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Study Of High Strength Fibre Reinforced Concrete Beams With Fibre Reinforced Polymer Frp Laminates

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Abstract - *Concrete is by far the most widely-used man made construction material and studies indicate that it will continue to be so in the years to come. Such a versatility of concrete is due to the fact that with the common ingredients, namely, cement, aggregate and water (and sometimes admixtures) it is possible to tailor the properties of concrete so as to meet the demands of any particular situation. The advances in concrete technology have paved way to make the best use of locally available materials by a judicious mix proportioning and proper workmanship, so as to result in a concrete satisfying the performance requirements. A worldwide use of high strength concrete during the last decade and an expansion in the material technology has made it possible to design concrete having superior mechanical properties and structural behavior. Whilst use of high strength concrete has accelerated, the progress in development of revised design standards have not progressed at the same rate. Acceleration is due to its enhanced mechanical properties and better structural performance as compared to Normal Strength Concrete. Also High Strength Concrete offers economy and superior performance in terms of strength and long-term behavior.*

In addition to probing the basic properties of concrete, the present research investigation addresses three major concerns. The first is to explore the possibility of using FRP for improving the performance of steel fibre reinforced high strength concrete beams. The second is to examine the enhancement in flexural capacity of steel fibre reinforced high strength concrete beams. The third is to evaluate the ductility of the steel fibre reinforced high strength concrete beams subjected to loading.

Key Words: *High Strength Concrete, loading, steel fibre reinforced high strength concrete*

1. LITERATURE REVIEW

Christos Papakonstantinou, Michael Petrou and Kent Harries studied the fatigue behavior of RC beams strengthened with GFRP sheets. Seventeen beams of 152 x 152 x 1321 mm were used in this study. Two non-strengthened beams and one strengthened beam were tested under monotonic loading. Fourteen beams were tested under cycling load at different load ranges. Six were non-strengthened and eight were strengthened with GFRP sheets. The maximum load in each case was chosen based on the percentage of the maximum stress in steel reinforcement as determined from the static tests and verified by strain measurements. The minimum load depended on frequency of loading and was selected to ensure stability of the test setup. The findings of the study showed that the fatigue life of strengthened beams was increased as compared with the nonstrengthened beams for the same applied load.

Heffernan and Erkiinvestigated the fatigue behavior of reinforced concrete beams strengthened with carbon fibre reinforced plastic laminates. Twenty 3 m and six 5 m beams were loaded monotonically and ally in this study. The beams were of size 150 x 300 mm. Two beams, without and with CFRP strengthening were loaded monotonically to failure at a rate of 1 mm/min stroke rate. The remaining beams were loaded ally to failure. These beams were loaded by applying a sinusoidal loading pattern at a rate of 3 Hz. Three ranges of stress were applied, low stress 84.1 kN, medium stress 98.00 kN and high stress 112.00 kN. The authors concluded that beams strengthened with CFRP sheets exhibit enhanced fatigue life at all stress levels.

John Aidoo, Kent A. Harries and Michael F. Petrou investigated the fatigue behavior of carbon fibre reinforced polymer strengthened reinforced concrete bridge girders. Eight reinforced concrete T-beams 6,100 mm long, 508 mm deep, having a 102 mm thick by 559 mm wide flange and 209 mm wide stem, with and without bonded FRP reinforcement on their tensile surfaces, were tested with a concentrated load at mid-span under constant amplitude loading. Four beams were retrofitted with CFRP materials on the soffit of the T-beam stem, 2 beams were provided with strip retrofit system and 2 beams were provided with fabric retrofit system. Two different CFRP systems were used. The remaining beams were used as control specimens. One control specimen was tested under monotonic loading and the remaining specimens were tested under condition. 3 beams were tested under low stress level with a control specimen yield load of 63% and 3 beams were tested under high stress level with a control specimen yield load of 80%. The fatigue life of reinforced concrete beams can be increased by the application of an FRP retrofit, which relieves some of the stress carried by steel. The authors concluded that the FRP retrofitted beam was stiffer when compared to control beam. For this reason, carbon FRP is preferred. It is observed, nevertheless, that stiff retrofit measures result in higher FRP-to-concrete bond stress.

Houssam Toutanji, Liangying Zhao, Yong Deng, Yue Zhang and Balaguru carried out a study on behavior of RC beams strengthened with carbon fibre sheets bonded by inorganic matrix. 17 RC beams were cast and tested. Four beams were tested under 50% of loading, three beams were tested under 60 % of loading, two beams were tested under 70% of loading and four beams were tested under 80% of loading. The relationship between fatigue strength, crack width and number of cycles was studied and analyzed. The authors concluded that both the load capacity and number of cycles of the RC beams were significantly increased with carbon fibre sheets. The fatigue strength increased by as much as 55% as compared to the control beams.

