ANALYSIS OF CONTINUOUS BEAM STRENGTHENED BY CARBON FIBRE REINFORCED POLYMER (CFRP) USING ANSYS SOFTWARE

Nilesh A Ahire[1*], Dr. Bikram Prasad [2]

Abstract:
Structures made of reinforced concrete have a shorter service life every day. This is a result of the reinforced structural elements—beams, columns, walls, floors, etc.—degrading. Numerous circumstances, such as heavy loads, fires, earthquakes, mistakes in the design, chemical attacks, etc., might cause these components to be damaged. Retrofitting procedures can be used to strengthen these structural elements.
Retrofitting is already spreading like wildfire over the globe as many historically significant public and private structures get really old and weaken over time. One of the best ways to make an insufficient building safe against future earthquakes or other natural pressures is to retrofit it. Retrofitting is the process of incorporating new elements into existing constructions such as bridges, historic buildings, and so forth. A retrofitted building is less likely to sustain damage from seismic activity in the near future. It seeks to reinforce a structure in order to meet the demands of the current seismic design rules. Retrofit goes beyond simple repair or even rehabilitation in this regard. It involves modifying existing structures to increase their resistance to seismic action, ground motion, and soil collapse brought on by earthquakes or other natural disasters like tornadoes, cyclones, and winds with high velocity generated by thunderstorms, snowfall, hailstorms, etc. Structures gradually lose their strength over time, although some are crucial from a public and social perspective. Retrofitting extends the structure's overall strength, resistance, and longevity. RC beam retrofitted with various thermoplastic polymer composite sheets was subjected to a finite element study using the Ansys V20 programme. Utilizing Ansys software, RC beams with various thermoplastic sheets were modelled. The bottom, top, and both sides were composed of bonding. The findings of the comparison between the reinforced beam and the aforementioned retrofitted beam's performances were presented in this project.
The project's goals are to hand design a G+3 structure before using ANSYS SOFTWARE to model the external continuous beam. After modelling, we use ANSYS SOFTWARE to statically analyse this continuous beam, and then we compute the results by both mannual and software. We recognise that there is little difference between the results obtained from Case 1 (solved in Ansys) and the calculations performed manually. The beam without wrapping experienced the largest deviation, measuring 6.8mm, while the wrapped beam only saw a 1.02mm deflection under controlled conditions. The best results are obtained while wrapping on CFRP sheet with a 450 degree orientation. The maximum shear strength of a wrapped beam is 90.951 KN, while the maximum shear strength of a beam without wrapping is 68.071 KN. The greater the maximum shear force that the beam can withstand, the more durable the beam is. The maximum BMD provided by the wrapped beam is 62.1*106 KNm, whereas the unwrapped beam provides BMD of 36.3*106 KNm. The percentage decrease in the deflection between both the beams can be seen as 15%.

Keywords: CFRP, RC , retrofit , compressive strength, BMD, SFD

[1]Research Scholar, Department of Civil Engineering, Oriental University, Indore, Madhyapradesh.
[2]Assistant Professor, Department of Civil Engineering, Oriental University, Indore, Madhyapradesh.
***Corresponding Author:** Mr. Nilesh A Ahire
* Research Scholar, Department of Civil Engineering, Oriental University, Indore, Madhyapradesh.
DOI:

1. INTRODUCTION

Reinforced concrete structures often have to face modification and improvement of their performance during their service life. The main contributing factors are, change in their usage, new design standards, corrosion in steel caused by exposure to an environment and accidental events such as earthquakes. In such circumstances there are two possible solutions, replacement or retrofitting. Full structure replacement might have determinate disadvantages such as high costs for material and labour, a stronger environmental impact and inconvenience to public. One of several reasons that cause the collapse of a multi-story building or bridge structure is the failure of the supporting members to withstand the earthquake loading. The failure of these members is mostly due to the lack of shear-resisting capacity and insufficient ductility provided by little amount of transverse steel. It is well known that the ductility of a reinforced concrete plays a very important role in preventing such a failure. That is why the study on the ductility of a reinforced concrete has been developing in the last two decades in many countries worldwide. One of the effective ways to improve the ductility of a member is by introducing sufficient transverse steel as confining steel for concrete core in a column. This effort is primarily intended to delay the sudden collapse of a structure and force it further to fail in a ductile manner.

