STUDY ON BEHAVIOUR OF RETROFITTED RC BEAM-COLUMN EXTERIOR JOINTS WITH GFRP

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ABSTRACT:
The issue of upgrading the existing civil engineering infrastructure has been one of great importance for over a decade. Deterioration of bridge decks, beams, girders and columns, buildings, and others may be attributed to ageing, environmentally induced degradation, poor initial design and construction, lack of maintenance, and to accidental events such as earthquakes. One of the techniques of strengthening of the RC structural members is through confinement with a composite enclosure. This external confinement of concrete by high strength fiber reinforced polymer (FRP) composite can significantly enhance the strength and ductility and will result in large energy absorption capacity of structural members. FRP material, which are available in the form of sheet, are being used to strengthen a variety of RC elements to enhance the flexural, shear, and axial load carrying capacity of these elements. An experimental investigation of the behavior of retrofitted FRP wrapped exterior beam-column joints with detailing as per IS 13920: 1993 under seismic conditions is presented. The experimental study on exterior beam-column joint of a multistory reinforced concrete building (G+ 4 storey) in Chennai Zone falling under the seismic Zone – III has been analyzed using STADD.Pro. The specimens were designed for seismic load according to IS 1893(Part-I): 2002 & IS 13920: 1993. The test specimen is reduced to one fifth model of beam-column joint from prototype specimen. Column confinement and beam stirrups are provided closely in joint region according to IS 13920: 1993. Three specimens were cast and tested to failure during the present investigation. One is control specimen, test up to post ultimate load. Another two specimen test up to 70% of the ultimate load and those specimens were retrofitted with GFRP wrapping.

1. INTRODUCTION

The behaviour of reinforced concrete moment resisting frame structures in recent earthquakes all over the world has highlighted the consequences of poor performance of RC beam-column joints. RC 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. In the analysis of reinforced concrete moment resisting frames, the joints are generally assumed as rigid.In Indian practice, the joint is usually neglected for specific design with attention being restricted to provision of sufficient anchorage for longitudinal beam reinforcement. This may be acceptable when the frame is not subjected to earthquake loads. The poor design practice of beam-column joints is compounded by the high demand imposed by the adjoining flexural members (beams and columns) in the event of mobilizing their inelastic capacities to dissipate seismic energy.

2. OBJECTIVE

- In order to increase the strength of beam column joint by using glass fibre reinforced polymer.
- In order to reduce the failure on beam column joint, similarly to attain the maximum strength.
- The use of glass fiber reinforced polymer into joint will enhance the strength of the joint similar to its original strength.

3. ANALYSIS OF BUILDING

Table 3.1 Analysis of building

Type of structure	Multi-storey rigid jointed plane frame (Special RC moment resisting frame)
Seismic zone	III (Chennai)
Number of stories	Five (G+4)
Floor height	3.2 m
Materials	M 20 Concrete, Fe 415 Steel
Size of Columns	Rect 0.53 x 0.30, Rect 0.76 x 0.30, Rect 0.45 x 0.30, Rect 0.45 x 0.23, Rect 0.64 x 0.30, Rect 0.60 x 0.40, Rect 0.30x 0.23, Rect 0.38 x 0.23.
Size of Beams	Rect 0.53 x 0.23, Rect 0.30 x 0.23, Rect 0.60 x 0.23, Rect 0.45 x 0.23, Rect 0.23 x 0.23, Rect 0.38 x 0.23.
Depth of slab	150 mm
Type of soil	Medium
Foundation depth	2 m
Live load on each floor	3 kN/m^2
Live load on roof	1.5 kN/ m^2
Floor finishes	1.2 kN/ m^2
Seismic analysis and design	As per IS 1893(Part-I): 2002 and IS 13920: 1993.

4. NATURAL PERIOD OTHER FACTORS AND LATERAL LOAD OF A PROPOSED BUILDING

Table 4.1 Loads on proposed building

Natural period (T)	0.38 sec (X-Dir), 0.22 sec (Z-Dir)
Damping	5%
S_a/g	2.5
Zone factor	0.16
Importance factor (I) for residential building	1.0
Response reduction factor (R) for SMRF	5.0
Design horizontal seismic co-efficient (A_h)	0.04
Base shear (V_b)	1460.84 Kn
Lateral load on building (Q_i)	
For X – Direction,	
Ground floor (Q_1)	30.71Kn
First floor (Q_2)	122.93 kN
Second floor (Q_3)	276.60 kN
Third floor (Q_4)	491.73 kN
Fourth floor (Q_5)	540 kN
For Z – Direction,	
Ground floor (Q_1)	40 kN
First floor (Q_2)	160 kN
Second floor (Q_3)	360 kN
Third floor (Q_4)	640 kN
Fourth floor (Q_5)	702 kN

