Study on Flexural Behaviour of RCC Beam with Minimum Shear Reinforcement and Replacing Different Fibers

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Abstract—*For more than three decades, a number of researchers have tried to use fibers to improve the performance of reinforced cement concrete (RCC) beams. The application of fiber-reinforced concrete can overcome the congestion-related problems of steel reinforcement by reducing the amount of stirrups or eliminating the stirrups. Due to the inhibition of crack propagation and widening through fiber-bridging mechanisms, it is well-known that the shear strength of RC beams can be improved by including fibers.*

This study aims to investigate the feasibility of eliminating the minimum shear reinforcement in reinforced sustainable high-strength concrete (HSC) beams by incorporating fibers. To do this, four large reinforced HSC beams, with and without stirrups and fibers, were fabricated and tested.

The suitability of electronic waste fibre, glass fibre and hooked steel fibres as fiber reinforcement in concrete will be studied. From studies it is observed that steel fiber reinforced concrete exhibits more strength compared to other 3 beams.

Keywords— *Feasibility, stirrups, fibers, shear*

1. INTRODUCTION

Diagonal cracks of a reinforced concrete beam occur when the principal tensile stress of concrete within the shear span exceeds the tensile strength of concrete. The addition of fibers into a reinforced concrete beam can enhance its shear failure strength, and if sufficient fibers are added, a brittle shear failure can be suppressed in favour of more ductile behaviour, and crack sizes and spacing can also be reduced. Fibers were used to boost the shear capacity of concrete or to partially replace the vertical stirrups in reinforced concrete structural members. This relieved reinforcement congestion at critical sections such as beam-column junctions and tubbing segments.

A possible reduction in the workability of the concrete, especially for high fiber contents, and possible variations in the material characteristics due to a non-homogeneous distribution of the fibers, might be the two most important obstacles for the breakthrough of steel fiber concrete in the precast concrete industry.

Structural concrete elements like beams always contain shear reinforcement if they are designed according to code. If no shear reinforcement is required according to the equilibrium equations, minimum shear reinforcement has to be provided. The production and placing of conventional shear reinforcement like stirrups is quite labour intensive and represents a non- negligible part in the production time and production cost of concrete elements. Therefore, the precast concrete industry is looking for methods to avoid the application of traditional shear reinforcement. For more than three decades, a number of researchers have tried to use discontinuous, randomly- oriented fibers to improve the performance of reinforced concrete (RC) beams. Due to the inhibition of crack propagation and widening through fiber-bridging mechanisms, it is well-known that the shear strength of RC beams can be improved by including fibers. The flexural strength of lightly-RC beams was also improved by adding fibers. Application of fiber-reinforced concrete (FRC) can overcome the congestion-related problems of steel reinforcement by reducing the amount of stirrups or eliminating the stirrups.

2. TEST SPECIMEN

Table 2.1 Details of beam casted

Sl No.	Beam	(kg/m^3)
1	CB	0
2	SFRCB	1.38
3	GFRCB	2.8
4	E-WRCB	2.4

In order to investigate the flexural behaviour of RC beams, 3 different beams were adopted and compared with the normal specimen. The study is to examine the feasibility of replacing the minimum shear reinforcement with hooked steel fibers, E-waste fibers and glass fibers. Number of stirrups, used for the reinforced FRC beams were less (due to the inclusion of hooked steel fibers, E waste fibers and glass fibers).

The control beam of cross-sectional dimensions of 150 mm width by 230 mm total depth. The total span of the beams was 2000 mm. The flexural reinforcement of all beams consisted of two deformed steel bars of 12 mm diameter in the tension side and two deformed steel bars of 10 mm diameter in the compression side.

Steel fiber reinforced beam was the next specimen**.** The specimen of same dimensions with changing the number of stirrups were casted. The number of stirrups were minimized to four in number and hooked steel fibers were added to it uniformly. The dosage of hooked steel fibers used is as per specifications.

Fig 2.1 Reinforcement Details of FRC Beams

Next specimen was glass fiber reinforced beam. The number of stirrups were minimized to four in number and glass fibers were added to it uniformly. Then concrete mix is placed and compacted and finished.

Beam with E-waste fibers was the next specimen. Here beam of 150mm width and 230mm depth and 2000mm length is casted. E-waste fibers were added to the beam. Then the beam is cured for 28 days.

3. RESULT AND DISCUSSIONS

The SFRC beams exhibited deflection-hardening behavior, showing a higher load-carrying capacity after matrix cracking; this was due to the excellent fiber-bridging capacity at the crack surface. Fibers bridge the facing crack surfaces to limit crack propagation and further opening through an anchorage effect that is caused by the end hooks and frictional resistance at the fiber-matrix interface.