When possible, it is often better to repair or upgrade the structure by retrofitting. The development of strong epoxy has led to a technique which has great potential in the field of upgrading structures. Basically the technique involves gluing steel plates or fibre-reinforced `with the concrete and help to carry the loads. Fibre-reinforced polymer (FRP) systems have been used to strengthen and retrofit existing concrete structures around the world since the mid-1980s. The number of projects using FRP systems worldwide has increased, from a few 20 years ago to several thousand today. Structural elements strengthened with FRP systems include beams, slabs, columns, walls, joints/connections, etc. FRP systems have also been used to strengthen masonry, timber, steel, and cast-iron structures. The behaviour of FRP strengthened reinforced concrete (RC) members is more complex than unstrengthen RC members and therefore, a clear understanding of their behaviour under different types of loading is important. The initial development of FRP systems for the retrofit of concrete structures occurred in the 1980s in both Europe and Japan.

2. OBJECTIVES

1. To study the behavior of reinforced concrete structure.
2. To model beam in ANSYS Software
3. To statically analyze this beam in ANSYS Software

3.METHODOGY

Methodology is 'a contextual framework' for research, a coherent and logical scheme based on views, beliefs, and values that guides the choices researchers, or other users, make. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge such that the methodologies employed from differing disciplines vary depending on their historical development. This creates a continuum of methodologies that stretch across competing understandings of how knowledge and reality are best understood. This situates methodologies within overarching philosophies and approaches. Overall, a methodology does not set out to provide solutions therefore, not the same as a method. Instead, a methodology offers a theoretical perspective for understanding which method, set of methods, or best practices can be applied to the research question/questions at hand.

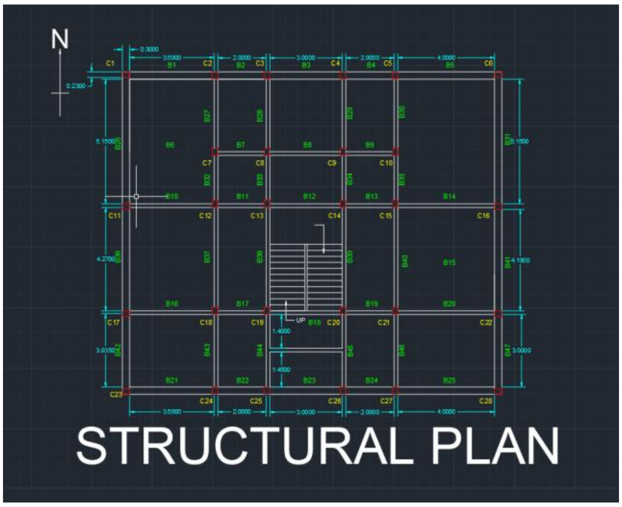

Figure 3.1Structural Plan of G+3 Builiding

DIMENSION OF BEAM

Beam Length 15880 mm depth, 266 mm and 230 mm

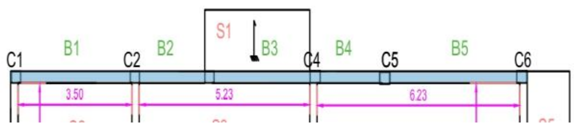

Figure 3.2 Dimension of selected Beam

PROPERTIES OF MATERIALS

Table 3.1 Properties of Materials.

Material	Descriptions	Specification
CFRP	Weave style	Hexcel woven (T-700)
	Areal weight of fabric (g/m^2)	98-670
	Standard width (mm)	1000
	Dry fabric thickness(mm)	0.35
	Tensile strength (Mpa)	3500
	Tensile modulus (Gpa)	228
	Elongation percentage (%)	4.761
Steel	Grade of steel (N/mm^2)	415
	Tensile Stress of Steel (MPa)	485
	Elongation of Steel (%)	20
Concrete	Grade of Concrete (MPa)	20
	Compressive Strenght (N/mm^2)	20
	Density (Kg/m^3)	2400
	Proportion (Ratio)	1:1.5:3
	Poission's Ratio	0.2
	Modular Ratio	13.33
Epoxy Resin (Sikadur C31)	Tensile Strength (MPa)	25
	Modulus of Elasticity (MPa)	5200
	Flexural Strenght (MPa)	6900
Epoxy Resin (Sikadur C300)	Tensile Strength (MPa)	45
	Modulus of Elasticity (MPa)	3500
	Flexural Strenght (MPa)	3000

Modelling of beam

A Continuous Beam with dimensions shown in Fig. 4 has been drawn in the present case. ANSYS V20 has been used to model the beam and the analysis part has also been conducted. The combination of loads (UDL) of 32.65 KN/m, 29.11 KN/m, 34.37 KN/m, 29.11 KN/m & 42.04 KN/m has been adopted to see the effect of the load on the Continuous Beam. The total deflection, SFD, BMD and Von-mises stress results have been shown.

