Experimental Investigation On RCC Beam Strengthening with Glass Fiber Reinforced Polymer

[1]Er. Sumit sharma ,

[1]Student RN College of Engg. & Technology Panipat,
[1]Civil Engg. Department.

Abstract : In this modern era, most of the buildings all over the world are made up of RCC. A structure is intended for a particular period and relying upon the idea of the structure, its plan life fluctuates. For a residential structure, this plan life could be as low as a quarter century, while for an open structure, it could be fifty years. Weakening in solid structures is a noteworthy test looked by the framework and extension businesses around the world. The decay can be predominantly because of natural impacts, which incorporates erosion of steel, progressive loss of solidarity with maturing, rehashed high force stacking, variety in temperature, solidify defrost cycles, contact with synthetics and saline water and introduction to ultra-violet radiations. As complete substitution or reproduction of the structure will be savvy, fortifying or retrofitting is a viable method to reinforce the equivalent.

In this research, the primary objective of this study is to examine the application of GFRP fabric wrap to strengthen concrete beams and the associated failure modes. the effects of the number of GFRP layers on the strength and ductility of beams are investigated. To study the ultimate load carrying capacity, deflection of normal beam and beams strengthened with GFRP fabric wrap. A comparison shall also be done with the ultimate load carrying capacity and deflection of normal beam and beams strengthened with GFRP wraps.

From conclusions, it is seen that from Experimental Study on Structural Strengthening of Beams using Glass Fibre Reinforced Polymer Composites conclude the strength of the beams can be increased by wrapping with Glass Fibre Reinforced Polymer Composites.

I. INTRODUCTION

A structure is intended for a particular period and relying upon the idea of the structure, its plan life fluctuates. For a residential structure, this plan life could be as low as a quarter century, while for an open structure, it could be fifty years. Weakening in solid structures is a noteworthy test looked by the framework and extension businesses around the world. The decay can be predominantly because of natural impacts, which incorporates erosion of steel, progressive loss of solidarity with maturing, rehashed high force stacking, variety in temperature, solidify defrost cycles, contact with synthetics and saline water and introduction to ultra-violet radiations. As complete substitution or reproduction of the structure will be savvy, fortifying or retrofitting is a viable method to reinforce the equivalent. The most mainstream strategies for fortifying of strengthened solid shafts have included the utilization of outer epoxy-reinforced steel plates. It has been found tentatively that flexural quality of an auxiliary part can be expanded by utilizing this procedure. Despite the fact that steel holding strategy is basic, practical and effective, it experiences a difficult issue of disintegration of security at the steel and cement interphase because of erosion of steel. Other normal fortifying strategy includes development of steel coats which is very compelling from quality, firmness and malleability contemplations. Be that as it may, it builds in general cross-sectional measurements, prompting increment in self-weight of structures and is work serious. To dispose of these issues, steel plate was supplanted by consumption safe and light-weight Fiber Reinforced Polymer (FRP) Composite plates. FRPCs help to build quality and pliability without exorbitant increment in firmness. Further, such material could be intended to meet explicit prerequisites by modifying position of strands. So solid individuals would now be able to be effectively and successfully fortified utilizing remotely reinforced FRP composites.

1.2 METHODS OF STRUCTURAL STRENGTHENING

Structural strengthening is a process whereby an existing structure is enhanced, to increase the probability that, the structure will survive for a long period of time and also against earthquake forces. This can be accomplished through the addition of new structural elements, the strengthening of existing structural elements, and/or the addition of base isolators.

Structural repair of reinforced concrete members incorporates numerous repair techniques depending on the structure's type of reinforcement, extent of deterioration, and type of distress. Different types of reinforcement require various demolition and surface preparation techniques. Typically, structural deterioration of reinforced concrete members can occur as surface scaling, spalling, cracking, corrosion of reinforcing steel, weathering, post-tension losses, deflection beam shortening, volume shrinkage and strength reduction. Moisture, chlorides, carbonation, and chemical attack induce freeze thaw disintegration, sulphate attack, erosion and alkali aggregate reaction. The rehabilitation measure includes various methods accordingly to the type of distress.

