# 13. CONCLUSION AND SUMMARY

1) The aim of Research study is to evaluate size effect parameter in RCC and Fibrous Moderate deep beam without web reinforcement. Loading was applied gradually in predefine fixed interval of load. Observations were made for Deflection, First cracking load, Ultimate load, Crack initiation, Crack pattern, and Modes of failure. Deflections at various positions were recorded using dial gauges. Result of deflection, first crack load, and Ultimate load were tabulated. The graphs were plotted for comparison. The crack pattern for various types of beam marked on face of beam photograph.

2) Ratio of Experimental results to the Theoretical results (Wexp / W theo) (1P) verses Depth of beam is plotted for various researchers such as P. J. ROBINS (1971), APPA RAO (2012), TANG AND CHENG (2006). Table 6-2 reveals that the Ratio is ranging between 0.57 to 0.96 for P J Robins formula, Range from 0.68 to 1.22 for Tang and Cheng formula and 0.80 to 1.53 for Appa Rao Formula for various beams depth. So it necessary to incorporate the Size Effect parameter in Mr P J Robins formula to obtain most Realistic value. Ratio observed in not close to unity.

3) It is observed that the ratio of experimental results to the theoretical results ($W_{exp}$ / $W_{theo}$)(2P) verses Depth of beam is plotted for various researchers such as P. J. ROBINS (1971),APPA RAO(2012), TANG AND CHENG (2006). Table 6-9 result shows that the ratio is ranging between 0.53 to 0.94 for P J Robins formula, Range of 0.64 to 1.17 for Tang and Cheng formula and 0.82 to 1.51 for Appa Rao formula for various beams depth.

4) It is observed that the Experimental results of the present work are compared with theoretical results for RCC beams. Theoretical results are calculated using P. J. ROBINS formula (1971) (Before the incorporation of size effect factor). Table 6-10 results calculated using Original Mr. P J ROBINS formula, the 71 % of experimental results are showing $\pm$59 % of variation compare to actual experimental results. This result shows that

Mr P J Robins Shear strength formula modify by incorporating the size effect parameter.

5) It is observed that the Experimental results of the present work are compared with the existing formula of size effect proposed by various researchers as APPA RAO (2012) and TANG AND CHENG (2006). In Table 6-10 shows that the 85% of experimental results showing $\pm$32% of variation in case of APPA RAO (2012) formula, and 71% of experimental results of tested specimen showing $\pm$30% of variation in case of TANG AND CHENG (2006) formula.

6) It reveals from the Table 6-11 that The Ultimate load carrying capacity of Fibrous beam is increased by 17.54 % compared to RCC Beams. The First Reading is discarded due to slipping of load at supports it shows the higher percentage.

7) It revels from the table 6-13 and 6-14 that The Nominal shear strength reduces approximately 29.85 % in RCC Moderate deep Beams and 48.15 % in Fibrous Moderate Deep Beams when Size of beam increases from 150 mm to 600 mm. As the depth of beam increases the Nominal shear stress decreases. Size effect parameter introduced in Moderate Deep beam.

8) A Modified P. J. ROBINS formula is proposed by incorporating a BAZANT Size effect factor in P. J. ROBINS (1971) formula using the Regression Analysis. The experimental results and theoretical Modified equation results found almost in close range by using Modified P J Robins' shear strength equation.

9) The original equation of Mr. P J ROBINS gives Uniform Nominal shear stress in all beams. It is prime requirement to incorporate the size effect parameter in P J ROBINS formula. The experimental Nominal shear stress decreases as the member depth increases, so the BAZANT size effect parameter incorporated into Mr. P J ROBINS formula. From Graph 6-13,14,15,16,17 reveals that by using Modified P J ROBINS formula, the Nominal shear stress is very close to experimental Nominal Shear Stress.

