CHAPTER 5
CONCLUSIONS

5.1 INTRODUCTION

In this experimental investigation, the effect of steel, carbon and fibrillated Polypropylene fiber in mono form and hybrid form on quaternary blended control concrete with respect to mechanical and durability properties and the flexural behaviour of the fiber reinforced concrete beams have been investigated. The experimental results have been compared with the analytical flexural strength models. Suggestions for further research work are also provided in this chapter.

5.2 CONCLUSIONS

The following conclusions are drawn from the present experimental investigation.

1. Workability decreases both in mono and hybrid fiber forms at higher fiber dosages. The maximum volume fraction of steel fiber recommended for hybrid combination should not be more than 0.5% considering the workability criteria.

2. Due to pozzolanic materials present in the mix, the strength is higher at 56 and 90 days than 28 days.

3. Among all the hybrid combinations considered in this investigation, a better positive synergy effect is observed with steel volume fraction of 0.5% in the mix S1C0P0 (0.5% steel +0.125% carbon+ 0.125% PP) and S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) for compressive, splitting tensile and flexural strength. The maximum compressive, splitting tensile and flexural strength at 28 days is
increased up to 40.53%, 49.44% and 77.73% in the mix S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) respectively than control concrete at 28 days. When compared to control concrete at 28 days, the maximum compressive, splitting tensile and flexural strength is increased up to 67.68%, 77.78% and 116.71 % in the mix S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) at 90 days respectively.

4. Hybrid combination of S3C1P1 (1.5% steel + 0.25% carbon+ 0.25% PP) can be considered as best for impact resistance of the concrete. In control concrete, N1 and N2 values at 28 days are 251 and 252 respectively whereas in S3C1P1 (1.5% steel + 0.25% carbon+ 0.25% PP) mix, N1 and N2 values are 1460 and 2479 respectively. The maximum values of N1 and N2 are achieved as 5.82 and 9.84 times than control concrete in S3C1P1 (1.5% steel + 0.25% carbon+ 0.25% PP) mix. Similarly, N1 and N2 values at 90 days are 1888 and 3358 respectively. The maximum values of N1 and N2 are achieved at 90 days as 7.52 and 13.33 times than control concrete at 28 days.

5. Among SPHFRC mix, S1P1 (0.5% steel + 0.25% PP) and S1P2 (0.5% steel + 0.5% PP) can be taken as the most appropriate hybrid combination for compressive, split tensile and flexural strength. The maximum compressive, splitting tensile and flexural strength at 28 days is increased up to 25.22 %, 29.17 % and 73.55 % in the mix S1P2 (0.5% steel + 0.5% PP) respectively than control concrete at 28 days. When compared to control concrete at 28 days, the maximum compressive, splitting tensile and flexural strength is increased up to 50.59%, 54.17% and 110.67% in the mix S1P2 (0.5% steel + 0.5% PP) at 90 days respectively.

6. Hybrid combination of S3P2 (1.5% steel + 0.5% PP) can be taken as the best for impact resistance of the concrete. In S3P2 (1.5% steel + 0.5% PP) mix, N1 and N2 values at 90 days are 1740 and 2987
respectively. The maximum values of N1 and N2 are achieved at 90 days as 6.93 and 11.85 times than control concrete at 28 days.

7. Among SCHFRC mix, S1C1 (0.5% steel + 0.25% carbon) and S1C2 (0.5% steel + 0.5% carbon) can be taken as the most appropriate hybrid combination for compressive, splitting tensile and flexural strength. The maximum compressive, splitting tensile and flexural strength at 28 days is increased up to 35.74%, 46.67% and 75.87% in the mix S1C2 (0.5% steel + 0.5% carbon) respectively than control concrete at 28 days. When compared to control concrete at 28 days, the maximum compressive, splitting tensile and flexural strength is increased up to 66.25%, 71.67% and 112.99% in the mix S1C2 (0.5% steel + 0.5% carbon) at 90 days respectively.

