CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

The failure of RC beams due to flexure is distinctly different from that of shear. The apparent reason for such difference is attributed to the geometric proportions and the shear span-to-depth ratio. Further, brittleness of RC members could be due to material and size. The brittle failures are encountered in large size RC members where the failure stress tends to decrease with increase in the size or depth of the beam. This is well-known phenomenon called the size effect in reinforced concrete members. The ignorance of the effect of size in the design of RC members results in variable margin of safety with respect to the size. Serious efforts made by several researchers resulted in the development of models for predicting the shear strength of RC members. With the use of high strength and high performance concretes, the design provisions with change in the material characteristics need change. The role of fracture mechanics in resolving several problems in RC beams by emphasizing the size effect law has been dealt with. The significance of the ductility and its quantification has been enumerated. The problem of RC beams in shear has not yet been resolved completely or there is no single unified expression to predict the shear strength of all types of beam (deep, short and slender).
From various analytical and experimental studies, the following conclusions can be drawn

1. The parametric study on the variation of shear strength of RC beams without web reinforcement has been made, and the results of this study have been compared with the code provisions and other expressions proposed by researchers.

2. Further, from the large set of test data, expressions for predicting the ultimate shear strength and diagonal cracking strength have been developed to apply for all types of beams. The prediction from the expression on the ultimate strength has been observed to be better correlated with experimental results.

3. An expression for diagonal cracking strength has also been developed showing nonnegligible size effect. But the size effect on the ultimate strength is more predominant than that on diagonal cracking strength.

4. The provisions of codes of practice without accounting for the size effect on large size HSC beams at low percentage of longitudinal reinforcement exceeds the observed strength. Hence, the size effect in design expressions for obtaining uniform safety margins and to achieve economy in the design has been emphasized. The expressions proposed have been proved to be useful in predicting the shear strength of RC beams without web reinforcement.
5. The modes of failure in RC deep beams are found to be influenced by the beam depth and the percentage of shear reinforcement. As the depth of beam and quantity of web reinforcement increase the failure mode changes from diagonal-tension to shear-compression.

6. Deep beams exhibited significant reserve shear strength measured as the ratio of ultimate shear strength to diagonal cracking strength, $V_u/V_{cr}$. Beyond diagonal cracking; small size beams exhibited high reserve strength compared with the large size beams. The small size beams exhibited high ductility showing that the large size beams should be designed with large quantity of shear reinforcement.

7. As the depth increases the shear strength of the beam decreases due to change of the mode of cracking as well as the quantity of energy dissipation. The increase of percentage shear reinforcement increases the ultimate shear strength of beams.

8. As the depth of the beams increases the crack width also increases. However, with increase of the quantity of shear reinforcement the crack width decreases. Despite brittle failures, deep beams showed better ductility with increase in the shear reinforcement.

9. The shear ductility of deep beams increases as the shear reinforcement increases. The increase in the ductility is significant with the shear reinforcement index greater than 0.6.
10. The ACI 318 shear strength provisions on deep beams are found to be conservative and the size effect is not recognized.

11. There appears a nonnegligible size effect on the diagonal cracking strength of RC deep beams, in which, as the beam depth increases from 600mm to 1200mm, the diagonal cracking strength has been found to decrease. In small size beams, the crack distribution is uniform with better ductility. About 20-25% decrease in the diagonal cracking strength was observed as the beam depth increased from 600mm to 1200mm.

12. As the beam depth is increased, RC deep beams exhibited brittle failure forming only one major diagonal crack. As the quantity of the horizontal shear reinforcement increased, the shear strength and the ductility of the beams increased.

13. The uniform distribution of the horizontal shear reinforcement only over the middle third of the beam depth increases the shear strength with significant ductility.

14. Very strong size effect has been observed in RC deep beams on the ultimate shear strength. About 35-55% decrease in the shear strength was observed when the beam depth was increased from 300mm to 1200mm.
8.2. Recommendations for Future Studies

a. RC deep beams with different types of shear reinforcement including anchored or headed bars along with high strength concrete incorporated with steel fibers in the shear span can be studied.

b. Analytical studies using refined strut and tie models can be planned.

c. Several new building 3D panel often used in building construction as walls and slab panels behaving deep beams due to their geometric proportions can be another study to be thought of.

d. Size effect in inclined struts of deep beams, where the ultimate is due to the failure of concrete, the contribution of web reinforcement in resisting the shear can be expressed in terms of minor concrete strut by conducting experiments.