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Strengthening and Retrofitting of RC Beam by using Fiber Reinforced Polymer Composites

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Abstract: In a present scenario, derangement in RC structures is an enormous challenge faced worldwide by the infrastructure. A civil engineering structure is intended for a specific period and its serviceable life relies upon the nature of that structure and location at which structure constructed. The different RC structures arranged in seismically zones are not equipped for withstanding under the activity of seismic actions. The requirement for the investigation of fortifying and retrofitting of RC structure is noticeable because of the expanded rate of seismic exercises. Various strategies for structural strengthening/retrofitting techniques have been created throughout the years such as outer holding of steel plates, stiffened steel plates, partial or full length wrapping FRP, external prestressing, carbon fibre wrapping, external bar reinforcement. Strengthening/retrofitting technique or method was basically developed keeping the RC structure, safety and serviceability in views. This paper shows the different FRP retrofitting and strengthening techniques and an exploratory investigation on retrofitted RC beams with fiber reinforced polymer sheets (GFRP). The main intention of this practice is to investigate the behaviour of flexural member (RC beam) after strengthening and retrofitting with FRP under the action of vertical transverse load. The full length wrapping technique over all the four sides of the flexural RC beam is utilized as the method of retrofitting/strengthening. The present tertiary of FRP composite materials its province and testing facilities in India are reviewed through this paper study.
Keywords: Strengthening, retrofitting, RC beam, FRP, wrapping, techniques.

I. INTRODUCTION

Retrofitting is the transformation of already constructed structures to make it high resistant to external forces, like seismic forces, wind force and vibration forces. In case of increase in live load, accidental loads and in excessive sever environmental conditions; we need to redesign the building as per new load combinations. Generally, we have to take decisions that whether to demolish the structure or retrofit it. It will depend upon the stressing level of the structure. Also it is to be checked that retrofitting system is capable of taking increased loads or not, if not, structure should be demolished. Many times it is seen that with some restoring measures, building can be retrofitted and the age could be increased for some more years. Depending upon the conditions, various methods of retrofitting can be used, but these can be chosen as per experience. Some methods of retrofitting are by using steel plates and jacketing of steel to structural elements, using steel bars bonded to structural elements external pre-stressing for the bridge girders, chemical methods (filling up the cracks by chemicals or adhesives) and using FRP composites bonded to surface of concrete. One of the techniques out of these for strengthening is externally bonded by GFRP sheets applied externally by wet lay-up method. Inclined GFRP sheet were used for retrofitting of beams weak in shear. Detail study was done on orientation, Breadth and spacing of GFRP strips and their effect on re-strengthening of flexural members. It was presumed that shear strength was improved by external application of GFRP. As tensile strength of GFRP sheet is quite good so it can be used as strengthening material in tension face of flexural members. Also a similar study was performed for shear strengthening of RC beams using hybrid composite plates fabricated by using glass fibers and carbon fibres. It was seen that on addition of 10% of fibres the tensile strength of hybrid composite plate was increased up to 130% from standard carbon fibre plate. FRP has been used in buildings damaged because of seismic loads or due to creep also. It might be also advantageous in non-seismic zones and can be utilized to increase the strength of RC beam which are under higher transverse vertical loads. Beam and slabs are strengthened in flexure and column in compression by using FRP composites using epoxy resin as a common adhesive for strengthening purpose. Recently an experimental was conducted on study of damaged RC beams retrofitted/strengthened with help of CFRP composites bonded externally. From this study, they observed that there was a 23% increase in for retrofitting in shear and 7% to 33% in case of retrofitting in flexure. The basic failure mode in testing was de-bonding which reduced the effectiveness of retrofitting. It was also recommended that numerical analysis should be done before to predict the behaviour of retrofitted beams so that suitable orientation should be selected. As casting of slab and beams are done.

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FRP jackets made-up of glass fibre were used as strengthening material on 4.55m long beams. They used 40 mm thick jacket for strengthening and for retrofitting. They concluded that proposed technique is effective in ultimate and serviceability limits. These fibres are available in market in form of sheets and they can be bonded with epoxy resin to get hardened material which possesses a good tensile strength.

