the test specimen during testing. Specially made twist arms or twist angles are placed at both supports of the beam having an arm length of 0.60 m. Load on the twist arm is applied through a Hydraulic jack and the loading is monitored through a proving ring attached to the jack. Absolute care has taken, such that, the plane of loading and twisting arm are perpendicular to the longitudinal axis of the beam. This avoids any possibility of bending of the beam instead of twisting and as a result the beam between the two supports is subjected to pure torsion. The complete test setup is schematically presented in fig. 1 Shows the actual test set up. Load is applied at an eccentricity of 0.66 m from the center of the beam.

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For every applied load, the corresponding dial gauge readings are noted, which were placed al L/3 distance from both end and considering average of two readings.

Fig. 1 Typical setup for Shear and Torsion Test

Observations and Calculations Shear Strength:

Shear Failure Load (Vu):-

Where,

δp = deflection load in Kg

Jp = Weight of jack in Kg

$\delta p = \delta$ * Factor

[Factor :- 10 div = 73.69 Kg]

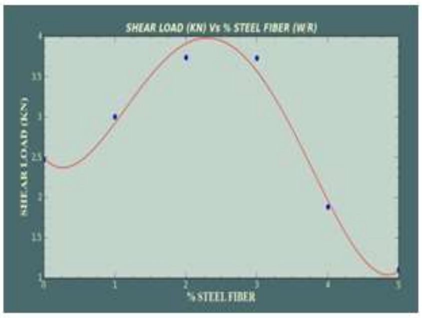

Fig. 2 Shear Load (kN) Vs % Steel Fiber (W/R)

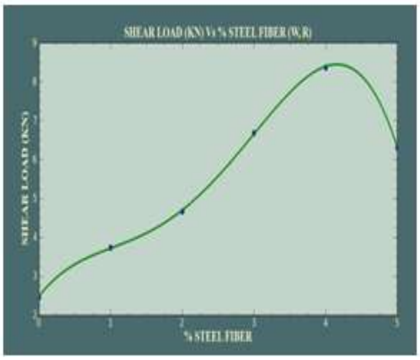

Fig. 3 Shear Load (kN) Vs % Steel Fiber (W.R)

The shear strength of SFRC beam increases with increase in content of steel fibers. There is increase in the strength up to certain percentage of steel fibers after that there is reduction in the strength. For 2.18 % of steel fibers the beam giving highest strength of 3.97 kN for without reinforced and for 4.07 % of steel fiber gives the highest strength of 8.46 kN It shows that even the percentage of steel fiber is more in case of reinforced beam but the shear resistance capacity is nearly twice of the plain concrete beam. Average increasing in strength for without reinforcement and with reinforcement is 62% and 160%.

Experimental Moment

Experimental Moment (M):-

Where,

Vu = Shear failure load in kN

l = lever arm in mm

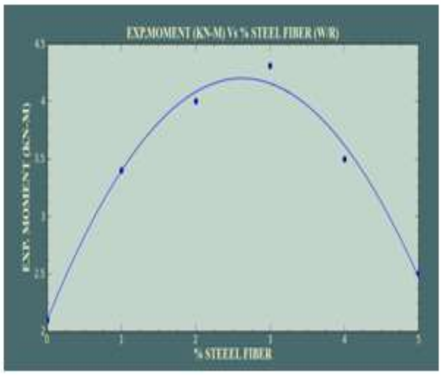

Fig. 4 Experimental Moment (kN-m) Vs % Steel Fiber (W/R)

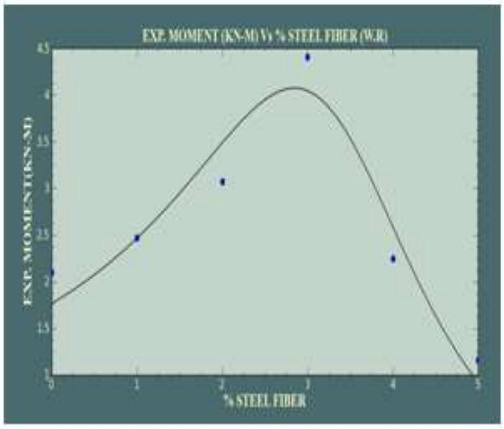

Fig. 5 Experimental Moment (kN-m) Vs % Steel Fiber (W.R)

The moment of SFRC beam increases between 4 to 5 % of steel fibers. The higher moment is due to reason that the steel fibers resisting the load. From the observations and graphs it is concluded that the steel fiber volume of 4.08 % and 4.20% of steel fiber giving maximum moment 2.59 kN-m and 2.91 kN-m. Average increasing in moment for without reinforcement and with reinforcement is 84% and 94%.

