

## **Investigation on Behaviour of Reinforced Concrete Beam Column Joints Retrofitted with FRP Wrapping**

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### **Abstract**

The performance of beam-column joints have long been recognized as a significant factor that affects the overall behavior of Reinforced Concrete framed structures subjected to large lateral loads. The reversal of forces in beam-column joints during earthquakes may cause distress and often failure, when not designed and detailed properly. One of the techniques of strengthening the reinforced concrete structural members is through external confinement by high strength fiber composites which can significantly enhance the strength and ductility which will result in large energy absorption capacity of structural members. Fiber materials are used to strengthen a variety of reinforced concrete elements to enhance the flexural, shear, and axial load carrying capacity of elements. Beam-column joints, being the lateral and vertical load resisting members in reinforced concrete structures are particularly vulnerable to failures during earthquakes. Hence this paper discussed that retrofit is often the key to successful seismic retrofit strategy.

## **1. Introduction**

### **1.1 General**

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 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. The simplest way to strengthen the joints is to wrap fiber sheets in the joint region in two orthogonal directions.

## 2. Experimental and Analytical Investigation

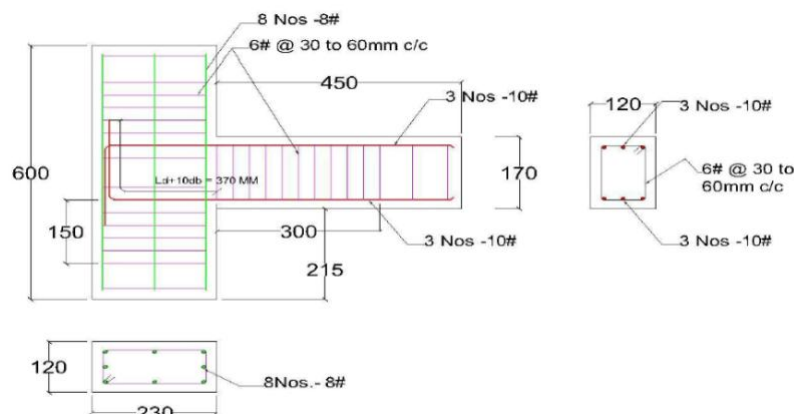
The experimental study on exterior beam column joint of a multistory reinforced concrete building in falling under the seismic Zone – III has been analyzed using STADD.pro. The specimens were designed for seismic load according to IS 1893(PartI):2002 & IS 13920: 1993. The structure is five storey two bay frames including 1.5 m foundation depth. The maximum moment is occurred at the ground floor roof level. We consider that particular joint for the experimental study.

### 2.1 Details of specimen

The test specimen was reduced to 1/5 th scale to suit the loading arrangement and test facilities. Prototype specimen having beam dimension of 305 X 460 including slab thickness and column dimension of 305 X 460. For testing model the dimension of beam was 120 X 170 mm without slab thickness and beam length of 450mm and that column size was 120 X 230 mm. Height of the column was 600mm.

### 2.2 Reinforcement details

The reinforcement details of beam column joint are shown in Figure 2.1 Main reinforcement provided in the beam was 10 mm diameter bars, 3 Nos at top and 3 Nos at bottom. The stirrups are 6 mm diameter bars at 30 mm c/c for a distance of 2d, i.e. 300 mm from the face of the column and at 60 mm c/c for remaining length of the beam. The longitudinal reinforcement provided in the column was 8 No's of 8 mm diameter bars equally distributed along four sides of column. The column confinements are 6 mm diameter bars at 30 mm c/c for a distance of 150 mm from the face of the column and at 60 mm c/c for remaining length of the column.



**Fig. 2.1:** Ductile Detailing of Beam Column Joint as per IS 13920; 1993.

### 2.3 Test setup and instrumentation

The specimen was tested in a reaction frame. A hydraulic jack was used to apply the axial load for column. To record the load precisely a proving ring was used. The load is applied forward cyclic and reverse cyclic and deflection measured from every 3 KN by using LVDT. The deflection was measured at the beam free end tip. Loading is applied gradually such as 3,6,9,12,15 KN respectively for forward direction and 3, 6, 9, 12, 15 KN respectively for reverse direction.

