IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 10, October 2015.

www.ijiset.com

ISSN 2348 – 7968

Study of Strength Development in Reinforced Concrete Beams Retrofitted by Different Types of Fiber Reinforced Polymers

Rosemol K George[1], Ashokkumar T[2] and Ananya John[1]

[1] Department of Civil Engineering, Indira Gandhi Institute of Engineering and Technology for women, Ernakulam, Kerala, India

[2] Department of Mechanical Engineering, Indira Gandhi Institute of Engineering and Technology for women, Ernakulam, Kerala, India

Abstract

In order to improve the performance of a Reinforced Cement Concrete (RCC) structure, it is better to repair or upgrade the structure by retrofitting. This study revealed the results of a nonlinear finite element analysis conducted on reinforced cement concrete beams strengthened with Glass Fiber Reinforced Polymer (GFRP) laminates, Carbon Fiber Reinforced Polymer (CFRP) laminates and Aramid Fiber Reinforced Polymer (AFRP) laminates. Five beams with different fiber length and orientation for each fiber retrofitted beams were cast and analyzed for the present study. All the beams were tested under four-point bending till failure. The results obtained through non liner Finite Element Method (FEM) analysis using ANSYS14.5 software can be used to study how different parameters affect retrofitted beam behavior and investigate how Externally Bounded Reinforcement (EBR) should be applied in order to obtain the maximum load carrying capacity**.**

Keywords: *Glass Fiber Reinforced Polymer, Carbon Fiber Reinforced Polymer, Aramid Fiber Reinforced Polymer, Finite element analysis***.**

1. Introduction

Reinforced concrete (RC) structures often have to face modification and improvement of their performance during their service life. In such circumstances there are two possible solutions: replacement or retrofitting. Full structural replacement might have determinate disadvantages such as high costs for material and labour, a stronger environmental impact and inconvenience due to interruption of the function of the structure, e.g. traffic problems. When possible, it is often better to repair or upgrade the structure by retrofitting in the last decade, the development of strong epoxy glue has led to the growth of externally bonded reinforcement (EBR) strengthening techniques which has great potential in the field of upgrading structures. Basically the technique involves gluing steel plates or (fiber reinforced polymer) FRP laminates to the surface of concrete. FRP can be convenient compared to steel for a number of reasons. These materials have higher ultimate strength and lower density than steel. The installation is easier and temporary support until the adhesive gains its strength is not required due to the low weight. They can be formed on site into complicated shapes and can also be easily cut to length on site.

Composite materials of fibers in a polymeric resin, also known as fiber- reinforced polymers (FRP), have emerged as an alternative over steel to repair, retrofit and strengthen buildings and bridges. FRP materials may offer a number of advantages over steel plates which include: light weight, noncorrosive, and exhibit high tensile strength. This work is comparative study of the behavior of concrete beams retrofitted with Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP), and Aramid Fiber Reinforced Polymer (AFRP) with different wrapping techniques. Finite Element Analysis is used to model the behavior numerically and is used to determine the overall behavior of a structure by dividing it into number of simple elements, each of which has well defined mechanical and physical properties.

The overall aim of the present study is to investigate and improve the understanding of the behavior of reinforced concrete beams retrofitted with three different fibers- CFRP, GFRP and AFRP. Also the project aims at examining the influence of length and orientation of fibers on the behavior of RCC beams. One control beam and the five retrofitted beams each with AFRP, CFRP and GFRP laminates were loaded until failure. It is intended to show that the type, length and the orientation of the fibers strongly influence the behavior of the retrofitted beams. With the ANSYS program, the models can be used to study how different parameters affect retrofitted beam behavior and investigate how Externally Bound Reinforcement (EBR) should be applied in order to get maximum increase of load capacity. The change in stiffness of the retrofitted beams can also be analyzed by conducting this study.

2. Experimental Analyses

2.1 FRP wrapping schemes

The RC beam specimen and the FRP wrapping schemes of 1.5 mm thickness, used for the present study has been shown schematically in the figure 1 and figure 2 respectively given below.

