COMPARATIVE STUDY OF FLEXURAL BEHAVIOUR OF R.C.C BEAM AND FLY ASH REINFORCED CONCRETE BEAM WRAPPED WITH GFRP SHEET

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ABSTRACT

This paper investigates the Comparative Study of Flexural behavior of R.C.C. beam wrapped with GFRP(Glass Fiber Reinforced Polymer) sheet. A total 8 beams, with (150×150) mm rectangular cross section and of span 700 mm were casted and tested. Three main variables namely, Initial Crack Load, Ultimate Load Carrying capacity,and deflection of Fly Ash reinforced beam and R.C.C. beam were investigated. In first set of four R.C.C beams two were strengthened with GFRP sheet in single layer from tension face which is parallel to beam axis subjected to static loading tested until failure; the remaining two beams were used as a control specimen. In second set of four Fly Ash Reinforced beams two were strengthened with GFRP sheet tested until failure ; the remaining two were used as a control specimen. Comparison has been made between results of two sets[1].

Keywords: Beam, Glass Fiber Reinforced Polymer Sheet, Reinforced Cement Concrete Beam, Fly Ash

I. INTRODUCTION

Retrofitting of existing structures has become a major part of the construction activity in many countries. Broadly, this can be attributed to aging of the infrastructure and increased environmental awareness in societies. Some of the structures are damaged by environmental effects, which include corrosion of steel, variations in temperature, freeze–thaw cycles, exposure to ultra-violet radiation and earthquake. There are always cases of construction-related and design-related deficiencies that need correction. Many structures, on the other hand, need strengthening because the allowable loads have increased, or new codes have made the structures substandard. This last case applies mostly for seismic regions, where new standards are more comprehensive than the old ones. The bending moments and shear forces are maximum at the joints. Therefore, the joints need to be ductile to efficiently dissipate the earthquake forces. Most failures in earthquake-affected structures are observed at the joints. Joint is combination of beam and column; beam being an important element in the framework of a structure it should be strengthened to maintain the stability. Traditional retrofitting techniques that use steel and cementations materials do not always offer the most appropriate solutions. Retrofitting with fiber-reinforced polymers (FRP) to strengthen and repair damaged structures is a relatively new technique.

Extensive researches are going on in the areas of application of FRP in concrete structures for its effectiveness in enhancing structural performance both in terms of strength and ductility. Retrofitting with fiber-reinforced polymers (FRP) may provide technically superior alternative to the traditional techniques in many situations. The FRPs are lighter, more durable and have higher strength-to-weight ratios than traditional reinforcing materials such as steel, and can result in less labor-intensive and less equipment-intensive retrofitting work. Structures were originally designed according to earlier codes to withstand only gravity loads and the impacts of earthquake are not considered. Even if it was considered the collapse might be due to the change in hazard level in that region. The use of fiber-reinforced polymers (FRP) composite materials for strengthening/ retrofitting of existing structure has increased in recent years. The FRP products can be used for structural strengthening/ retrofitting of existing building and bridges and for construction. Strengthening/ retrofitting is required when there are increases in the applied loads, human errors in initial construction, accident event such as earthquakes and when a structural member losses its strength due to deterioration over time. The cost associated with replacing the structure back in service immediately is relatively high that strengthening/ retrofitting become the most efficient solution. There are different available materials like FRP, steel, concrete etc. for retrofitting of the structure, but use of FRP is increasing rapidly. This is due to the fact that FRP materials have several advantages over steel and other materials. They are lightweight with superior strength and stiffness-to-weight ratio, they have relatively high corrosion resistance, and FRP laminates can be easily bonded to concrete surfaces.[2] Typical uses of FRP in construction are as follows:

- FRP wraps are used on columns to increase the column ductility,
- FRP plates are bonded to the surface of concrete members (beam, slab, walls) to improve the flexure and shear capacity of the concrete members,
- FRP reinforcing bars and pre-stressing strands are used as an alternative to steel reinforcing.

