RCC Beam and Column with Retrofit Composite System using FRP

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Abstract

Fibre reinforced polymer (FRP) composite framework are utilized as a part of numerous applications. This paper briefly studies the history of FRP composite system and RCC shafts and sections. The different uses of fibre reinforced polymer (FRP) are also studied. This paper also manages the different methods of applying fibre fortified polymer (FRP) composite system. The purpose of this paper is to study the retrofitting procedures technically. Experimental results of RCC beam and column with and without applying FRP composite system are also compared in this paper. The comparison is done on the basis of applying various combinations of fibre reinforced polymer (FRP) systems.

Keywords: FRP, WFRP, CFRP-S, GFRP-S, GFRP-R, Epoxy Resin

I. INTRODUCTION

State of California became worried about seismic assessment and recovery rules because of the need of incorporated guidelines of seismic retrofitting. Large portions of the test and explanatory studies on retrofitting methodologies were led after this time. Because of the dynamic examination there was a noteworthy improvement in seismic retrofitting and recovery techniques. Thus the retrofitting method could be chosen according to significance of structure and the coveted basic execution amid seismic occasion with specific backslide interims.

Fibre strengthened polymer is a composite material made of a polymer grid fortified with strands, for example, glass, carbon, aramid or basalt. Fibre fortified polymers (FRPs) are a class of cutting edge composite materials that began from the air ship and space commercial enterprises. They have been utilized generally as a part of the therapeutic, brandishing products, car and little ship commercial enterprises. FRP has high quality to weight proportions, and magnificent imperviousness to erosion and ecological debasement. It is extremely adaptable and frames a wide range of shapes and is anything but difficult to handle amid development. Huge numbers of the focal points in these materials have turned out to be progressive as far as time requirements and sturdiness of these structures [13]. The FRP composite material is for the most part utilized as a retrofitting material to the present structure. The high calibre and light weight of these materials and the way that they are currently accessible as flimsy sheets give an alluring and prudent answer for fortifying existing solid extensions to expand their pliability, flexure and shear limit because of the expanding interest to utilize heavier truck load. The higher material expense is regularly balanced by decreased work, utilization of overwhelming apparatus, and close down costs, making FRP reinforcing frameworks extremely focused with conventional fortifying systems. The development in India through the most recent quite a while demonstrates that there is a further extension for coordinated effort of innovation and the accessible indigenous materials and use of FRP. FRP sheets are basically of two sorts as,

- Carbon fibre strengthened polymer (CFRP)
- Glass fibre strengthened polymer (GFRP)

There are additionally some other retrofitting procedures accessible relying on the condition and kind of structure. The selection of examination strategy for applying retrofitting methods chiefly relies on specialized, budgetary and sociological conditions. There are some different elements influencing the determination of examination techniques according to Thermou and Elnashai 2002 as,

- Cost versus significance of the structure
- Available workmanship
- Duration of work/interruption of utilization
- Fulfilment of the execution objectives of the proprietor
- Functionally and stylishly good and correlative to the current building
- Reversibility of the intercession
- Level of value control
- Political and/or verifiable hugeness
- Structural similarity with the current auxiliary framework
- Irregularity of firmness, quality and malleability
- Adequacy of neighbourhood solidness, quality and flexibility

- Controlled harm to non-auxiliary parts
- Sufficient limit of establishment framework
- Repair materials and innovation accessible

The fibre reinforced polymer (FRP) literature review study. The various comparison used in this project study is done to select the proper fibre reinforced polymer (FRP) composite technique that can be used as a retrofitting technique. The details of various composite techniques to be compared experimentally are as follows,

A. Notations

- WFRP: Without utilizing Fibre Reinforced Polymer composite system.
- CFRP-S: With using Carbon Fibre Reinforced Polymer Sheets single wrap system.
- GFRP-S: With using Glass Fibre Reinforced Polymer Sheets single wrap system.
- GFRP-R: With using Glass Fibre Reinforced Polymer Rods system.
- CFRP-S & GFRP-R: With using composite system of Carbon Fibre Reinforced Polymer Sheets single wrap and Glass Fibre Reinforced Polymer Rods composite system.
- GFRP-S & GFRP-R: With using composite system of Glass Fibre Reinforced Polymer Sheets single wrap and Glass Fibre Reinforced Polymer Rods (GFRP-R) composite system [16].

II. MATERIAL PROPERTIES

In fibre reinforced polymer (FRP) composite system there are mainly two types as carbon fibre reinforced polymer (CFRP) and glass fibre strengthened polymer (GFRP) [7]. FRP has high strength to weight ratios, and excellent resistance to erosion and ecological debasement [12]. It is very flexible and forms all kinds of shapes and is easy to handle during construction [7].