Various Retrofitting techniques include:

- Injection of cracks
- Removal and replacement
- Ferro cement
- Plate bonding
- Concrete jacketing
- Steel plate adhesion
- Steel jacketing or addition of external steel elements
- Strengthening with fiber-reinforced polymeric (FRP) composites

1.3 FAILURE OF FRP STRENGTHENED STRUCTURES

1.3.1 Flexural Failure

Flexural failure of a strengthened RC beams is quite similar to failure of non-strengthened RC members, taken the additional FRP as additional reinforcement into account. When debonding is prevented, flexural failure of a FRP strengthened beam is governed by either FRP rupture (Figure 1.9) or crushing of the concrete in the compressive zone (Figure 1.10). Both failure modes could occur before or after yielding of the internal steel reinforcement. However, in practical applications, flexural failure is hardly ever observed, as, in general, failure is governed by debonding of the externally bonded FRP.

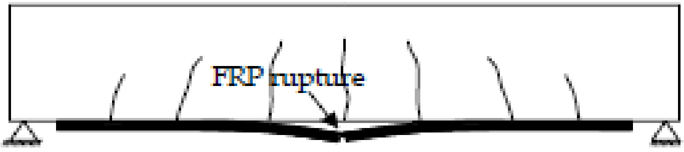

Figure 1.8. FRP rupture

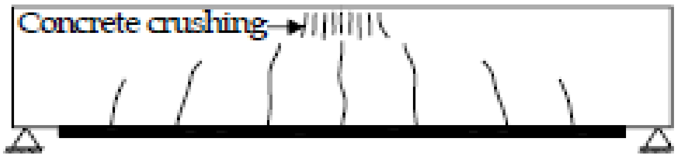

Figure 1.9. Concrete crushing

1.3.2 Shear Failure

FRP that is used to strengthen a structure in flexure does not significantly contribute to the shear capacity of the beam and is therefore often neglected in the verification of the shear capacity. Shear failure could become the governing failure mode (Figure 1.11), as the flexural capacity is increased. Shear failure should however be avoided due to the brittleness of this type of failure. If additional shear capacity is needed, it is possible to strengthen the structure in shear with FRP.

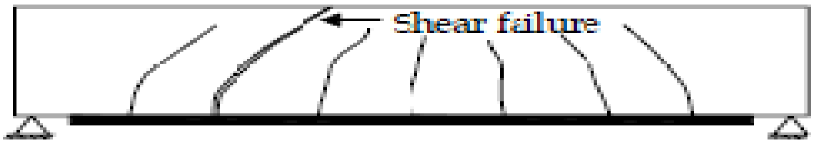

Figure 1.10. Shear failure

1.3.3 Debonding of the Externally Bonded FRP

Failure after debonding of the FRP is in most cases the governing failure mode of FRP-strengthened structures. Several debonding mechanisms can be distinguished, which can initiate at several locations along the length of the laminate (Figure 1.12).

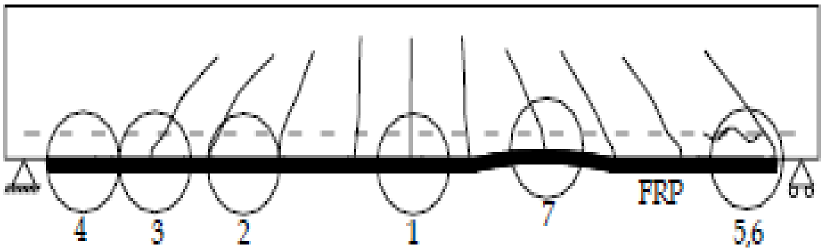

Figure 1.11. Possible debonding mechanisms of a FRP-strengthened beam.