Rania AI-Hammoud investigated the flexural behaviour of corroded steel reinforced concrete beams under repeated loading. This investigation was carried out on thirty beams of size 152x254x2000mm repaired with carbon fibre reinforced polymer (CFRP) sheets. The authors reported that repairing with CFRP sheets increased the fatigue capacity of beams with corroded steel reinforcement beyond that of the unrepaired beams with un-corroded steel reinforcement.

Rania AI-Hammoud investigated the flexural behaviour of thirty numbers of beams (152x254x2000mm) with corroded steel reinforcement and repaired with CFRP sheets under repeated loading. The author concluded that, repairing with two layer of flexural CFRP sheet at a high corrosion level increased the flexural fatigue capacity of corroded beams by 42% at 50000 cycles and 17% at 750000 cycles compared to the corroded beams. Further they found that there was no difference in strength between repairing the beams with a single layer and a double layer of CFRP sheet. When severely cracked beams were repaired with FRP, their life was extended by about 10 times, suggesting that beams in service could be effectively rehabilitated using FRP. Highmodulus FRP sheets have excellent tensile and fatigue strength properties but little global ductility.

2. AIM & OBJECTIVES OF THE STUDY

Aim of present work in to explore the possibility of using FRP for improving the performance of steel fibre reinforced high strength concrete beams and also to examine the enhancement in flexural capacity of steel fibre reinforced high strength concrete beams.

2.1 Objectives of Research Work

The proposed project is intended to achieve the following objectives:

• To assess the enhancement in mechanical strength of high performance concrete beams with micro-reinforcement.

• To examine the effect of FRP strengthening on the deformation characteristics of high strength fibre reinforced concrete beams.

• To study the effect on ductility of high strength steel fibre reinforced concrete beams strengthened with FRP subjected to loading.

3. METHODOLOGY

A preliminary study was conducted to identify the optimum fibre volume fraction. For this study, 36 cubes, 36 cylinders and 36 prisms were cast and tested. The variables considered for the study was the steel fibre volume fraction (0.5%, 1.0% and 1.5% to total volume of concrete).

3.1 Details of Test Specimens

150 x 150 x 150 mm cubes were used for determining the compressive strength of steel fibre reinforced concrete. 150 x 300 mm cylinders were used for determining the static modulus of elasticity. 100 x 100 x 500 mm prisms were used to determine the modulus of rupture. The details of control specimens are presented in Table shows the preparation sequence of test specimens.

Table-1: Details of control specimens

Specimen Designation	Fibre Volume Fraction, V_f(%)
CB	0
SF 0.5%	0.5%
SF 1%	1.0%
SF 1.5%	1.5%

Figure-1: for Casting, Mixing of SFRC, Placing of Concrete, Cast Specimens

4. Materials:

Ordinary Portland cement 53 Grade was used for all mixes. Fine aggregate used was river sand with a specific gravity of 2.64 and conforming to grading zone II of IS 383- 1970 specification. Silica fume with a specific gravity of 2.2 was used as a micro-filler. The coarse aggregate used was crushed granite with a specific gravity of 2.79 and passing through 20mm sieve and retained on 12.5mm. To ensure better workability, a hyper plasticizer (BASF Master Gelinium SKY 8233 Chemicals) was used. Steel fibres having an aspect ratio 80 were used in the study. Concrete having a compressive strength of 66.1MPa was used. The designed mix proportion was 1:0.05:1.73:2.51 with water cement ratio of 0.36. For concrete with fibres, hyperplastizer was used in appropriate dosage to maintain a slump of about 100 mm. The mix details are presented in Table.

Table-2 The mix details

Cement	Silica Fume	Fine Aggregate
450 kg/m^3	25 kg/m^3	780 kg/m^3

Coarse Aggregate	Water
20 mm - 680 kg/m^3 12 mm - 450 kg/m^3	160 lit/m^3

Steel fibres used in this investigation were Dramix steel fibres (ZC 60/0.75) supplied by Bekaert Fibre Technologies, Belgium. The steel fibres were with hooked ends. Their physical and mechanical properties of fibres are presented in Table.