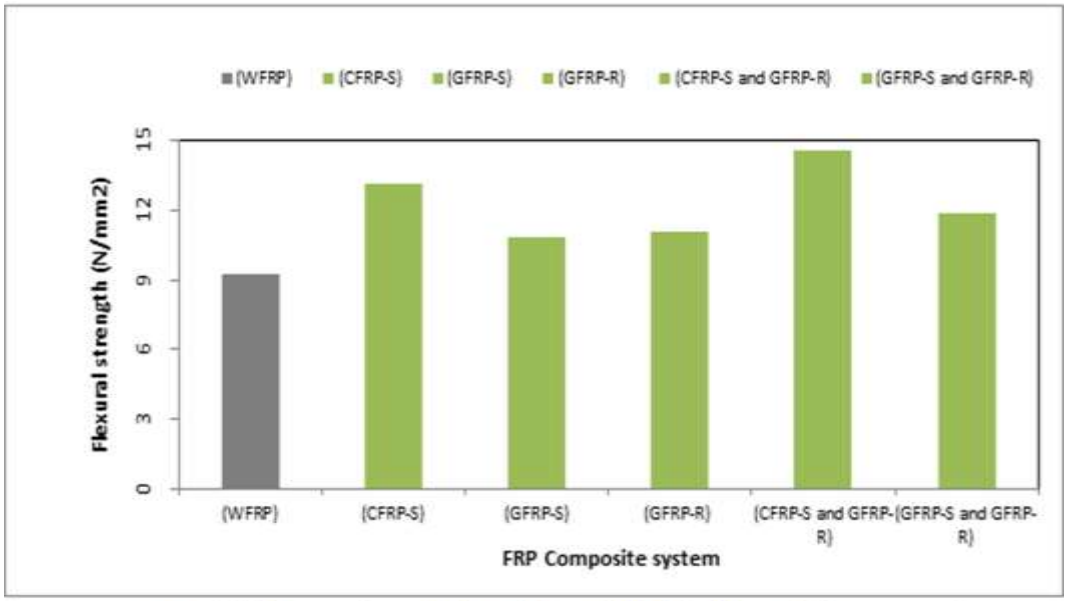
The CFRP-S used in the project is SikaWrap-450C having the dry fibre properties as tensile E-Modulus minimum value of 230,000 N/mm2, tensile strength minimum value of 4,000 N/mm2 (nominal) and Elongation at break is 1.7%. Similarly, for GFRP-S and GFRP-R used in the project is SikaWrap-430G and Epoxy Bonded Glass Pultruded Rod respectively [13]. The following material having the properties as tensile E-Modulus minimum value of 76,000 N/mm2 (nominal), tensile strength minimum value of 2,300 N/mm2 (nominal), Elongation at break is 2.8% and tensile strength of minimum 750 MPa, cross breaking strength of minimum 900 MPa, Axial compressive strength of 400 MPa respectively. The Fibre density of CFRP-S and GFRP-S are 2.56 g/cm3 and 1.82 g/cm3 respectively. The epoxy resin used for bonding of sheets and rods was Sikadur-330 Comp A and Comp B.

III. EXPERIMENTATIONS

In experimental work, we have considered two grades of concrete i.e. M_{25} and $M_{40.}$ All the basic tests were performed for the material used in the concrete. The main comparison was done on the basis of compressive and flexural strength testing of column and beam respectively. For comparison, we have taken an average of three samples for each composite material. The flexural strength was tested on two-point loading machine and compressive strength on Compression test machine. The casting procedure of beam and column samples is as,

- As per design mix, the samples are casted in laboratory and kept for curing of 28 days in a water tank.
- After 28 days of curing the samples are taken out of water and dried for a day. On next day the epoxy resin (Sica Dur 330) is applied on the samples with the help of painting brush.
- After that the Sica Carbon Fiber Reinforce Polymer sheet (CFRP-S) or Sica Glass Fiber Reinforce Polymer sheet (GFRP-S) is laid on the sample within 1 hr. time of applying epoxy resin.
- Now after laying the sheet, it is pressed with a roller for perfect fitting of sheet on sample.
- The ready samples are tested after a minimum curing of 2 days.

The above procedure is applied for both mixes i.e. M_{25} and M_{40} grade of concrete. The results of both the grades are compared separately by using the various combinations of fibre reinforced polymer (FRP) material as previously discussed.



