CHAPTER 8
CONCLUSIONS

Fibre Reinforced Self-Compacting Concrete (FRSCC) of M30 grade using three kinds of fibres was developed. It has satisfied all the guidelines prescribed by EFNARC. The FRSCC so developed was used to cast wall panels (as scaled down models) and the specimens were tested for obtaining vertical and flexural load-carrying capacities. Based on the investigations carried out on Fibre Reinforced Self-Compacting Concrete Mixes and Wall Panels, the following conclusions are presented in this chapter.

8.1 FRSCC Mixes

8.1.1 Fibre Reinforced Self-Compacting Concrete can be produced by incorporating different types of fibres. However, the use of appropriate dosage of superplasticizer and viscosity modifying agent is essential to maintain the fresh properties of self-compacting concrete.

8.1.2 In the case of high dispersion of glass fibres, a dosage of 600 grams of fibres/m$^3$ of concrete is used as optimum dosage by suitably adjusting the dosage of admixtures.

8.1.3 The aspect ratio and volume of steel fibres are selected satisfying the fresh and hardened properties of self-compacting concrete by suitably adjusting the dosage of admixtures.
8.1.4 In the case of Hybrid Fibre Reinforced Self-Compacting Concrete, the dosages of glass and steel fibres were obtained by trial mixes by suitably adjusting the superplasticizer and VMA dosages in order to satisfy the fresh SCC properties.

8.2 Compressive Strength of FRSCC

8.2.1 The compressive strengths of the FRSCC design mixes are found to be increased by the addition of fibres.

8.2.2 The addition of glass fibres and steel fibres has shown improved compressive strengths. The increase in compressive strength in SFRSCC was found to be higher than that of GFRSCC.

8.2.3 In the case of HFRSCC, the compressive strengths were found to be further enhanced due to the combined action of glass and steel fibres, and the increase in compressive strength is 11.84% over plain SCC.

8.3 Split Tensile Strength

8.3.1 The addition of fibres improved the split tensile strength which is found to be maximum in HFRSCC. Hence, it is concluded that the hybridization of glass and steel fibres is useful in improving the strength properties of FRSCC.

8.4 Effect of Confinement

8.4.1 The addition of fibres along with confinement of FRSCC with steel hoops enhanced the compressive strength, indicating further confinement effect in the FRSCC.
8.4.2 It is observed that the addition of fibres is helpful in lower confinements only. Beyond 1.062% confinement, the addition of any type of fibres doesn’t show any effect on compressive strengths.

8.5 Stress-Strain Behaviour

8.5.1 The stress - strain behaviour of SCC and FRSCC mixes was found to be almost similar. However, it is observed that the addition of fibres has improved the stress values for the same strains.

8.5.2 Increase in strain values were observed at peak stresses in all FRSCC mixes.

8.5.3 From the stress-strain behaviour of all types of FRSCC, it is concluded that the ultimate load-carrying capacity and strains at peak stresses are more in SFRSCC and HFRSCC for mixes upto 1.062% confinement.

8.5.4 The hybridization of SCC with glass and steel fibres has shown superior performance amongst all FRSCC mixes

8.6 Ductility Factors

8.6.1 The addition of fibres to SCC has increased the ductility factors in both confined and unconfined states. The ductility factors are found to be the highest in HFRSCC indicating the superior performance of HFRSCC.

8.7 Plasticity Ratios

8.7.1 The plasticity ratio helps in the quantitative assessment of increase in ductility. From the plasticity ratios calculated as suggested
by Martiney (1984), higher plasticity ratios were obtained for HFRSCC indicating the improvement in ductility of HFRSCC.

8.8 Modulus of Elasticity

8.8.1 Initial Tangent Modulus and Secant Modulus

8.8.1.1 It is observed that initial tangent modulus and secant modulus were found to be more in FRSCC. The hybridization of fibres has resulted in further increase in these modulii and the confinement of HFRSCC has further enhanced the modulii of elasticity.

8.8.1.2 Mathematical equations were predicted for estimating the secant modulus of elasticity in terms of $f_{ck}$, which are as follows:

\[
E = 5430 \sqrt{f_{ck}} \text{ for plain SCC } \quad \ldots \ldots \ldots 8.1 \\
E = 5720 \sqrt{f_{ck}} \text{ for GFRSCC } \quad \ldots \ldots \ldots 8.2 \\
E = 5870 \sqrt{f_{ck}} \text{ for SFRSCC } \quad \ldots \ldots \ldots 8.3 \\
E = 5960 \sqrt{f_{ck}} \text{ for HFRSCC } \quad \ldots \ldots \ldots 8.4
\]

8.9 Strength Confinement Factors and Strength Enhancement Ratios

8.9.1 Empirical equations relating to the strength enhancement ratio and confinement parameter were established for the confined SCC and confined FRSCC, which are as follows.

\[
\frac{f'_{o}}{f_{o}} = 1 + 11.68 \left[ \frac{\rho_{f} f_{y}}{f_{o}} \right]^{1.5} \text{ for confined SCC } \quad \ldots \ldots \ldots 8.5 \\
\frac{f'_{o}}{f_{o}} = 1 + 13.46 \left[ \frac{\rho_{f} f_{y}}{f_{o}} \right]^{1.5} \text{ for confined FRSCC } \quad \ldots \ldots \ldots 8.6
\]
8.10 Wall Panels

The SCC developed using glass fibre, steel fibre and hybrid fibre (combination of glass and steel fibres) was used to cast scaled-down model wall panels which were tested in the laboratory. Scaled-down model wall panels using plain SCC were also cast and tested in the laboratory for compressive vertical load-carrying capacity (with a zero and minimum eccentricity), out-of-plane bending capacity (pure bending). It was found that the model wall panels that were cast using three kinds of fibres have shown substantial increase in their load-carrying capacities compared with the model wall panels made with plain SCC. It was also observed that the failure mode of model wall panels made using different fibres was not sudden compared to the model wall panels made with plain SCC, indicating ductile behaviour.

8.10.1 The axial compressive load carrying capacities of prototype wall panels are predicted by making use of experimental test results on model wall panels and principles of structural mechanics. It was observed that increase in the load-carrying capacities (predicted values) of prototype wall panels are 4.21%, 41.61% and 52.66% for glass fibre, steel fibre and hybrid fibres, respectively, compared with plain SCC wall panels.
8.10.2 The predicted compressive load carrying capacities of wall panels made using glass fibre, steel fibre and hybrid fibre SCC under minimum eccentric load conditions, are found to be increased by 4.26%, 41.53% and 52.68%, respectively, compared with the predicted values of prototype wall panels made using plain SCC.

8.10.3 The predicted flexural strength (out-of-plane bending) of GFRSCC, SFRSCC and HFRSCC wall panels are found to be 2.97%, 16.08% and 21.87%, respectively.

From the test results, it is understood that the failure mode of fibre reinforced wall panels was not sudden, which is a desirable quality for the wall panels.

8.11 Scope for Further Work

1. The behaviour of hybrid fibre reinforced SCC with other types of fibres can be investigated.

2. The behaviour of hybrid fibre reinforced high strength SCC can be investigated.

3. The behaviour of prototype HFRSCC wall panels can be investigated.

4. The behaviour of HFRSCC wall panels with different end conditions can be investigated.

5. Non-linear material behaviour of FRSCC can be investigated using FEM modeling techniques.