A. Aim

To investigate and improve the behaviour of RC beams retrofitted with glass fiber reinforced polymer composites GFRP.

B. Objectives

In the present scenario an endeavor has been taken to perform the innovative retrofitting techniques for repair, restoration and strengthening of various types of RCC structure. The objective of this study to describe the process and findings carried out by the researchers around the globe on advanced retrofitting techniques such as reinforced concrete jacketing, steel jacketing, wrapping of FRP, steel bracing system, addition of shear walls, seismic isolation system, shotcrete method presents in the current available literature.

1) To determine flexural strength of RC beam under the application of vertical loads.
2) To enhance the seismic performance of RC beam during the earthquake shaking.
3) To determine the maximum allowable deflection.
4) To increase the ability of GFRP and concrete working together to resist the forces.

II. METHODOLOGY

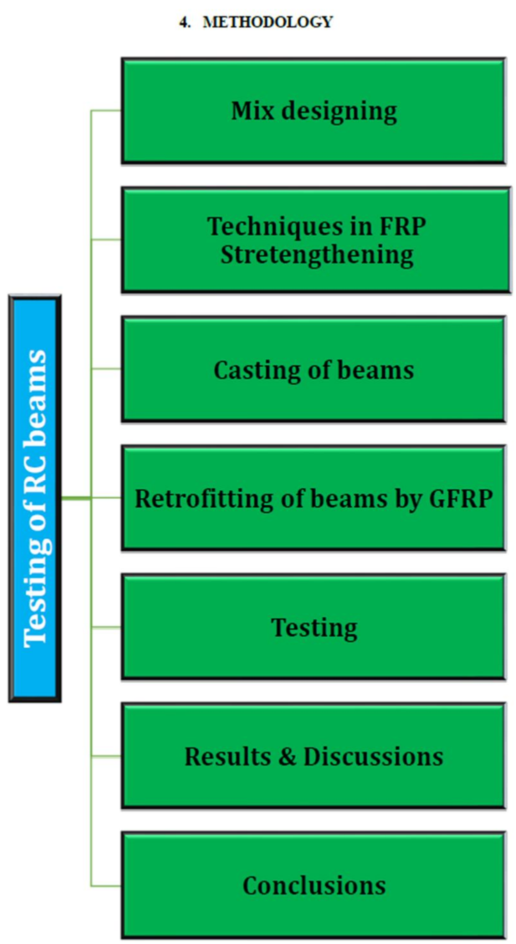

Fig.1. Organization and method of study

III. SELECTION OF MATERIALS

1) *Cement:* The Cement of grade-43 (OPC) was used for casting of RC beams. Cement used for beams was confirming as per Bureau of Indian standard(IS-8112:1989). The specific gravity, final setting time and initial setting time was a 3.15, 600 minute and 30 minute resp.
2) *Coarse Aggregate:* Locally available crushed stones, basalt stone were used for casting of concrete. Both 10mm and 20 mm coarse aggregate were used. The material confirmed IS 383-1970. The Specific gravity of 10mm and 20mm aggregate was 2.67 and 2.7 respectively. Water absorption was 0.75%.
3) *Fine Aggregates:* Locally available river bed sand used according to Bureau of Indian standard(IS: 383-1970) provision it was in range of zone II. Specific gravity of CA was 2.6 and water absorption was 1.5%.
4) *Water:* Tap water use for the casting of concrete and curing of concrete. Water should fulfil all requirements as per IS 456-2000

Design concrete mix of 1**:**1.3426: 2.692 by weight is used to achieve the compressive strength of 20 N/mm2. The water cement ratio 0.5 was used. Three concrete cube were cast and tested at the end of 28 days to know the compressive strength. The observed arithmetic compressive strength of the cube specimens was 26.87 N/mm2. Tor steel Fe-500 of 8mm diameter bars were used for longitudinal reinforcement and mild steel of 6mm diameter bars were used for shear reinforcement. The GFRP sheets used for retrofitting.