The debonding mechanisms that can be distinguished are;

1. Debonding at flexural cracks
2. Debonding due to high shear stresses
3. Debonding at shear cracks
4. Debonding at the end anchorage
5. Plate-end shear failure
6. Concrete cover rip-off
7. Debonding due to the unevenness of the concrete surface

When a FRP-strengthened beam cracks, high stress concentrations will develop in the FRP at the intersection with a crack. These stress concentrations are transferred to the concrete by means of shear stresses at both sides of the crack. It is expected that exceeding the shear strength only result in local non-progressive debonding close to the crack tip of the (flexural) crack, as the stress concentration will decrease after debonding over a short distance (Figure 1.12).

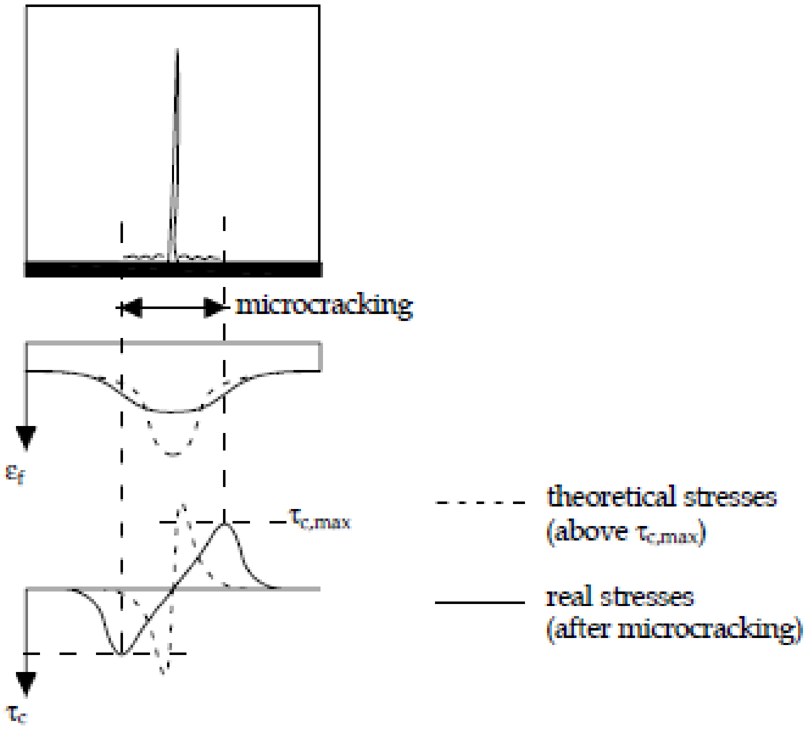

Figure 1.12 Local debonding at flexural cracks

II SCOPE AND OBJECTIVE

The primary objective of this study is to examine the application of GFRP fabric wrap to strengthen concrete beams and the associated failure modes. More particularly, the effects of the number of GFRP layers on the strength and ductility of beams are investigated. To study the ultimate load carrying capacity, deflection of normal beam and beams strengthened with GFRP fabric wrap. A comparison shall also be done with the ultimate load carrying capacity and deflection of normal beam and beams strengthened with GFRP wraps. The scope of the study is to improve the strength of the existing structure for the updation of current code.

The scope of this investigation is to study the effectiveness of GFRP sheets and the increase of the flexural strength of concrete beams by Fiber-reinforced polymer (FRP).

The main objectives of this investigation are:

- To study the structural behaviour of reinforced concrete (RCC) beams under static loading condition.
- To study the contribution of externally bonded Fiber Reinforced Polymer (FRP) sheets on the flexural behavior of RCC beams.
- To examine the effect of different parameters number of layers, enhancement of load carrying capacity and load deflection behavior of beam.