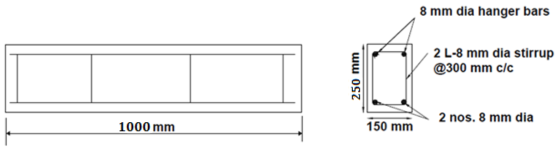

Fig 1 Reinforcement details of the beam specimen

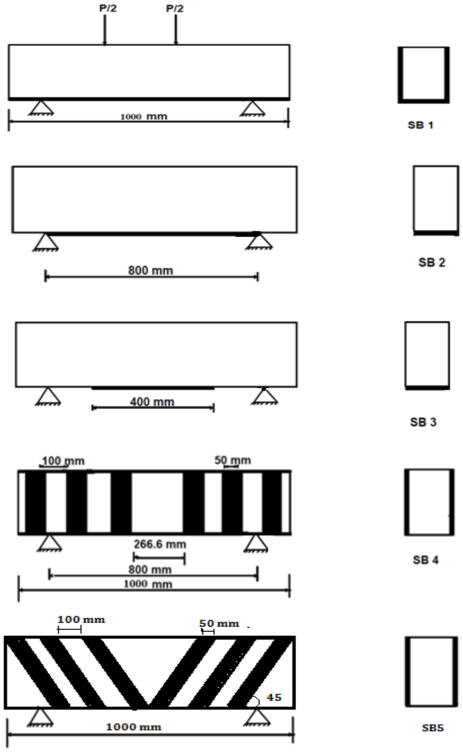

Fig 2 Different wrapping schemes

2.1.1 Strengthened in both shear and flexure

The strengthened beam designated SB1(Strengthened Beam1) was U –wrapped, that is strengthened in both shear and flexure. For that, the wrapping was provided on two shear sides and on the bottom flexure side throughout the length.

2.1.2 Strengthened in flexure

The strengthened beam designated SB2 and SB3 was strengthened in flexure only. For that, the wrapping was provided only on the bottom flexure side of the specimen. In SB2, FRP wrapping was provided over the entire effective span (800 mm) of the specimen, while in SB3 wrapping was provided over half the effective span (400mm) length of the specimen.

2.1.3 Strengthened in shear

The strengthened beam designated SB4 and SB5 was strengthened in shear only. For that, the wrapping was provided only on the two sides of the specimen. In SB4, 3 numbers FRP strips of 50 mm width, spaced at 100 mm center to center was placed over a distance of 266.6 mm from both the supports. In SB5, 3 numbers of FRP strips of 50 mm width, spaced at 100 mm center to center was placed at 45 degree with the longitudinal axis of the specimen.

2.2 Finite element analysis

A non –linear finite element analyses were done using ANSYS 14.5. The following are the properties assigned for the specimens.

2.2.1Element Types

Solid65, Eight-node solid element was used to model the concrete. Steel reinforcement and steel plates were modeled using link180 element. Solid185 elements are used to model the FRP.

2.2.2 *Material Properties*

2.2.2.1 For M30 concrete.
Modulus of elasticity= 30000N/mm^2
Poisson's ratio =0.2

2.2.2.2 For steel and steel plates
Modulus of elasticity=200000 N/mm^2
Poisson's ratio = 0.30
Yield stress =415N/mmm^2
Tangent modulus =20MPa

2.2.2.3 For FRP sheets.
Table 1 shows the material properties assigned for the FRP materials- AFRP, CFRP and GFRP laminates used for the study.

Table 1 : Material property of FRP

Properties	*AFRP*	*CFRP*	*GFRP*
Ex, (MPa)	13600	165000	21000
Ey, (MPa)	1482.1	9650	7000
Ez, (MPa)	1482.1	9650	7000
Gxy, (MPa)	549.13	5200	1520
Gyz, (MPa)	547	5200	2650
Gzx ,(MPa)	549.13	3400	1520
NUxy	0.32	0.3	0.26
NUyz	0.35	0.3	0.3
NUzx	0.035	0.45	0.26

3. Results and discussions

The results of the ultimate load and maximum deflection of the control beam and strengthened beam specimens are tabulated below. Here SB1A, SB1C, SB1G represents Strengthened beam retrofitted with AFRP, CFRP and GFRP respectively. And similarly for other retrofitted beams.

