Experimental Investigation on GFRP Wrapped R.C Beam Column Joint

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Abstract— *This paper presents the seismic behavior of beam column joint using Glass Fiber Reinforced polymer (GFRP) wraps. The dimensions of the specimens were fixed to be 0.2 m x 0.15 m cross section and the height of column was fixed as 1m and the cantilever length of the beam was fixed as 0.8m to carry out the experimental work. The column portion was reinforced with 4 No's of 8mm diameter in tension side and 4 No's of 8 mm diameter in compression side. The beam portion was reinforced with 2 No's of 8 mm diameter in tension side and 2No's of 8 mm diameter in compression side. The performances of the specimens are compared in terms of lateral load versus displacement curves. The grade of concrete proposed was M20 and the grade of steel was Fe 415. Four numbers of exterior beam column joint were cast and tested under lateral loading. The specimens was designed as per IS 13920:1993. Out of four specimens one was control specimen and the remaining three specimens were wrapped with 1 layer, 2 layers, and 3 layers of GFRP. Results by experimental work shows that GFRP specimens carries more load carrying capacity than the control specimen.*

***Keywords—* column joint, GFRP sheet, Number of wrap, Number of GFRP layers, Reinforcement**

I. INTRODUCTION

In RC buildings, portions of columns that are common to beams at their intersections are called beam-column joints. Beam-column joints being the lateral and vertical load resisting members in RC structures are particularly vulnerable to failures during earthquakes and hence their confinement is the key to successful seismic strengthening strategy.

Beam column joints in a reinforced concrete moment resisting frame are crucial zones for transfer of loads effectively between the connecting elements (i.e., beams and columns) in the structure. Recently strengthening of RC structures using GFRP has become very popular. The current amount of work is related to fiber- reinforced polymers (FRP) composites as a repair material for strengthening of structures. These new generation materials are used to improve the strength and seismic load resistance of existing structures. In normal design practice for gravity loads, the design check for joint is not critical and hence not warranted. But, the failure of reinforced concrete frames during many earthquakes has demonstrated heavy distress due to shear in the joints that culminated in the collapse of the structure.

A new technique has emerged recently which uses fiber reinforced polymer (FRP) sheets to strengthen the beam-column joints which have a number of favorable characteristics such as ease to install, immunity to corrosion and high strength. Fiber materials are used to strengthen a variety of reinforced concrete elements to enhance the flexural, shear and axial load carrying capacity of elements. The results obtained that the FRP strengthening technique is highly efficient and effective. Based on the review of literature it is found that experimental investigation on FRP wrapped reinforced beam column joints. Hence an attempt has been made to carry out an investigation on beam column joint specimens wrapped with GFRP

II. EXPERIMENTAL PROGRAM

A) MATERIALS USED

a) CEMENT: Ordinary Portland cement type (grade 53) was used for this investigation and it is confirm to the IS 12269-1987. Chemical composition and Physical properties of cement given in the below the table.

TABLE 1
CHEMICAL COMPOSITION OF CEMENT

chemical composition of cement	
constituents	***Contents***
CaO	63.25
SiO_2	22.42
Al_2O_3	4.68
Fe_2O_3	3.68
MgO	0.25
Na_2O	0.75
K_2O	1.74
Loss of ignition	0.45

TABLE 2
PHYSICAL PROPERTIES OF CEMENT

Physical properties of cement	
Specific gravity	3.15
Specific surface (m^2/kg)	303
Initial setting time (min)	30
Final setting time (min)	600

b) **FINE AGGREGATE:** Locally available sand is used as fine aggregate. The sand confirming to IS: 2386 (part I) 1963 is used as fine aggregate. Physical properties of the sand is given in the below table.

TABLE 3
PHYSICAL PROPERTIES OF SAND

Physical properties of sand	
Specific gravity	2.95
Colour	Gray
Shape of grains	Sub angular
Fineness modulus	2.68

c) **COARSE AGGREGATE:** Coarse aggregate are the crushed stone is used for making concrete. The commercial stone is quarried, crushed, and graded. The size of coarse aggregate 20 mm is used .Physical properties of the coarse aggregate is given in the below table.

TABLE 4
PHYSICAL PROPERTIES OF COARSE AGGREATE

Physical properties of coarse aggregate	
Specific gravity	2.7
Shape	Angular
Fineness modulus	7.73

d) **WATER:** Ordinary tap water used for mortar preparation. Water should be clean and free from organic materials and deleterious amounts of dissolved acids, alkalies, and salts.

e) **GFRP:** Glass fiber is a material consisting of numerous extremely fine fibers of glass. Glass fiber is commonly used as an insulating material. Glass fiber is also used as a reinforcing agent for many polymer products; to form a very strong and light fiber-reinforced polymer(FRP) composite material called glass-reinforced plastic (GRP), popularly known as "fiberglass".