4. RESULT & DISCUSSION

Finite Element Method (FEM) method has been used in order to obtain the analytical solution for continuous beam with/without CFRP. In ANSYS, model analysis is used to determine its deformation in deflection with CFRP materials. We found that the beam with CFRP wrap is more durable than normal beam. The results of analysis done in ANSYS is quite more appealing than manually done analysis. In ANSYS, color-coding is used for showing the nodes/elements under stresses. Analytical and FEM results are observed. Analytical predictions are validated with the experimental results taken from literature and a good match was found. Predicted and experimental results for overall deformation are compared for both the specimens

CASE- 1: Here, the beam shown is the beam without CFRP-

Model by using ANSYS Software-

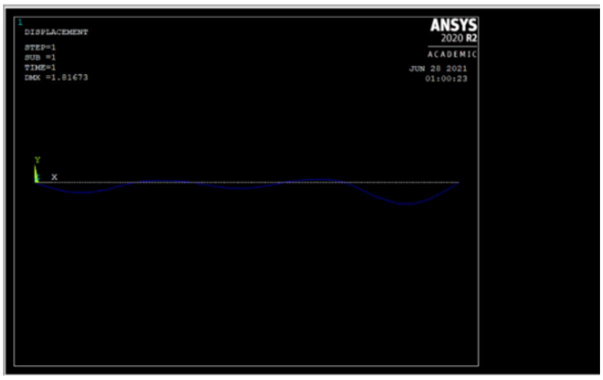

Figure 4.1 Deformed shape of our Continuous

Beam after applying loads.

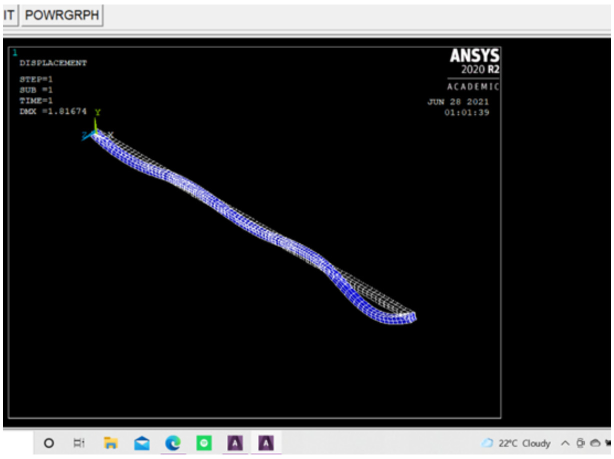

Figure 4.1 Isometric view of our deformed Continuous Beam.

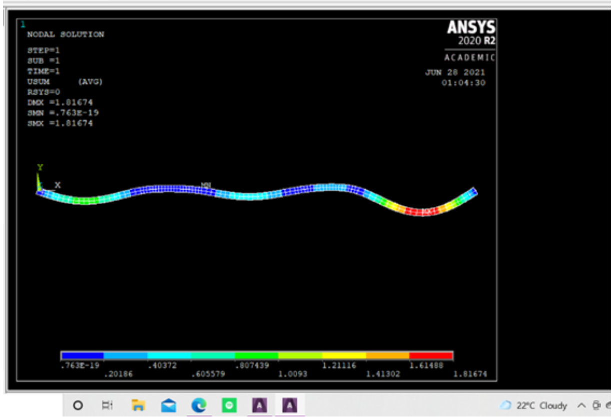

Figure 4.2 Total deformation of the Continuous Beam.

