CHAPTER 4

CONCLUSIONS AND SUGGESTIONS FOR FUTURE STUDIES

4.1 CONCLUSIONS

From the extensive experimental investigations, the following important conclusions are arrived:

- The optimum replacement of cement for developing the M 20, M 30 and M 40 grade binary blended concrete by FA and RHA was found to be 20% and 18% respectively based on the 28 days required target mean strength and 90 days compressive strength results.

- The slump value of 20% FA based M 20, M 30 and M 40 grade binary blended concrete was found to be slightly higher whereas 18% RHA based M 20, M 30 and M 40 grade binary blended concrete slightly less compared to control concrete. The addition of SF for developing M 20, M 30 and M 40 grade ternary blended concrete reduced slump value compared to control and binary blended concrete. Addition of 12% SF drastically reduced the slump value due to the more water demand of SF particles.
The air content of 20% FA and 18% RHA based M 20, M 30 and M 40 grade binary blended concrete was found to be slightly less compared to control concrete. Air content of 4% SF mixed FA / RHA based ternary blended concrete was found to be less compared to the control, binary blended concrete and 8% and 12% SF based ternary blended concrete.

The addition of 20% FA increased the initial setting time approximately 30% and also increased the final setting time approximately 20% compared to control concrete. The addition of 18% RHA increased the initial setting time of binary blended concrete approximately 35% and also increased the final setting time approximately 30% compared to control concrete. The addition of 8% SF along with 20% FA / 18% RHA enhanced the setting time characteristics of blended concrete.

The compressive strength of 7 days cured 20% FA and 18% RHA based M 20, M 30 and M 40 grade binary blended concrete was found to be less compared to control concrete. The compressive strength of 8% SF mixed FA / RHA based ternary blended concrete was found to be more compared to the control, binary blended concrete and 4% and 12% SF based ternary blended concrete.

The splitting tensile strength of FA / RHA based M 20, M 30 and M 40 grade binary blended concrete was found to be less compared to the control concrete. 7 days cured 8% SF mixed FA / RHA based ternary blended concrete showed higher splitting tensile strength than the control and binary blended concretes. The 4% and 12% SF mixed FA / RHA based
ternary blended concrete had lower splitting tensile strength than 8% SF based ternary blended concrete.

- The relationship between compressive strength and splitting tensile strength of FA and SF based ternary blended concrete was found to be good fit with the correlation proposed by Ahemed and Shah 1985 and Rashid et al 2002.

- The bond strength of 7 days cured FA / RHA based binary blended concrete was found to be less compared to control concrete. From the results, it can be seen that the addition of SF in the FA and RHA blended concrete improves the bond strength for all grades of concrete and 8 % SF is found to be the optimum.

- The relationship between compressive strength and elastic modulus of 8% SF mixed 20% FA / 18% RHA based ternary blended concrete was found to be good fit with relationship proposed by ACI 318 R-95 and Oluokun et al 1991.

- The SWA of 7 days cured 20% FA and 18% RHA based M 20, M 30 and M 40 grade binary blended concrete was found to be slightly more compared to control concrete. The addition of 8% SF in FA / RHA based blended concrete decreased the SWA approximately 40% compared to the control and binary blended concrete at the age of 7 days. The SWA of 28 days cured binary blended concrete was found to be less compared to control concrete. Addition of SF further reduces the SWA of 28 days cured ternary blended concrete.

- The effective porosity of 7 days cured FA / RHA based binary blended concrete showed slightly higher than the 7 days cured control concrete whereas 28 days cured binary blended
concrete showed slightly lesser porosity than the control concrete. The addition of 4%, 8% and 12% SF in FA / RHA based ternary blended concrete reduced the porosity considerably. The maximum reduction of porosity (upto 30% of control concrete) was observed for 8% replacement level of SF.

- The sorptivity of 7 days cured FA / RHA based binary blended concrete was found to be high compared to the 7 days cured control concrete whereas for 28 days cured binary blended concrete had lesser sorptivity than the control concrete. The addition of 4%, 8% and 12% SF in FA / RHA based ternary blended concrete reduced the sorptivity compared to the binary blended concrete and also found that the addition of 8% SF showed the maximum reduction of sorptivity.

- It is observed from the SEM analysis that the micro structural voids and crakes were noticed in 7 days cured control concrete and un-hydrated mineral admixture particles were also observed in FA / RHA based binary blended concrete. The SEM results of 7 days cured 8% SF based ternary blended concrete showed a dense microstructure.

- The OCP of 7 days cured M 20, M 30 and M 40 control concrete specimens were found to be less than the threshold value during the initial period, which indicates that rebars are in active condition of corrosion. Initiation of corrosion of rebars embedded in the control concrete was found to be earlier compared to binary and ternary blended concrete. The specimens of 7 days cured M 20, M 30 and M 40 grade FA based binary blended concrete reach the threshold value of
corrosion potential after 6, 18 and 36 cycles of exposure respectively. From the results, it is found that there is no indication of corrosion initiation from 7 days cured M 30 and M 40 grade concrete specimens throughout the study. It is observed that corrosion potential are lesser than the threshold value up to the study period of 48 cycles for 28 days cured M 20, M 30 and M 40 grade FA and SF based ternary blended concrete and hence no possibility of corrosion initiation. The similar kinds of observations were also noticed for the RHA and SF based ternary blended concrete.

