CHAPTER 5

CONCLUSIONS

The following conclusions can be drawn from this investigation:

- For each 10% replacement of PPC with LP and RHA, there was an increase in compressive strength by about 12% which was not seen in OPC with 10% RHA and 10% LP. There was a drop in the compressive strength values beyond each 15% replacement of RHA and LP. Also there was a drop in compressive strength when unequal percentages of RHA and LP were added. Therefore, blending of RHA and LP were done in equal percentages for split tensile, flexure and durability tests.

- The quaternary system involving replacement of PPC with 10% LP and 10% RHA (PRL10) resulted in 40% more split tensile strength, 5% more flexural strength and 15% more bond strength of concrete than the control specimen, performing better than the ternary mixes. Therefore, the further durability tests were confined to PPC with replacement of LP and RHA.

- The water absorption results indicated that quaternary systems reduced the water absorption by about 15%, when compared to the control system.

- RCPT test results show that, when compared to the control system (PPC), all the quaternary blended concrete specimens showed lesser chloride ion penetrability values of 850 Coulombs at the end of 60 days.
For PRL10, the chloride diffusion coefficient decreased by 60% and 70% for 28 days and 60 days curing, respectively.

The Impressed Voltage test results also showed that PRL10 showed lesser anodic current values. The reduction in anodic current is by 50% for PRL10 compared to the PPC system.

Anodic Polarization studies revealed that for PRL5, PRL10, PRL15 and PRL20, the current flow reduced by 3.23, 4.3, 9.8 and 5.5 times lower than the PPC system, which indicates the pore refinement and better performance of RHA system.

LPR confirmed that the resistance values were found to increase with the increase in percentage of replacement of LP and RHA.

The corrosion rate obtained from AC Impedance measurements show decrease in current flow by about 20% with increase in percentage of replacement.

OCP measurements taken after 120 days of curing clearly showed that the quaternary systems PRL5 and PRL10 have less negative potential than control system.

In no case was the pH less than 11.3 in all the mix systems.

From XRD studies it was identified that, the carbonation of lime mortar took place beyond 10% replacement of RHA and LP which caused magnesium silicate formation.

From EDAX/SEM results, it was found that PPC contains 11.61% of Calcium, whereas LP and RHA replaced systems showed 6.71%, 11.87%, 23.35% and 42.13% of Calcium for PRL5, PRL10, PRL15 and PRL20, respectively. In addition PPC contains 23.54% of silica, wherein LP and RHA replaced systems showed 28.44%, 28.46%, 18.28% and 5.61% of silica PRL5, PRL10, PRL15 and PRL20, respectively.
• In case of quaternary blending, there was an increase in compressive, split tensile and flexural strength for cement with 20% fly ash, 10% of LP and 10% of RHA (PRL10), making it perform better than all other systems which was confirmed by the durability tests and microstructural studies.

5.1 RECOMMENDATIONS

As expected, for ternary blending of OPC, LP and RHA, the increase is significant upto 5% replacement (ORL5) both in compression and split tension and for 10% replacement (ORL10), only split tensile strength increases and compressive strength decreases. It is seen that there is an increase in compressive and split tensile strength for quaternary blending of PPC with 10% of LP and 10% of RHA (PRL10). The increase in strength is due to the consumption of LP to form denser CSH gel in the early stages. Then the pozzolanic action of RHA results in formation of further CSH gel. PRL10 also gives higher flexural strength compared to the other mix systems. Beyond 10% LP and RHA replacements (PRL15 and PRL20), there is a reduction in strength observed due to the delayed formation of CSH gel and leaching of excess lime. Therefore, based on strength criteria, the tolerable limit of replacement is 10% of LP and RHA with PPC (PRL10).

The durability tests are also on par with the strength tests. The RCPT test results showed that, addition of LP and RHA considerably reduced the charge passed through the concrete samples, like the diffusion coefficient data confirmed the better performance of PRL10. The impressed voltage test results also showed that PRL10 showed lesser anodic current values, which was confirmed by the anodic polarization results, where the quaternary systems have very low electrical conductivity compared to control systems. The microstructural studies including SEM/EDAX, XRD and TG/DTA also ascertained the above test results.
5.2 SUGGESTIONS

The utilization of SCMs in the construction industry has increased tremendously. There is a lot of potential for usage of fly ash, RHA and LP in concrete. However, the characterization of blending quaternary cement is not much established due to lack of systematic study and limited availability of data. The following suggestions are made for exploring effective utilization of quaternary blended cement in construction industry:

- The quaternary blended cement performs well in strength and durability factors, which is evidenced in the microstructure also.
- The addition of various types of fibres in the quaternary mix is expected to increase the tensile and flexural strength of the specimens. The study has a wide scope for future investigation.
- Further investigations have to be carried out regarding cracking, creep, temperature development and deformation.
- The use of the SCMs in road works and bridge approaches could be investigated further, as it has a high potential due to huge consumption.
- Furthermore, an investigation on the pore structure of the quaternary mix, other properties that affect durability such as gas permeability, freeze-thaw resistance, etc. and a study correlating the ponding tests with RCPT results for the quaternary mix may be another avenue to explore.