5. MATERIAL USED

- **CEMENT:**

Table 5.1 Properties of cement

Type of Cement	Specific gravity	Initial setting time
OPC-53 grade	3.15	30 minutes

- **COARSEAGGREGATE**

Table 5.2 Properties of coarse aggregate

Size of aggregate	Specific gravity
Passing through 20mm sieve	2.70

- **FINEAGGREGATE**

Table 5.3

Size of aggregate	Specific gravity
Passing through 4.75mm sieve	2.64

Properties of fine aggregate

GLASS FIBER REINFORCED POLYMER

Table 5.4 Properties of Glass fibre reinforced polymer

Material properties	Glass Fibre Reinforced Polymer
Elastic modulus (MPa)	17900
Poisson's ratio	0.25

6. ANALYSIS RESULT

Results obtained from the analysis, it is concluded that, the maximum moment occurred at the ground floor roof level. So the exterior beam-column joint in the ground floor roof level was to be taken for experimental program. This joint will reduced to 1/5th scale for the experimental program.

Table 6.1 Dimension details of prototype & mode

PROTOTYPE	1/5th MODEL
For Beam: Size : 230 x 600 x 4290 mm **For Column:** Size : 400 x 600 x 3200 mm	**For Beam:** Size : 150 x 200 x 430 mm **For Column:** Size : 150 x 300 x 640 mm

7. LOADING MEASUREMENT

•LOAD DEFLECTION BEHAVIOUR

Table 7.1 Experimental Results of RC Beam-Column Joint

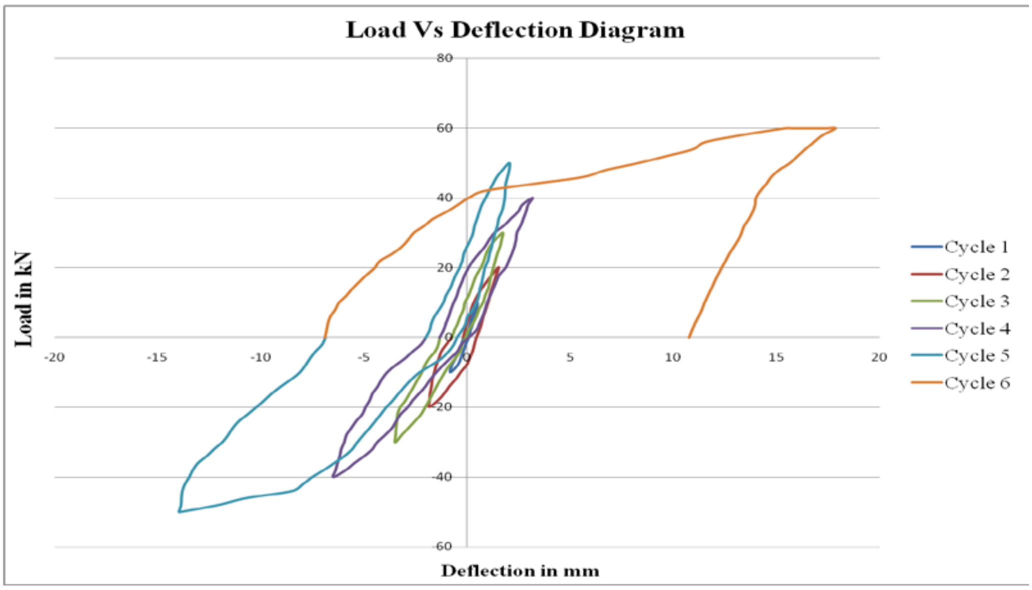
(a). Forward Cycles for Control Specimen (Δy = 2.6 mm)

Cycle No.	Max. Load in kN	Max. Deflection in mm
1	10	0.48
2	20	1.51
3	30	1.71
4	40	3.16
5	50	8.30
6	60	15.42

(b). Reverse Cycles for Control Specimen (Δy = 3.1 mm)

Cycle No.	Max. Load in kN	Max. Deflection in mm
1	10	0.83
2	20	1.83
3	30	3.49
4	40	6.48
5	50	13.9

