CHAPTER 7

CONCLUSION AND SCOPE FOR FUTURE WORKS

7.1 GENERAL

The present study investigated the effectiveness of using copper slag (a waste material obtained from sterlite industry, tuticorin) for the partial replacement of sand, cement and combination of both in concrete and RCC elements. The elements considered for study were

i) RCC beams of size 1500 x 150 x 150mm
ii) Short columns of size 1000 x 100 x 100mm
iii) Long columns of size 1900 x 150 x150mm

Since copper slag is a high density material and contains around 60% of Fe$_2$O$_3$, durability and corrosion characteristics were also incorporated in this investigation. Another part of this research was the applications of copper slag to reduce lateral or seismic earth pressure. In this investigation, copper slag was used as backfill material in retaining walls and the displacement characteristics was performed through shake table test.

7.2 CONCLUSION

Based on the investigations, the following conclusions were drawn.

- The utilisation of copper slag in concrete provides additional environmental as well as technical benefits for all related
industries. Partial replacement of copper slag in fine aggregate and cement reduces the cost of making concrete.

- Replacement of copper slag (100% replacement with sand) increases the self weight of concrete specimens to the maximum of 15-18%.

- The initial and final setting time of copper slag admixed concrete is higher than control concrete.

- Water absorption of copper slag was 0.16% compared with 1.25% for sand. Therefore, the workability of concrete increases significantly with the increase of copper slag content in concrete mixes. This was attributed to the low water absorption and glassy surface of copper slag.

- The results of compressive, split tensile strength test have indicated that the strength of concrete increases with respect to the percentage of copper slag added by the weight of fine aggregate up to 40% (S40). Further additions of copper slag caused reduction in strength due to an increase of free water content in the mix.

- There was more than 60% improvement in the flexural strength of concrete beams with 40% (S40) copper slag replacement for sand. The flexural strength of beams were increased up to 60% (S60) replacement, when compared to control mixes. After that the strength was suddenly decreased to 12% for S80 mixes and 22% for S100 mixes. The reason for reduction in strength was, the low absorption properties of
copper slag can leave excess water in concrete, which can cause excessive bleeding at higher copper slag content.

- When RCC short columns replaced with copper slag for the replacement of sand, the highest axial compressive strength was achieved by S40 mix, which was found about 29.280 N/mm² compared with 19.685 N/mm² for control columns. There is an increase of 28.20% of axial compressive strength was achieved for S40 columns, compared to control columns.

- There is an increase of 28.67% of ultimate load carrying capacity was achieved for flexure beams, when copper slag replaced with 40% of sand. The stiffness of S40 beams was increased to 33.34% at yield load and 17.83% at ultimate load compared to control mixes.

- Copper slag admixed long columns was found to provide better ductility and be more effective regarding load carrying capacity compared to control columns.

- The surface water absorption of concrete was reduced with up to 40% copper slag replacement for sand. The volume of permeable voids decreased with the replacement of up to 40% copper slag. Therefore it can be concluded that, copper slag, in the range of 40–50%, could potentially replace sand in concrete mixtures.

- Utilisation of copper slag as Portland cement replacement in concrete and as a cement raw material has the dual benefit of eliminating the costs of disposal and lowering the cost of the concrete.
• When copper slag replaced with cement, addition of hydrated lime by 1.5% to the weight of cement gives improvement in the rate of strength gain. S-type hydrated lime was used as activator for pozzolanic reaction to improve the strength gain in copper slag admixed concrete.

• The maximum compressive, split tensile strength was achieved at 15% (C15) replacement to the weight of cement. There is an increase of compressive strength was achieved around 15.13% compared to control mixes. But, this is 26% lower than S40 specimens. Similarly, for split tensile strength test, the strength was increased to 15.23% for C15 specimens compared to control mixes, whereas this is 10% lower than S40 specimens.

• It was observed that, the copper slag replacement for sand is more effective than cement.

• For cement replacement, ultimate load carrying capacity of copper slag admixed RCC beams has increased to 25% with that of control specimens.

• The addition of copper slag in RCC long columns results in an increase of ultimate buckling load for the optimum percentage of 15 with sand.