TABLE 5
PHYSICAL PROPERTIES OF COARSE GLASS FIBER

Name	Glass fiber
Colour	White
Technical data of fiber	E-Glass, 610 gsm
Modulus of elasticity	73 kN/mm^2
Tensile strength	3400 N/mm^2
Total weight of sheet in main direction	610 g/m^2
Density	2.6 g/cm^3
Ultimate strain	4.5
Thickness for static design weight/density	1 mm
Safety factor for static design	1.5

f) **MIX PROPORTION:** A mix design for M20 grade concrete was done as per IS 456 – 2000. The water to cement ratio in the production of concrete is taken as 0.4 weight % of cement.

TABLE 6
MIX PROPORTION

Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (Kg/m^3)
191.61	479	488	1166
0.4	1	1.02	2.43

III. EXPERIMENTAL WORK

A) **SPECIMEN DETAILS:** The experimental program consisted of testing four reinforced concrete beam-column joint specimens. The column had a cross section of 200 mm x 150 mm with an overall height of 1000 mm and the beam had a cross section of 150 mm x 125 mm with cantilever length 800 mm. The column portion was reinforced with 4 No's of 8 mm diameter in tension side and 4 No's of 8 mm diameter in compression side. The beam portion was reinforced with 2 No's of 8 mm diameter in tension side and 2 No's of 8 mm diameter in compression side. They were designated such that failure would be due to flexural in the joint during the test, so as to evaluate the contribution of GFRP to the flexural capacity of joint.

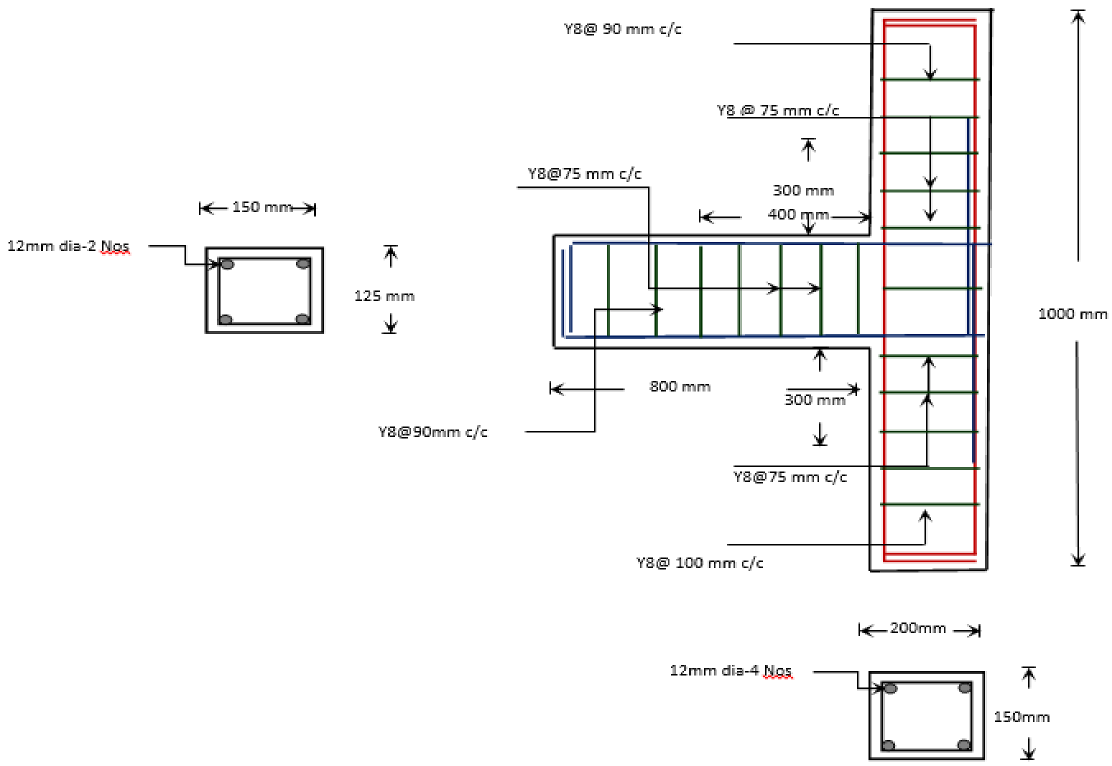

FIG. 1 BEAM COLUMN JOINT

B) **PREPARATION OF MOULD:** Moulds made of country, wood has been prepared for casting the beam column joint specimen. It consists of a long plate and two L-shaped plates and this assembly was bolted together by using square plates at the ends. The inner dimensions of the mould were 200x150x1000 mm in the column portion and 150x125x800 mm in the beam portion.

