CHAPTER 5

SUMMARY AND CONCLUSIONS

The comprehensive studies were carried out on the strength characteristics and durability performance of fly ash aggregate concrete as noted below.

(a) Study on strength characteristics of fly ash aggregate concrete.

(b) Study on durability performance of fly ash aggregate concrete.

(c) Mix proportioning of fly ash aggregate concrete.

Based on the results obtained the following conclusions are drawn.

The experiments were conducted on fly ash aggregate concrete. The strength characteristics of fly ash aggregate concrete with different cement fly ash proportions were studied at different ages. The fly ash aggregates were very effective in improving the strength and durability of concrete.

The primary objective was to evaluate the mechanical properties of FAAC with various cement fly ash proportions at different ages. The compressive strength, split tensile strength and flexural strength were studied and the relationship with the compressive strength also have been arrived. The influence of fly ash aggregates in concrete at different ages of concrete was
investigated. The conclusions from the experimental investigations are as follows:

Fly ash aggregate concrete with cement fly ash proportion 15:85 gives better results at all ages. The compressive strength, split tensile strength and flexural strength of the above proportion gives better performance. The main aim of adding fly ash aggregates in concrete is to increase the strength.

At all ages of one day, 3 days, 7 days, 14 days, 28 days, 56 days and 90 days, the compressive strength of FAA with cement fly ash proportion 15:85 is more than that of control concrete. It may be noted the increase in fly ash content in producing FAA shows an increasing trend of compressive strength up to this level at all ages. From the results, the optimum level of cement fly ash proportion to form FAA is 15:85. The compressive strength mainly depends on the percentage of fly ash because of its high pozzalanic nature when mixed with cement to form more densely packed C-S-H gel.

The cylinder compressive strength increases with increase in cube compressive strength. The cylinder compressive strength mainly depends on the percentage fly ash added with cement to form the aggregates. The optimum level of proportion is 15:85 which yields higher strength at all ages. The fly ash cement matrix increases the cylinder compressive strength.

The split tensile strength increases with increase in compressive strength. The relation between split tensile strength and compressive strength of FAAC with cement fly ash proportion 15:85 at the age of 28 days is 

\[ f_t = 0.142f_c^{1.158} \]

The flexural strength increases with increase in compressive strength. The relation between flexural strength and compressive strength of FAAC at the age of 28 days is 

\[ f_f = 0.384f_{ck}^{0.87} \]
The modulus of elasticity increases with increases of compressive strength and tensile strength. The relation between compressive strength and modulus of elasticity is computed as \( E_c = 5153f_c^{0.447} \). The modulus of elasticity values obtained from experiment is higher compared to the expression given by IS 456-2000.

The main factor which causes the deterioration of concrete structure is permeability. The rapid chloride ion penetration test was conducted to study the permeability characteristics with different cement fly ash proportions of FAAC. The accelerated corrosion test resistance was conducted to study the effect of fly ash aggregates against corrosion. The following are the conclusions arrived at from the above studies.

Fly ash aggregates reduce the permeability of concrete resultantly reducing, the loss in weight of steel reinforcement due to corrosion. Fly ash aggregates reduce the sorptivity and saturated water absorption significantly.

Saturated water absorption of concrete mainly depends on the permeability of the concrete mix. The addition of fly ash aggregates reduced permeability of concrete by lowering the size of pores on the cement paste in concrete. The cement fly ash proportions 22.5:77.5 reduce the saturated water absorption considerably. It is observed that the addition of fly ash aggregates reduced saturated water absorption significantly.

Inclusion of fly ash aggregates in concrete decreased the sorptivity. Sorptivity depends on the percentage of fly ash in aggregate because of its pozzolanic nature to form more densely packed C-S-H gel. The cement fly ash proportion 22.5:77.5 reduced the sorptivity to a greater extent. The sorptivity increases with increase in saturated water absorption. The relationship between saturated water absorption and sorptivity is \( Y= 110.9x + 1.761 \).
There is significant reduction in loss of weight due to corrosion of reinforcement when the fly ash aggregates are added. The fly ash aggregates also delayed the initiation of corrosion. The corrosion of embedded steel in concrete mainly depends on the permeability of the concrete mix. The addition of fly ash aggregates reduced the permeability of concrete by lowering the pores in the cement paste matrix.

The fly ash aggregate cement fly ash proportion 22.5:77.5 significantly improves the resistance against corrosion. Addition of fly ash aggregates replacing the conventional aggregates play a major role in the corrosion resistance of the embedded steel in concrete because of its high reactivity towards the liberated hydration constituents of cement. The fly ash particles formed a more cohesive paste due to its to high fineness. Thus the porosity of the paste is decreased. This results in the decrease in permeability. Therefore the corrosion resistance increased in fly ash aggregate concrete.

The fly ash aggregates with cement fly ash proportion 15:85 improves resistance against chloride ion penetration. The chloride ion penetration resistance and strength of FAAC is due to the presence of hydrated phases with low density phase products and smaller voids in the hydrated paste. Improvement in strength of transition zone between the aggregate and hydrated cement increases the chloride resistance and strength.

Fly ash aggregate concrete with all cement fly ash proportions showed high acid resistance. The fly ash aggregate concrete mixtures reveal that the hardened matrix is denser and more impermeable when compared to that of control concrete with conventional aggregates which leads to increase in acid resistance. In the SEM analysis also these points were observed.

All the cement fly ash proportions of fly ash aggregate concrete showed high carbonation resistance. The carbonation depends on
microstructure of concrete. The microstructure depends not only on the composition of cement paste but also on the type of light aggregate used. Since the fly ash aggregates have pozzolanic reactivity, calcium hydroxide produced during hydration interacts with the pozzolanic material and produce calcium silicate hydrates. The microstructure is densified and the free calcium hydroxide decreases. So fly ash aggregate concrete has more carbonation resistance than control concrete.

The stronger the concrete, the more is the force required to pull out. Fly ash aggregate concrete with cement fly ash proportion 15:85 showed high pullout resistance due to the high bond strength between cement paste and steel reinforcement. Since this proportion has high compressive strength, split tensile strength and flexural strength, the pull out strength is also more.

The significant parameters like type of aggregate, cement content, Water/cement ratio, workability, strength and relative density influence the mix proportions. Based on the results of the trial mix, a considerable reduction in cement content and water cement ratio were observed. A considerable savings in cost of fly ash aggregate concrete with all cement fly ash proportions was observed when compared to control concrete.

5.1 SCOPE FOR FUTURE STUDIES

Design parameters for FAAC such as 28 day characteristic compressive strength, characteristic tensile strength, creep coefficient and partial safety factors have to be studied. The influence of chemical components of fly ash aggregates need to be studied. The influence of chemical admixtures are to be studied. The strength and durability performance of light weight aggregate concrete with mineral admixtures like rice husk ash, silica fume and GGBS can be investigated.