



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 5, May 2022

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.118

# A Review on Behavior of Beam Column Joint with FRP under Cyclic Loading

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**ABSTRACT:** Earthquakes have exposed the vulnerability of existing reinforced concrete beam column joints to seismic loading. Concrete jacketing and steel jacketing were the two common methods adopted for strengthening the deficient reinforced concrete beam column joints. This type of retrofitting results in substantial increase in the cross-sectional area and the self-weight of the structure, more over the retrofitted joints have poor resistance for weather attacks and are labour intensive. A new technique has emerged recently which uses fibre reinforced polymer (FRP) sheets to strengthen the beam-column joints which have a number of favourable characteristics such as ease to install immunity to corrosion and high strength. The simplest way to strengthen the joints is to wrap fibre sheets in the joint region in two orthogonal directions.

**KEYWORDS:** beam column joint , FRP, ANSYS

## I. INTRODUCTION

Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. With better understanding of seismic demand on structures and with our recent experiences with large earthquakes near urban centers, the need of seismic retrofitting is well acknowledged. Prior to the introduction of modern seismic codes in the late 1960s for developed countries (US, Japan etc).

The retrofit techniques outlined here are also applicable for other natural hazards such as tropical cyclones, tornadoes, and severe winds from thunderstorms. Whilst current practice of seismic retrofitting is predominantly concerned with structural improvements to reduce the seismic hazard of using the structures, it is similarly essential to reduce the hazards and losses from non-structural elements. It is also important to keep in mind that there is no such thing as an earthquake-proof structure, although seismic performance can be greatly enhanced through proper initial design or subsequent modifications.

The main objective of jacketing is to increase the load carrying capacity of the structural elements against the lateral load. A considerable increase in ductility and stiffness of the section can be obtained depending on the type of jacketing (Vaghani, 2014). There are several techniques of jacketing of damaged structural elements. One of the most common technique is Reinforced Concrete Jacketing (RCJ). In this process the existing member is wrapped with concrete, reinforced with longitudinal steel and ties or with fabric wire. There are basically three methods of RCJ namely beam jacketing, column jacketing and beam column joint jacketing. The main advantages of RCJ is it increases the shear and flexural capacity and easy to construct. Because of that it is widely used techniques of retrofitting all over the world and several kinds of research work has been done on the utilities of RCJ.

## II. STATE OF DEVELOPMENT

**A. Torabi et. al.** Evidence from past earthquakes has shown that during significant events, there are always a number of structures that stay stable but experience different forms of damage in their members. Among these members, beam-column joints in the moment frames are more susceptible to seismic loading and may experience different modes of failure. In this paper, stiffened steel plates are used to repair and retrofit a full-scale damaged RC beam-column joint. The retrofit method is based on joint enlargement. A full scale external beam-column joint is designed and constructed as an ordinary moment resisting frame based on ACI 318M-11 provisions. The structure is then subjected to progressive quasi-static cyclic loading to failure. The damaged joint is then repaired to its former configuration using pressurized epoxy resin and retrofitted by stiffened steel plates. The repaired and retrofitted joint is then subjected to the same cyclic loading protocol to failure. Seismic performance parameters such as strength, stiffness, ductility and energy dissipation capacity of the original joint and the repaired and retrofitted joint are then extracted from their

capacity backbone curves and compared. Results show that the proposed repair and retrofit technique not only regenerated the original capacity but also increased capacity and improved the joint performance by relocating the plastic hinge beyond the repaired region.

**Alper Ilki et. al.** In this study, four full-scale beam-column joint subassemblies were tested under reversed cyclic loads. The specimens were constructed to represent corner joints of relatively old reinforced concrete structures. Therefore, all specimens were cast using low quality of concrete and plain reinforcing bars with inadequate detailing. Two sub assemblages (Group A) included joint, beam, upper storey and lower storey columns, a transverse beam and a part of slab, while the other two sub assemblages (Group B) did not include the transverse beam and slab. One specimen from each group was tested as reference specimens, while the remaining one specimen from each group was tested after the joints were retrofitted using carbon FRP sheets. The aim of the study was both to investigate the effect of FRP retrofit of beam-column joints and the effect of transverse beam and slab on the behaviour of reference joints and retrofitted joints. The test results were evaluated in terms of damage development, failure patterns and hysteretic behaviour characteristics, such as degradation of strength and stiffness, and energy dissipation. At the end of the study, significantly better performance was obtained for the FRP retrofitted specimens, both in terms of shear strength of the joint and energy dissipation during loading cycles. It should be noted that special attention was paid for the retrofit method to be practically applicable.