III LITERATURE REVIEW

GENERAL

- Studies have specifically focused on structural strengthening of RCC beam using GFRP. This includes the work of
- **D.N. Shinde et al (2014)** investigates the Flexural behavior of R.C.C. beam wrapped with GFRP (Glass Fiber Reinforced Polymer) sheet. Experimental results shows that Effective procedure of wrapping enhances the strength considerably and flexural retrofitting also increases the shear strength of concrete.
- **Rameshkumar U More et al (2014*)*** studied experimentally the flexural behaviour of the beam externally bonded aramid fiber reinforced polymer specimens subjected to two point loading mechanism only..Ultimate load carrying capacity in beams is found to be increasing with increase in layer of AFRP strip.With increase in degree of damage, deflection at ultimate load is found to be decreasing by applying AFRP strip.
- **Sandeep G. Sawant et al (2013*)*** investigates the effect of number of GFRP layers and its orientation on ultimate load carrying capacity and failure mode of the beams.Results shows that U-Shape wrap and bottom wrap was good for improving shear strength as well as for reducing deflection of RC member as compare to both side wrap.
- **Patel Mitali R et al (2012)**carried out experimental work on shear strengthening of different beams using FRP and the effect of different parameters on the strength of beams strengthened externally with FRP sheets or strips. Results show that for strengthening of beam in shear, use of strips of CFRP was best mechanism. This mechanism has largest residual strength and less brittle failure.51% increase in shear capacity was achieved with addition of CFRP reinforcement externally.

IV MATERIALS

CEMENT

Portland Pozzolona Cement (PPC)-53 grade was used for the investigation. It was tested for its physical properties in accordance with Indian Standard specifications.

FINE AGGREGATE

Locally available fine aggregates are used in the investigation.

COARSE AGGREGATE

Locally available coarse aggregates are taken and sieved to the required quantity of volume to the maximum nominal size of 20 mm. Care is taken to arrive the size of coarse aggregate ranging from 4.75 mm to the maximum nominal size of 20 mm.

WATER

Potable water available in Concrete and highway laboratory of department of civil engineering is used for mixing the concrete and curing the specimens.

REINFORCING STEEL

HYSD 10mm and 8mm diameter bar is used as main reinforcement. 6 mm dia. mild steel bars is used as a shear reinforcement.

GLASS FIBRE

Woven Glass Fibre Reinforced Polymer is used for wrapping the specimens.

RESIN

Polymer resin is used for wrapping the specimens with GFRP.

ACCELERATOR

It is used along with catalyst to harden the resin from liquid states to solid states.

CATALYST

Catalyst increases the rate of a chemical reaction of two or more reactants and helps in rapid hardening of the mix

PIGMENT

A pigment is a material that changes the color of mix. Blue pigment is used for wrapping the specimens with GFRP.

PREPERATION OF MOULD

Fresh cement, being plastic requires some sort of structure work to form it to the required shape and furthermore to hold it till it sets. The structure work has, subsequently, got the chance to be reasonably structured. It ought to be sufficiently able to take the dead burden and live load, during development and furthermore it must be inflexible enough to withstand any bulging, twisting or hanging because of the load.The form work used for casting of all specimen consists of mould prepared with 3.5mm thick iron plate at the sides and 5 mm thick plate at the bottom. These plates are bolted together using angle section of dimension 40 mm by 40 mm by 6 mm inorder to gain more stiffness.

Figure. Moulds

V RESULTS AND DISCUSSIONS

LOAD VS DEFLECTION GRAPH

The analysis of beam specimens are made and corresponding Deflection are obtained for the corresponding loads applied. The deflections where noted at mid span, Y1 and one-third span, Y2 for corresponding loads. Load vs Deflection graph is plotted as shown in figure 11.1 and 11.2.