Figure 7.1 Load-Deflection Diagram



8. BEHAVIOUR OF GFRP WRAPPED BEAM-COLUMN JOINT

Table 8.1 Experimental Results of GFRP Beam-Column Joint for D70GFRP1

(a). Forward Cycles for D70GFRP1 (Δy = 1.8 mm)

Cycle No.	Max. Load in kN	Max. Deflection in mm
1	10	0.32
2	20	0.53
3	30	1.04
4	40	1.15
5	50	1.13
6	60	1.85
7	70	6.3

(b). Reverse Cycles for D70GFRP1 (Δy = 2.2 mm)

Cycle No.	Max. Load in kN	Max. Deflection in mm
1	10	0.26
2	20	0.86
3	30	1.8
4	40	2.54
5	50	3.81
6	60	5.24
7	50	29.5

Table 8.2 Experimental Results of GFRP Beam-Column Joint for D70GFRP2

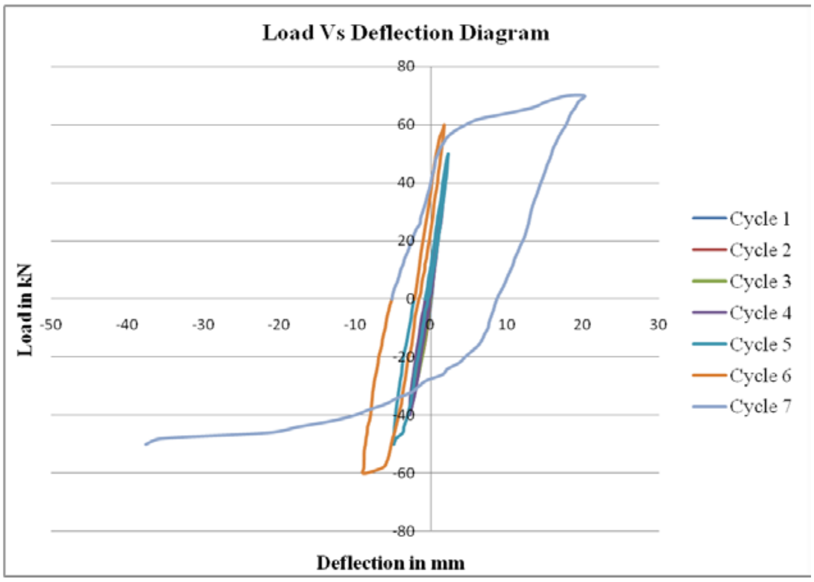
(a). Forward Cycles for D70GFRP2 (Δy = 2.5 mm)

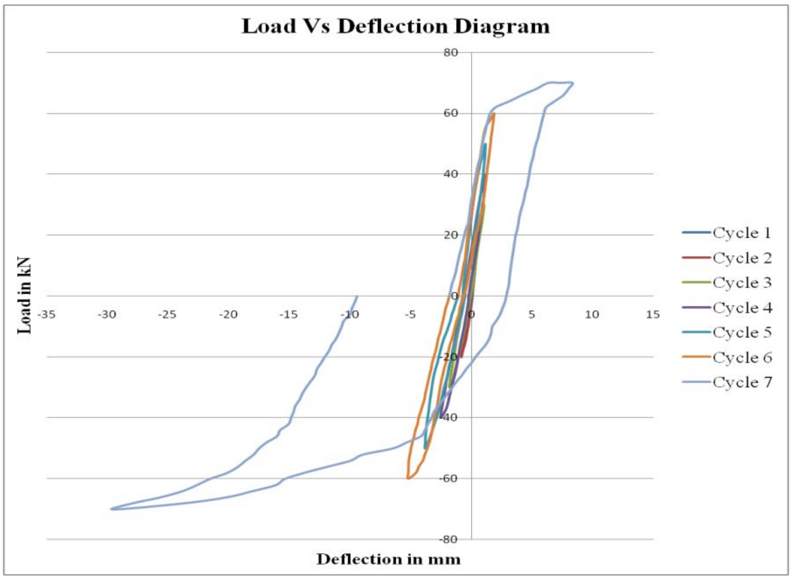
Cycle No.	Max. Load in kN	Max. Deflection in mm
1	10	0.36
2	20	0.74
3	30	1.28
4	40	1.88
5	50	2.33
6	60	1.77
7	70	17.95

(b). Reverse Cycles for D70GFRP2 (Δy = 2.2 mm)