10) Size effect factor given by $((1+d/\lambda o\ da)^{(-0.5)})$ Mr. P.J. ROBINS (1971) formula Modified by incorporating size effect factor . $\lambda o=13.68$ constant was found out by using Linear Regression analysis. From the Modified Mr. P J ROBINS formula Ratio of Experimental result to the Theoretical results were calculated. The graphs were plotted (Wexp/Wtheo) v/s Beam Depth. The result shows that ratio is ranging from 0.93 to 1.18 (RCC 1P Table 6-16) , 0.94 to 1.10 (RCC+ Fiber 1P Table 6-17) , 0.86 to 1.31 (RCC 2P Table 6-18) and 0.97 to 1.17 (RCC+ Fiber 2P Table 6-19) in good range. Ratio obtain close to unity.

11) It reveals from Table 6-20,21,22,23 that Experimental results of the present research work are compare with Modified Mr. P J ROBINS formula and the results show that $\pm$15% of variation in case of RCC beams and $\pm$ 10% of variation in case of Fibrous beams. This shows importance of size effect parameter in Shear Strength Equation. Fibrous beam results close to Modified equation.

12) Graphs (7-18 to 7-25) shows that the Ultimate Shear Stress decreases with the increase in beam depth, which indicate incorporate of the size effect parameter in present Shear Strength Equation. The shear stress calculated by Original S. N. Patel and S. K. Damle's Equation is not decrease with increase in beam depth. It means size effect parameter required to be incorporate in original equation. Nature of graph for Modified S. N. Patel and S.K. Damle's Equation is similar to nature of graph for Experimental results. While graph for Nehdi-Optimized Equation, Cheng and Tang Equation and Original Equation does not give good agreement with experimental results.

13) Size Effect parameter such as Shear span to depth ratio, Compressive strength of concrete for RCC beams and Volume of Fiber and Aspect ratio for PFRC and SFRC beams incorporate in Original Eurocode-02:2004 equation. Table 8-2 reveals that the Ratio of Experimental results to Modified Eurocode equation results in nearly Unity for RCC Beams, PFRC Beams and SFRC Beams.

14) It is observed from Table 8-3 that All data taken from Past thesis work. The Experimental results and Modified Eurocode equation results are almost similar while other researcher, code ACI 318:2008 [5], Zsutty and G. Apppa Rao and R Sudarshan[41] results not in close range with experimental results.

15) It reveals from Graph 8-7 that by Incorporating Size Effect parameter in Eurocode equation the Experimental results are almost consistent and within approximation almost in close range. The final values differ slightly with Modified Eurocode equation. Experimental results not close to G Appa Rao and R sudarsan , Zsutty and ACI -318 code.

16) Experimental results of the present work were compared with theoretical result of RCC and Fibrous beam series. Theoretical results are calculated using Canadian standard formula CSA A23.3-04[6]. It is observed that (Table 9-10) Theoretical results and experimental results were showing 84 to 89 % of variation. This result needs to Modify the Canadian standard formula by incorporating the size effect parameter.

17) Size Effect parameter such as Shear span to depth ratio (a/D), Longitudinal reinforcement ratio (ρ) and Effective length to overall depth ratio (le/D) incorporate in Canadian Structural Association code shear strength formula (CSA A23.3-04)[6]. It reveals from Table 9-5 that the ratio Experimental results and Theoretical original CSA equation provide value in very high range. Incorporating size effect parameter, the ratio of experimental results and Modified CSA equation is nearly unity. The Modified Canadian Structural Association formula CSA A23.3-04[6] results is convergent with the experimental results. It indicates Size effect parameter is vital parameter in shear strength formula given in CSA A23.3-04[6] code. ( Appendix V).

18) Experimental results of the present research work are compared with Modified CSA A23.3-04[6] formula and the results show that 4 to 20% variation in all the cases. For Fiber reinforced concrete series additional Fiber factor added to the Modified equation for better prediction of shear strength for better accuracy of the proposed equation. A greater number of

test results and experimental results were required to obtain best fit equation for predicting the shear strength of Moderate Deep Beam.

19) It reveals from the Table 9-10 that the Experimental load and Modified shear strength of CSA A23.3-04[6] code is almost in close range results. Other results such as G.Appa Rao , Modified IS:456 2000 , Original CSA and Modified Shear strength formula of CSA A23.3-04[6] code were not match with experimental results.