Table-3 Details of Fibre

Sl. No.	Fibre properties	Fibre Details
		Steel
1	Length (mm)	60
2	Size/Diameter (mm)	0.75 mm dia
3	Aspect Ratio	80
4	Density (kg m-3)	7850
5	Specific Gravity	-
6	Young's Modulus (GPa)	210
7	Tensile strength (MPa)	1225
8	Shape	Hooked at ends

4.1 Preparation of Control Specimens

A tilting type drum mixer was used for mixing fresh concrete. The cement, sand and coarse aggregate were placed inside the drum and then dry mixed. To this dry mixture, 80% of water and 0.80% of hyperplastizer (BASF Master Gelinium SKY 8233 44 Chemicals) were added slowly and mixed thoroughly. Fibres were then added slowly and evenly along the walls of the drum to avoid formation of fibre balls and clustering. The remaining water and hyperplastizer were added slowly and then mixed thoroughly. The specimens were cast in batches, each batch consisting of three prisms, three cylinders and three cubes. The specimens were cast in steel moulds and vibrated using a vibrating table. All the specimens were de-moulded after 24 hours of casting and then cured for 28-days before being tested.

4.2 Testing Procedure

Cubes and cylinders were tested in a standard manner in a 2000 kN capacity compression testing machine. The cylinder was provided with appropriate instrumentation to determine the elasticity modulus experimentally. The prisms were tested over a simply supported span of 400 mm under four point-bending in a loading frame. The deflections were measured at the mid-span using a dial gauge of 0.01 mm accuracy. The above tests were conducted as per IS:516(1959). The measurements were taken at different load levels until failure.

4.3 Experimental Plan

A total of 15 rectangular reinforced concrete beams were cast for the present research work. The beams were 150 mm x 250 mm in cross-section and 3000 mm long. The beams were tested in four-point bending over a simple span of 2800 mm. Longitudinal steel ratio adopted for the beam specimens was 0.67%. 2 numbers of 12mm diameter bars were used for tension reinforcement and 2 numbers of 10 mm diameter bars were used as hanger bars. 2-legged 8 mm diameter stirrups were provided at 125 mm c/c, in order to avoid any shear failure. The detailing of internal reinforcement is shown in Fig.. Of the above fifteen beams, 1 beam served as baseline specimen, 2 beams were cast with 1% fibre volume fraction, 12 beams were cast with a fibre volume fraction of 1% and strengthened with GFRP laminate in a virgin condition. The variables considered for the study included type of GFRP laminate and thickness of GFRP laminates. The specimens were tested under four point bending. 8 beams were tested under monotonically increasing loading and manual readings were recorded directly into a spreadsheet program and 7 beams were tested. The specimens were tested under twopoint loading system. Sufficient data was obtained on the strength, deformation, fatigue life and failure characteristics of steel fibre reinforced high strength concrete beams with GFRP laminates as well as steel fibre reinforced high strength concrete beams.

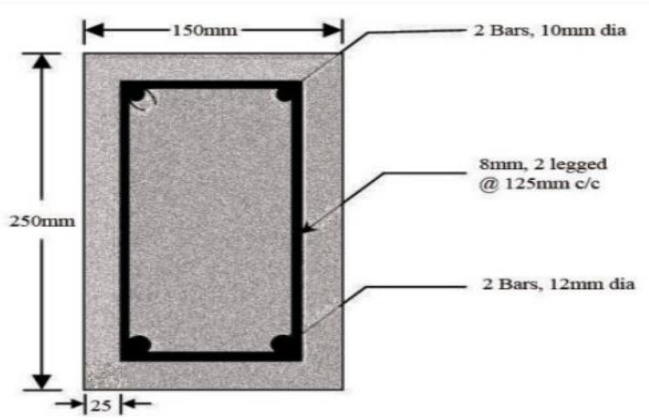

Figure-1: Reinforcement details of beam

Details of the fifteen specimens prepared for the experimental work are presented in Table 3.4. The beams with 1% fibre volume fraction were provided with three different GFRP laminates having two different thicknesses 3 mm and 5 mm. The GFRP laminates also varied in their configuration, viz., Chopped Strand Mat (CSM), Woven roving (WR) and Uni-Directional Cloth (UDC).

4.4 Material Properties

The concrete used for the beam specimens had a compressive strength of 66.1MPa. The tension reinforcement consisted of high yield strength deformed bars of characteristic strength 456MPa. The internal links consisted of high yield strength deformed bars of characteristic strength 426MPa. Three types of GFRP laminates were used for the study, namely, Chopped Strand Mat (CSM), Woven Roving (WR) and Unidirectional Cloth (UDC) of 3mm thickness. The properties of GFRP are presented in Table.