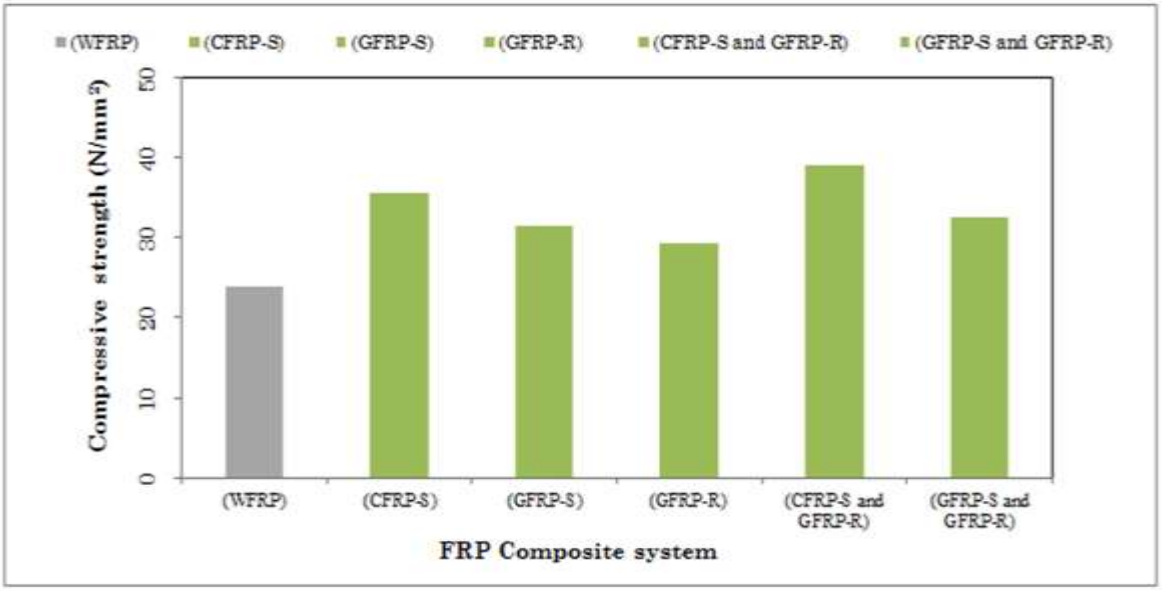
Graph 1: Comparison of flexural strength test for M_{25} grade beam samples

IV. RESULTS AND DISCUSSION

As per the experimentation in this project, all total 72 samples for M25 and M40 grade were casted in the laboratory. For flexural test beam samples of size 100 ×100 ×500 mm and for compressive test columns (cylinder cores) of size d=150 mm and D=300 mm were casted. The samples without applying FRP material for both grade of concrete were tested after 28 days of curing in water tank. The test results for compressive and flexural strength are discussed below. The remaining samples were taken out of water tank after 28 days for applying FRP composite material.

The single layer wrap of CFRP-S and GFRP-S was applied on an average of three samples. 3 rods of 8 mm dia. of GFRP-R were inserted in an average of three samples each. The rods were inserted in sample by drilling a hole of 12 mm dia. throughout the width of the sample. The combination of CFRP-S to GFRP-R and GFRP-S to GFRP-R was also applied to an average of three samples each. Epoxy resin was used for bonding of FRP sheets and rods with the samples.

The tests performed on the samples were flexural test and compression test. The comparisons done with the samples are based on the variation of applying fibre reinforced polymer (FRP) composite material. The following are the observation tables and comparison graph for M_{25} grade of concrete for flexural strength of beam. In observation tables below, the flexural strength for CFRP-S, GFRP-S, GFRP-R, Combination of CFRP-S to GFRP-R and Combination of GFRP-S to GFRP-R are compared with the samples of normal concrete i.e. WFRP.



Graph 2: Comparison of compressive strength test for M_{25} grade concrete column samples

As shown in graph 1, first bar shows the average value of flexural strength of normal concrete. Now, from graph 1 we can conclude that with use of CFRP-S the flexural strength of beam (13.15 N/mm^2) increases with 40-45% as contrast with typical cement (WFRP). The maximum flexural strength of beam is obtained from the combination of carbon fibre reinforced polymer sheet (CFRP-S) to glass fibre reinforced polymer rods (GFRP-R) i.e. 14.59 N/mm^2. The percentage increase of flexural strength of combination of CFRP-S to GFRP-R is about 55-60% as for ordinary cement of M25 evaluation. The flexural strength of concrete is calculated from the obtained loads. The formula for calculating the flexural strength of beam is,

$$\text{Flexural strength} = \frac{Pl}{bD^2}$$

Similarly, the comparisons of compressive strength of samples are to be done with respect to normal concrete tests of M25 evaluation concrete. The heaps are obtained by performing the compressive test. The compressive strength of column sample is calculated from the formula as,

$$\text{Compressive strength} = \frac{P}{A}$$

The compressive strength is calculated for every combination of FRP composite system used in the project [5]. It is calculated to compare the results with respect to normal concrete (WFRP) of M_{25} grade of concrete column sample. The observation tables above are showing the results of compressive strength of the column samples. From the observation tables we can check that the compressive strength of column samples goes on increase with the use of fiber reinforced polymer (FRP) composite system. In FRP composite system the combination of carbon fiber reinforced polymer sheet (CFRP-S) and glass fiber reinforced polymer rods (GFRP-R) shows the highest amount of compressive strength i.e. 38.97 N/mm2. This combination shows an increase of 60-65% increase in compressive strength of column sample as compared to the normal concrete. The following other blend of fiber fortified polymer (FRP) composite material also shows the reasonable increase in the compressive strength of M25 grade concrete column sample as shown in graph 2.