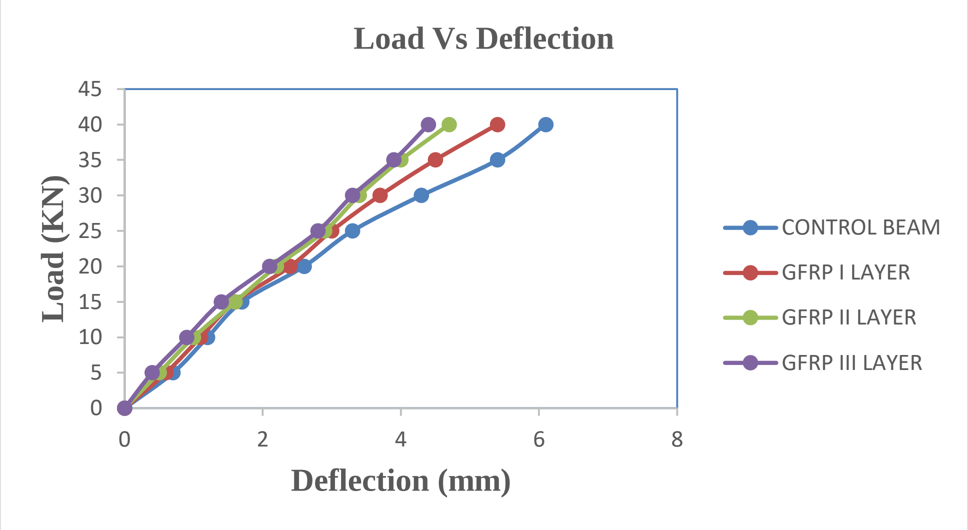

Figure Load Vs Deflection Graph, Y1

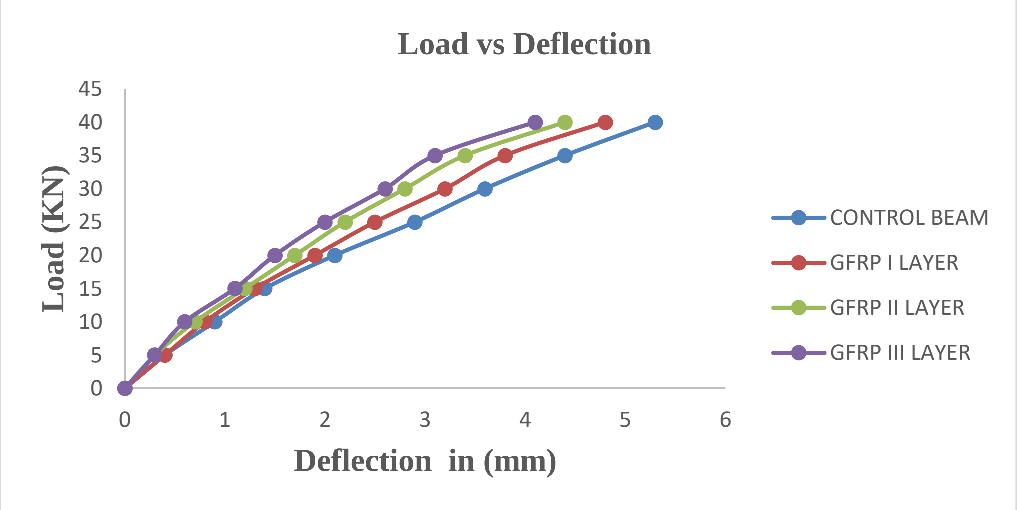

Figure Load Vs Deflection Graph, Y2

From the figures of load vs Deflection and the table from appendix, it is observed that the deflection of beams increases with the increase in load. It was also noted that, as the number of GFRP layer increases, the deflection decreases for a corresponding load.

LOAD AT INITIAL CRACK

Under two point static loading of beam examples, at every augmentation of burden, deflection and crack improvement were watched .In CB commencement of break happens at a heap of 30 KN. The crack inception of beam examples BS I, II and III were not unmistakable because of utilization of GFRP around the beam. The breaks were just unmistakable in the wake of arriving at extreme load

It was noted that vertical cracks were found at the center one- third span, propagating from the bottom towards the top conforming that the beam fails for flexure alone.