**A. Arul Gnanaprasam et. al.** In this study, basalt (natural fibres) as monolithic composite (BFRP) and as hybrid composite along with glass (artificial fibres) were used for strengthening of beam-column joints. Totally six specimens were prepared and tested under monotonic loading. Specimen details used were: two control specimens, two specimens for monolithic wrapping and remaining two specimens for hybrid wrapping. The test results were compared with control and rehabilitated specimens. The performance of the treated joints was studied using the following parameters: initial and ultimate cracking loads, energy absorption, deflection ductility and stiffness at ultimate. From the test results, it was found that the hybrid combination of Basalt and Glass FRPs were found to be more effective in the treatment of beam-column joints. The strong column weak beam concept was achieved by failure in beam portion which helped in preventing the catastrophic failure of the entire structure.

**U. Akguze et. al.** Special emphasis is given to the feasibility and efficiency of a retrofitting intervention using glass fibre reinforced polymer (GFRP) composites. A performance-based retrofit approach is adopted with attention given to the targeted specific limit states or design objectives. In addition, a numerical study is presented to calibrate and develop versatile finite element (FE) model, based on micro plane concrete, to simulate the response of the 3D corner as-built joint under bidirectional loading with concurrent varying axial load and compared with the experimental results.

**Adarsh. C. et. al.** For any structure the behaviour of the beam- column joint is important determining the nature of behaviour of that particular structure. If the joint behaves as brittle, then that structure will undergo brittle failure, whereas if it is ductile, it will undergo ductile failure. Hence this study is concentrated on the behaviour of beam-column joint retrofitted with FRP under seismic conditions. Among different retrofitting schemes, FRP retrofitting technique is considered in this paper. This paper covers different FRP retrofitting techniques at beam-column joint, its numerical as well as experimental studies conducted so far. The scope of composite materials in retrofitting beam-column joint is also being evaluated. The present status of FRP composite materials its scope and testing facilities in India are also reviewed through this study.

**D.A. Pohoryles et. al.** Results from full-scale cyclic tests on the CFRP retrofitted specimen are compared to the behaviour of a deficient, pre-1970's design specimen and a specimen designed to modern guidelines. The observed failure mechanisms and global lateral capacities for the Eurocode 8 and retrofitted specimen show that the CFRP retrofit is effective in improving seismic behaviour. By means of a combined selective weakening and strengthening scheme, a change in hierarchy of strengths can be achieved, which leads to an improved ductile behaviour with significant strength enhancement. The results suggest that a CFRP retrofit scheme can be devised for realistic, significantly under-designed structures in order to achieve a similar performance to modern RC structures designed to sophisticated seismic guidelines.

**A. Ilki , C. Demir et. al.** Since most of the existing beam-column joints in relatively old structures have not been constructed properly in terms of reinforcement detailing, they are in urgent need of retrofitting, particularly in terms of shear strength. To address a solution for this problem, from beginning of 1990s up to now, many researchers spent efforts on retrofitting of beam column joints by making use of conventional and FRP (fibre reinforced polymer)



materials. In this study, after the introduction of typical failure modes of RC beam-column joints, available results on the behaviour and retrofitting of exterior and corner beam-column joints are reviewed and discussed. Furthermore, the most common FRP retrofitting schemes and contribution of the FRP retrofitting to behaviour of exterior beam columns are examined. Additionally, the large-scale structural tests conducted at Istanbul Technical University (ITU) on retrofitting of beam column joints built with low strength concrete and plain bars by FRP sheets are summarised. Based on the available research, it seems possible to include the issue of seismic retrofit of RC joint using FRP materials in the future versions of seismic design/retrofit guidelines/codes.

### III. CONCLUSION

This paper focuses only on the literature review of previously published studies. From the above given literature review the results of few paper are discussed below In this Literature review study, four full-scale beam-column joint sub assemblages were tested under reversed cyclic loads. In another paper this contribution, the latest research findings into the effects of multiracial loading on the seismic performance of as-built and FRP retrofitted three-dimensional (3D) beam-column joints with and without floor slabs are presented. one of the paper covers different FRP retrofitting techniques at beam-column joint, its numerical as well as experimental studies conducted so far. The scope of composite materials in retrofitting beam-column joint is also being evaluated. The present status of FRP composite materials its scope and testing facilities in India are also reviewed through this study. one of the paper deals with the strengthening of existing buildings using local and global systems. The strengthening of the structure can be done by increasing the stiffness, boosting the deformation capacity and allowing for more energy dissipation (global)

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**INNO SPACE**  
SJIF Scientific Journal Impact Factor  
**Impact Factor: 8.118**



**ISSN** INTERNATIONAL  
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