V. CONCLUSION

In this particular paper we have studied that the fibre reinforced polymer (FRP) composite material can be used as retrofitting material for damaged structures. As FRP rods are having high strength to weight ratio and appreciable resistivity to corrosive and degrading environment they can be the replacement to the steel rods used in the reinforcement.

The minimum and maximum increase in the flexural strength of the M_{25} grade beam samples is 15-20% and 55-60% respectively. The maximum increase in flexural and compressive strength was seen in the combination of CFRP-S and GFRP-R (i.e. 14.59 N/mm^2 and 38.97 N/mm^2) with about 60% with respect to normal concrete sample (WFRP). The technique of FRP composite material can be applied on normal concrete or as a retrofitting to beams and columns.

REFERENCES

[1] IS 8142:1976 “Method of test for determining setting time of concrete by penetration resistance”
[2] IS 8112:1989 “43 Grade ordinary Portland cement specification (First Revision)”
[3] IS 650:1991 “Standard sand for testing cement specification (Second Revision)”
[4] IS 456:2000 “Plain and reinforced concrete code of practice (Fourth Revision)”
[5] IS 10262:2009 “Indian standard recommended method of concrete mix design”
[6] “Concrete technology theory and practice (Revised Edition)”, M. S. SHETTY, July 2012.
[7] “Earthquake resistant design of structure”, Pankaj Agrawal and Manish Shrikhand, August 2012.
[8] Nicholas Lawler and Maria Anna Polak, “Development of FRP Shear Bolts for Punching Shear Retrofit of Reinforced Concrete Slabs”, 10.1061/(ASCE)CC.1943-5614.0000188.
[9] Tong Guo, M.ASCE[1]; Weijie Xu[2]; Lianglong Song[3]; and Longwu Wei[4], “Seismic-Isolation Retrofits of School Buildings: Practice in China after Recent Devastating Earthquakes”, 10.1061/(ASCE)CF.1943-5509.0000411.
[10] R. Jafarzadeh, Ph.D.; J. M. Ingham, M.ASCE; K. Q. Walsh; N. Hassani; and G. R. Ghodrati Amiri, “Using Statistical Regression Analysis to Establish Construction Cost Models for Seismic Retrofit of Confined Masonry Buildings”, 10.1061/(ASCE)CO.1943-7862.0000968.
[11] Pouria Bahmani, A.M.ASCE; John W. van de Lindt, F.ASCE; Mikhail Gershfeld, M.ASCE; Gary L. Mochizuki, M.ASCE; Steven E. Pryor, M.ASCE; and Douglas Rammer, M.ASCE, “Experimental Seismic Behavior of a Full-Scale Four-Story Soft-Story Wood-Frame Building with Retrofits. I: Building Design, Retrofit Methodology, and Numerical Validation”, 10.1061/(ASCE)ST.1943-541X.0001207.
[12] Omar Chaallal, M.ASCE; Munzer Hassan; and Michel LeBlanc, “Circular Columns Confined with FRP: Experimental versus Predictions of Models and Guidelines”, 10.1061/(ASCE)1090-0268(2006)10:1(4).
[13] Yu-Fei Wu[1]; Tao Liu[2]; and Leiming Wang[3], “ Experimental Investigation on Seismic Retrofitting of Square RC Columns by Carbon FRP Sheet Confinement Combined with Transverse short Glass FRP Bars in Bored Holes” , 10.1061/(ASCE)1090-0268(2008)12:1(53).
[14] B. Shan[1] and Y. Xiao, M.ASCE[2], “Time-Dependent Behavior of FRP Retrofitting RC Columns after Subjecting to Simulated Earthquake Loading”, 10.1061/(ASCE)CC.1943-5614.0000405.
[15] Dong-Sheng Gu[1]; Gang Wu[2]; Zhi-ShenWu[3]; and Yu-Fei Wu[4], “Confinement Effectiveness of FRP in Retrofitting Circular Concrete Columns under Simulated Seismic Load”, 10.1061/(ASCE)CC.1943-5614.0000105.
[16] Himanshu H. Mane[1]; N. H. Pitale, “Review on Use of FRP Composite System with RCC Beam and Column”, ISSN (online): 2349-784X.