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Technical Note

A STUDY OF CONFINED STEEL FIBER REINFORCED CONCRETE IN THE PLASTIC HINGING REGIONS OF RC BEAMS

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Abstract

The structures subjected to earthquake, nuclear blast forces etc., demand more ductility to absorb strain energy. The limited ductility of concrete also affects the performance of structure under static loads. Almost all codes of practice around the world stipulate only the ductile failure of structural components, which is the major drawback of the over reinforced concrete beams. It is well known that the confinement of concrete increases the compressive strength and ductility, the latter to a larger degree. Such concrete is called ductile concrete. The limitations on the spacing of stirrups will restrict the improvement in the ductility of concrete confined by the stirrups. The use of Steel Fiber Reinforced Concrete along with the stirrup confinement in the possible plastic hinging regions may enhance the overall ductility of concrete structures. Such engineered application of SFRC may be termed as Engineered Steel Fiber Reinforced Concrete (ESFRC).

This paper presents an experimental investigation to study the behaviour of ESFRC by varying the volume percentage content of steel fiber. Four rectangular reinforced concrete beams, with the steel fiber reinforced concrete in critical sections along with the stirrup confinement, have been tested. The findings of the investigation indicate that up to about 80 percent of ultimate strength, the behaviour of ESFRC beams was similar to that of beams with rectangular tie confinement. The effect of the steel fiber was felt prominently beyond the post ultimate stage. The ductility is increased due to increase in percentage of fiber content.

Keywords: Steel fiber reinforced concrete(SFRC); confinement; plastic hing

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1. Introduction

Ensuring sufficient ductility in structures is one of the prime objectives in the design philosophy of reinforced concrete. The provision of ductility gives sufficient warning before failure. To fulfil the requirements of ductility several methods such as provision of reinforcement, confinement by stirrups were in use. However, the confinement provided by stirrups is limited due to the spacing limits. Also it is established in the literature [1,2], that the stirrup reinforcement provided beyond what is required for resisting the shear failure will only provide confinement. Hence with the practical minimum spacing that can be provided at the critical sections, there is a limitation to the quantity of confinement, which can be provided by the stirrups. Thus it may not be possible to sufficiently confine the structure and thereby achieving required ductility by providing the laterals alone. Steel Fiber Reinforced Concrete is defined as a concrete made of hydraulic cements containing fine and coarse aggregates and discontinuous discrete steel fibers.

Hence it is proposed to incorporate discontinuous and discrete steel fibers in addition to the confinement of concrete by lateral ties / stirrups, only at the critical sections such as possible hinging regions, to improve the ductility of reinforced concrete sections. The concrete in which only the critical sections are strengthened with the engineered use of steel fibers can be termed as Engineered Steel Fiber Reinforced Concrete (ESFRC). The SFRC [3] can be advantageously be used to impart ductility to cement concrete composites.

The present investigation is carried out to study the behaviour of simply supported reinforced concrete beams wherein the ESFRC is used in the critical section (the maximum moment section). Purposefully the beams were made over reinforced (by providing higher percentage of steel than that required for making the section balanced) and the effect of ESFRC on the behaviour of such beams was studied. This is because of the fact that the over reinforced sections are normally less ductile.

2. Experimental Programme

An experimental investigation was conducted by casting and testing four simply supported rectangular beams with ESFRC in the hinging regions, in flexure. The parameter varied in this investigation was the volume percentage content of steel fiber. The beams were of 120mm wide, 200mm deep and 2.1m long with 1.7m as span. The volume percentage content of fiber was taken as 0,0.5, 1.0 and 1.5. The aspect ratio of fiber was taken as 50.

2.1. Materials

The G.I. wire of 0.58mm diameter was used. The cement used was OPC of 43 grade confirming to IS 8112-1981. Machine crushed hard granite chips passing 12.5 mm sieve and retained on 4.75mm sieve was used as coarse aggregate. River sand procured locally available was used as fine aggregate. The steel used for longitudinal reinforcement was HYSD bars of Fe415 grade. All beams were reinforced with 2 no. of 16mm ϕ longitudinal bars and two legged 6mm ϕ stirrups at 80 mm center to center. The mix was 1:2.6:4 with 0.6 water cement ratio. The tension reinforcement provided in the beam makes the beam to behave as over reinforced one. The

maximum moment section (considered as critical section) of the beam was strengthened by placing ESFRC of varying fiber content.

2.2. Casting of Beams

Steel channels of 200mm height were placed back to back and were tightened by nuts and bolts to maintain the width of beam as 120mm. The inner side of the moulds was lubricated by grease and cover blocks of proper thickness were placed to maintain the effective depth of the beam as 175mm.

The reinforcement cage was placed on the cover blocks in the moulds. The required amount of steel fiber was mixed with aggregate and cement in dry state on the plat form and then water is added.

The steel fiber reinforced concrete was placed in the flexure zone and the remaining portion was filled with the concrete without fibers and compacted with vibrator.

2.3. Testing of Beams

The beams were tested under two point loading after a curing period of 28 days, on the TINIUS – OLSEN testing machine of 200 kN capacity. Specially fabricated curvature meters were used to measure curvatures in the central zone of 600mm of the beam. The details of test setup were shown in Figure 1. Strain rate control of loading was achieved by adjusting carefully the inlet valve of the testing machine so that the movement of cross head was controlled. The testing was continued till the load had fallen to 85 percent of ultimate load or the test set up became unstable which ever is earlier.