IV. TECGNIQUES IN FRP STRENGTHENING

A. Basic Technique

The basic FRP strengthening technique involves manual application of either wet lay-up or fabricated systems by means of cold cured adhesive bonding. Basic in this method is that the outside reinforcement is bonded/wrapped onto the concrete member surface with the strands as parallel as for all intents and purposes conceivable in the course of principal tensile stresses.

Fig.2. Wet lay-up system

B. Special Technique

Besides the basic techniques, several special techniques have been developed. Some of them are a follows.

1) *Automated Wrapping:* This strategy/technique was first invented in Japan. This includes ceaseless twisting of wet strands under a slight point around columns or different structures.
2) *Pre-stressed FRP:* Now and again, it might be invaluable to bond the outer FRP reinforcement onto the concrete member surface in a pre-stressed state. Both lab and investigative research demonstrate that pre-stressing represents a significant contribution to the advancement of the FRP strengthening technique, and techniques have been created to pre-stress the FRP composites under genuine condition.
3) *Fusion-bonded-pin-loaded Straps:* This technique involves replacing solid and relatively thick strips known as pin- loaded strap.

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4) *In-situ Quick Curing using Heating Devices:* Instead of cold curing of the bond interface (curing of the two main component adhesive under environmental temperature), heating devices can be used. In this way it is possible to reduce curing time, to allow bonding in regions where temperatures are too low to allow cold curing, to apply the technique in winter time, to work with proper FRP types, etc.
5) *CFRP Inside Slits:* CFRP in concrete slits is considered as a special method of supplementing reinforcement to concrete structures. The slit cuts are cut into the concrete member with a depth less than the concrete cover. CFRP strips, for example, with a thickness of 2 mm and a width of 20mm are reinforced into these cuts. vi. Pre-assembled shapes: Prefab kind of FRP EBR systems generally applied as straight strips. However, these can be produced in other forms, depending upon their application. By shaping them, prefab systems can be employed in applications where normally the more flexible wet lay-up systems can be used. vii. FRP impregnation by vacuum: it is quite common in the plastic industry.
6) *Wet lay-up Systems:* Dry unidirectional fiber sheet and semi-unidirectional fabric (woven or knitted), where fibers run predominantly in one direction partially or fully covering the structural element. Installation on the concrete surface requires saturating resin usually after a primer has been applied. Two different processes can be used to apply the fabric:-

   The fabric can be applied directly into the resin which has been applied uniformly onto the concrete surface.

   The fabric can be impregnated with the resin in a saturator machine and then applied wet to the sealed substrate. Dry multidirectional fabric (woven or knitted), where fibers run in at least two directions. Installation requires saturating resin. The fabric is applied using one of the two processes described above.

   Resin pre-impregnated uncured unidirectional sheet or fabric, where fibers run predominantly in one direction. Installation may be done with or without additional resin.

   Resin pre-impregnated uncured multidirectional sheet or fabric, where fibers run predominantly in two directions. Installation may be done with or without additional resin.

   Dry fiber tows (untwisted bundles of continuous fibers) that are wound or otherwise mechanically placed onto the concrete surface. Resin is applied to the fiber during winding. Pre-impregnated fiber tows that are wound or otherwise mechanically placed onto the concrete surface. Product installation may be executed with or without additional resin.

V. CASTING OF BEAMS

The molds were prepared using wooden plank. The dimensions of the RC beams were identical. The gross cross sectional dimensions were 150 mm x 250 mm and length 1200mm. The design mix proportion was used for casting of the beam. Six RC beams were cast, one as reference specimens and five RC beams for retrofitted by GFRP. Two bars of 8mm diameter provided as compression reinforcement and two bar of 10mm diameter provided as tension reinforcement at the soffit of the beam. bars of 6 mm diameter provided as shear reinforcement.