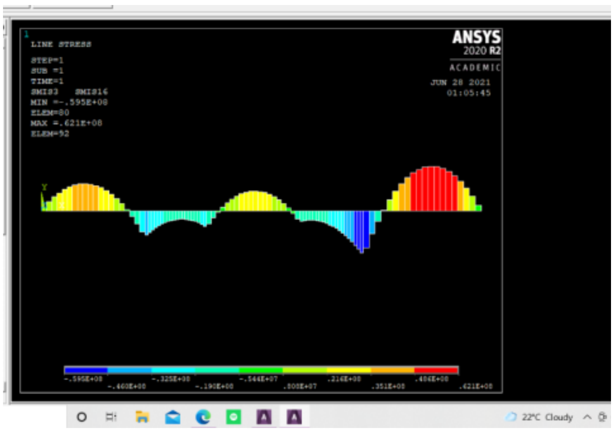

Figure 4.3 Bending Moment Diagram.

Figure 4.4 Shear Force Diagram.

CASE- 2: Here, the beam shown is bonded with the CFRP Composite material-

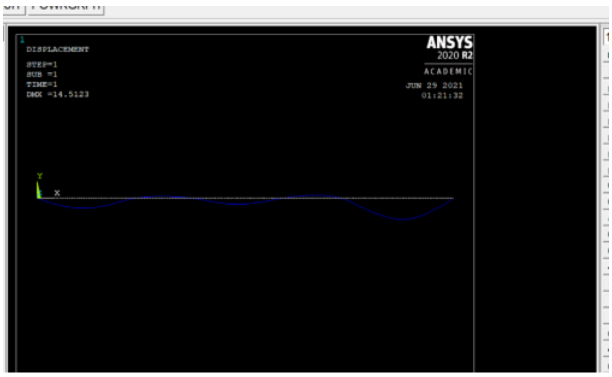

Figure 4.5 Deformation of continuous beam with CFRP.

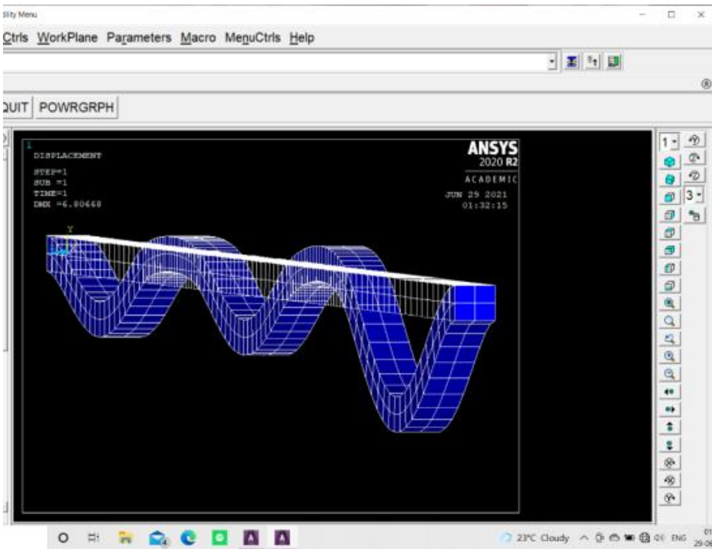

Figure 4.6 Deformed beam bonded by CFRP

under loads.

Figure 4.7 Bending Moment Diagram.

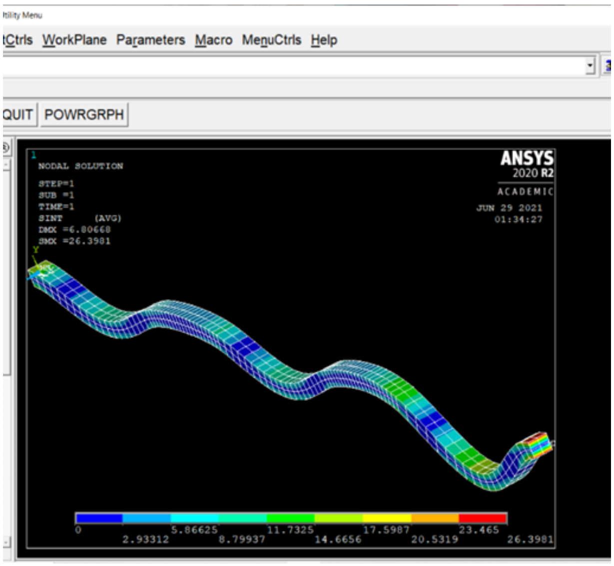

Figure 4.8 Stress Distribution.