The use of FRP laminates for this application offers several desirable attributes, such as resistance to corrosion, high strength, lightweight, and ease of handling. Flexure strengthening of concrete beams is accomplished by epoxy bonding the FRP plates to the tension face for shear & flexural strengthening; the FRP plates are bonded to the beam. The use of FRP laminates at the beam has many practical applications in the area of repair.
These include:[3]

- Retrofitting of an existing structure can be expansive and time consuming. The uses of fiber laminates present a quick and economical method to strengthen and repair beam.
- The fiber composites are not adversely affected by weather and salt therefore, the composites laminate will not be subjected to problems associated with corrosion as in the case of steel reinforcing bars.
- The laminate can act as a protective cover at the joint by reducing the exposed concrete surface area where moisture or salts can penetrate into the joint and cause corrosion of reinforcing bars.

II. EXPERIMENTAL INVESTIGATION

2.1 General

The main objective of this experimental program is to study the behavior of under reinforced concrete beams in flexure and when these are strengthened with GFRP. The typical results are analyzed in the light of flexure strength enhancement at first crack load and ultimate load and failure mechanism respectively.

2.2 Testing Program

The objective of testing program was to find out the load versus deformation behavior of retrofitted and control beams. The test program involved:[4] Casting and testing of eight (8) beams, using M30 grade of concrete and Fe 500 (TMT) grade steel. Ordinary Portland cement, natural river sand and the crushed aggregates of 10 mm and 20 mm maximum sizes were used.

A. Four (4) were designed as (R.C.C) Balanced section, reinforced with 2-12mm diameter at bottom, 2–8mm diameter at top using 6mm diameter stirrups @ 90 mm c/c.

B. Four (4) were designed as (F.R.C.C) Balanced section, reinforced with 2-12mm diameter at bottom, 2–8mm diameter at top using 6mm diameter stirrups @ 90 mm c/c.

The elastic modulus of the concrete is 2.4 x 10^4 N/mm2. After 3 day curing, 7 days curing and 28-days curing, companion cubes (150 x 150 x 150 mm) casted along with the beams were tested in compression to determine the 3 day, 7 day and 28-day compressive strength and modulus of elasticity[5].

Table1: Compressive Strength of concrete

Sr.No.	Cubes (150× 150×150)	3 days Strength N/mm²	7 days Strength N/mm²	28 days Strength N/mm²	Remarks
1	Specimen 1	20	27	48	Satisfied
2	Specimen 2	21	26	52	Satisfied
3	Specimen 3	19	29	42	Satisfied

Table 2: Compressive strength of Fly Ash Concrete

Sr.No.	Cubes (150× 150×150)	3 days Strength N/mm²	7 days Strength N/mm²	28 days Strength N/mm²
1	FA10	15	20.78	26.6
2	FA20	16.25	20.11	28.15
3	FA30	16.5	22.16	31.1.8
4	FA40	15.23	17.15	25.5

2.3 Specimen And Reinforcement Details

The experimental programme consists of the testing of 4 R.C.C.and 4 Fly Ash Reinforced beam specimens. The beam had a cross-section of (150×150)mm with an overall length 700 mm. Out of 8 beams 4 were designed as under reinforced, reinforced with 2- 12 mm diameter bar at bottom, 2-8 mm diameter bar at top using 6mm dia. Stirrups @ 90 mm c/c as shown in fig.2.1 and remaining 4 beams were designed as weak in flexure , reinforced with reduction of 70% main bottom steel and shear stirrups maintaining same as under reinforced as shown in fig 2.2. They were designed such that failure would be due to flexural in beam during the test, so as to evaluate the contribution of GFRP to the flexural capacity of beam. All the eight reinforced concrete beam casted and cured for one month. The experimental programme consist of strengthening using glass fiber reinforced polymer. Out of these eight specimen four under reinforced specimen named as RCC1,RCC2,RCCR1,RCCR2 and other four weak in flexure specimen named as WF1,WF2,WFR1,WFR2 before conducting test[6].

