Study of Performance of Beam Column Joint Retrofitted With Fibre Reinforced Polymers (FRP)

Prof. Rahul.M. Phuke
Department of Structural Engineering
College of Engineering & Technology.
Akola, India
phukerm@gmail.com

Amol R. Parate
Department of Structural Engineering
College of Engineering & Technology.
Akola, India
parateamol63@gmail.com

Abstract- The exterior and corner beam-column joints are among the weakest members of RC (reinforced concrete) frames in terms of unstable resistance. Poor unstable performance of inadequately careful exterior / corner joints will cause total or partial collapse of concrete frame structures. Since most of the prevailing beam-column joint sin comparatively previous structures haven't been made properly inters of re-enforcement detailing, they're in urgent want of retrofitting, significantly in terms of shear strength. To handle an answer for this drawback, from starting of 1990s up tocurrently, several researchers spent efforts on retrofitting of beam column joints by making use of typical and FRP (fiber reinforced polymer) materials. During this study, once the introduction of typical failure modes of RC beam-column joints, available results on the behavior and retrofitting of exterior and corner beamcolumn joints are reviewed and mentioned. Furthermore, the most common FRP retrofitting schemes and contribution of the FRP retrofitting to behavior of exterior beam columns are examined.

1. Introduction

Although exterior beam-column joints are one in all the foremost essential regions of the buildings throughout earthquakes, insufficient transverse reinforcement details, quality of materials and problematic anchorage details in beamcolumn joints are quite common in comparatively recent existing buildings. for several times, these deficiencies have caused severe damages or partial/total collapse of structures throughout earthquakes in this study, typical failure modes of un-retrofitted and FRP retrofitted beam-column joints are concisely introduced and also the FRP retrofitting schemes applied to RC beam-column joints are reviewed

2. Literature View

Abhijit Mukherjee and Mangesh Joshi (2005) carried out an investigation on the performanceof reinforced concrete beam-column joints under cyclic loading. Joints were cast with adequate and deficient bond of reinforcements at the beam-column joint. FRP sheets and strips have been applied on the joints in different configurations. The columns were subjected to an axial force while the beams were subjected to a cyclic load with controlled displacement. The amplitude of displacement is increased monotonically using a dynamic actuator. The hysteretic curves of the specimens were plotted. The energy dissipation capacity of various FRP configurations was compared. In addition, the control specimens were reused after testing as damaged specimens that are candidates for rehabilitation. The rehabilitation was carried out using FRP and their performance was compared with that of the undamagedspecimens

Sandeep S. Pendhari et al (2008) reviewed the applications of fiber reinforced polymer composites (FRPC) for external strengthening in civilconstructions. They focused on experimental as well as analytical and numerical research contributions. The main structural components such as beams, columns and beam-column joints were reviewed and structural behavior of each component was discussed briefly. General concluding remarks were made along with possible future directions of research. Lakshmi.G.A et al (2008) carried a detailed investigation on strengthening of beam column joints under cyclic excitation using FRP composites. Three typical modes of failure namely flexural failure of beam, shear failure of beam and shear failure of column were discussed. Comparison was made in the terms of load carrying capacity. Three exterior beam column joint sub assemblages were cast and tested under cyclic loading. All three specimens were retrofitted using FRP materials and the results were compared with controlled specimens.

3 Mix Design of M 30 grade by IS 10262-2009

3.1 Trial mix 1

Target Strength for Mix Proportioning

f'ck =fck + 1.65 s

f'ck = target average compressive strength at 28 days,

fck = characteristic compressive strength at 28 days, and

s = standard deviation.

From Table I, standard deviation, s = 5 N/mm^2

Therefore, target strength = 30 + 1.65 x 5 =38.25 N/mm^2

Selection of Water-Cement Ratio

From Table 5 of IS 456, maximum water-cement ratio = 0.45.

Based on experience, adopt water-cement ratio as 0.40.

0.40 < 0.45, hence O.K.

Selection of Water Content

From Table 2, maximum water content =186 liter (for 25 to 50 mm slump range) for 20 mm aggregate

Estimated water content for 100 mm slump $=186+\frac{6}{100}X\ 186$ =197 liter

Calculation of Cement Content

Water-cement ratio= 0.40

Cement content = $\frac{140}{0.40}$ = 350 kg/m^3

From Table 5 of IS 456, minimum cement content for 'severe' exposure condition = 320 kg/m3

350 kg/m^3 > 320 kg/m^3, hence, O.K.

Proportion of Volume of Coarse Aggregate and Fine Aggregate Content

From Table 3.volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II)

for water-cement ratio of 0.40 =0.62.

In the present case water-cement ratio is 0.40. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62.