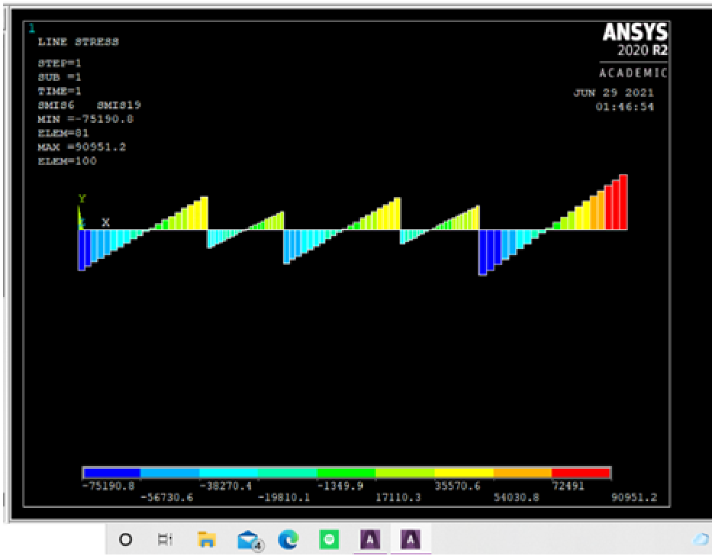

Figure 4.9 Shear Force Diagram.

A comparison can be seen in the following table with the total load (UDL) acting on Continuous Beam = 167.28 KN.

Table 4.1 Deformation and Stresses.

Type of Beam Solved	**Total Deformation (mm)**	**BMD (KNm)**	**SFD (KN)**
Continuous Beam Solved Manually (Without Wrapping)	6.35	$35.04*10^6$	66.77
Case-1# (Without Wrapping)	6.8	$36.3*10^6$	68.071
Case-2# (With Wrapping)	1.02	$62.1*10^6$	90.951

\# - Solved in Ansys Software.

5. Conclusion

From the study it is concluded that many existing structures that were built according to past design codes and standards are often found vulnerable to earthquake damage. Due to inadequate detailing, under estimated earthquake loads or material deterioration by time, the high cost of new construction and historical importance of older buildings has led building owners to renovate/retrofit the structures rather than replace the existing structures. In this, the Continuous Concrete Beam has been solved in the present problem. FEM (Finite Element Method) software i.e. ANSYS, help in solving the beam problem. The total deflection, SFD, BMD and Von-mises stress results have been plotted.

By studying, we came to the conclusion, that the statistical behaviour cannot be determined in manual analysis, but in Ansys the simulation of the member can be statistically analysed under any loading. The time required for solving the beam is minimized. In manually calculations there are many chances of error & so the Ansys can be used. Due to the complication of the problem, one may find difficult to design and solve the problem, but in Ansys it can be handled smoothly. In manual analysis the minute nodal displacement is same due to symmetry but in Ansys the nodal displacement may vary a little due to the support condition.

Following are the conclusions derived from the studies conducted as a part of this study:

- Some of the concrete elements such as beams may be deficient in Flexural and is in need of strengthening.
- The external wrapping with CFRP sheets can increase the flexural capacity of RC beams.
- CFRP is promising material for strengthening of beams under any loading condition.
- We came to the point that the calculation done manually and the model solved in Case-1 have nearly same values of deflection, i.e. 6.8mm. The major changes can be seen after the wrapping of CFRP sheets over the beam (Case-2).
- The maximum deflection was found in the beam without wrapping (Case-1) having the deflection of 6.8mm. And that to the beam with wrapping (Case-2) gives deflection of 1.02mm which can be in controlled condition.
- Wrapping on CFRP sheet with the orientation of 45^0 gives the best results.
- Maximum shear strength of the beam with wrapping (Case-2) is 90.951 KN. And that to of beam without wrapping (Case-1) is 68.071 KN. The maximum shear force taken by the beam, the more the sustainable the beam is.
- Maximum BMD offered by the Beam with wrapping (Case-2) is $62.1*10^6$ KNm, whereas, the without wrapping (Case-1) gives BMD of $36.3*10^6$ KNm.
- We can conclude that, ‘as we increase the elasticity of member it results the more durability of the member’.
- Percentage decrease in the deflection between Case-1 & Case-2 of the beams can be seen as 15%.