Figure Crack pattern on the specimen

RESULTS OF ULTIMATE LOAD

After the elastic range all the specimens are subjected to failure and hence the ultimate loads are determined. Visible crakes first appeared at the center one-third surface of the beam and then propagated from the bottom of the beam towards the top, hence conforming flexural failure.

Table Test Results of Ultimate Load (Pu)

Type	Ultimate Load, Pu(kN)
CB	76
BS I	99
BS II	122
BS III	147

The ultimate loads for the specimens are tabulated in table and a plot is made between ultimate load on different specimens as shown in Fig. It is observed that the ultimate load increases with increase in the number of layers of GFRP wrapping.

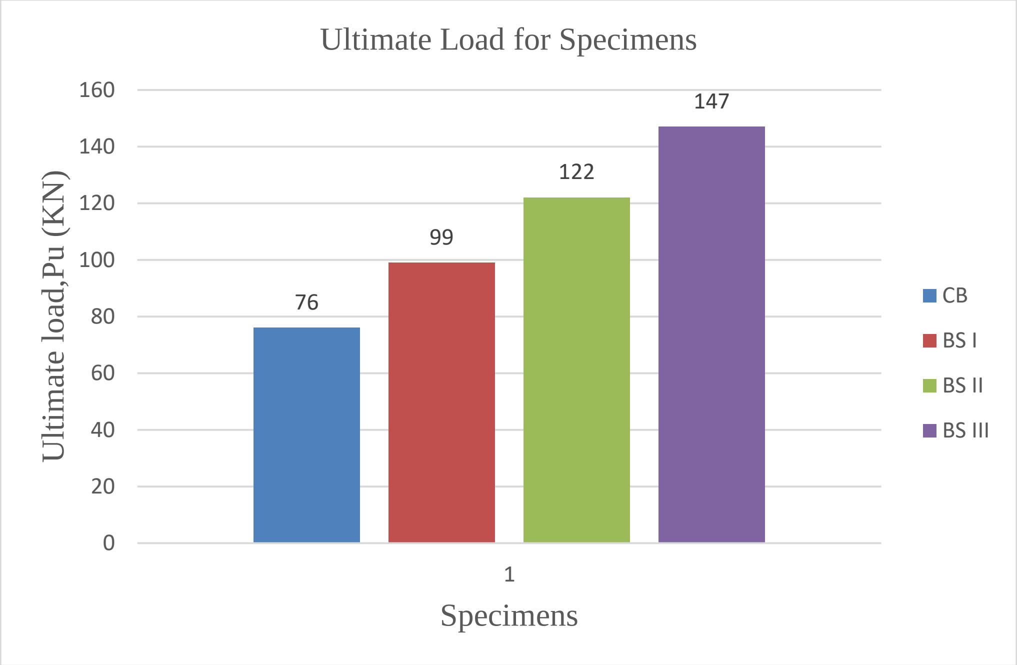

Figure Ultimate Load on different specimens

VI CONCLUSIONS

The accompanying ends are drawn from the test outcomes.

i) It is concluded that an increment of 23.23% of ultimate load (Pu) is observed in BS I when compared with CB.

ii) It is concluded that an increment of 35.24% and 18.85% of ultimate load (Pu) is observed in BS II when compared with CB and BS I respectively.

iii) It is concluded that an increment of 48.29%,32.65% and 17.06% of ultimate load (Pu) is observed in BS III when compared CB,BS I, BS II respectively.

iv) The deflection of Reinforced Concrete Beams increases with increase in load within the elastic range.

Hence from Experimental Study on Structural Strengthening of Beams using Glass Fibre Reinforced Polymer Composites conclude the strength of the beams can be increased by wrapping with Glass Fibre Reinforced Polymer Composites.