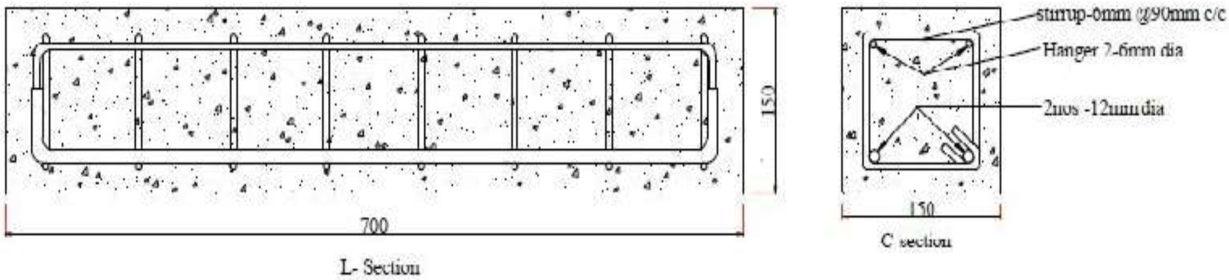

Fig.1: Reinforcement details of R.C.C. balance section

2.4 Casting And Curing

The mould is arranged properly and placed over a smooth surface. The sides of the mould exposed to concrete were oiled well to prevent the side walls of the mould from absorbing water from concrete and to facilitate easy removal of the specimen. The reinforcement cages were placed in the moulds and cover between cage and form provided was 20 mm. Cement mortar block pieces were used as cover blocks. The concrete contents such as cement, sand, aggregate and water were weighed accurately and mixed. The mixing was done till uniform mix was obtained. The concrete was placed into the mould immediately after mixing and well compacted. The test specimens were remolded at the end of 24 hours of casting. They were marked identifications. They are cured in water for 28 days. After 28 days of curing the specimen was dried in air and white washed.

2.5 Application Procedure Of Gfrp Wrap

2.5.1 Surface Preparation (Specimen)

As per recommendations of retrofitting work to get strengthening of structural elements, Surface preparation is an important task in our experimental work. This task was done with the help of grinding machine (To avoid undulation on surface of specimen), Emery cloth, Carborandum stone (for smooth surface), Blower machine (cleaning the dust).

2.5.2 Preparation Of Retrofit Test Specimens

The GFRP sheets were bonded to the tension face of the specimens after 28 days of casting. Before applying the epoxy, the concrete surface was smoothened and cleaned to insure a good bond between the epoxy glue and the concrete surface. The epoxy was hand-mixed and hand-applied at an approximate thickness of about 1 mm. The bond thickness was not specifically controlled, but the excess epoxy was squeezed out along the edges of the sheet, assuming complete epoxy coverage. More details about the methodology utilized to fix the GFRP sheets to the different beams are discussed.

2.5.3 Test Set-Up

The specimen were tested by using Universal testing machine by keeping the beam in horizontal position with two loading system of 20 cm internal loading distance and hinge at distance of 5 cm from the end support. The sustained loading was applied from top of the beams until we could identify the hair cracks and we have noted down the first cracking loads, further the loading is continued until we get the ultimate load that the steel in tension face can take no more upcoming loads and transfers it to the concrete section ultimately.

Fig.2: Experimental Setup for testing of beams

III. EXPERIMENTAL TEST RESULTS

Table 3: Results

Sr. No.	Beam Designation	Cracking Load (KN)	Avg. Cracking Load (KN)	% Increase	Ultimate failure load (KN)	Avg. failure Load (KN)	% Increase
1	RC1	49.05	48.575	-	88.00	87.575	-
2	RC2	48.10			87.15		
3	GFRC1	82.55	82.15	69.11	145	145	65.57
4	GFRC2	81.75			145		
5	FRC1	47.70	47.425	-	94.75	95.00	-
6	FRC2	47.15			95.25		
7	FGFRC1	80.50	80.125	68.95	150.45	152.10	60.10
8	FGFRC2	79.75			153.75		

IV. OBSERVATIONS FROM RESULT

4.1 R.C.C Beam (Balanced Section)

- The Avg. cracking load of retrofitted beams GFRC1, GFRC2 is 82.15 KN and of control beams RC1, RC2 is 48.575KN. The Avg. cracking load of retrofitted beams is 69.11% more than the control beams.