Cycle No.	Max. Load in kN	Max. Deflection in mm
1	10	0.43
2	20	1.16
3	30	1.97
4	40	2.76
5	50	4.86
6	60	8.81
7	50	37.54

Figure 8.1 Load-Deflection Diagram for both D70GFRP1 and D70GFRP2 specimen

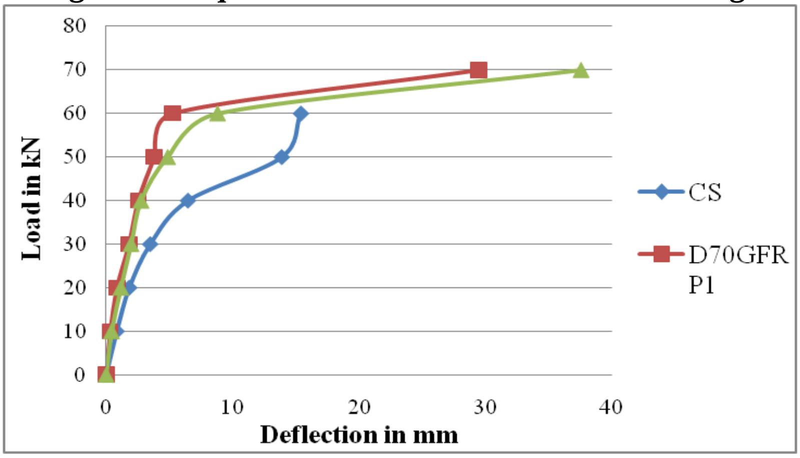




9. COMPARSION RESULT

- **DEFLECTION BEHAVIOUR OF BEAM-COLUMN JOINT**

Figure 9.1 Equivalent Static Load – Deflection Diagram



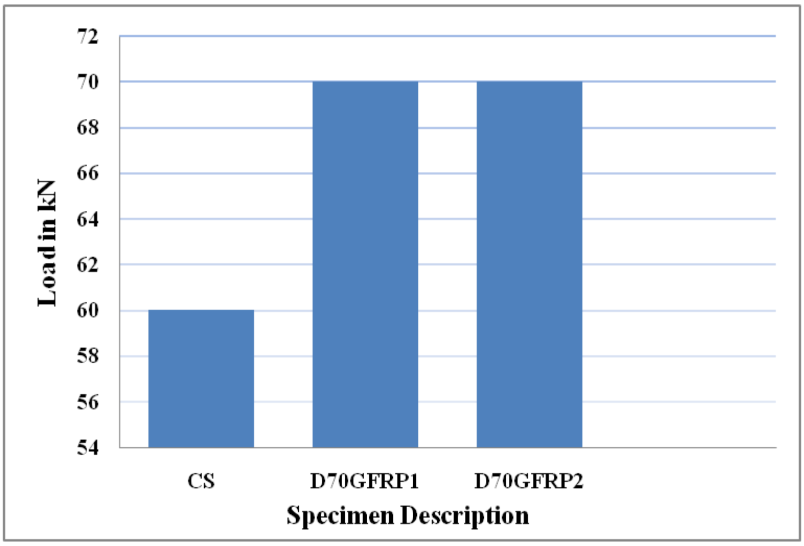


Table 9.2 Comparison results for Conventional & Retrofitted Specimens

SI. No.	Parameters of the specimen	Control specimen (CS)	Retrofitted specimens	
			Single layer specimen (D70GFRP1)	Double layer specimen (D70GFRP2)
1	Load carrying capacity in kN	60	70	70
2	ductility factor	6.19	9.31	10.45

CONCLUSION

An experimental study was carried out on three numbers of Beam-Column joints which were tested under cyclic loading. Based on the investigation reported in earlier chapters, the following conclusions are drawn.

• The structural behaviour of RCC beam-column joint exterior type has been studied analytically by using standard software package STAAD.Pro.

• In general, the retrofitted specimen has been able to regain its original strength. The ultimate load carrying capacity of retrofitted specimens was considerably 1.17 times greater than conventional concrete specimen.

• Retrofitted specimen with single layer wrapping (D70GFRP1) has 60% more energy absorption capacity than control specimen. Double layer wrapping specimen (D70GFRP2) has 2.6 times greater than control specimen.

• The ductility factor of the RC beam-column joint has been considerably increased by the way of GFRP wrapping. Single layer wrapping (D70GFRP1) shows 50% more ductile and Double layer wrapping specimen (D70GFRP2) gives 68.82% more ductile than conventional specimen

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