VII REFERENCES

1. **Nikita Jain, Varun Kumar Sikka (2015)**. ‘‘Strengthening Of RC Beams with Externally Bonded GFRP’s.’’ *IOSR J. Mech & Civil Engg (IOSR-JMCE) Volume 12, Issue 2 Ver. VI (Mar - Apr. 2015).*
2. **Douglas Tomlinson and Amir Fam (2014)**. ‘‘ Performance of Concrete Beams Reinforced with Basalt FRP for Flexure and Shear.’’ *J. Compos. Constr 10.1061/ (ASCE) CC.1943-5614.0000491 1-0.*
3. **D.N. Shinde, Pudale Yojana M, Nair Veena V (2014)**‘‘Flexural Behaviour of Reinforced Cement Concrete Beam Wrapped with GFRP sheet.’’ *International Journal of Research in Engineering and Technology, Volume: 03 Special Issue: 03 May-2014*
4. **Rameshkumar U More, D. B. Kulkarni (2014***)* ‘‘Flexural Behavioural Study on RC Beam with externally bonded Aramid Fiber Reinforced polymer .’’ *International Journal of Research in Engineering and Technology, Volume: 03 Issue: 07 Jul-2014.*
5. **Sandeep G. Sawant, A. B. Sawant, M. B. Kumthekar (2013)**‘‘ Strengthening of R.C.C. Beam- Using Different Glass Fiber .’’ *(IJIES) ISSN: 2319–9598, Volume-1, Issue-2, January 2013.*
6. **Patel Mitali R, Dr.R.K.Gajjar (2012)**‘‘Shear Strengthening of Different Beams using FRP.’’ *IJAERS/Vol. I/ Issue II/January-March, 2012*
7. **Amir Mofidiand Omar Chaallal (2011)**. ‘‘Retrofitting of RC Beams with FRP Influencing Factors and Conceptual Debonding Model.’’*J. Compos. Constr 10.1061/ (ASCE) CC.1943-5614.0000153 62-74.*
8. **Indrajit Ray, George C. Parish, Julio F. Davalos and An Chen (2011)**. ‘‘Effect of Concrete Substrate Repair Methods for Beams Aged by Accelerated Corrosion and Strengthened with CFRP.’’ *J. Compos. Constr 10.1061/ (ASCE) AS.1943-5525.0000030 227-237.*
9. **Khaled Galal and Amir Mofidi (2009)**. ‘‘Strengthening RC Beams in Flexure Using New Hybrid FRP Sheet/Ductile Anchor System.’’ *J. Compos. Constr 10.1061/ (ASCE) CC.1943-5614.0000006* 217-225.
10. **M. Di Ludovico, Ph.D.; G. Manfredi, Ph.D.; E. Mola, Ph.D.; P. Negro, Ph.D.; and A. Prota, Ph.D. (2008)**. ‘‘Seismic Behavior of a Full-Scale RC Structure Retrofitted.Using GFRP Laminates.’’*J. Struct. Engg 10.1061/(ASCE)0733-9445(2008)134:5 810-821.*
11. **Yalim, B., Kalayci, A. S., and Mirmiran, A. (2008)**. “Performance of FRP-Strengthened RC beams with different concrete surface profiles.” *J. Compos. Constr, 626–634.*
12. **Sing-Ping Chiew, Qin Sun and Yi Yu (2007)**. ‘‘Flexural Strength of RC Beams with GFRP Laminates.’’*J. Compos. Constr 10.1061/(ASCE)1090-0268(2007)11:5 497-506.*
13. **Guido Camata and Benson Shing (2005)**. ‘‘Evaluation of GFRP Honeycomb Beams for the O’Fallon Park Bridge.’’ *J. Compos. Constr 0.1061/ (ASCE) 1090-0268(2005)9:6 545-555.*
14. **Anthony J. Lamanna, Lawrence C. Bank, David W. Scott (2004)**. ‘‘Flexural Strengthening of Reinforced Concrete Beams by Mechanically Attaching Fiber-Reinforced Polymer Strips.’’ *J. Compos. Constr 10.1061/(ASCE)1090-0268(2004)8:3 203-210.*