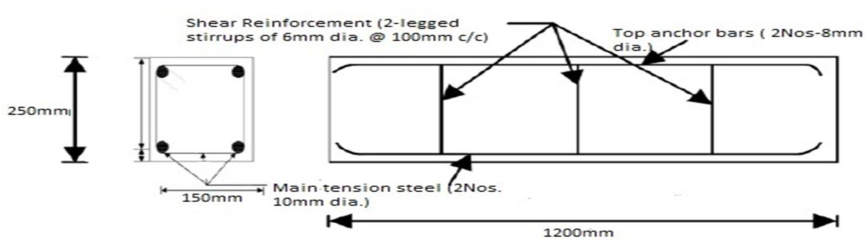

FIGURE-1. Reinforcement detailing of the beam

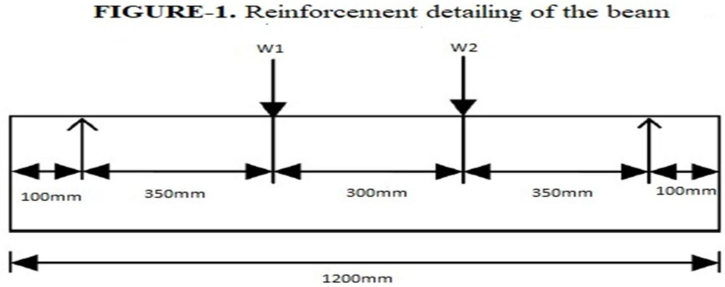

FIGURE-2. Loading diagram

Fig.3. Reinforcement and test loading details

VI. RETROFITTING OF RC BEAMS

The full length wrapping of GFRP around all the four sides of RC beam is used as a method of retrofitting. Before wrapping of GFRP, the surface of RC beam scrub with the help of wire brush and after that cleaned with water to remove all dirt. The RC beams are permitted to dry for 24hours. The GFRP sheet is cut as per the size of beams. After that, the epoxy resin primer is mixed in accordance with manufacturer's instructions. The mixing of epoxy matrix is completed in a plastic bucket (Base: Hardener = 2Kg : 1 Kg). After mixing, the epoxy matrix mixture is applied to the surface of beams. The beams are cured for 8hours. The epoxy matrix is mixed in a plastic bucket as per instructions given by manufacturer to produce a proper mixture of base and hardener (Base : Hardener = 3.7 : 1.3). The coating is applied on the beams and fibre sheets for effective bonding of the sheets with the concrete surface. Then the GFRP sheets is placed on the top of beam surface coating and epoxy resin is crushed through the meandering of the texture. Air bubbles entrapped in between sheet and beam surface are eliminated.

During hardening, a pressure applied to the GFRP sheets wrapped beam in order to remove the excess epoxy matrix and to assurer good bond between the epoxy, beam and the sheets. This procedure is performed at room temperature. Before testing, the RC beams strengthened/Retrofitted with GFRP sheets are restored for 3days at a room temperature.

Mixing of epoxy primer

Application of epoxy primer

Application of GFRP sheets

Retrofitted Beams

Fig.4. Retrofitting of RC beam by using GFRP

VII. EXPERIMENTAL SET UP OF RC BEAMS

The flexural test were carried out on reference beams and retrofitted beams. The testing procedure for the all the specimens was same. The curing period for the beams is 28days. The surface of reference beams is washed for visibility of cracks. The surface of GFRP retrofitted RC beams is washed with cotton cloth. The two-point flexural test is utilized for testing. The load is transmitted through a load cell.

Fig.5. Experimental set-up of RC beams

The beams were roller supported at the ends. The beam was set over the two roller supports leaving 100 mm from the edge of the beam. The remaining 1000mm length of beam separated into three sections as appeared in figure number two. Two point loading flexural test arrangement was done. The Mechanical dial gauge were used for recording the reading of deflection of beam under the application of loading. The deflections of the beams were recorded till the visible of the first crack using mechanical dial gauge. The dial gauge was removed after the visible of the crack and the load was further applied till fracture load.

Fig.6. Testing of GFRP retrofitted RC beams

One reference beam and five retrofitted beams was tested for their ultimate strengths. It is found that all the beams were fractured in flexure. It is concluded that the reference beam had less Fracture load carrying capacity and high deflection values compared to that of externally strengthened beams using GFRP sheets.

