CHAPTER 6

CONCLUSIONS

Based on the above investigation, the following conclusions are drawn.

6.1 MECHANICAL PROPERTIES

- Copper slag can be used in the place of fine aggregate as its original gradation is similar to sand. Supplementary process is not needed by means of crushing.
- According to IS:383-1970, gradation of 40% of copper slag replaced to sand fits with zone II. Copper slag 20%, 60%, 80% and 100% satisfies Zone I criterion which shows that the particle sizes are coarser than sand.
- Copper slag enhances the workability up to 60% replacement. Beyond 60% replacement, segregation and bleeding in concrete occurs that is conquered by the addition of PPF, which utilizes the excess water and regulates the water content in concrete.
- Hydration of C_3S produces excess CH (calcium-hydrates) in concrete which is consumed by the copper slag to form more C-S-H (calcium-silicate-hydrate) gel which stimulates the pozzolanic activity of copper slag.
- It is observed through the SEM image that the Ca(OH)_2 present in control concrete disappeared in copper slag concrete which shows that the copper slag consumes the unreacted Ca(OH)_2 to produce reacted component called C-S-H gel.
- Utilization of copper slag in cement mortar exhibits 70% improvement in compressive strength of mortar with 50% copper slag substitution in comparison with the control mixture.
In cement mortar, the maximum compressive strength at 28 days is 39.11N/mm² for 20% copper slag and 0.4% PPF, which is 83% higher than control mix.

In cement mortar, even 80% copper slag has produced a compressive strength of 37.11N/mm² at 28 days, which is almost 75% greater than the compressive strength of control mix.

Even if the sand is fully replaced with copper slag it can give higher compressive strength than control concrete. The strength value does not fall below the target mean strength as well as the compressive strength of control concrete. In that point of view, the copper slag alone can compete as an alternate material to sand.

Regression analysis by SPSS statistical package to predict the compressive strength of concrete achieves regression coefficients of 0.762, 0.918, 0.807 and 0.971 at 28, 56, 90 and 180 days respectively.

Split tensile test of concrete disclosed that the maximum split tensile strength of 3.537 N/mm² has been perceived at C40P4 mix, which is 31.58% greater than the reference mix.

Maximum flexural strength of plain concrete at 28 days for C40P2 mix is 9.58 N/mm² which is 26.05% increase compared to control concrete.

Flexural performance of Reinforced Cement Concrete beam revealed that the copper slag can be used up to 40% with polypropylene fiber of 0.4% without any deleterious effect on concrete performance.

The ultimate load carrying capacity has been increased to 7.56%, 13.33% and 2.22% for C20P2, C40P2 and C60P2 respectively. C20P2 mix has 70% more initial stiffness than the control specimen which shows the fiber addition increases the stiffness.
- Cyclic behaviour of reinforced concrete explored that the ultimate load carrying capacity of concrete made with 40% of copper slag replacement to sand (without PPF) ranges from 61kN to 67.7kN whereas the load carrying capacity of PPF concrete (without copper slag) varies from 55.44kN to 80.08 kN. This shows that addition of PPF enhances the load carrying capacity under cyclic load.

- Ultimate load carrying capacity of copper slag 40% with 0.4% PPF is more when compared to control beam. However, the load taken by the concrete proportion C0P3 (copper slag 0% & PPF 0.6%) is higher than the concrete with copper slag. It manifests the efficiency of adding PPF in concrete.

- Copper slag 40% replaced to sand performs well under impact loading than any other proportion. C40P3 specimen shows 111.72% increase in number of blows compared to control specimen.

6.2 DURABILITY PROPERTIES

- According to IS 13311(Part 1):1992, the quality of concrete of all replacements is good and excellent. It is observed that even 80% of copper slag replacement can able to produce good quality concrete.

- Concrete made with copper slag-PPF exhibits lower water absorption (1% to 3%) which tends to accelerate the hydration process. At 28 days, the water absorption of C40P3 concrete is 1.675% which is 46.89% lesser than that of control concrete.

- Concrete made with 60% copper slag represents higher alkalinity than other replacements. The addition of PPF in concrete increases the alkalinity and balances the effect of acidic nature of copper slag.

- Capillarity of concrete decreases with the increase of copper slag content. With respect to time, the rate of sorptivity decreases.
Concrete made with copper slag and PPF shows lesser capillarity than control concrete.

- Under acid environment, it is found that the decay of compressive strength of copper slag concrete with PPF is lesser than control concrete.
- The rate of depreciation of compressive strength at 60 days is ranging from 23% to 24% for all replaced concrete and the depreciation in control concrete is 28.32%. It implies that the copper slag concrete with PPF provides effective protection over sulphate attack.
- Charge passed during chloride ingress at 90 days is lesser than 28 days for all proportions except C40P2. Lower values at 90 days indicate impermeability of concrete to chloride ingress.
- Hence, the problem with the scarcity of the river sand can be overcome by the utilization of copper slag. Copper slag contributes to high compressive strength and polypropylene fiber gives higher tensile strength. When it combines properly effective utilization of copper slag is possible.

### 6.3 SCOPE FOR FUTURE WORK

Review of literature and research findings of this experimental work suggests the following future works

- This experimental work is carried out to utilize the copper industry byproduct to the maximum extent in construction actives along with synthetic fiber in M30 grade. The percentage of replacement can be increased by adopting a proper combination of admixtures like fly ash, silica fume etc.
- Copper slag is replaced with natural sand. Nowadays ‘M sand’ is popular in the construction field. Hence the effect of concrete with partial replacement of copper slag and M sand can be studied to
acquire maximum benefit of sustainable environment.

- Copper slag can be analysed for utilisation in manufacturing of hollow blocks, bricks and pavement blocks.
- Further fatigue strength and resistance to fire can be analyzed.