FIG.2 BEAM COLUMN JOINT MOULD

C) 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 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 demoulded 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.

FIG. 3 CASTING OF BEAM COLUMN JOINT

D) EXPERIMENTAL SETUP: The schematic view of the test set up as shown. A 1000kN hydraulic jack mounted vertically to the loading frame was used for simulating the axial gravity load on the column. A constant axial load of 100kN, which is about 20 percent of the axial capacity of the column was applied to the columns for holding the specimen in position and to simulate column axial load. Two ends of the column were given an external axial hinge support, in addition to two lateral hinge support provided at the bottom and top of the column. The point of application of the lateral load was at 50 mm from the free end of the beam. The test was displacement controlled and the specimen was subjected to an increasing cyclic displacement up to the failure.

FIG 4. EXPERIMENTAL SETUP

IV. TEST RESULTS AND GRAPHS

The load and the corresponding deflections on control and glass fiber specimens were plotted on graphs. These results were obtained by conducting load test on control specimens and glass fiber specimens. The graphs are plotted based on loads and deflections of both the specimens.

A) CONTROL SPECIMEN: The control specimen has been designed and detailed as per code IS 13920:1993.The lateral load was applied at an interval of 50kN. The initial crack was developed at 300kN. The specimen was failed at an ultimate load of 450kN. Deflection for the corresponding load was taken by the dial gauges.

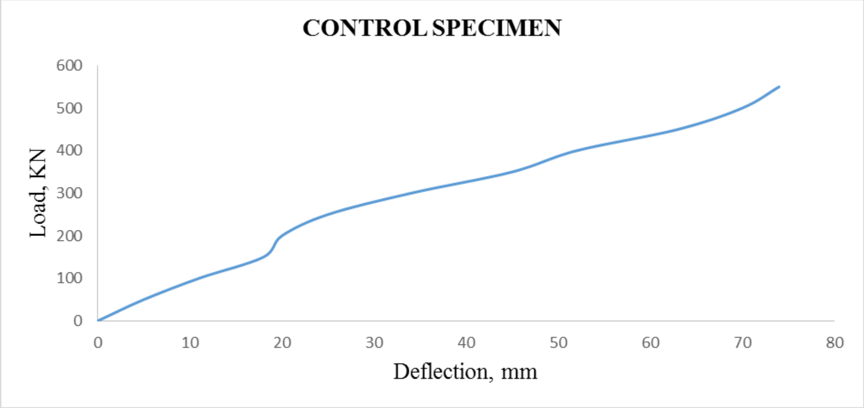

FIG. 5 LOAD VS DEFLECTION OF CONTROL SPECIMEN

B) CONTROL +GFRP (1 Layer): The control specimen has been designed and detailed as per code IS 13920:1993. This specimen was wrapped with 1 layer of GFRP. The lateral load was applied at an interval of 50kN. The initial crack was developed at 400kN. The specimen was failed at an ultimate load of 453kN. Deflection for the corresponding load was taken by the dial gauges.

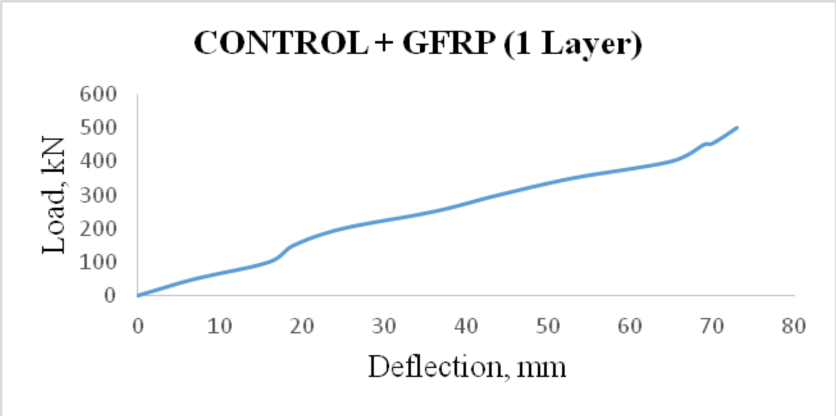

FIG. 6 LOAD VS DEFLECTION OF CONTROL + GFRP (1 LAYER) SPECIMEN

C) CONTROL +GFRP (2 Layers): The control specimen has been designed and detailed as per code IS 13920:1993. This specimen was wrapped with 2 layers of GFRP. The lateral load was applied at an interval of 50kN. The initial crack was developed at 400kN. The specimen was failed at an ultimate load of 470kN. Deflection for the corresponding load was taken by the dial gauges.