Fig. 7. Cracks and deflection of beams

The deflection of the each beams were recorded. The demeanour of the load deflection curve is compared with beams retrofitted by different GFRP sheets having the equal steel reinforcement. It is noted that the performance of retrofitted beams when wrapped with GFRP sheets are preferable than the reference beams. The deflection was very small of retrofitted beam wound with GFRP sheets. The externally retrofitted beams using GFRP sheets also reduced the development of crack formation of the beams. Since the full length wrapping technique is used for retrofitting and strengthening of beams, initial cracks are not visible. Further increase in transverse loading, formation of the cracks took place but it had less visibility of cracks.

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Table.1. Beam with external wrapping of GFRP and Cracks

BEAM NO.	NOTATION	DESCRIPTION	CRACK WIDTH
01	WR1	Beam Without Retrofitting (Reference beam)	No Cracks
02	WR2	Reinforced with one layer of GFRP Sheets.	0.51 mm
03	WR3	Reinforced with one layers of GFRP Sheets.	No Cracks
04	WR4	Reinforced with Two layers of GFRP Sheets.	0.51mm
05	WR5	Reinforced with Two layers of GFRP Sheets.	0.59mm
06	WR6	Reinforced with Two layers of GFRP Sheets.	0.56mm

VIII. EXPERIMENTAL RESULTS

The test results are as shown in table:

Table.2. Test results of tested beam

Beam	Crack Load(KN)	Ultimate Load (KN)	Deflection (mm)	Average Load (KN)
WR1	48.50	69.00	18.0	69.00
WR2	52.80	93.50	12.41	90.00
WR3	58.50	86.50	13.61	
WR4	56.00	104.50	10.24	120.66
WR5	38.50	131.50	16.31	
WR6	60.50	126.00	8.38	