- The Avg. ultimate load carrying capacity of retrofitted beams GFRC1, GFRC2 is 145KN and of control beams RC1, RC2 is 87.575KN. The Avg. ultimate load carrying capacity of retrofitted beam is 65.57 % more than the control beam.

4.2 Fly Ash Reinforced Concrete Beam (Balanced Section)

- The Avg. cracking load of retrofitted beam FGFRC1, FGFRC2 is 80.125KN and of control beam FRC1, FRC2 is 47.425KN. The Avg. cracking load of retrofitted beam is 68.95% more than the control beam.
- The Avg. ultimate load of retrofitted beam FGFRC1, FGFRC2 is 152.1 KN and of control beam FRC1, FRC2 is 95KN. The Avg. ultimate load of retrofitted beam is 60.10% more than the control beam.

V. COMPARISION OF RESULTS

5.1 Load At Initial Crack

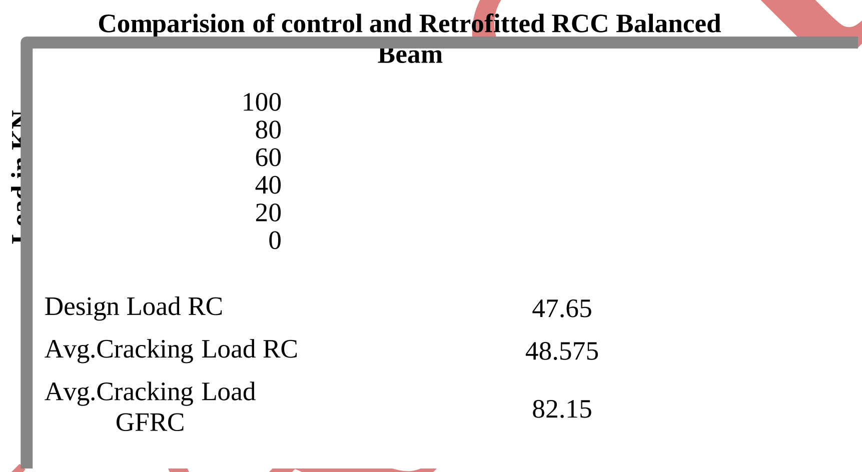

Fig.3: Comparison of controlled and Retrofitted RCC Balanced beam

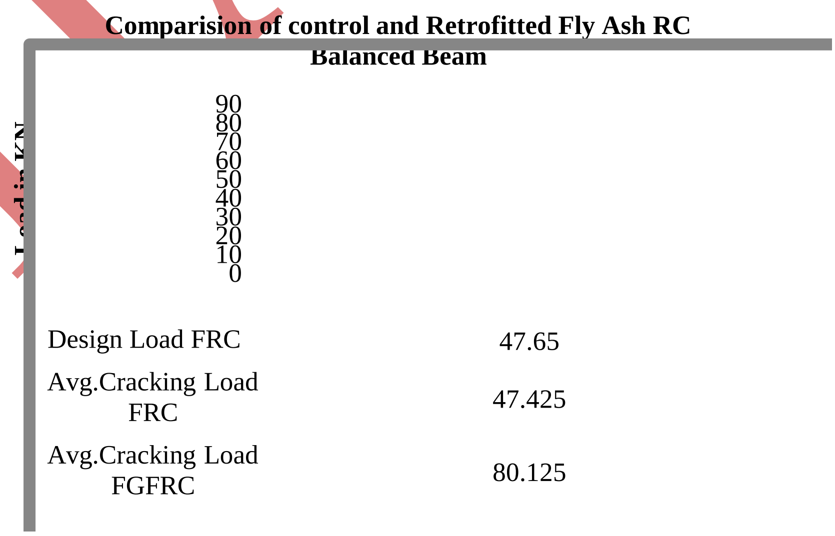