- The weight loss of rebar embedded in control concrete was found to be high compared to binary blended concrete. The weight loss of rebar embedded in the 8% SF and 20% FA / 18% RHA based ternary blended concrete was found to be approximately 50% less compared to the control concrete.

- The time taken to crack the FA / RHA based binary blended concrete was found to be slightly higher than the control concrete. The time taken to crack the 8% SF mixed FA / RHA based ternary blended concrete was found to be two times higher than the time of control concrete.

- The charge passed through control concrete was found to be more and the degree of chloride ion penetrability was found to be moderate based on ASTM limits. The charge passed through 7 days cured 20% FA and 18% RHA based binary blended concrete was found to be slightly less compared to the control concrete. The 8%SF based ternary blended concrete specimens permitted approximately 70% less chloride ions compared to control concrete. Based on ASTM limits, it is
found that the degree of chloride ion penetrability through 8%SF based ternary blended concrete is very low.

- For 7 days cured FA and RHA based binary blended concrete had lesser macro-cell current flow than that of control concrete. It is also observed that the 28 days cured binary blended concrete showed only half of the macro-cell current flow compared to the macro-cell current flow of control concrete. The SF based ternary blended concrete specimens for all the replacement levels such as 4%, 8% and 12% of SF showed lesser amount of macro-cell current flow compared to binary and control concrete. Based on the results, it can be concluded that the ternary blended concrete containing 8% SF replacement level had good resistance to chloride ion penetration than the control and binary blended concrete.

- The chloride concentration of 7 days cured control concrete was found to be high than the FA / RHA based binary blended concrete. The 28 days cured binary blended concrete showed lesser chloride ingress compared to the control concrete. The 7 days cured 8% SF based ternary blended concrete showed nearly half of chloride ingress through the concrete and also one third amount of chloride ingress was noticed for 28 days cured 8% SF based ternary blended concrete compared to control concrete.

- The expansion of control mortar prism due to sulphate attack was found to be high compared to binary blended concrete. The expansion of 8% SF based ternary blended prisms was found to be only 6% of expansion compared to control concrete.
- The SDF of FA / RHA based M 20, M 30 and M 40 grade binary blended concrete was found to be less than the control concrete due to sulphate attack. The 8% SF and 20% FA / 18% RHA based ternary blended concrete had only negligible amount of SDF compared to the control concrete.

- The mass loss of 7 days cured M 20, M 30 and M 40 grade control concrete was found approximately 24%, 21% and 16% respectively when immersed in 5% H₂SO₄ solutions. The mass loss of FA / RHA binary blended concrete was approximately 30% - 40% less than the control concrete. For 7 days and 28 days cured ternary blended concrete, the mass loss was found to be less than 9%.

- The control concrete had more SDF due to acid attack. The FA / RHA based binary blended concrete had lesser (60.07% of control concrete) SDF than the control concrete. The SDF of The 8% SF based ternary blended concrete was found to be approximately 75% lesser than the control and 50% lesser than the binary blended concrete.

- The 7 days cured FA / RHA based binary blended concrete had more depth of carbonation than the control concrete. The depth of carbonation of 7 days cured ternary blended concrete was found to be less than the control and binary blended concrete. For 28 days cured 8% SF and 20% FA / 18% RHA based ternary blended concrete, the depth of carbonation was found to be negligible.

- The cost of FA based binary blended concrete is found to be approximately 8% less than the cost of control concrete whereas RHA based binary blended concrete is found to be approximately 4% less than the cost of control concrete.
Though the cost of ternary blended concrete is marginally higher (less than 2%) than the cost of control concrete, the benefits of ternary blended concrete such as reducing the setting time, increasing the early age strength, improving the corrosion resistance, enhancing the micro-structural properties and improving the resistance against chemical attack are abundant compared to the control and binary blended concrete. The better enhancement of early age strength, improving the corrosion resistance, enhancing the micro-structural properties etc., could improve the serviceability of concrete structures.

- Based on the experimental study, the following mix combinations of cementitious materials found to suitable for developing the ternary blended concrete:

  72% Cement + 20% FA + 8% SF
  74% Cement + 18% RHA + 8% SF

### 4.2 SUGGESTIONS FOR FUTURE STUDIES

- The performance of various structural aspects of SF and FA / RHA mixed ternary blended reinforced cement concrete needs to be studied in detail.

- The performance of special structural concrete prepared using SF and FA / RHA mixed ternary blended concrete needs to be studied in detail.

- The use of SF and FA / RHA mixed ternary blended mortar for masonry construction needs to be studied.