20) It reveals from the Table 9-9 that the ratio of Experimental load to theoretical load is nearly Unity, while other researcher's ratio is more than 1. (Table 9-11) Hence, Size effect parameter incorporate in original equation of CSA A23.3-04[6] code shear strength formula is more accurate which can estimate the applied load.

21) Size effect parameter such as Diameter of bar to Percentage of Reinforcement ($\Phi/\rho$), Effective length to overall depth ratio (Leff/D) for RCC Beams and Fiber Factor as Volume of Fiber and Aspect ratio are taken for PFRC and SFRC Beams. The size effect parameter incorporates in crack width formula given by Gergly and Lutz. By incorporating the size effect parameter, the actual Modified Gergly and Lutz formula shows exact trend which was obtained by experimental crack width results for Moderate Deep Beam.

22) A Modified Gergly and Lutz formula for prediction of maximum crack width is obtained from statistical analysis. It gives satisfactory results within ±15% range when compared with experimental results.

23) It can be concluded that bond between reinforcement and concrete plays a major role for deciding the crack width as the whole stress transfer mechanism depends on it. Bond strength depends on the diameter of bar and longitudinal reinforcement ratio.

24) It can be concluded that the Aspect ratio of fibers and amount of fibers greatly affect the cracking behavior of concrete. A Fiber factor considered as deductive term in main crack width prediction formula of reinforced concrete. Results of the equation well correlates with the experimental results of Fibrous concrete Beam.

25) It is observed that when crack pattern was compared between Normal concrete and Fibrous concrete, similar crack pattern was observed in experiments. Normal concrete shows cluster of micro cracks while fibers arrests that micro cracks and a distinct crack exist which is responsible for complete failure of a specimen.

26) The specimens remain in elastic stage when flexural crack occur. After Flexural crack occurrence the diagonal shear crack occurs. it widens quickly under increasing load. Sometimes the flexure crack and shear crack merge together and finally lead to beam failure.

**SUGGESTION**

1) To avoid honey combing in concrete proper mixing and compaction should be done.
2) To avoid unsymmetrical loading proper longitudinal and lateral leveling of beam should be done.
3) Throughout mixing of polypropylene fiber and steel fibers should be done for homogeneous concrete mix.

**FUTURE SCOPE OF WORK**

1) In this research work Size effect parameter taken as Compressive strength of concrete (fck), Diameter of bar to Percentage of Reinforcement (Φ/ρ), Shear span to depth ratio (a/d), Effective length to overall depth ratio (Le/D), Fiber aspect ratio (diameter/length), % of fiber reinforcement. In Future the other parameter taken such as Longitudinal reinforcement ratio (ρt), Shear reinforcement ratio (ρw) , Steel rebar arrangement ,Grade of steel (fy), Steel stress (fs) ,Strain in rebar (εs) ,Strain in concrete at level of reinforcement (εc) ,Concrete cover (Cc),Bond factor (bond between steel and concrete at level of reinforcement),Duration of load application, Modular ratio (m),Strain distribution factor, Modulus of Elasticity of steel (Es),Depth of neutral axis (xu),Maximum bar spacing (s).
2) Investigation further can be extended for Moderate Deep Beam for Hybrid Fibers with respect to volume of fiber used in concrete.
3) Effect of fibers in Prestress concrete Moderate Deep Beam can be studied in detail.

4) In Moderate Deep Beam change the a/d ratio and L/D ratio for future work.
5) Wide scope for Analysis of Shear deformation behavior of Moderate Deep Beam by FEM using linear and Non linear approach.
6) Investigation can be further extended by using higher grade of concrete.
7) Fiber Factor can be modified to find the shear strength of Moderate Deep Beams more precisely.
8) Effect of Fiber material properties on crack width can be investigated.
9) Change the SCM material instead of OPC in concrete. Effect of SCM (supplementary cementations material) on crack pattern and crack width for Moderate Deep Beam.
10) Use of DIC (Digital Image correlation) can provide exact width of crack along with the load increment.
11) Effect of Crack width and crack spacing in Moderate Deep beam and Deep Beam.