Table 2 : Maximum deflection and Ultimate load obtained for all the specimens

Beam code	*Max. Deflection (in mm)*	*Ultimate Load (kN)*	*% increase in load carrying capacity*
CB	0.390	139.5	-
SB1A	0.201	188	34.2
SB1C	0.199	214	53.4
SB1G	0.216	182	30.4
SB2A	0.198	178	27.6
SB2C	0.194	199	42.6
SB2G	0.197	182	23.3
SB3A	0.188	149	7.1
SB3C	0.186	154	12.5
SB3G	0.190	147	5.4
SB4A	0.217	178	27.6.
SB4C	0.215	193	38.6
SB4G	0.216	182	30.4
SB5A	0.298	184	31.9
SB5C	0.293	197	41.2
SB5G	0.306	183	31.2

The deflection was reduced in all retrofitted beams and the lowest deflection was observed in the beam strengthened with CFRP in flexure. Providing a layer of FRP composites of 1.5 mm thickness has resulted in achievement of improved load carrying capacity of the entire strengthened specimens.

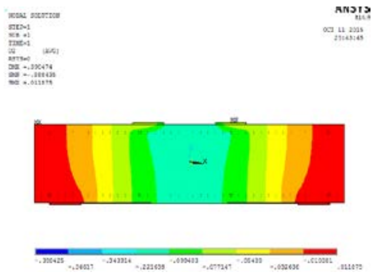

Fig 3: The displacements in the model after non-linear finite element analysis for CB

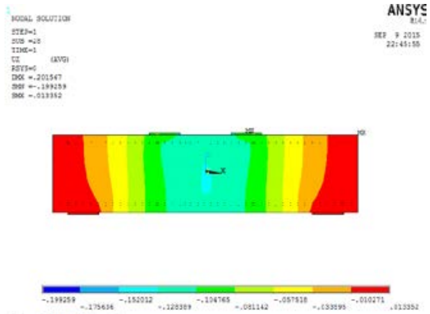

Fig 4: The displacements in the model after non-linear finite element analysis for SB1A

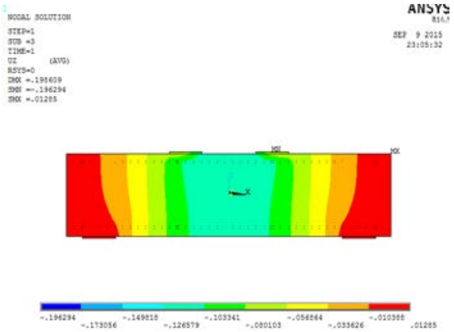

Fig 5: The displacements in the model after non-linear finite element analysis for SB2A

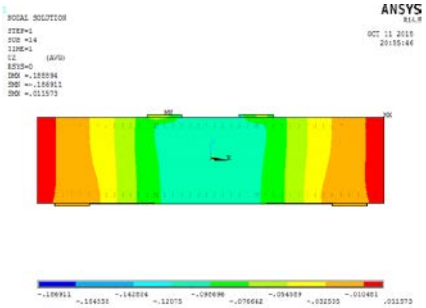

Fig 6: The displacements in the model after non-linear finite element analysis for SB3A

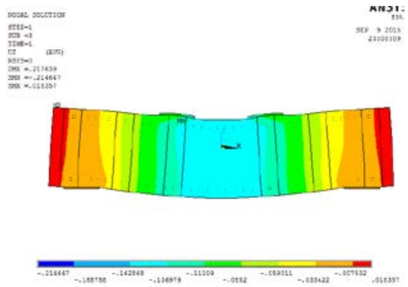

Fig 7: The displacements in the model after non-linear finite element analysis for SB4A