### 2.4 Comparison between experimental study and FEM analysis

Experimental results are compared with FEM model analysis in stadd.pro, the behavior of the exterior beam column joint are similar. Maximum stresses are occurred at the junction for the ultimate loading at the beam tip. The crack patterns are formed and clearly visible in the model as shown in Figure 2.2. The maximum stress are developed in the FEM model at junction the tensile stress at top exceed the maximum tensile stress and compressive stress occurred at bottom in the forward cyclic loading as shown in Figure2.3.



Figure 2.2: Failure due to Ultimate Load for Control Specimen.

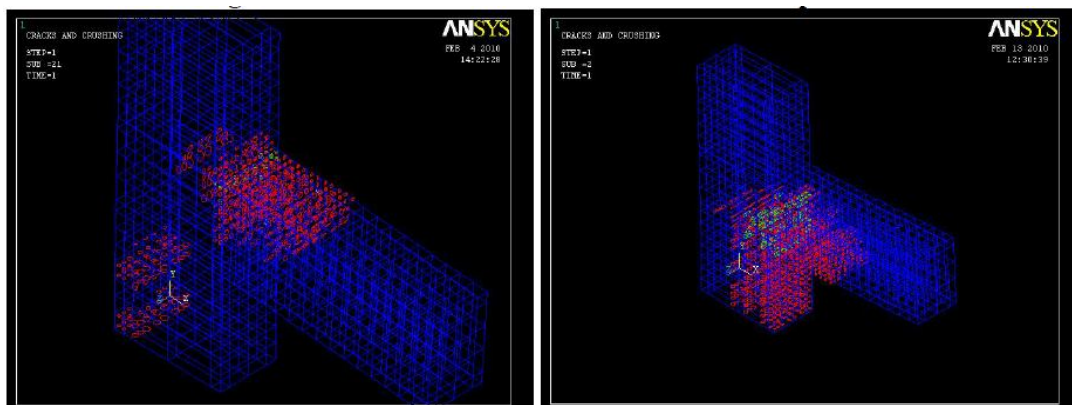


Figure 2.3: Maximum Stress and Crack Pattern due to ultimate load.

### 2.5 Preparation of Retrofitted Specimens

The Exterior beam column joint specimen named as SL1 (Single Layer) & DL2 (Double Layer) was tested subject to quasistatic cyclic loading simulating earthquake loads. The Load was applied by using screw jack totally 5 cycle were imposed. The beam column joint was gradually loaded by increasing the load level during each cycle. The load sequence consists of 3kN, 6kN, 9kN and upto 70% ultimate load. The deflection measured at tip during the cycle of loading. As the load level was increased in each cycle.

### 2.6 Load Carrying Capacity

The first crack was witnessed during 4 th cycle at the load level of 17.0kN. As the load level was increased, further cracks were developed in other portions. The 70% of ultimate load carrying capacity of the SL1 & DL 2 specimens was 20.0kN recorded at 5 th cycle. After the testing of the two specimens the cracks are filled with the fiber glass paste mixed with unsaturated polyester resin. The surface area was covered with help of fiber glass paste in all direction. The Spalling of the concrete portion are filled with this fiber glass paste.

### 2.7 Wrapping of GFRP mat with Resin

Glass fiber mat classE grade 300 (chopped Fiber) was used to wrapping the specimens the mat are cut into desired shape. The Unsaturated Polyester resin with accelerator of Cobalt 6% and catalyst of .01% was added with resin mix thoroughly. The Fiber glass mat placed over the specimen and the resin was applied uniformly in all direction with help of brush. Single Layer thickness was applied to the specimen of EXT1, Double Layer Thickness was applied to the Specimen of EXT 2. The specimens are allowed to dry in the room temperature up to 16 Hr.

### 2.8 Loading and load deflection behavior

The GFRP wrapped specimen was subjected to quasistatic cyclic loading simulating earthquake loads. The load was applied by using screw jack Totally 14 cycles were imposed. The cyclic load versus deflection was presented in Figure 2.4

