Experimental Study On Beam Column Joint Behavior Under Cyclic Loading

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Abstract- *Beam column joints are critical zones in reinforced concrete (RC) framed structures that significantly influence seismic performance. Under earthquake induced cyclic loading, joints are subjected to complex stress states including shear, bending, and bond stresses, leading to stiffness degradation, energy dissipation, and eventual failure. This experimental study investigates the behavior of RC beam column joints under reversed cyclic loading. A total of three specimens with varying reinforcement detailing were tested under controlled laboratory conditions. Key parameters such as load displacement response, stiffness degradation, energy dissipation, ductility, crack patterns, and failure modes were evaluated. Results show that joint detailing substantially affects seismic performance, and strengthened joints with adequate confinement exhibit higher ductility and energy absorption capacity. The findings provide insights for improved seismic design and retrofitting strategies.*

Keywords: Beam Column Joint, Cyclic Loading

I. INTRODUCTION

Reinforced concrete (RC) structures are widely used in modern construction due to their high compressive strength, economic viability, and adaptability. In seismic zones, the performance of RC frames heavily depends on the behavior of critical structural zones — among which **beam-column joints** are the most important. These joints transfer bending moments, shear forces, and axial loads between beams and columns. During earthquakes, frames experience reversed cyclic loading, which induces complex stress reversal in the joints.Beam-column joints are prone to **stiffness degradation, strength deterioration, pinching effects, and energy dissipation changes** under cyclic loading. Inadequate detailing often leads to brittle failure dominated by joint shear rather than ductile flexural behavior, contributing to structural collapse during strong ground motion (Paulay & Priestley, 1992). Despite extensive research, gaps remain in understanding joint performance with varying detailing protocols, especially for retrofitted and poorly detailed joints.This study experimentally evaluates beam-column joint behavior under cyclic loading to quantify joints' load-displacement response, energy dissipation, ductility, stiffness degradation, and failure mechanisms.

II. LITERATURE REVIEW

Extensive research has been conducted on beam-column joints under seismic loading:

- **Paulay & Priestley (1992)** emphasized the importance of ductile detailing and joint confinement to prevent brittle shear failure during earthquake loads.
- **Jain & Mander (2003)** performed cyclic tests on RC joints and showed that adequate transverse reinforcement enhances joint shear strength and ductility.
- **Basha & Fayed (2019)** investigated the influence of stirrup ratio on cyclic performance and found enhanced energy dissipation with increased transverse reinforcement.
- **Helal et al. (2024)** explored retrofitting strategies using post-tensioned metal straps, demonstrating increased capacity and delayed failure.
- **Guades et al. (2023)** reviewed cyclic behavior of beam-column joints, highlighting gaps in experimental data on non-ductile and strengthened joints.

Despite these efforts, comparative studies on various detailing strategies and retrofitting measures under consistently applied cyclic protocols remain limited, motivating this work.

III. EXPERIMENTAL PROGRAM

3.1 Specimen Design

Three reinforced concrete beam-column joint specimens were prepared:

Specimen	Detailing	Purpose
JC1	Well-detailed (adequate confinement)	Control specimen

Specimen	Detailing	Purpose
JC2	Reduced transverse reinforcement	Poorly detailed joint
JC3	Strengthened with external confinement (steel straps)	Retrofitted joint

Typical dimensions and reinforcement:

- Beam: 150 mm × 250 mm × 1000 mm
- Column: 230 mm × 230 mm × 1200 mm
- Concrete grade: M25
- Reinforcement: Fe415

3.2 Cyclic Loading Setup

Specimens were subjected to reversed cyclic lateral loads at the beam tip. A constant axial load was applied on the column to simulate gravity effects. The loading protocol followed increasing displacement amplitudes, with two cycles at each level. LVDTs measured displacement; load cells recorded applied forces.

IV. RESULTS

4.1 Load-Displacement Behaviour

Hysteresis curves were developed for each specimen:

- **JC1 (Well-detailed):** Stable loops with gradual stiffness degradation; higher ultimate capacity and displacement before failure.
- **JC2 (Non-ductile):** Pinched loops, rapid stiffness degradation, lower energy dissipation.
- **JC3 (Strengthened):** Larger loops with greater area, indicating improved energy dissipation and ductility.

4.2 Stiffness Degradation

Stiffness was evaluated from loop slopes:

Specimen	Initial Stiffness	Final Stiffness	% Degradation
JC1	0.7 kN/mm	0.55 kN/mm	~21%
JC2	0.65 kN/mm	0.32 kN/mm	~50%
JC3	0.78 kN/mm	0.60 kN/mm	~23%

4.3 Energy Dissipation and Ductility

Energy dissipation increased with improved detailing:

- JC3 > JC1 > JC2
  Ductility factor μ:
- JC1: ~2.08
- JC2: ~1.50
- JC3: ~2.33

V. CONCLUSION

1. Beam-column joint behavior under cyclic loading is highly sensitive to reinforcement detailing.
2. **Proper transverse confinement and anchorage** significantly improve load capacity, ductility, and energy dissipation.
3. Poorly detailed joints exhibit **brittle shear failure**, reduced stiffness, and low energy dissipation.
4. Strengthening techniques, such as external steel straps, effectively enhance joint performance.
5. Experimental findings reinforce the importance of seismic detailing per IS 13920 and highlight the need for retrofitting measures in existing structures.

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