Fig.4: Comparison of controlled and Retrofitted Fly Ash RC Balanced beam

5.2 Ultimate Load Carrying Capacity

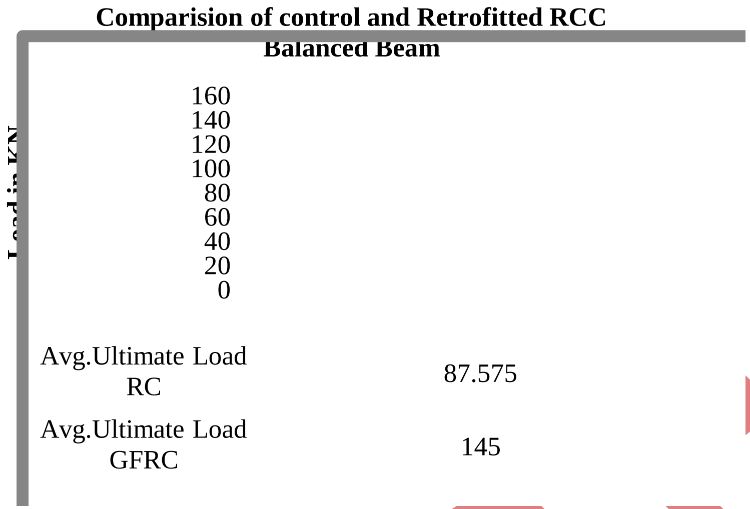

Fig.5: Comparison of controlled and Retrofitted RCC Balanced beam

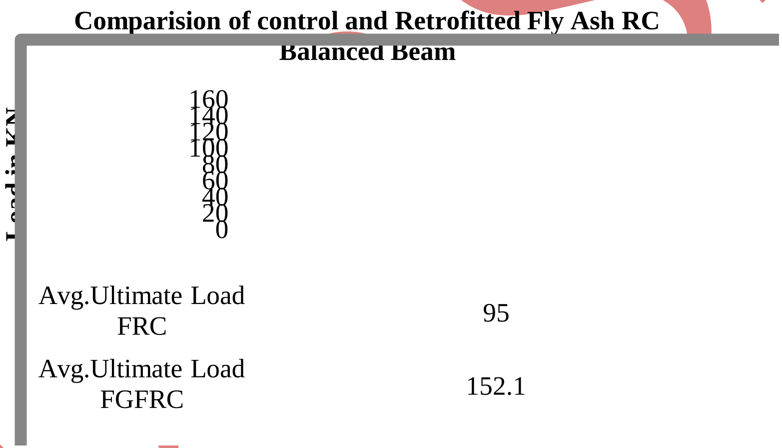

Fig.6: Comparison of controlled and Retrofitted Fly Ash RC Balanced beam

5.3 Load Deflection Behaviour

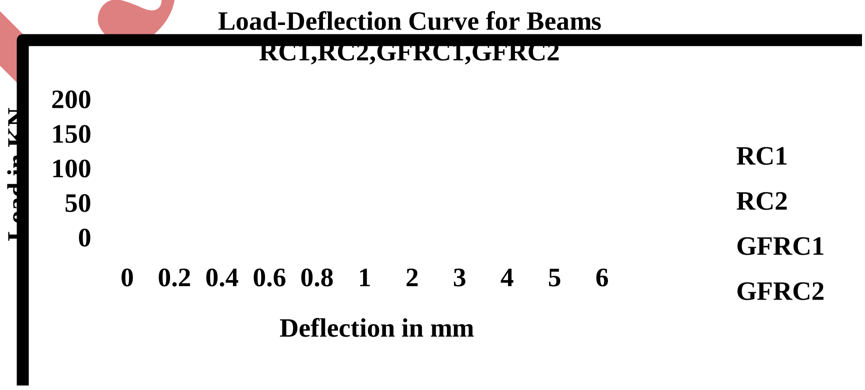

Fig.7: Load- Deflection Curve of Beams RC1, RC2, GFRC1, GFRC2

From the load and deflection data of SET A beams RC1, RC2, GFRC1, GFRC2, load Vs Deflection curve is plotted for all the four beams. From this load Vs deflection curve, it is clear that the beam GFRC1, GFRC2 has higher ultimate load carrying capacity compared to control beams RC1, RC2. Beam GFRC1, GFRC2 had also undergone higher deflection compared to control beam at same load.

