Chapter 7   Conclusions

7.1 Summary: The general approach of all the existing methods of concrete mix design is, to identify a starting set of mix proportions following the codal guidelines, based on paste to aggregate approach and making adjustment in the proportions after every trial mixes until desired mix requirement parameters are satisfied.

7.2 Conclusions: The conclusions of research work are as mentioned here;

1] A computer program is developed using spreadsheet application for design of concrete mixes of different grades based on Indian Standard Institute (ISI) method, American Concrete Institute (ACI) method, and Department of Environmental Engineering (DOE) method. The program follows the standard recommended guidelines of concrete mix design, which is provided in the set of tables, graphs and empirical relations given in the above three methods of concrete mix design.

2] After comparative studies, the major differences amongst different methods of concrete mix design were examined. In order to compare these three methods, calculation processes are briefly summarized, for design of M20, M30, and M40 grades of concrete. Variations amongst the process, parametric comparison and research scope to establish the different relation among the various parameters of concrete mix design are established.

3] The five layers fuzzy inference system and artificial neural network were developed to estimate quantity of constituents of concrete based on Indian Standard Institute (ISI) method, American Concrete Institute (ACI) method, and Department of Environmental Engineering (DOE) method of concrete mix design. The results obtained from five layers fuzzy inference system (FIS) and artificial neural network (ANN) are evaluated and compared with conventional method of concrete mix design. The results show that FIS and ANN have strong potential for estimating the ingredients of concrete to meet the design requirements with available materials specifications.

4] The maximum size, shape and particle size distribution of aggregates are significantly influence the workability, durability, and strength behaviors of concrete mixtures. The present work finds the importance of optimal packing factor to meet required properties of the concrete. The voids are filled with the cement paste composed to meet requirements of strength and durability.

The voids between the aggregate particles are indicates the amount of cement paste require to fill the space between the aggregate to produce concrete of desired workability. A higher packing density indicates a smaller voids ratio and thus, a smaller amount of cement paste is needed.
A new method of concrete mix design developed based on aggregate to paste approach instead of paste to aggregate, with minimum voids, water, cement and maximum packing density.

The method takes into account the effect of grading of aggregates on various important properties of concrete to design concrete with special properties of workability, durability and strength significance.

The packing of aggregate combinations of different particle size is main controlling factor for the workability of fresh concrete and it depends upon the fluidity of the paste and the optimum aggregate combination based on the least volume of voids.

The concept of optimization has been applied to proportion a concrete mix, satisfying the specific site requirements of workability, durability and the compressive strength of concrete in the hardened state. The decision variables in the proposed optimization model are the quantity of concrete ingredients, cement, fine, coarse aggregates and water. The constraints formulated involve:

a. The specified limits of slump for the acceptable range of workability.
b. Compressive strength of concrete is mainly depends on the water-cement ratio and aggregate grading.
c. Durability specified minimum water cement ratio and minimum cement content.
d. Criteria intended to proportion aggregates to yield a combined aggregate satisfying grading limits.

It is observed that the new method provides minimum water, cement, water cement ratio and density for the same mix conditions. Hence it is more practical and economical method to adopt.

The concept of live concrete is introduced with new theory of concrete mix based on aggregate to paste philosophy.

The Optimum mix design depends, to a large extent, on the density value and grain size distribution of the ingredients. The proposed theory provided the optimum solution for given problems. The new mix satisfied the multi-objective functions set at the start of mix design stipulations, taking into account the materials specifications constraints and their complex relations. The expert knowledge system provided an algorithm that optimized the proportions of concrete ingredients based on particle size distributions and mix design requirements.

The work presented the result of a new mix design developed for low to high strength concrete ranging from M20 to M60 grades of concrete. It involved the process of experimentally determining the most suitable concrete mixes in order to
achieve maximum strength, durability, workability, and durability with optimum use of the available material resources.

The new method proposed here took review of a concrete mix design, which should focus on the following important issues:

- Does the mix meet the performance requirements of the specifications with respect to the strength and other characteristics such as durability, workability, and density?
- Is the historical or trial batch test data adequate to justify the specific site condition mix requirements?
- Do the materials being used comply with the project requirements as evidenced by test results, certifications, and standard guidelines?

The expert system proposed here not only provides a single optimum solution, but various optimum solutions, which are more realistic for actual use in the field.

The new theory proposed here will be act as a useful mix design aid for the selection of accurate quantity and quality of concrete constituents for specific design stipulations, specifications, and provide information points of reference and checking to acceptable design practices.

7.3 **Recommendations for further research:** The further research work may be carried out in the area of concrete mix design and here highlighted some of the recommendations;

- Gentic algorithm based soft computing tools may be used to design the concrete mix.
- Linear and non-linear programming based multi-objective mathematical modeling can be used.
- Monograms of concrete mix design may be developed.