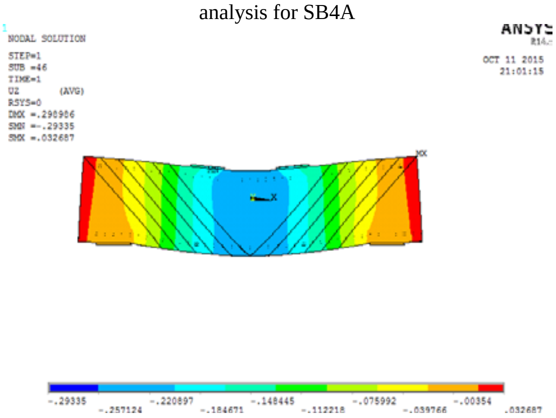

Fig 8: The displacements in the model after non-linear finite element analysis for SB5A

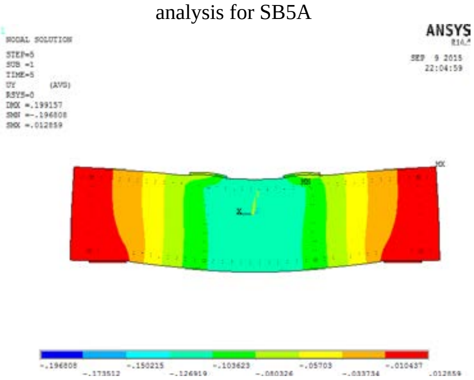

Fig 9: The displacements in the model after non-linear finite element analysis for SB1C

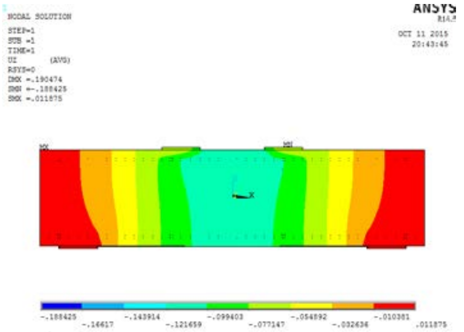

Fig 10: The displacements in the model after non-linear finite element analysis for SB2C

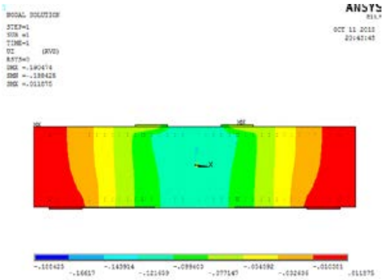

Fig 11: The displacements in the model after non-linear finite element analysis for SB3C

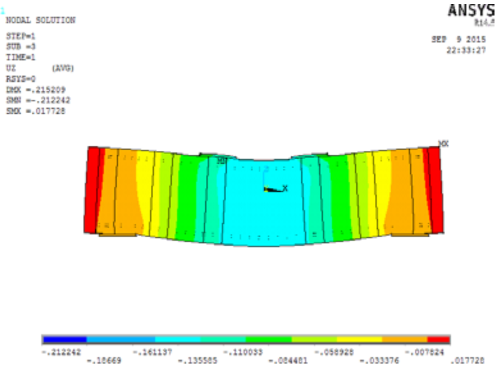

Fig 12: The displacements in the model after non-linear finite element analysis for SB4C

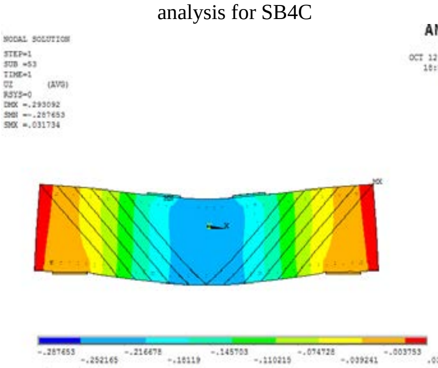

Fig 13: The displacements in the model after non-linear finite element analysis for SB5C

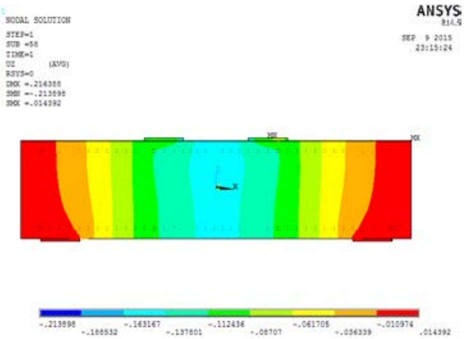

Fig 14: The displacements in the model after non-linear finite element analysis for SB1G