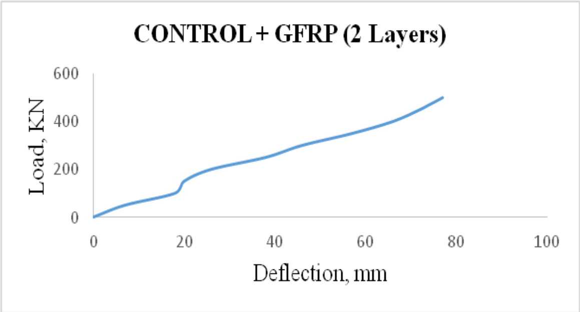

Fig. 7 Load Vs Deflection Of Control + Gfrp (2 Layers) Specimen

D) CONTROL +GFRP (3 Layers): The control specimen has been designed and detailed as per code IS 13920:1993. This specimen was wrapped with 3 layers of GFRP. The lateral load was applied at an interval of 50kN. The initial crack was developed at 450kN. The specimen was failed at an ultimate load of 530kN. Deflection for the corresponding load was taken by the dial gauges.

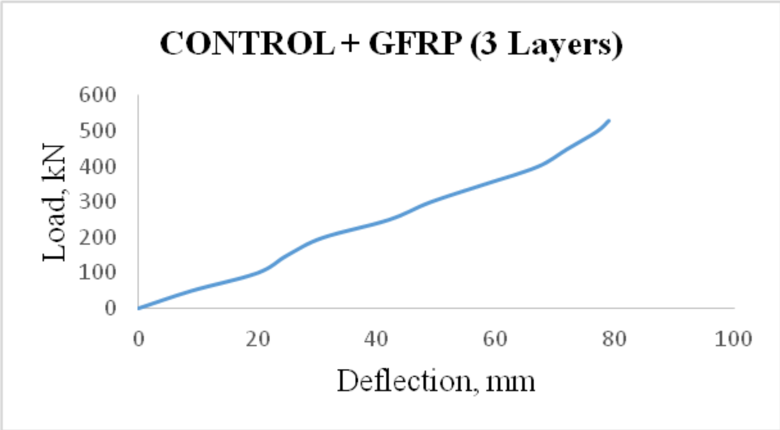

FIG. 8 LOAD VS DEFLECTION OF CONTROL + GFRP (3 LAYERS) SPECIMEN

V. DISCUSSION ON TEST RESULTS

A) LOAD STUDY: With reference to the test results, the loads on control specimen at first crack stage are compared to the loads on glass fiber specimens at first crack stage. It is observed that the load carrying capacity of glass fiber specimens are increased when compared to the control specimen. From these values the percentage of increase in load carrying capacity of glass fiber specimens over control specimen are tabulated.

TABLE 7
YIELD POINTS OF THE GLASS FIBER SPECIMENS

Sample No	Load at first crack (kN)		Percentage of increase in strength
	Control specimen	Glass fiber specimen	
1	300	350	16.67
2	300	400	33.33
3	300	450	50.00

B) DEFLECTION STUDY: The deflections on control specimen at first crack stage are compared to the loads on glass fiber specimens at first crack stage. It is observed that the load carrying capacity of glass fiber specimens were decreased when compared to the control specimen. From these values the percentage of decrease in deflections of glass fiber specimens over control specimen are tabulated.

TABLE 8
DEFLECTIONS OF THE GLASS FIBER SPECIMENS

Sample No	Deflections at first crack (mm)		Percentage of decrease in deflection
	Control specimen	Glass fiber specimen	
1	34	27	25.92
2	34	22	54.55
3	34	19	78.35

C) DUCTILITY: The ratio of the ultimate displacement (Δult) and the yield displacement (Δ yield) of the joint.

TABLE 9
DUCTILITY FACTOR OF BEAM COLUMN JOINT

Sample No	Yielding deflection (mm)	Ultimate deflection (mm)	Ductility factor
1	34	56	1.647
2	53	78	1.472
3	66	84	1.273
4	72	92	1.34

VI. CONCLUSION

Based on the experimental investigations carried out on the control and beam-column joint specimens using GFRP wrapping, the following conclusions were drawn:

1. The experimental results clearly demonstrate that GFRP wrapping can enhance the structural performance of RC beam column joint under static loading.
2. Increasing the number of GFRP layers increase the axial compressive strengths of the beam column joint.
3. Control + GFRP (1 layer) is 1.06% more load carrying capacity than the control specimen.
4. Control + GFRP (2 layers) is 1.346% more load carrying capacity than the control specimen.
5. Control + GFRP (3 layers) is 1.448% more load carrying capacity than the control specimen.

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