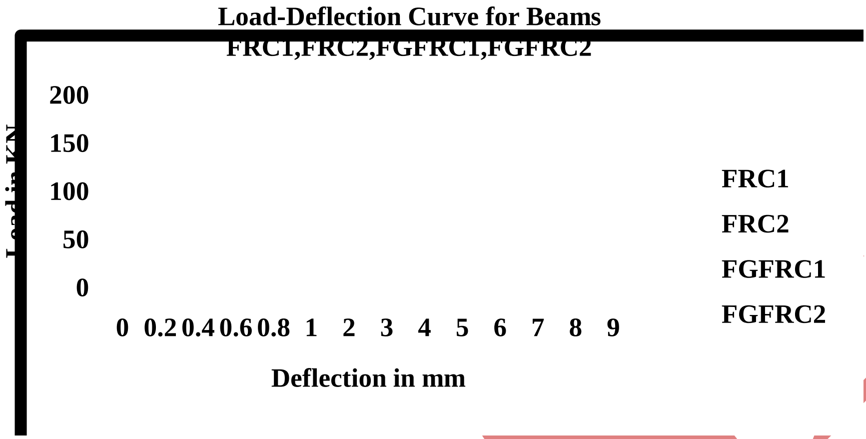

Fig.8: Load-Deflection curve of beams FRC1, FRC2, FGFRC1, FGFRC2

From the load and deflection data of SET B beams FRC1, FRC2, FGFRC1, FGFRC2, load Vs Deflection curve is plotted for all the four beams. From this load Vs deflection curve, it is clear that the beam FGFRP1, FGFRP2 has higher ultimate load carrying capacity compared to control beams FRC1, FRC2. Beam FGFRC1, FGFC2 had also undergone higher deflection compared to control beam at same load.

Beams FRC1, FRC2 has higher ultimate load carrying capacity and deflection compared to beams RC1, RC2 from SET A. Load carrying capacity of retrofitted beams FGFRC1, FGFRC2 and GFRC1, GFRC2 was nearly same but deflection of FGFRC1, FGFRC2 was greater than GFRC1, GFRC2.

VI. CONCLUSION

Based on experimental results following conclusions are drawn

1) Initial flexural cracks appear at a higher load by retrofitting the beam at the soffit as well as on the two sides of beam up to neutral axis from soffit. The Avg. cracking load of retrofitted beams GFRC1, GFRC2 is 82.15 KN and of control beams RC1, RC2 is 48.575KN. The Avg. cracking load of retrofitted beams is 69.11% more than the control beams.
2) The Avg. ultimate load carrying capacity of retrofitted beams GFRC1, GFRC2 is 145KN and of control beams RC1, RC2 is 87.575KN. The Avg. ultimate load carrying capacity of retrofitted beam is 65.57 % more than the control beam.
3) The Avg. cracking load of retrofitted beam FGFRC1, FGFRC2 is 80.125KN and of control beam FRC1, FRC2 is 47.425KN. The Avg. cracking load of retrofitted beam is 68.95% more than the control beam.
4) The Avg. ultimate load of retrofitted beam FGFRC1, FGFRC2 is 152.1 KN and of control beam FRC1, FRC2 is 95KN. The Avg. ultimate load of retrofitted beam is 60.10% more than the control beam.

5) The increase in Avg. cracking load and Avg. ultimate load after retrofitting of Reinforced concrete beam and Fly Ash Reinforced concrete beam is nearly same.

6) Retrofitted beams are having less deflection at maximum load as compared to control beams.

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