15. **Sherrill Ross, Andrew Boyd, Martin Johnson3, Robert Sexsmith and Nemy Banthia (2004)**. ‘‘Potential Retrofit Methods for Concrete Channel Beam Bridges Using Glass Fiber Reinforced Polymer.’’*J. Bridge. Engg 10.1061/ (ASCE) 1084-0702(2004)9:1 66-74.*
16. **Henrik Thomsen, Enrico Spacone, Suchart Limkatanyu and Guido Camata (2004)**. ‘‘Failure Mode Analyses of Reinforced Concrete Beams Strengthened in Flexure with Externally BondedFiber-Reinforced Polymers.’’*J. Compos. Constr 0.1061/ (ASCE) 1090-0268(2004)8:2 123-131.*
17. **Gregor Fischer and Victor C. Li (2003)**. ‘‘Deformation Behavior of Fiber-Reinforced Polymer Reinforced Engineered Cementitious Composite (ECC) Flexural Members under Reversed Cyclic Loading Conditions.’’ *ACI Structural Journal/January-February 2003 25-35.*
18. **J. F. Bonacci and M. Maalej (2001)**. ‘‘Behavioral Trends of RC Beam Strengthened With Externally Bonded FRP.’’ *J. Compos. Constr (ASCE) Vol. 5, No. 2, May, 2001 102-113.*
19. **Abhijit Mukherjee and Mangesh V. Joshi (2001)**. ‘‘Seismic retrofitting technique using fibre composites.’’ *The Indian Concrete Journal/December 2001 1-6.*
20. **Aiello, M. A., and Ombres, L. (2000)**. “Load-deflection analysis of FRP reinforced concrete flexural members.” *J. Compos. Constr., 10.1061/ (ASCE) 1090-0268(2000)4:4 164–171.*
21. **Oral Buyukozturk and Brian Hearing (1998)**. ‘‘Failure Behaviour of Precracked Concrete Beams Retrofitted With FRP.’’ *J. Compos. Constr (ASCE) Vol. 2, No.3, August, 1998. 138-144.*
22. **Ahmed Khalifa, William J. Gold, Antonio Nanni, Abdel Aziz M.I. (1998)**. ‘‘Contribution of Externally Bonded FRP to Shear Capacity of Flexural Members.’’ *J. Compos. Constr (ASCE) Vol. 2, No.4, Nov. 1998, 195- 203.*
23. **Joseph M. Bracci, Sashi K. Kunnath, and Andrei M. Reinhorn (1997)**. ‘‘Seismic Performance and Retrofit Evaluation of Reinforced Concrete Structures.’’ *J. Compos. Constr (ASCE) vol.123, No. 1, January 1997 1-10.*
24. **Tom Norris, Hamid Saadatmanesh and Mohammad R. Ehsani (1997)**. ‘‘Shear And Flexural Strengthening of R/C Beams With Carbon Fiber Sheets.’’*J. Struct. Engg, Vol. 123, No.7, July, 1997 903-911.*
25. **Hamid Saadatmanesh and Mohamad R. Ehsani (1991)**. ‘‘RC Beams Strengthened With GFRP Plates Experimental Study.’’ *J. Struct. Engg (ASCE) Vol. 117, No. 11, November, 1991 3417-3433.*
26. ***IS:383-1970*** “Indian Standard Specification for Coarse and Fine Aggregates from Natural sources for Concrete.”
27. ***IS 2386-1963 (Part III and Part IV)*** “Indian Standard Methods of Test For Aggregates For Concrete.”
28. ***IS 516-1959*** “Indian Standard Methods of Test for strength on concrete.’’
29. ***IS 1199-1959*** “Indian Standard Methods of Sampling and Analysis of concrete.’’
30. ***IS 10262-2009***“Indian Standard Concrete Mix Proportioning.’’
31. ***IS 5816-1999*** “Splitting tensile strength of concrete method of test”