NOTE - In case the coarse aggregate is not angular one. then also volume of coarse aggregate may be required 10 be increased suitably, based on experience.

For pumpable concrete these values should be reduced by 10 percent.

Therefore, volume of coarse aggregate = 0.62 x 0.9 = 0.56.

Volume of fine aggregate content =I - 0.56 =0.44.

Mix Calculations

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m3

b) Volume of cement $= \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} X \frac{1}{1000}$

$= \frac{350}{3.15} X \frac{1}{1000} = 0.111\ m^3$

c) Volume of water $= \frac{\text{Mass of water}}{\text{Specific gravity of water}} X \frac{1}{1000}$

$= \frac{140}{1} X \frac{1}{1000} = 0.140\ m^3$

d) Volume of all in aggregate = [a- (b +c +d)]
= 1-(0.111 +0.140) = 0.743 m^3

e) Mass of coarse aggregate
= e X volume of fine aggregate X Sp.Gravity of fine aggregate 1000

= 0.743 x 0.56 x 2.74 x 1000 = 1140 kg/m^3

f) Mass of fine aggregate = e X volume of fine aggregate X Sp. Gravity of fine aggregate 1000

= 0.743 x 0.44 x 2.74 x 1000

= 896 kg/m^3

Cement= 350 kg/m^3

Water = 140 kg/m^3

Fine aggregate= 896 kg/m^3

Coarse aggregate= 1140 kg/m^3

Water-cement ratio= 0.40

The slump shall be measured and the water content and dosage of admixture shall be adjusted for achieving the required slump based on trial, if required. The mix proportions shall be reworked for the actual water content and checked for durability requirements.

Two more trials having variation of ±10 percent of water-cement ratio in above shall be carried out and a graph between three water-cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirement shall be met.

Table 4.2: Mix proportion of for trial 1

Mix	Cement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water kg/m^3
	350	896	1140	140
Proportion	1	2.56	3.25	0.40

3.2 Trial mix 2

Target Strength for Mix Proportioning

f'ck =fck + 1.65 s

f'ck = target average compressive strength at 28 days,

Fck = characteristic compressive strength at 28 days, and

s = standard deviation.

From Table I, standard deviation, s = 5 N/mm^2

Therefore, target strength = 30 + 1.65 x 5 =38.25 N/mm^2

Selection of Water-Cement Ratio

From Table 5 of IS 456, maximum water-cement ratio = 0.45.

Based on experience, adopt water-cement ratio as 0.36.

0.36 < 0.45, hence O.K.

Selection of Water Content

From Table 2, maximum water content =186 liter (for 25 to 50 mm slump range) for 20 mm aggregate

Estimated water content for 100 mm slump =186+$\frac{6}{100}$X 186 =197 liter

Calculation of Cement Content

Water-cement ratio= 0.36

Cement content = $\frac{140}{0.36}$ = 388.88 kg/m^3

From Table 5 of IS 456, minimum cement content for 'severe' exposure condition = 320 kg/m3

388.88 kg/m^3> 320 kg/m^3, hence, O.K.

Proportion of Volume of Coarse Aggregate and Fine Aggregate Content

From Table 3.volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II)

For water-cement ratio of 0.36 = 0.64.

In the present case water-cement ratio is 0.40. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.36 = 0.64.

NOTE - In case the coarse aggregate is not angular one. then also volume of coarse aggregate may be required 10 be increased suitably, based on experience.
For pumpable concrete these values should be reduced by 10 percent.
Therefore, volume of coarse aggregate = 0.64 x 0.9 = 0.576.
Volume of fine aggregate content =I - 0.576 =0.424.
Mix Calculations
The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m^3
b) Volume of cement = $\frac{\text{Mass of cement}}{\text{Specific gravity of cement}}$ X $\frac{1}{1000}$
$= \frac{388.88}{3.15}$ X $\frac{1}{1000}$ = 0.123 m^3

c) Volume of water = $\frac{\text{Mass of water}}{\text{Specific gravity of water}}$ X $\frac{1}{1000}$
$= \frac{140}{1}$ X $\frac{1}{1000}$ = 0.140 m^3

d) Volume of all in aggregate = [a- (b +c +d)]
= 1-(0.123 +0.140) = 0.731 m^3

e) Mass of coarse aggregate = e X volume of fine aggregate X Sp.Gravity of fine aggregate X 1000
= 0.731 x 0.576 x 2.74 x 1000
= 1153.69 kg/m^3
f) Mass of fine aggregate = e X volume of fine aggregate X Sp. Gravity of fine aggregate 1000
= 0.731 x 0.424 x 2.74 x 1000
= 849.24 kg/m^3

Cement= 388.88 kg/m^3
Water = 140 kg/m^3
Fine aggregate = 849.24 kg/m^3
Coarse aggregate = 1153.69 kg/m^3

Water-cement ratio= 0.36

The slump shall be measured and the water content and dosage of admixture shall be adjusted for achieving the required slump based on trial, if required. The mix proportions shall be reworked for the actual water content and checked for durability requirements.