REFERENCES

1. ACI Committee 544. (2018). State-of-the-Art Report on Fiber Reinforced Concrete. American Concrete Institute (ACI).
2. Adil, A., & Arif, M. (2016). Performance Evaluation of Fiber Reinforced Concrete (FRC) under Different Curing Conditions. Construction and Building Materials, 114, 868-875.
3. Bencardino, F., Rizzuti, L., Spadea, G., & Swamy, R. N. (Eds.). (2017). Fiber Reinforced Concrete: Present Challenges and Future Opportunities. Springer.
4. Cai, Y., Yang, J., & Li, V. C. (2015). Recent Advances in Fiber Reinforced Concrete for Improved Durability. Construction and Building Materials, 84, 241-255.
5. Y. N. V. Sravanthi and Marabathina Maheswara Rao, (2019), “Finite Element Analysis of a Reinforced Concrete Beam by Retrofitting with Different Thermoplastic Polymer Composites using Ansys”, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 8 Issue 09.
6. M. K. Kumar, Md. Adil Pasha, Md. Mir Khan, CH. Nagarajun (2018), “Model Analysis of a Cracked Cantilever Beam using ANSYS WORKBENCH”, ISSN-2349-5162, JETIR, Volume 5, Issue 9.
7. Anjusree K. C., R. M. P James, (2019), “Analysis Of Shear And Deflection Behaviour Of CRC Beam Using ANSYS”, International Journal of Applied Engineering Research, ISSN 0973-4562, Volume 14, Number 12, (Special Issue).
8. Ibrahim G. Shaabana, Mohamed Said, (2018), “Finite element modelling of exterior beam-column joints strengthened by Ferro-cement under cyclic loading”, Case Studies in Construction Materials 8, 61–7862.

9. Pradeep Singh et.al (2016), "Finite Element Analysis of Reinforced Concrete Beam using ANSYS", ISSN (PRINT): 2393-8374, 2394-0697, Vol-3, ISSUE-1.
10. Mr Rajendra P. Deshpande and Dr Kiran B. Ladhane, (2015), "Analysis of RC Frame Strengthened by FRP Laminates using ANSYS Software", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 4 Issue 08.
11. Kandekar and Talikoti, (2019), "Strength and Durability Study of Aramid Fibres in Retrofitting of Reinforced Concrete Structure", Engineering Sciences, Volume 31, Issue 4, Pages 340-344.
12. Ahmed Sameer, Younus, & Ammar A. Abdul Rahman, (2013), "Evaluation of torsional capacity of square RC columns strengthened with CFRP using finite element modelling", American Journal of Civil Engineering; 1(3): 111-123.
13. Arindom Bora, Tejaswini M.L., Kiran S.M., (2018), "Finite Element Analysis of Different Types of FRP on Beam-Column Joint", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 7 Issue 05.
14. Santhakumar et al., (2007), "Behaviour of retrofitted reinforced concrete beams under combined bending and torsion: A numerical study", Electronic Journal of Structural Engineering.
15. P. Y. Ghodke, D. H. Tupe, G. R. Gandhe, (2017), "Modal Analysis Of Cracked Continuous Beam Using ANSYS", IRJET, ISSN: 2395-0056, Volume: 04 Issue: 02.
16. ANSYS Mechanical APDL Theory Reference, Release 15.0, 16.3, 18.0, 20.1, November 2013.
17. S. Bharathi, Mrs M. Nithya, (2017), "Experimental and Analytical Investigation on Beam-Column Joint Strengthening With GFRP Sheet", IJEDR, Volume 5, Issue 2, ISSN: 2321-9939.
18. Grama R. Bhashyam, (2002), "ANSYS Mechanical - A Powerful Linear & Nonlinear Simulation Tool", ANSYS Inc.
19. Seyed S. Mahini, Hamid R. Ronagh, (2009), "Numerical Modelling of FRP Strengthened RC Beam-Column Joints, Structural Engineering and Mechanics, Vol. 32.
20. Nagendra Prasad .N, Naresh kumar .Y, (2017), "Torsional Behaviour of Reinforced Concrete 'L' Beam", IJARBEST, Vol. 3, Special Issue 35.