CHAPTER-9
SUMMARY AND CONCLUSIONS

9.1 SUMMARY
In the present investigation, in-depth comprehensive study was made regarding the distribution and variation of shear strain along the vertical axis of the beam. The aim of the investigation is to provide a systematic and comprehensive study on the cracking characteristics with respect to crack width & crack patterns in Fiber Reinforced Cement Concrete Moderate Deep Beams. In course of investigations, three empirical equations are proposed to estimate the shear strength of Fibrous Moderate Deep Beams using different types of fibers. Also, five empirical equations are proposed to calculate the maximum crack width of Fibrous Moderate Deep Beams.

9.2 CONCLUSIONS

9.2.1. For the beams having L/D ratio 3 or more (i.e. D30 and D40 series beams), the predominant failure is flexure failure in flexure zone. In all these beams cracks were initiated in flexure zone and failed due to predominant flexure crack in flexure zone. Minor thin shear cracks were developed but not extended further even due to increase in load.

In case of beams having L/D ratio less than 3 (i.e. D50 and D60 series), the predominant failure is shear failure in shear zone. Examining the photographs of tested beams it was found that initially few cracks were developed in pure moment zone. Later, the diagonal tensile crack was developed at a distance of about D/2 to D/3 from soffit in shear span with the increase of load further. The diagonal crack started extending both ways towards loading point and support point. It was also observed that no flexural cracks were developed further. These diagonal cracks so formed were nearly parallel to each other with a “strut like” appearance between the loading points. The indication of “strut like” appearance was observed in beam of series D50 and D60. Diagonal compression failure was observed with an inclined crack developed along the line joining the load and support point which is followed by second
parallel crack after a small increase in load. Failure is due to destruction of concrete strut between these cracks. It is observed during testing that shear failure in D50 and D60 series of beams is always initiated by splitting action, this phenomenon of failure being similar to that of cylinder under diametrical compression i.e. Brazilian split test.

9.2.2. For a/D ratio less than 1.5, R.C.C. beams with stirrups provide little more shear resistance than Fibrous Moderate Deep Beams without stirrups and for a/D ratio more than 1.5; shear resistance of Fibrous Moderate Deep Beams without stirrups is nearly same as the R.C.C. Moderate Deep Beams with stirrups. This shows that stirrups (conventional shear reinforcement) may be effectively partially replaced by fibers with proper design [Table group 4.6].

9.2.3. On comparison of the variation of strain at varying depth, it can be concluded that no significant strain variation is observed at depth 0.0 to 75 mm from outer surface of beam.

9.2.4. Steel fibers are relatively expensive. Polypropylene fibers are better than Steel fibers in comparison of cost to benefit ratio as well as rusting [appendix-1].

9.2.5. The large deflection at collapse in Fiber Reinforced Concrete beams indicates the post cracking ductility imparted is due to the fibers. In all the fibrous concrete beams, deflections are reduced at any given load level compared to those of a beam which does not contain the fibers. Right from the beginning of the loading, these deformational characteristics are influenced by the fibers. Due to presence of fibers it is concluded such modifications results in less wide cracks, lower deflection. It is concluded all these desired improvements are obtained due to inclusion of fibers in the concrete.

9.2.6. The graphical presentations for the variation of principal tensile strain [Fig. 4.39-4.49] along the inclined axes in shear zone show good agreement with the P. J. Robins and F. K. Kong's concept of an elliptical stress pattern
along the line joining the load and support point. From the results, it can be established that the incorporation of fibers increases the tensile cracking strain of plain concrete. The result also shows that fibers played significant role in controlling the first cracking of composite.

9.2.7. The graphical presentations for the variation of shear strain [Fig. 4.5-4.38] at top surface and at in-depth surface along the vertical axes in shear zone show D shape of strain distribution. This is in good agreement with the theoretical shear stress distribution of parabolic nature along the vertical axes of the beam.

9.2.8. By the detailed analysis and from the results presented in the previous chapter, it can be concluded that fibers are better option compare to the conventional web reinforcement (i.e. stirrups) to resist shear. At the beam-column junctions where more shear reinforcement is required, fibers can be the best alternatives to avoid congestion of reinforcement along with crack arresting mechanism. It is also logically concluded that the fibers may be the partial replacement of web reinforcement (stirrups).

9.2.9. Steel fibers helps in strength enhancement of concrete beams, Polypropylene fibers helps in strain enhancement of concrete beams and Hybrid fibers (Steel and Polypropylene fibers combined) helps in both strength and strain enhancement.

9.2.10. The proposed empirical equations to estimate Ultimate Shear Strength of Fibrous Moderate Deep Beam gives satisfactory and reliable result. From the Table 5.1 it is concluded that with a few exceptions, the computed shear capacity agrees fairly well with the observed value of shear loads.

9.2.11. The proposed empirical equations to estimate maximum crack width of Fibrous Moderate Deep Beam gives satisfactory and reliable result. From the Table 6.89 it is concluded that with a few exceptions, the computed maximum crack width agrees fairly well with the observed value of crack width.
9.2.12. After careful observation of photographs of the tested beams [Fig.6.1-6.88 (Chapter-6)], it is concluded that the crack patterns in the Fibrous Moderate Deep Beam depend more on shear span to depth (a/D) ratio rather than on span to depth (L/D) ratio.

9.2.13. Use of Steel fiber arrests Macro-cracks in the concrete, whereas use of Polypropylene fiber arrests Micro-crack. From the results, it is inferred that Fibrous Beams shows good strain energy absorption and ductile nature of failure before collapse.

9.2.14. It may be suggestive that the Ultimate shear strength of Fibrous Moderate Deep Beams without web reinforcements (stirrups) is 70 to 75 % more than that of the RCC Moderate Deep Beams without web reinforcements [Table group 4.8]. It may be concluded that shear reinforcement in the form of stirrups can be effectively partially replaced by fibers with proper design.

From the limited extent of this work, the findings arising out of this study would find practical applications in the field of Civil and Structural Engineering.

9.3 SUGGESTIONS

The following suggestions should be adopted to get good result of tested beams:

- Proper mixing and compaction should be done to avoid honey combing in concrete.
- Leveling of beams should be done properly to avoid unsymmetrical loading.
- Use admixture to get proper workability.
- Add 10% to 15% grit in concrete mix to get homogeneous concrete.
- Use needle vibrator to get proper compaction.
9.4 SCOPE FOR THE FUTURE WORK

- Investigation can be extended on Polypropylene fiber and/or Steel fiber for different volume proportions of fibers.

- Wide scope for analysis of shear deformational behavior of Moderate Deep Beams by FEM using linear or non-linear approach.

- Investigation can further be extended for Moderate Deep Beams for Hybrid FRC for different volume proportions of fibers.

- Effect of variation of a/D ratio can also be analyzed with changed fiber types.

- Investigation can be extended for high strength Moderate Deep beam using various fibers.

- Effect of fibers on Pre-stressed concrete Moderate Deep Beam can be studied in detail.