Two more trials having variation of ±10 percent of water-cement ratio in above shall be carried out and a graph between three water-cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirement shall be met.

Table 4.3: Mix proportion of for trial 2

Mix	Cement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water kg/m^3
	388.88	849.24	1153.69	140
Proportion	1	2.18	2.96	0.36

3.3 Trial mix 3

Target Strength for Mix Proportioning
f'ck =fck + 1.65 s
f'ck = target average compressive strength at 28 days,
fck = characteristic compressive strength at 28 days, and
s = standard deviation.
From Table I, standard deviation, s = 5 N/mm^2
Therefore, target strength = 30 + 1.65 x 5 =38.25 N/mm^2
Selection of Water-Cement Ratio
From Table 5 of IS 456, maximum water-cement ratio = 0.45.
Based on experience, adopt water-cement ratio as 0.44.
0.44 < 0.45, hence O.K.
Selection of Water Content
From Table 2, maximum water content =186 liter (for 25 to 50 mm slump range) for 20 mm aggregate
Estimated water content for 100 mm slump $=186+\frac{6}{100}X\ 186$
=197 liter
Calculation of Cement Content
Water-cement ratio= 0.44
Cement content $= \frac{140}{0.44} = 318.18\ kg/m^3$
From Table 5 of IS 456, minimum cement content for 'severe' exposure condition = 320 kg/m3
318.18 kg/m^3> 320 kg/m^3, hence, O.K.

Proportion of Volume of Coarse Aggregate and Fine Aggregate Content
From Table 3.volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.44 =0.60.

In the present case water-cement ratio is 0.40. Therefore volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10 the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).

Therefore corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.44 = 0.60

NOTE - In case the coarse aggregate is not angular one. then also volume of coarse aggregate may be required 10 be increased suitably, based on experience.
For pumpable concrete these values should be reduced by 10 percent.
Therefore, volume of coarse aggregate = 0.60 x 0.9 = 0.54.
Volume of fine aggregate content =I - 0.54 =0.46.
Mix Calculations
The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m^3

b) Volume of cement $= \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} X \frac{1}{1000}$

$= \frac{318.18}{3.15} X \frac{1}{1000} = 0.101\ m^3$

c) Volume of water $= \frac{\text{Mass of water}}{\text{Specific gravity of water}} X \frac{1}{1000}$

$= \frac{140}{1} X \frac{1}{1000} = 0.140\ m^3$

d) Volume of all in aggregate = [a- (b +c +d)]

= 1-(0.101 +0.140)= 0.753 m^3

e) Mass of coarse aggregate = e X volume of fine aggregate X Sp.Gravity of fine aggregate 1000

= 0.753 x 0.54 x 2.74 x 1000 = 1114.13 kg/m^3

f) Mass of fine aggregate = e X volume of fine aggregate X Sp. Gravity of fine aggregate 1000

= 0.753 x 0.46 x 2.74 x 1000

= 849.24 kg/m^3

Cement = 388.88 kg/m^3
Water = 140 kg/m^3
Fine aggregate = 949.08 kg/m^3
Coarse aggregate= 1114.13 kg/m^3
Water-cement ratio = 0.44

The slump shall be measured and the water content and dosage of admixture shall be adjusted for achieving the required slump based on trial, if required. The mix proportions shall be reworked for the actual water content and checked for durability requirements.

Two more trials having variation of ±10 percent of water-cement ratio in above shall be carried out and a graph between three water-cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirement shall be met.

Table 4.4 Mix proportion of for trial 3

Mix	Cement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water kg/m^3
	318.18	949.08	1114.13	140
Proportion	1	2.98	3.50	0.44

3.4 Standard cube for trial 1

Quantity for 6 cubes of dimension 150×150×150 mm:

1. Cement : 8.502 kg
2. Sand : 21.768 kg
3. Aggregate : 27.696 kg
4. W/C ratio : 0.40

Observation table:

Table 4.5: Observation of Cube Trial 1

Sr. no.	Area of C/S mm²	Wt of standard cube kg	Mean	Density Kg/m³	Compressive strength			
					7 days N/mm²	Mean	28 days N/mm²	Mean
1	22500	8.4	8.45	25	19.3	18.96	31.23	31.4
2	22500	8.5		25	18.4		31.58	
3	22500	8.4		25	19.2		31.39	

Calculation:

$$\text{Compressive strength} = \frac{\text{loadapplied}}{\text{crossectionalarea}}$$