Fig 3.1 Cracking pattern of control beam

Fig 3.2 Cracking pattern for SFRC Beam

Fig 3.3 First Crack of SFRC Beam

Fig 3.4 Cracking Pattern of GFRC Beam

Fig 3.5 First Crack of GFRC Beam

Fig 3.6 Cracking Pattern of EFRC Beam

Table 3.2 Test Result

Serial number	Beam designation	First cracking load (k N)	Ultimate load(k N)	Deflection(mm)
1	CB	35	69	18.25
2	SFRCB	42	77.6	4.87
3	GFRCB	39	73	15.38
4	EFRCB	37	72.5	18.45

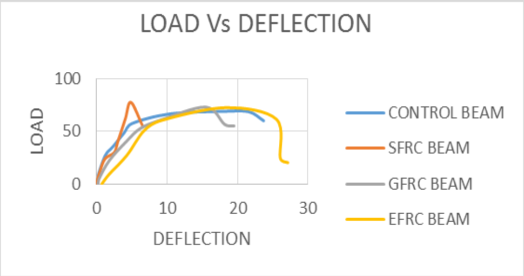

Fig 3.7 Load VS Deflection graph

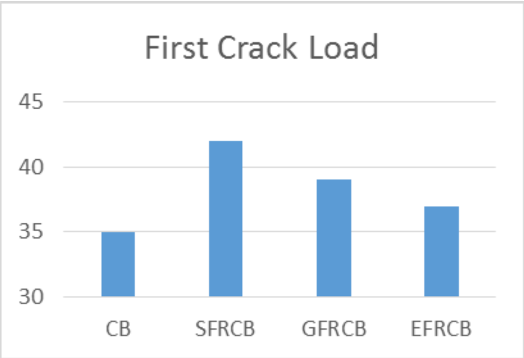

Fig 3.8 First crack load comparison

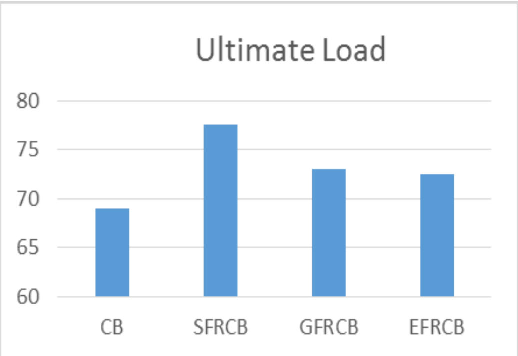

Fig 3.9 Ultimate load comparison

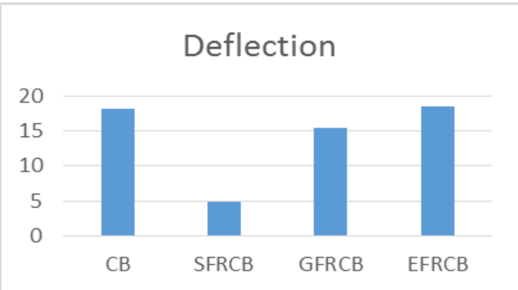

Fig 3.10 Maximum deflection comparison

Before initial cracking, the flexural load increased very sharply with a slight increase in the deflection. Once initial cracks occurred in the concrete from the bottom surface of the beams, the stiffness decreased due to the reduced effective cross-sectional area, which resists compressive and tensile stresses of an external load; however, the flexural load continuously increased because the longitudinal steel rebars were still within the elastic range. After the steel bar yielded, a significant decrease in the stiffness was observed for R-HSC beams.

As a result, a substantial increase in the deflection with a slight increase in the flexural load was obtained. A sudden load drop was obtained due to the crushing of concrete at the top of the beams. The R-FRC beams also exhibited a very sharp increase in the flexural load versus deflection up to the initial cracking point, which is identical to what was observed for R-HSC beams. Immediately after the initial cracking, a decrease in the stiffness was also observed for the R-FRC beams; however, the magnitude of the decrease was smaller than the R-HSC beams because the incorporated fibers bridged the cracks and inhibited further crack widening. The R-FRC beams exhibited a gradual decrease in the flexural load-carrying capacity after reaching the peak load; this was caused by the softening behaviour of material, which is inconsistent with the behaviour of R-HSC beams. The deflection-hardening SFRC exhibited softening behavior after reaching the yield strength, and the load-carrying capacity of R-FRC beams was also gradually reduced after the onset of the softening behaviour, finally converging to the capacity of the R-HSC beams where the tensile stress is only resisted by the internal steel rebars. Consequently, a similar or slightly higher flexural load-carrying capacity was obtained for both R-HSC and R-FRC beams at large deflections. All of the tested RC beams exhibited a flexural failure mode. It is worth noting that the R-FRC beams without stirrups provided a higher load-carrying capacity compared to the R-HSC beams with stirrups. This is caused by the deflection-hardening behaviour of FRC imparted by the excellent fiber-bridging capability.

4 CONCLUSION

In this study, the feasibility of eliminating the minimum shear stirrups of reinforced HSC beams by including certain volume % of fibers were examined. For this, reinforced HSC beams were first designed to have the minimum shear stirrups.
Based on the above discussions, the following conclusions were drawn:
1) The minimum shear reinforcement of reinforced HSC beams can be effectively eliminated by including fibers.
2) Compared to the reinforced HSC beams with stirrups, the reinforced FRC beams by minimizing stirrups exhibited higher flexural strength but smaller ultimate deflection and ductility.
3) By including fibers, the failure mode of lightly-reinforced HSC beams was transformed from concrete crushing to longitudinal steel bar rupture due to a crack localization phenomenon.

4) Based on a comparison between the experimental results, determining the fiber orientation factor for high-strength SFRC was suggested.
5) Minimizing major amount of stirrups and incorporating fibers it can retain higher amount of ultimate strength.

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