4.5 Glass Fibre Reinforced Polymer

Glass fibre reinforced polymer laminates having the following configurations were used for the investigation. i. Chopped Strand Mat (CSM) ii. Woven Roving (WR) iii. Uni-Directional Cloth (UDC) The glass fibre reinforced polymer laminates were applied on the soffit of the beam specimens using epoxy adhesive.

Table-4 Various configurations of GFRP

Beam Designation	Fibre Volume Fraction (%)	Steel Ratio	GFRP Laminate type	GFRP Thickness (mm)	Composite Ratio
CB	-	0.67	-	-	-
SF	1.0	0.67	-	-	-
SFC3	1.0	0.67	CSM	3	1.989
SFW3	1.0	0.67	WR	3	1.989
SFU3	1.0	0.67	UDC	3	1.989

5. TEST RESULTS AND DISCUSSION

The significant influence of adding fibres in concrete is to delay and control the initiation and propagation of tensile cracking of the composite material. The strengthening mechanism of fibres involves transfer of stress from concrete to the fibre by interfacial shear or by interlocking between the fibre and matrix. The fibre and the matrix share the tensile stress until the matrix cracks and then the stress is transferred to the fibres. This change in the mechanism of failure causes significant improvement in ductility, toughness, impact resistance, shrinkage, fatigue life and durability of composite matrix. A total of 36 cubes, 36 cylinders and 36 prisms were cast and tested in this investigation to study the mechanical properties of steel fibre reinforced high strength concrete specimens.

5.1 Effect on Compressive Strength

From the test results it can be observed that the steel fibre reinforced high strength concrete exhibits an increase in compressive strength with 1% fibre volume fraction. The compressive strength of steel fibre reinforced high strength concrete showed increased compressive strength ranged from 5.45% to 12.87% at volume fraction ranging over 0.5% to 1.5% compared to control concrete at the age of 28 days. From the obtained results, it can be inferred that 1% fibre volume fraction gives optimum results.

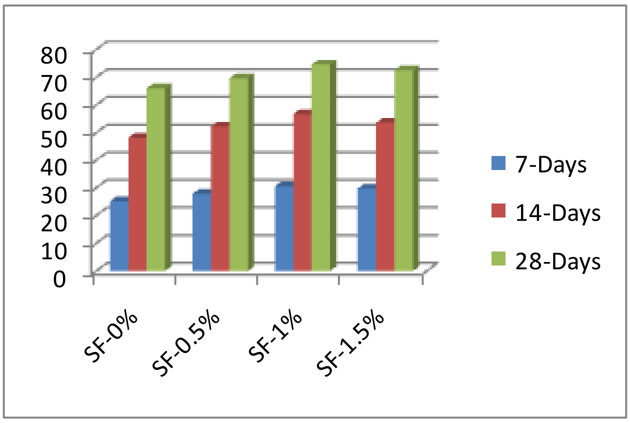

Figure-2: Comparison of compressive strength values for 7, 14and 28 days

5.2 Effect on Modulus of Elasticity

There was significant improvement in modulus of elasticity of high strength concrete by the incorporation of fibres. The modulus of elasticity of steel fibre reinforced high strength concrete showed increased modulus of elasticity ranged from 2.03% to 6.03%.

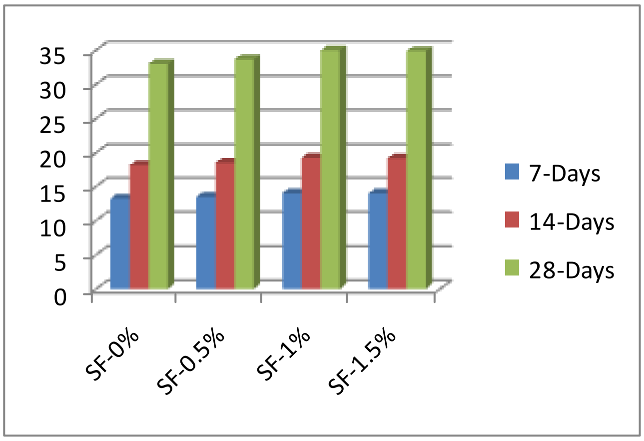

Figure-3- Effect of modulus of elasticity for different time period

5.3 Effect on Modulus of Rupture

The results indicate that modulus of rupture for fibrous concrete was significantly higher than that of control concrete even at volume fraction as low as 0.5%. The improvement in flexural strength of steel fibre reinforced high strength concrete at various fibre volume fractions. The improvement in flexural strength varied from 39.76 % to 81.56 % at fibre volume fraction ranging over 0.5 % to 1.5% compared to control concrete at the age of 28 day.