Torsional Moment

$$T = \frac{G\,\theta}{L} \times J$$

Where,

G = Modular Rigidity in N/mm^2

J = Polar Moment of Inertia in mm^4

L = Length of Specimen in mm

θ = Angle of twist in radian

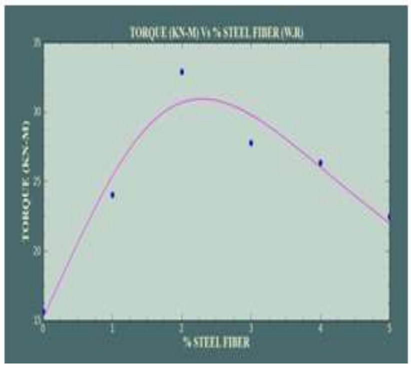

Fig. 6 Torque (kN-m) Vs % Steel Fiber (W/R)

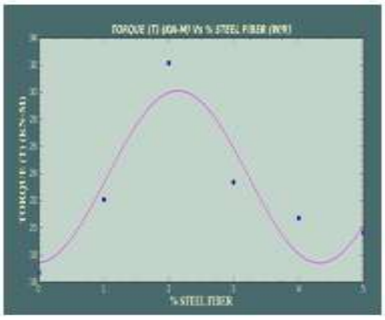

Fig. 7 Torque (kN-m) Vs % Steel Fiber (W.R)

The results showing gradual increase in torsional strength up to certain percentage of addition of steel fibers. After that there is decrease in the strength. The observation shows that addition 2.21% and 2.07 % of steel fibers gives maximum torsional strength of 31.02 kN-m and 30.16 kN-m for with and without reinforcement.

Percentage of fibers for both experimental moment (flexural moment) and torsional moment with and without reinforcement is nearly same because the reinforcement is longitudinal and it is having very less contribution to resist the rotation.

Average increasing in moment for without reinforcement and with reinforcement is 52.09% and 53.58%.

Conclusions

The wet and dry density at 7 and 28 days has increased marginally for fly ash concrete over normal PCC. This may be due to partial cement replacement by fly ash, which densifies the concrete because of its micro filler effect due to the relatively finer particle size.

The mechanical properties of concrete are enhanced with the addition of fly ash. All the properties of concrete like compressive strength, split tensile strength and flexural strength is increased. Also there is reduction in porosity as well as reduction in absorption capacity of the concrete as compared with normal concrete.

In general, the significant improvement in various strengths is observed with the inclusion of Hooked end steel fibres in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fibre content. The optimum fibre content to impart maximum gain in various strengths varies with type of the strengths.

Satisfactory workability is maintained with addition of fly ash and silica fume by using superplasticizers.

With increasing fiber content, mode of failure is changed from brittle to ductile failure when subjected to compression and bending.

The strength models developed for SFRC predicts the results of various strengths which are in good compliance with experimental results.

The properties like shear, torsion and bending is also improved due to addition of fibers in the concrete. This is obvious because the addition of fibers resists the development of internal micro crack in the concrete, which are responsible for the failure of the structure.

The optimum dose fiber for shear is 2.18 % and 4.07 % for with and without reinforcement respectively.

For torsional moment 2.21 % and 2.07 % volume fibers gives optimum strength. It concludes that the longitudinal reinforcement in the beams having less resistance in shear, torsion and moment.

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Table I

% of Steel Fiber	Average Shear Load in (kN) for	
	Without reinforcement	With reinforcement
0.0	2.47	2.47
0.5	2.43	2.50
1.0	3.00	3.73
1.5	3.57	3.78
2.0	3.74	4.66
2.5	3.73	5.48
3.0	3.73	6.68
3.5	2.59	7.35
4.0	1.58	8.37
4.5	1.38	5.70
5.0	1.10	6.31

Table II

% of Steel Fiber	Average Moment in (kN-m) for	
	Without reinforcement	With reinforcement
0.0	1.95	2.95
0.5	2.36	2.60
1.0	2.40	2.47
1.5	2.65	2.34
2.0	3.00	3.14
2.5	4.15	3.50
3.0	4.31	4.41
3.5	3.46	3.13
4.0	3.50	2.25
4.5	2.09	2.16
5.0	2.50	1.16

Table III

% of Steel Fiber	Average Torque in (kN-m) for	
	Without reinforcement	With reinforcement
0.0	16.69	15.64
0.5	20.22	16.77
1.0	22.10	24.82
1.5	25.60	26.98
2.0	32.16	32.83
2.5	28.69	31.69
3.0	23.53	27.87
3.5	20.46	25.13
4.0	20.73	26.41
4.5	19.70	24.49
5.0	19.65	20.59