Chapter 9

Conclusion

9.1 General

Summary of findings of the studies discussed in the chapters 3 to 8 and recommendations for further research is included in this chapter.

9.1.1 Superplasticizer- PPC compatibility studies

Compatible combination of cement superplasticizer was selected based on the saturation dosage of superplasticizer in the initial stage and at 30 minutes. Among all superplasticizer used, LS based superplasticizer was not compatible with any cement. Loss of workability is found to be less for PCE based superplasticizer. Lower saturation dosage is obtained for mix made with cement of low alumina content. It is also observed that slump loss rate reduces for mixes containing cement of higher sulphate content. Cement with less loss ignition is more compatible to all superplasticizer than that with high loss of ignition.

9.1.2 Superplasticizer dosage optimization in concrete

Based on the observations of workability test and compression test conducted on concrete, it is concluded that saturation dosage of superplasticizer in concrete is higher than that of mortar of same cement to sand proportion. Compressive strength of superplasticized concrete was higher than that of control specimen containing no superplasticizer. A marginally lower strength is observed in concrete (with and without SP) made with cement having lower alumina content.

9.1.3 Rheological studies on cement paste

Based on the observations of rheological test conducted at three different test temperatures (15°C, 27°C, 35°C) on superplasticized cement paste made with PPC and OPC with different fly ash replacement levels, it is concluded that the yield stress values and plastic viscosity values decreases with every increase in SP dosage until saturation dosage of SP.
Lowest yield stress and plastic viscosity for all the mixes were at the respective saturation dosage. The yield stress and plastic viscosity of cement pastes increased with the increase of temperature and fly ash content. The rate of increase is steeper at higher temperature due to acceleration of cement hydration reactions. At higher dosage of SP, variation of yield stress values with temperature is less when compared to the variation at lower SP dosages. Lowest yield stress and plastic viscosity is observed (especially at higher temperature) by cement paste made with cement of lower alumina (Al$_2$O$_3$) content.

There is no noticeable change in the saturation dosages of SP with difference in test temperatures. For all the test temperatures PCE based superplasticizer showed lowest yield stress and plastic viscosity.

9.1.4 Influence of SP- PPC Combination on self compacting concrete (SCC)

SCC mixes were tested for fresh and hardened stage properties. Those mixes which satisfy the rheological tests were only considered in this study. But in some mixes, even though they satisfy the rheological properties there is considerable reduction in the compressive strength. This may be due to the air entrainment with the addition of superplasticizer. But mixes with PCE based superplasticizer showed good slump flow value and hardened stage properties.

9.1.5 Modeling the properties of cement paste and SCC

- Paste flow behaviour (marsh cone flow time and mini slump spread diameter) and rheological behaviour (yield stress and plastic viscosity) of cement paste and fresh (slump flow, J-Ring, V-funnel) and hardened stage properties (compressive strength and split tensile strength) of SCC were predicted using random kitchen sink algorithm with the application of regularised least square algorithm. Prediction ability of the model was checked by calculating mean absolute error (MAE) and root mean square error (RMSE) of the predicted data. RMSE value of the predicted marsh cone flow time, mini slump spread diameter, yield stress and plastic viscosity cement paste are 0.039, 0.0213, 0.04 and 0.02 and their MAE values are 0.035, 0.0173, 0.03 and 0.01 respectively.
• RMSE values of the predicted slump flow, J-Ring, V-funnel, compressive strength and split tensile strength of the SCC mixes are 0.013, 0.038, 0.049, 0.046 and 0.029 respectively and their MAE values are 0.010, 0.029, 0.032, 0.036 and 0.022 respectively.

• Prediction error value calculated for flow behaviour and rheological behaviour of paste and fresh stage and hardened stage properties of the SCC are less than 0.05. Hence this model could predict these properties satisfactorily. There is potential to improve the model subsequently by incorporating the effect of the change in mixing methods, test set up, placing methods etc in the training data. Such an improved model generated with an extensive data base will be useful for industries to limit the number of trials and thus minimize wastage of materials and labour.

9.1.6 Strength and durability aspects of varying SP binder combination

From the strength (compressive and split tensile strength) and durability (sulphate attack, acid attack, RCPT, sorptivity and rate of absorption) study conducted on mortar and concrete mix containing PPC and OPC with different percentages fly ash (15, 25 and 35), following conclusions are derived.

• 28th day compressive and split strength of the concrete specimen decreases with increase in fly ash replacement and increase with superplasticizer addition. But 90th day compressive strength increases with increase in fly ash content. From micro structural analysis, it is observed that pore size of the superplasticized mixes are in the range of 100 to 1000 microns. Decrease in air void size is observed with increase in fly ash percentage. More interconnected pores are present in mixes containing LS based superplasticizer than mixes containing PCE based superplasticizer.

• Sorptivity values of the concrete (without superplasticizer) reduces with increase in fly ash content. At zero percentage fly ash level, sorptivity value of all OPC mixes containing superplasticizer are less than that of control mix without superplasticizer.

• There is no significant difference in percentage reduction in strength due to acid attack for mixes containing different percentage fly ash. For mixes
containing PCE based superplasticizer, the percentage reduction in strength is very less at higher percentage level of fly ash. But in concrete mixes containing LS, SMF and SNF based superplasticizer, percentage reduction in strength is more in fly ash replaced concrete than that of control mix without fly ash. Least reduction in strength is observed for PCE based concrete mix with 35% fly ash replacement.

- Fly ash concrete and superplasticized concrete showed better chloride resistance than the control concrete specimens. The PCE based superplasticized mixes shows a reduction in charge passed at higher fly ash replacement percentage. The LS based superplasticized mixes shows a moderate range RCPT value throughout with all fly ash replacement. In SMF based superplasticized concrete mixes, there is no much pattern of variation. For varying fly ash replacement percentage, a low RCPT value is shown by the SNF based superplasticized concrete mixes.

- There is increase in sulphate resistance for mixes with fly ash replacement percentage and with the addition of superplasticizer. Highest resistance to sulphate is observed for mixes containing PCE based superplasticizer. Percentage reduction in strength due to acid attack decreases with increase in fly ash content and also with the addition of superplasticizer (for mixes containing no fly ash). Effectiveness of PCE based superplasticizer in reducing the compressive strength loss is mainly visible at higher fly ash replacement levels; but for LS based SP its effectiveness is reduced at higher replacement percentage.

- Improvement in durability characteristics is observed for the mixes containing commercially available PPC than that containing site blended PPC (ie OPC+25% FA).

9.2 Recommendation for further research

Continued research on the following aspects will be useful to have deeper understanding in this area of research.

- Effect of variation of water cement ratio, mineralogical aspect of cement, curing temperature, mixing sequence etc on the fresh stage properties of superplasticized cement matrix.
• Rate of hydration and heat generated during hydration of superplasticized cement matrix.

• Rheological studies with different experimental set up, different loading pattern, different pre-shearing rate and using different flow model (to determine the rheological parameter).

• Improvement in RKS model for predicting the fresh and hardened properties of SCC by incorporating the effect of change in mixing methods, curing methods, placing methods etc in the training data.

• Extended durability study including plastic shrinkage, drying shrinkage, alkali silica reaction test etc.