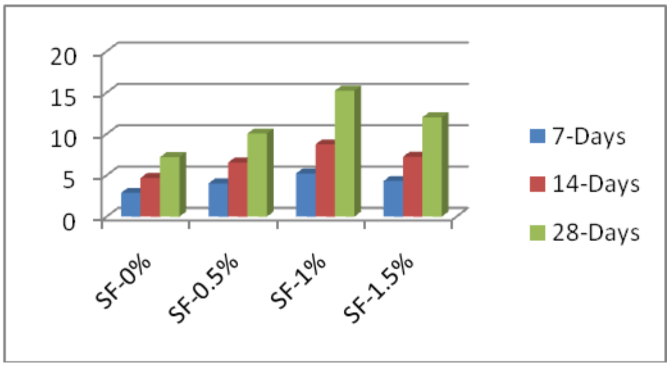

Figure-4: Effect on modulus of rupture for different days

5.4 Test Beams under Static Loading:

The results of experimental investigation carried out on eight beams which include the control beam (CB), steel fibre reinforced high strength concrete beams (SF) and GFRP strengthened steel fibre reinforced high strength concrete beams.

Table-5 Experimental Investigation

Specimen-Designation	First-Crack-Load-(kN)	Deflection-at-First-Crack-Load-(mm)
CB	50	3.2
SF	65	3.4
SFC3	70	3.6
SFW3	70	3.7
SFU3	95	4.2

6. CONCLUSIONS

The epoxy bonding of GFRP laminates offers an attractive means of strengthening SFRC beams in flexure. Based on the results obtained from laboratory experiments, the following conclusions are drawn.

1. An overall evaluation of the flexural test results and load-deflection indicate that steel fibre reinforced high strength reinforced concrete beams strengthened with UDCGFRP laminates exhibit higher load carrying capacity and ductility.

2. The steel fibre reinforced high strength reinforced concrete beams strengthened with 3mm UDCGFRP laminate exhibit an increase of ultimate load when compared with the steel fibre reinforced high strength reinforced concrete beam.

3. The steel fibre reinforced high strength reinforced concrete beams strengthened with 3mmUDCGFRP laminate exhibit a decrease of in deflection at ultimate load when compared with the steel fibre reinforced high strength reinforced concrete beam.

4. Flexural cracks were observed in all the beam specimens. The observed cracks were mostly in constant moment region. The reduction in crack width and number of cracks was found to be 75% and 77.78% at ultimate load level for steel fibre reinforced high strength reinforced concrete beams strengthened with 3mmUDCGFRP laminate. The average spacing of cracks decreased to 51.12% at ultimate load level for steel fibre reinforced high strength reinforced concrete beams strengthened with 3mmUDCGFRP laminate.

REFERENCES

1. ACI Committee 544.1R-96(Reapproved)(2002), State of the Art of Report on Fibre Reinforced Concrete-Reported by ACI Committee 544.

2. ACI Committee 544.4R (1988) (Reapproved 2002), Design Considerations for Steel Fiber Reinforced Concrete, ACI Structural Journal, 85(5), 563-58.

3. Alagusundaramoorthy, P., Harik, I. E., & Choo, C. C. (2003), Flexural Behavior of R/C Beams Strengthened with Carbon

Fiber Reinforced Polymer Sheets or Fabric, Journal of Composites for Construction, 7(4), 292-301.

4. Antonio F. Barbosa and Gabriel O. Ribeiro (1998), Analysis of Reinforced Concrete Structures using ANSYS Nonlinear Concrete Model, Computational Mechanics, 13(2), 1-7.

5. Aoude, H., Belghiti, M., Cook, W. D., & Mitchell, D. (2012), Response of Steel FiberReinforced Concrete Beams with and without Stirrups, ACI Structural Journal, 109(3), 359-368.

6. Balaguru, P. N., & Shah, S. P. (1992), Fiber-Reinforced Cement Composites, McGraw Hill, In., New York.

7. Bentur, A., & Mindess, S. (1983), Concrete Beams Reinforced with Conventional Steel Bars and Steel Fibres: Properties in Static Loading, International Journal of Cement Composites and Lightweight Concrete, 5(3), 199-202.

BIOGRAPHIES

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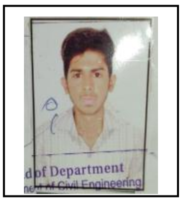

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