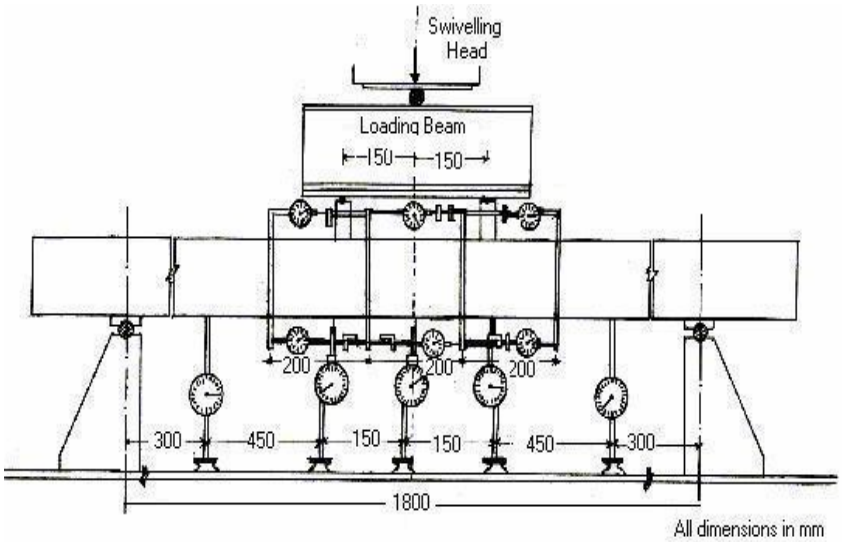

Figure 1. Test Setup

3. Results and Discussion

From the recorded readings, the moments and curvatures were calculated. By normalizing these values, moment curvature diagrams were plotted and shown in fig(2). The results of the investigation indicated that up to 80 – 85% of ultimate strength, beams with ESFRC behave exactly similar to the beams with rectangular tie confinement alone. The increase in moment carrying capacity with the use of ESFRC was considerable. The effect of fibers is significant in the post ultimate stage, which increased the ductility of beams, as represented by the area under normalized M – Ø diagrams shown in Figure 2. Even though the beams are over reinforced the ductility increased to a large extent due to increase in volume percentage content of fiber. The decrease in crack widths, spacing of cracks and increase in number of cracks was noticed with the increase in volume percentage content of steel fiber. The presence of ESFRC in reinforced concrete beams developed a near horizontal plateau of moment – curvature diagrams. Also it was found that the limit state of serviceability of an ESFRC beams in terms of limiting value of deflection was as good as that of corresponding confined reinforced concrete section. The tested beams were shown in Figure 3.

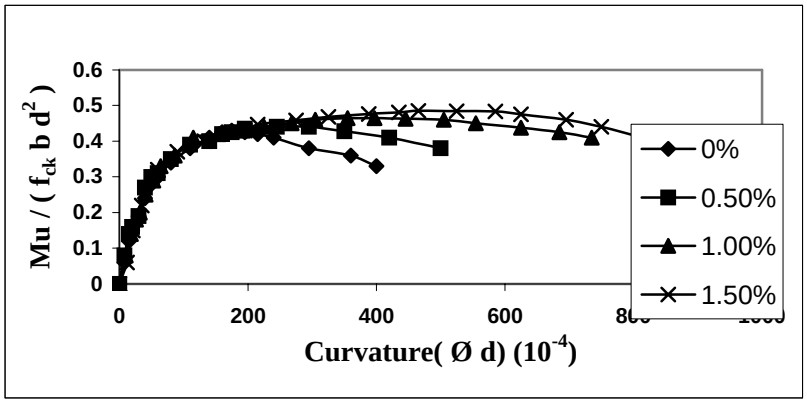

Figure 2. Moment – cuvature diagram

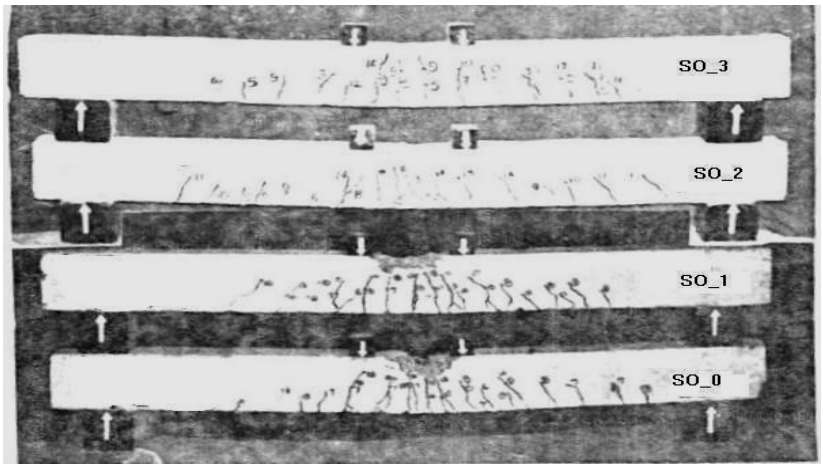

Figure 3. Tested Beams

4. Conclusions

- The use of ESFRC resulted in improvement in moment curvature characteristics of reinforced concrete beams.
- The serviceability limit state of deflections is not violated with the use of ESFRC.The effect of steel fiber is prominent beyond the ultimate stage.The reinforced concrete beams with higher percentage of tension steel (i.e.over reinforced sections) can be made to develop a ductile failure (tension failure), by providing ESFRC.

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