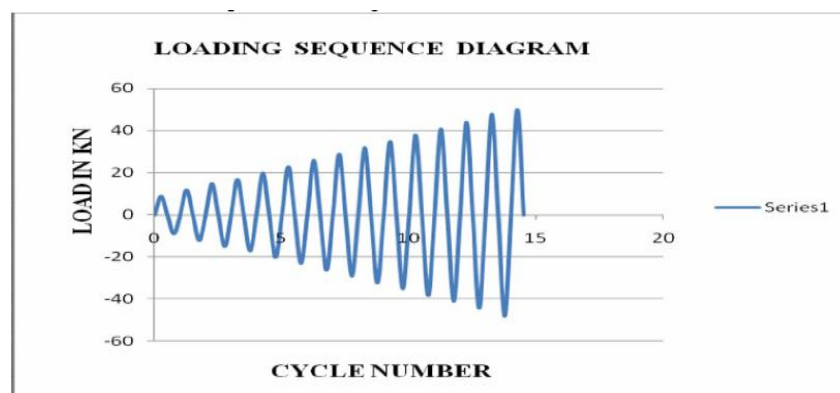
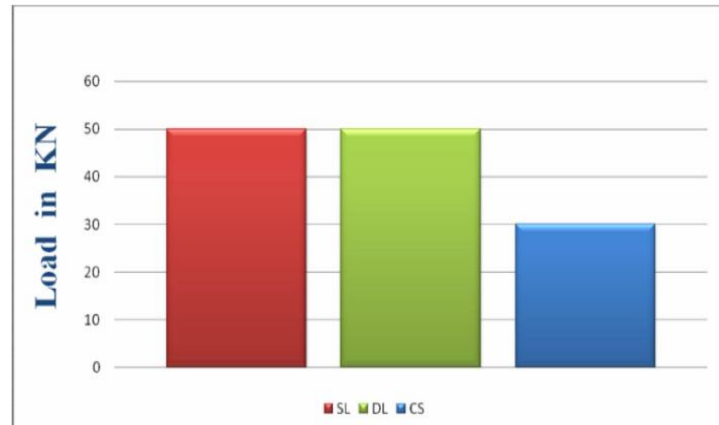
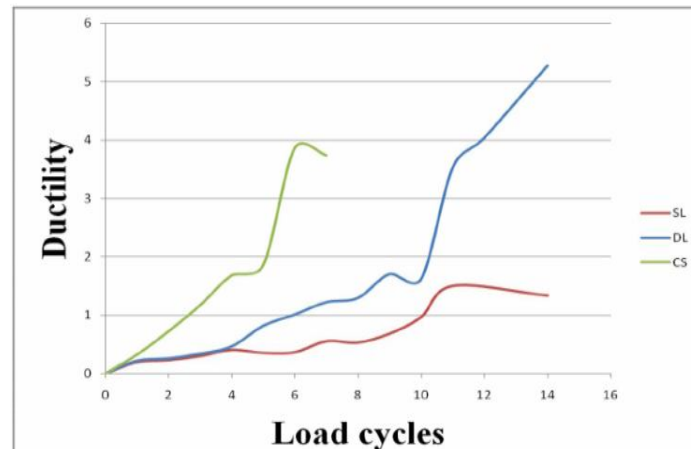


Figure 2.4: Load sequence Diagram.



**Figure 2.5:** Comparison of Load Carrying Capacity for Control & Retrofitted Specimens.



**Figure 2.6:** Comparison of Ductility factor for Control & Retrofitted Specimens.

### 3. Conclusions

Beam column joint in the moment resisting frame have traditionally been neglected in design process while the individual connected elements, that is, beam and column, have received considerable attention in design. Research on beam column joint of reinforced concrete moment resisting frame was started only in the 1970s. The 1993 version of IS 13920 – 1993 incorporated some provision on the design of beam column joints. However, the Provisions are inadequate to prevent shear and bond failure of beam column joint in severe seismic shaking. Therefore, these provisions need to be upgraded substantially with inclusion of explicit provisions on shear design and anchorage requirement. This article proposes provision for shear design of beam column joint and anchorage requirements of tension beam bars in the joint area. It also suggests provisions for the confinement of wide beam and column connections. The plastic hinge formation at the joint after the ultimate load.

- The structural behavior of RCC beam column joint exterior type has been studied analytically by using standard software packages STAAD Pro and ANSYS.
- Experimental investigation has been carried out and the test results show that the structural behavior of exterior beam column joint model has been similar to that of the analytically predicted one.
- The Loading Carrying capacity of the retrofitted Specimen is 60% More than that of the Control Specimen.
- The Load Deformation characteristics also improved to large extent in the case of the Retrofitted specimen over the control specimen.
- The enhancement in the energy absorption capacity of the retrofitted specimen was in the rang of 30% 60% over the control specimen.
- The Failure was in the column Portion of the joint for the control specimen which is to be avoided. In case of the Retrofitted specimen the failure was noticed in the beam portion only and the column was intact and this is the most preferred type of failure under seismic load which will prevent progressive collapse of the structure.

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