1st cube: Compressive strength$=\frac{P}{A} = \frac{702675}{150 \text{ X } 150}$

$= 31.23$ N/mm^2

2nd cube: Compressive strength$=\frac{P}{A} = \frac{710550}{150 \text{ X } 150}$

$= 31.58$ N/mm^2

3rd cube: Compressive strength$=\frac{P}{A} = \frac{706275}{150 \text{ X } 150}$

$= 31.39$ N/mm^2

3.5 Standard cube for trial 2

Quantity for cubes of dimension 150×150×150 mm:

1. Cement : 9.444 kg
2. Sand : 20.634 kg
3. Aggregate : 28.032 kg
4. W/C ratio : 0.36

Observation table:

Table 4.6: Observation of Cube Trial 2

Sr. no.	Area of C/S mm²	Wt of standard cube kg	Mean	Density Kg/m³	Compressive strength			
					7 days N/mm²	Mean	28 days N/mm²	Mean
1	22500	8.4	8.45	25	18.1	17.96	29.2	29.13
2	22500	8.5		25	17.5		28.9	
3	22500	8.4		25	18.3		29.3	

Calculation:

$$\text{Compressive strength} = \frac{\text{loadapplied}}{\text{crossectionalarea}}$$

1st cube:Compressive strength$=\frac{P}{A}= \frac{751500}{150 \text{ X } 150}= 33.4$ N/mm^2

2nd cube: Compressive strength$=\frac{P}{A} = \frac{758250}{150 \text{ X } 150}= 33.7$ N/mm^2

3rd cube: Compressive strength$=\frac{P}{A} = \frac{753750}{150 \text{ X } 150}= 33.5$ N/mm^2

3.6 Standard cube for trial 3

Quantity for 6 cubes of dimension 150×150×150 mm:

1. Cement : 7.222 kg
2. Sand : 23.064 kg
3. Aggregate : 27.072 kg
4. W/C ratio : 0.44

Observation table:

Table 4.7: Observation of Cube Trial 3

Sr. no.	Area of C/S mm²	Wt of standard cube kg	Mean	Density Kg/m³	Compressive strength			
					7 days N/mm²	Mean	28 days N/mm²	Mean
1	22500	8.4	8.45	25	21.6	21.1	33.4	33.53
2	22500	8.5		25	21.4		33.7	
3	22500	8.4		25	20.3		33.5	

Calculation:

$$\text{Compressive strength} = \frac{\text{loadapplied}}{\text{crossectionalarea}}$$

1st cube: Compressive strength$=\frac{P}{A} = \frac{657000}{150 \text{ X } 150}= 29.2$ N/mm^2

2nd cube: Compressive strength$=\frac{P}{A}= \frac{650250}{150 \text{ X } 150}= 28.9$ N/mm^2

3rd cube: Compressive strength= $\frac{P}{A} = \frac{659250}{150 \times 150} = 29.3$ N/mm^2

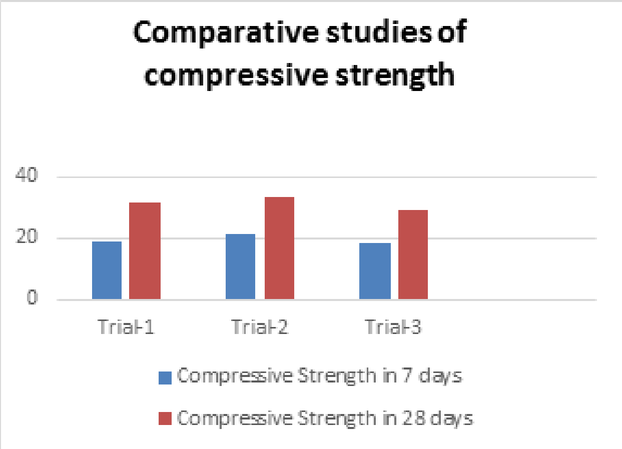

Fig. 3 Comparative Study of Compressive Strength

From these three trials we conclude that the compressive strength for trial-2 is maximum as compared to other trials. So, used trial-2 proportions.

CLOSING REMARKS

The current situation in Beam-Column joints has been a rigorous and in depth analysis to overcome the failures by proposing new equations for joint shear, new models are projected, completely different strengthening and retrofitting ways are mentioned, is finished using experimental data.

Inview of the on top of literature survey that is based on various categories it are often seen that most of the study has been applied i.e. Strengthening and retrofitting techniques. From the on top of literature study

It are often observed that only a few analysis papers are revealed on innovative style and description of exterior beam-column joints.

Due to this observation and literature survey, it's been decided to work in innovative style of reinforcement pattern in external RC beam-column joints.

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