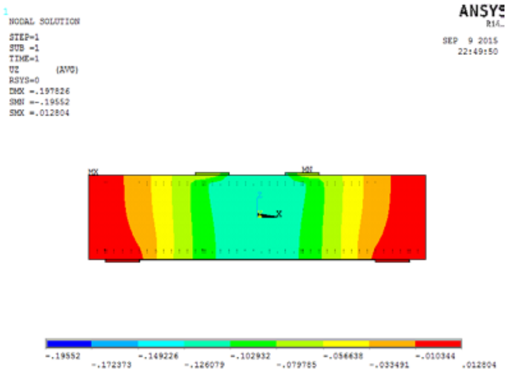

Fig 15: The displacements in the model after non-linear finite element analysis for SB2G

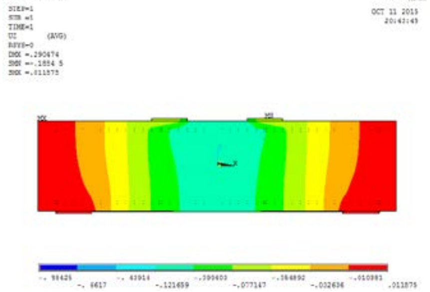

Fig 16: The displacements in the model after non-linear finite element analysis for SB3G

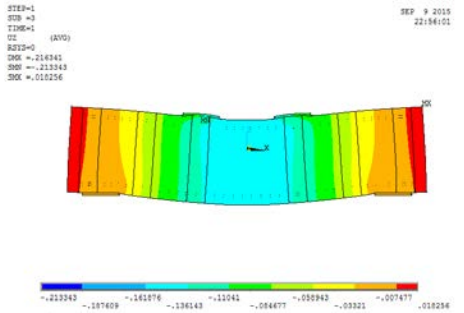

Fig 17: The displacements in the model after non-linear finite element analysis for SB4G

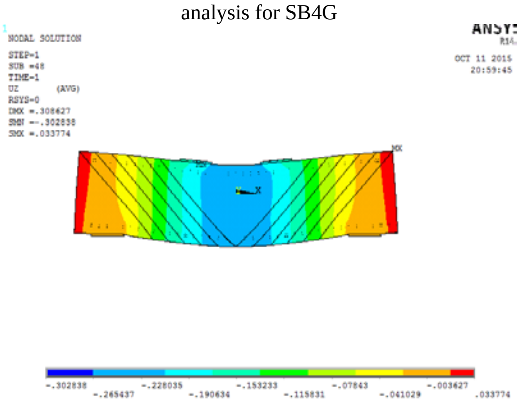

Fig 18: The displacements in the model after non-linear finite element analysis for SB5G

4. Conclusions

The main objective of the project is to study the effect of AFRP, CFRP and GFRP on behaviour of composite beams under increased loading condition and to understand the best wrapping technique among the six models of each FRP.

The following conclusions are drawn from the study

- Increase in ultimate load of about 53.4% was achieved in specimen SB1C strengthened in both flexure and shear (U wrapped with CFRP), fully wrapped in three sides. The similar pattern was observed in U wrapped AFRP and GFRP strengthened beams. From this it can be inferred that increase in area of FRP wrapping increased load carrying capacity of the concrete member..
- When wrapping was provided only on half length of the effective span, the increase in load carrying capacity was only up to 12.5% (SB3C). This means that insufficient strengthening lengths do not produce the intended strengthening effect.
- Analytical results showed that the increasing the FRP length in flexural retrofitting can make the FRP more effective for concrete repair and strengthening.
- The deflection was reduced in all retrofitted beams and the lowest deflection was observed in the beam strengthened with CFRP in flexure (Sb3C).
- The stiffness of the FRP- retrofitted beams is increased to that of the control beams. This means that, the stiffness of the beam increases with increase in load carrying capacity.
- The study shows that among AFRP, CFRP and GFRP, CFRP wrapped beams has higher strength than others, followed by AFRP.