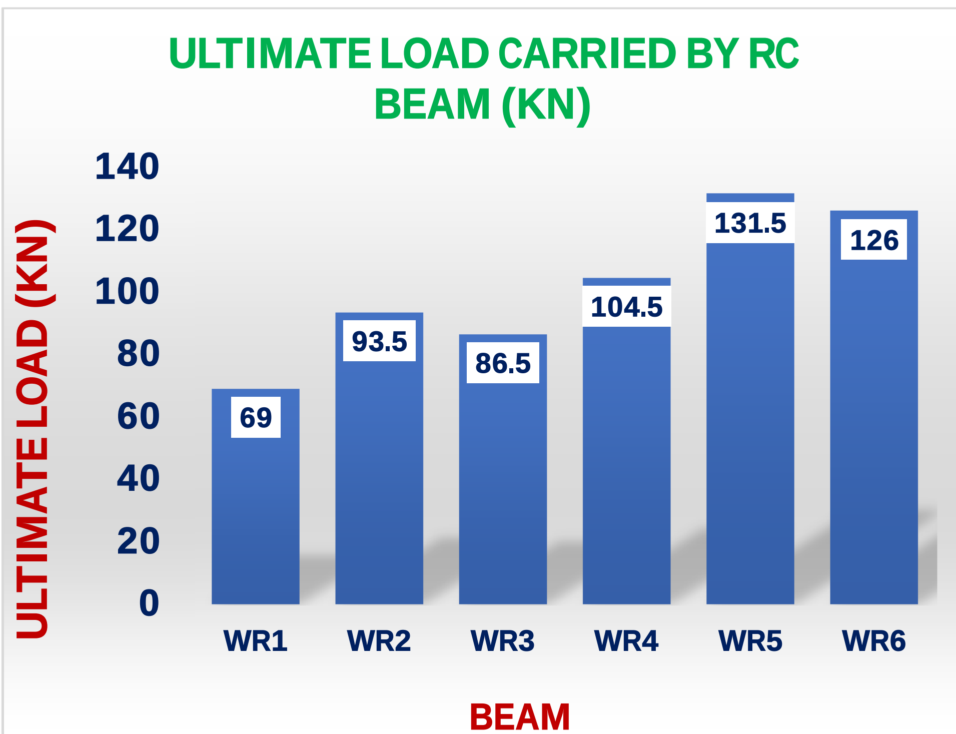

Fig.8. Ultimate Load Carried by RC beam

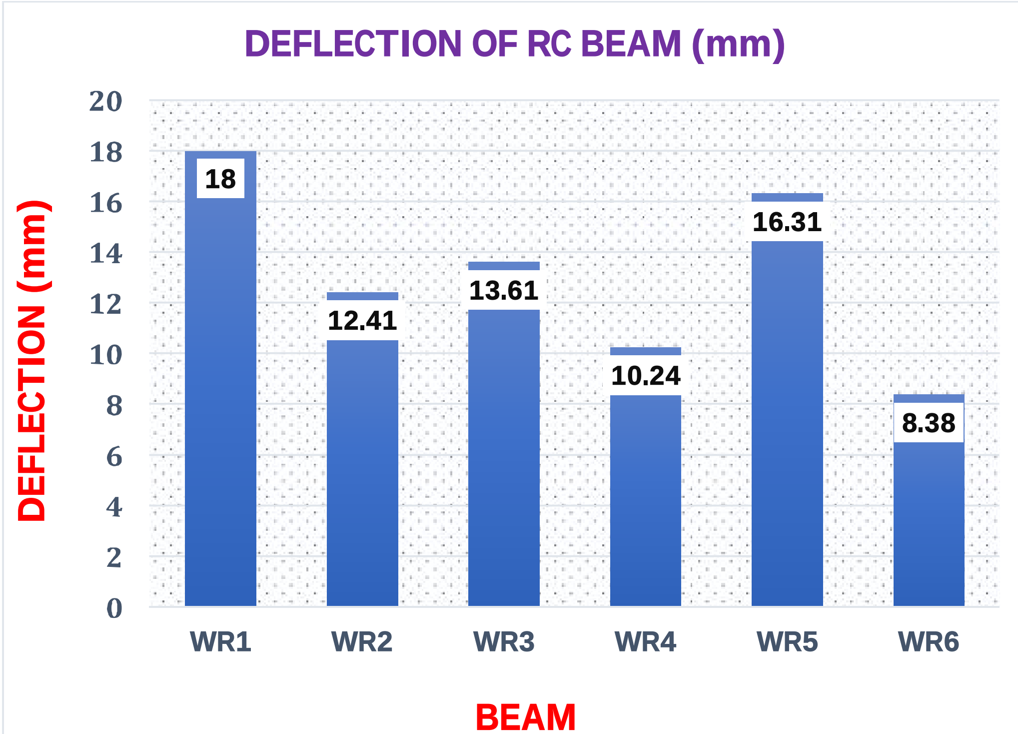

Fig.9. Deflection of RC Beams

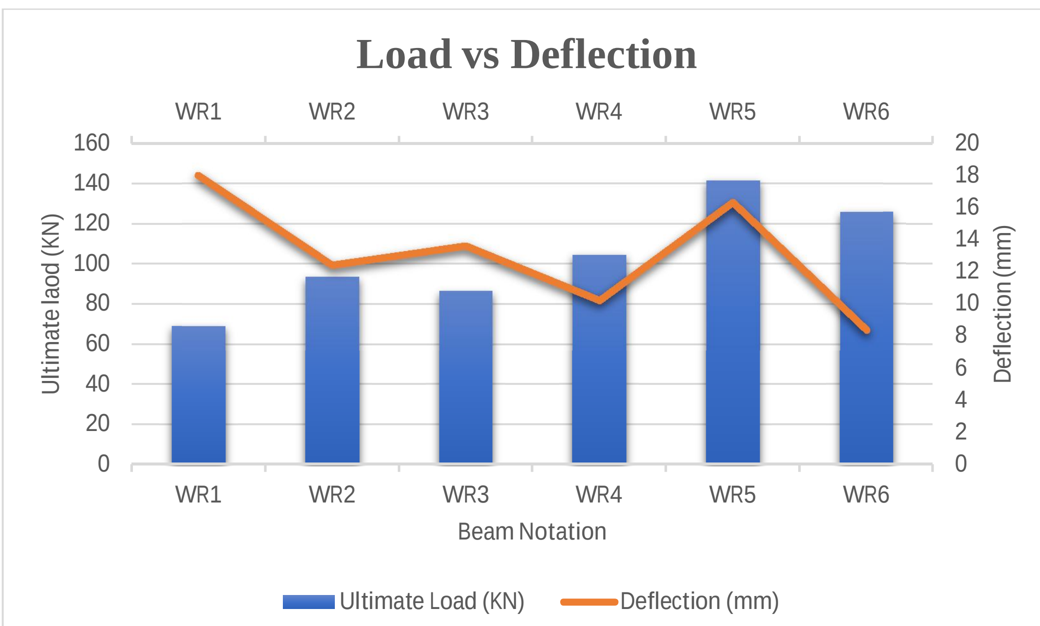

Fig.10. Load vs Deflection

Retrofitting of beams increase the fracture load of the flexural members. The reference beam had an ultimate load of 69 KN, whereas the retrofitted beams Reinforced with one layer of GFRP Sheets had an average ultimate load of 90 KN and the retrofitted beams Reinforced with two layer of GFRP Sheets had an average ultimate load of 120.66 KN. The ultimate load capacity of the GFRP retrofitted beams Reinforced with one layer of GFRP Sheets increased by 30.43% more than the reference beam. The ultimate load capacity of the GFRP retrofitted beams Reinforced with two layer of GFRP Sheets increased by 74.88% more than the reference beam.

IX. CONCLUSIONS

This paper shows an experimental investigation performed to know the behavior of RC beam retrofitted with GFRP. From the noted test results, the following conclusions are listed.

1) The retrofitted beams Reinforced with one layer of GFRP Sheets had an average ultimate load of 90 KN which is 30.43% more than the reference beam and 34.06% less than the reinforced beams with two layer of GFRP sheets.
2) The retrofitted beams Reinforced with two layer of GFRP Sheets had an average ultimate load of 120.66 KN which is 74.88% more than the reference beam and 34.06% more than the reinforced beams with one layer of GFRP sheets.
3) The inflection of the flexural beams are reduced due to full length wrapping of GFRP sheets around all the surfaces of the beam. The primary cracks in the retrofitted beam was very less at a maximum load than that of an un-strengthened reference beam.
4) The retrofitting of the RC beams utilizing GFRP sheets is promote to be more advantageous in increasing the flexural strength and maximum load capacity of beams.