• There is an increase of 14.47% of compressive strength in combination mixes (CMB) compared to control mix. The compressive strength improvement is slightly lesser than S40 and C15 specimens but greater than C05 and C10 specimens.
• There is an increase of 5.47% in split tensile strength for CMB mixes compared to control (CC) specimens. This value is 20% lower than S40 mixes and 10% lower than S15 specimens.

• Flexural and buckling behaviors of CMB specimens are greatly increased compared to control mixes. The stiffness value and deflection ductility value of CMB specimens was more than control mixes and hence it shows its ductile behavior. Ultimate strength of concrete and RCC beams were increased when copper slag replaced for combination specimens.

• For higher replacement of copper slag in cement (greater than 20%) and sand, (greater than 50%) the compressive and split tensile strength decreases due to an increase of free water content in the mix.

• The average pulse velocity of S20, S40 and S60 (sand replaced specimens) concrete increased to 4.55%, 10.82%, 3.15% than that of control concrete. This implies that the quality and compressive strength of copper slag admixed specimens was excellent than control specimens. The average pulse velocity of C05 & C15 (cement replaced specimens) concrete increased to 5.74% and 6.31% with that of control specimens.

• It was found that all the systems are showing high negative potentials than (-270 mV) Vs SCE indicating the active condition of the rebar. Both control and copper slag concrete showed very high negative potential of more than 250 mV initially at 7 – 10 days. This shows the active condition of rebars. After 15 days the values reduced simultaneously for
increasing number of days due to formation of protective rust coating over rods.

- As per ASTM C1202, the value obtained from Rapid chloride penetration test, copper slag admixed concrete is graded under the category “very low”. As such, it is indicating lesser permeability of slag admixture concrete. The important observation is that addition of slag definitely reduces the pores of concrete and makes the concrete impermeable.

- From acid resistance test, it was observed that the concrete containing copper slag was found to be low resistant to the H\textsubscript{2}SO\textsubscript{4} solution than the control concrete.

- The addition of copper slag for the replacement of sand shows higher resistance against Sulphate attack whereas addition of copper slag for the replacement of cement gives lower resistance.

- Accelerated corrosion test reveals that the corrosion rate of copper slag admixed uncoated rebar is somewhat higher when compared to control specimens. But when the rebar is coated with zinc phosphate paint the corrosion rate had become zero.

- X-ray diffraction results indicated the pozzolanic behavior of copper slag admixed concrete increases when hydrated lime is used as an activator for cement replaced specimens.

- From shake table test, it is observed that the acceleration due to force frequency is lower in copper slag backfill, compared to sand, even at higher base excitation.
Displacement test results revealed that the displacement of retaining wall greatly reduced when copper slag used as backfill material. When copper slag content increases in backfill, then the displacement decreases.

The maximum displacement of CS100 was obtained as 1.13mm whereas for S100, the maximum displacement was 2.25mm. Therefore from this result it can be concluded that copper slag is reduced the displacement of retaining wall when used as backfill material.

Eventhough copper slag replaced specimens had higher densities, earth pressure due to seismic vibrations are reduced due to its higher shear strength and angle of internal frictions.

When copper slag replaced with sand, the total lateral earth pressures are greatly reduced. The peak earth pressure was obtained for S100 replacement was 0.041kN/m whereas for CS100, it was reduced to 0.027kN/m. Total active earth pressure on retaining walls are greatly reduced to 34.15% compared to control sand.

Seismic shake table test results shows that the lateral earth pressure acting on retaining wall is reduced when copper slag used as backfill material. Eventhough copper slag has higher density than sand , because of its higher shear strength and angle of internal friction, the seismic lateral earth pressure is greatly reduced.

From these results, it can be concluded that copper slag is a good backfill material than sand and it can be used as backfill in retaining walls.
7.3 SCOPE FOR FUTURE WORKS

- This research was intended to examine the influence of copper slag additions in concrete and RCC elements for M20 mixes. The same word can be extended to higher grades of concrete mixes with varying water/cement ratio.

- Copper slag can be effectively replaced in making bricks, hollow blocks and pavement blocks.

- Since copper slag has higher shear strength value it can be used for soil stabilization.

- Copper slag can be replaced along with fly ash, silica fume and granulated blast furnace slag in concrete and RCC members which can be tested for mechanical performances.