References

[1] Kinjal V Ranoliaa, B K Thakkarb, J D Rathodb , “Effect of Different Patterns and Cracking in FRP Wrapping on Compressive Strength of Confined Concrete”, Science Direct, Procedia Engineering 51, 2013, pp.169 – 175

[2] R. A. Hawileh ,”Finite element modeling of reinforced concrete beams with a hybrid combination of steel and aramid reinforcement”, Science Direct, October 2014.

[3] Lila M. Abdel-Hafez, Alaa Eldin Y. Abouelezz , Ahmed M. Hassan, “Behaviour of RC columns retrofitted with CFRP exposed to fire under axial load”, Civil Eng. Dept., Minia University, Minia, Egypt, February 2014.

[4] Kachlakev D, M Curry D.D ,”Behaviour of full scale reinforced concrete beams retrofitted for shear and flexural with FRP laminates”, Composites 31, pp. 445-452

[5] Swamy R.N and P. Mukhopadhyaya, ”Role and Effectiveness of Non- Metallic Plates in strengthening and Upgrading Concrete Structures”, Proceedings of the second International RILEM Syposisum, August 1995, pp 473-482.

[6] Adhikary BB and Mutsuyoshi H, “Behaviour of concrete beams strengthened in shear with carbon fiber sheets”, Journal of Composites for Construction 8, pp. 258-264.

[7] Sing-Ping Chiew, Qin Sun and Yi Yu, “Flexural Strength of RC Beams with GFRP Laminates”, Journal of composites for construction, ASCE 2007 pp. 497-506

[8] Pannirselvam N, Raghunath P.N and Suguna. K, “Strength Modelling of Reinforced Concrete Beam with Externally Bonded Fiber Reinforcement Polymer Reinforcement”, American Jounal of Engineering and Applied Sciences, 2008. 1(3), pp. 192-199.

[9] Amer M. Ibrahim, Mohammed and S.H Mahmood, “Finite Element Modelling of Reinforced Concrete Beams Strengthened with FRP Laminates”, European Journal of Scientific Research 30, 2009 pp.526-541.

[10] Sundarraja M.C. and Rajamohan S, “Strengthening of RC beams in Shear Using GFRP Inclined Strips - An Experimental Study”, Construction and Building Materials 23, 2009, pp. 856-864.

[11] Sachin P Sidagonawar, E. Ramesh Babu etal , **“**Analysis on Earthquake Resistant Properties of RC Core Steel Composite Columns Using Ansys” ,Indian Journal Of Applied Research, September 2014,Vol.4, pp. 186-191.

[12] Beena Kumari, Naveen Kwatra, ”Finite Element Modeling of a Multi-Storeyed Retrofitted Reinforced Concrete Frame**”** ,Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 8, October. 2013, pp. 08-22.

[13] P. Bhuvaneshwari and K. Saravana Raja Mohan, “Strengthening of Shear Deficient Reinforced Concrete Beams Retrofitted with Cement-based Composites”, Jordan Journal of Civil Engineering, Volume 9, No. 1, 2015.

[14] Xiaoshan Lin & Y.X. Zhang, ”Nonlinear Finite Element Analysis of Composite Steel/FRP-reinforced Concrete Beams Using a New Beam Element”, The 5th International Conference on FRP Composites in Civil Engineering Beijing, China, September 2010.

[15] Tara Sen and Dr. H. N. Jagannatha Reddy ,”Finite Element Simulation of Retrofitting of RCC Beam Using Coir Fiber Composite”, International Journal of Innovation, Management and Technology, Vol. 2, April 2011.

[16] R. Santhakumar, R. Dhanaraj, E.Chandrasekaran, “Behaviour of retrofitted reinforced concrete beams under combined bending and torsion : A numerical study”, Electronic Journal of Structural Engineering, 2007.

[17] Umesh Basappa and Amirtham Rajagopal,”Modeling of CFRP strengthened RCC beam using the nonlinear finite element method”, Department of civil engineering, Indian Institute of Technology Hyderabad, October 2012.

[18] Tara Sen, Umesh Mishra and Shubhalakshmi B.S “Nonlinear Finite Element Analysis of Retrofitting of RCC Beam Column Joint using CFRP”, International Journal of Engineering and Technology, Vol.2, No.5, October 2010.