Hence it is recommended that GFRP wrapping is much suited for the retrofitting of RC Beams.

REFERENCES

[1] Gustavo J. Parra-Montesinos(2005), "High-Performance Fiber-Reinforced Cement Composites: An Alternative for Seismic Design of Structures", *ACI Structural Journal*, Volume. 102, No. 5,September-October
[2] Hiroya Hagio, Hideo Katsumata and Kohzo Kimura, "The Beam Retrofitted by Carbon Fiber-Experiment and Designs", http://www.iitk.ac.in/nicee/wcee/article/0451.pdf
[3] Mrs. Tara Sen and Dr.H.N. Jagannatha Reddy (2011), "Finite Element Simulation of Retrofitting of RCC Beam Using Coir Fibre Composite (Natural Fibre)", *International Journal of Innovation, Management and Technology*, Vol. 2, No. 2, April
[4] Nishikant Dash (2009), "Strengthening of reinforced concrete beams using glass fibre reinforced polymer composites", *Thesis*.
[5] Ahmad Abdel Hamid, Hany Elshafie, El-Sayed Nasr and Ezat Fahmy, "Retrofitting of reinforced concrete beams using advanced composite overlays", http://www.quakewrap.com / frp % 20 papers / Retrofitting – Of-Reinforced –Concrete-Beams-Using- Advanced-Composite-Overlays.pdf
[6] Dr. K.P. Jaya (2011), "Retrofitting and Rehabilitation of Structures", Paper presented in one day conference on „Repair, Restoration and Rehabilitation of Concrete Structures conducted by ICI-TNCC‟.
[7] E. B. Perumal Pillai, B. G. Vishnuram, M. Lenin Sundar and M. Siddhantha Boopathi, "Strengthening of reinforced concrete beams and columns using GFRP composites", Proceedings on the National Seminar on „Futuristics in concrete and construction engineering‟, SRM Engineering College, Kattakulathur.
[8] F. G. Farhat and B.L Karihaloo, "Performance of RC Beams Retrofitted With CARDIFRC® After Thermal Cycling", http://www.icf11.com/proceeding/extended/4111.p