8. Hybrid combination of S3C2 (1.5% steel + 0.5% carbon) can be taken as the best for impact resistance of the concrete. In S3C2 (1.5% steel + 0.5% carbon) mix, N1 and N2 values at 90 days are 1821 and 3205 respectively. The maximum values of N1 and N2 are achieved at 90 days as 7.25 and 12.72 times than control concrete at 28 days.

9. The water absorption percentage in the control mix at 28 and 90 days are 4.32% and 3.33% respectively. When compared to control concrete, water absorption is lesser in mono and hybrid fibrous mixes. The minimum water absorption is found in S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) mix as 3.74% and 2.31% at 28 and 90 days respectively.

10. The sorptivity is higher in the control concrete with $4.63 \times 10^{-3} \text{cm/} \sqrt{\text{min}}$ at 28 days and $3.32 \times 10^{-3} \text{cm/} \sqrt{\text{min}}$ at 90 days. The minimum sorptivity value of $3.28 \times 10^{-3} \text{cm/} \sqrt{\text{min}}$ and $1.96 \times 10^{-3} \text{cm/} \sqrt{\text{min}}$ are found in S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) mix at 28 and 90 days respectively.
11. There is no significant weight change in all the cube specimens subjected to sulphate environment. The compressive strength reduction is observed in all the specimens subjected to sulphate environment. The maximum compressive strength reduction is found in control concrete is as 12.12% at 90 days. The minimum strength loss of 8.49% is for S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) when subjected to sulphate attack for 90 days.

12. Acid attack test results show that the percentage weight loss decreases with the addition of fibers either in mono form or in hybrid form. The minimum weight loss percentage is found in the mix S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) as 2.29% at 90 days. The maximum compressive strength reduction is found as 14.13%, 27.95% and 36.87% in control concrete at 28, 56 and 90 days respectively. The minimum strength reduction is found in the mix S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) as 23.11% at 90 days.

13. All the hybrid mixes are found to be very effective with low permeability to chloride iron penetration as per ASTM C1202 – 97.

14. The first crack load and the ultimate load carrying capacity increases in all fibrous concrete beam specimens with the addition of fibers.

15. When compared to all the hybrid mixes, better positive synergy effect is observed in the beam with mix S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) at 0.5% volume fractions of steel fibers whereas mix S2C2 (1% steel + 0.5% carbon) performed well at 1% volume fractions of steel fibers. The maximum ultimate load carrying capacity of the beam is increased up to 51.98% in S1C1P1 (0.5% steel + 0.25% carbon+ 0.25% PP) at 0.5% volume fractions of steel fibers and is increased up to75.95% in S2C2 (1% steel + 0.5% carbon) at 1% volume fractions of steel fibers.
16. The energy absorption capacity is increased in all the hybrid fiber reinforced concrete beams than the control beam. The energy absorption capacity is increased up to 117% in the mix S1C1P1 (0.5% steel + 0.25% carbon + 0.25% PP) and 226.67% in the mix S2C2 (1% steel + 0.5% carbon) compared to control beam.

17. The ductility index is increased in hybrid fiber reinforced beams than control beam. The ductility index is increased up to 48.56% in the mix S2C2 (1% steel + 0.5% carbon).

18. The experimental ultimate load results are compared with the analytical flexural strength models. The experimental results are in good agreement with the models.

Thus, it is concluded that the mechanical and durability properties of quaternary blended concrete with SCMs can be significantly improved by adding steel, carbon and fibrillated polypropylene fiber in hybrid form.

5.3 SUGGESTIONS FOR FURTHER WORK

The scope for further study on quaternary blended concrete reinforced with hybrid fibers is as follows:

i. Shear strength of beams made with hybrid fiber quaternary blended reinforced concrete beams can be studied.

ii. The behavior of quaternary blended hybrid fiber reinforced concrete beams under cyclic loading can be investigated.

iii. The behavior of quaternary blended hybrid fiber reinforced concrete beam column joints under static and dynamic loading can be investigated.