ABSTRACT

In the last few decades earthquakes have struck different parts of the world. Recent earthquakes have demonstrated that most of the reinforced concrete structures specially the beam-column joints are vulnerable during earthquakes. The basic requirement of design is that the joint must be stronger than the adjoining hinging members, usually the beams or columns. The existing reinforced concrete beam-column joints which are designed as per code IS 456:2000 do not meet the requirements given in the ductility code IS 13920:1993. Hence the beam-column joints that are not designed as per the ductility code may not perform well when subjected to seismic forces. They must be strengthened in order to improve there performance during earthquakes. Until 1990, concrete jacketing and steel jacketing were the two common methods adopted for strengthening the deficient reinforced concrete beam-column joints. Concrete jacketing increases the cross sectional area and self-weight of the structure. Steel jackets are poor in resisting weather attacks. Both methods are labour intensive and difficult to implement at the site. A new technique for strengthening the reinforced concrete structural members is through confinement with an external fiber reinforced polymer sheets. The effectiveness of the strengthening has to be evaluated experimentally. An attempt has been made to carryout an experimental investigation to compare the performance of beam-column joints that are designed as per code IS 456:2000 with that of beam-column joints detailed as per the code IS 13920:1993 for various grade of concrete and various axial loads on column to find out the deficiencies of the joints detailed as per code IS 456:2000. An experimental investigation has been carried out under static load and reversal load to find the load carrying capacity and energy absorption capacity of reinforced concrete beam-column joint specimens that are detailed as per code IS 456:2000 and retrofitted with various fiber reinforced polymer sheets such as glass fiber reinforcement polymer(GFRP) sheets, carbon fiber reinforcement polymer(CFRP) sheets, aramid fiber reinforcement polymer(AFRP) sheets, sisal fiber sheets and hybrid fiber reinforced polymer sheets for various grades of concrete and various axial loads on column. An Ansys modeling of beam-column joints has been carried out to determine the effect of grade of concrete on load carrying capacity of beam-column joint.

One hundred and ninety eight specimens were designed and detailed as per the code IS 456:2000 and eighteen specimens were designed and detailed as per the code IS 13920:1993. The main difference between the specifications of both the codes is anchorage length, spacing of stirrups and spacing of lateral ties. The beam-column joint specimens as per code IS 456:2000, the specimens as per code IS 13920:1993 and the specimens as per code IS 456:2000 retrofitted with various fiber reinforced polymer sheets were tested to failure. The various types of fiber reinforced polymer sheets used during the present investigation are GFRP, CFRP, AFRP and Sisal fiber sheets. Some specimens were retrofitted with hybrid fiber reinforced polymer sheets such as GFRP & CFRP and GFRP & AFRP. The experimental investigation consists of testing of beam-column join specimens under static load and load reversal case. The specimens were tested in the loading frame with the column in the horizontal plane. It is reported in the literature that when the axial load on the column exceeds 50 % to 60 % of its capacity, the effect of axial load will be more predominant on the joint. But in the case of the seismic forces, the effect of lateral load will be more predominant. Hence in order to truly reflect the performance of the joint under seismic load conditions, it was decided to restrict the axial loads of column is less than 50 % of load carrying capacity of the column. The experimental investigation consisted of applying three axial loads of 15 %, 30 % and 45% of load carrying capacity of the column and applying a point load at the free end of the cantilever beam portion till the failure of the specimen. The loading was continued till the joint failed by crushing of concrete in the case of control specimens and rupture of wrap in the case of retrofitted specimens. Based on the experimental investigations, it is found that the beam-column joint specimens retrofitted with two layer of carbon fiber reinforced polymer sheets gives the maximum increase in the load carrying capacity and energy absorption capacity. This is followed by aramid fiber reinforced polymer sheets wrapping. Glass fiber reinforced polymer sheets and sisal fiber sheets wrapping almost gives the same increase in the load carrying capacity and energy absorption capacity. In the case of hybrid layers consisting of orthogonal mesh of two different types of fiber reinforced polymer sheets, the combination of carbon fiber reinforced polymer sheets with any other fiber reinforced polymer sheets gives the maximum increase in the load carrying capacity and energy absorption capacity.

Finite element analysis of beam-column joints has been carried out to understand the effect of grade of concrete on the performance of beam-column joints. Solid 65 element has been used for modeling the concrete, link 8 element has been used for modeling the reinforcement and solid 45 element has been used for modeling the fiber reinforced polymer sheets. Linear finite element analysis did not yield the results since the finite element model was found to be much stiffer and predicted values of the deflections at the free end of the beam were found to be lower than the experimental results. However the non-linear finite element analysis gave better results and the variations between the Ansys results and experimental results were found to be less than 10 %. From the Ansys analysis, it is found that the deflection of the specimen detailed as per code IS 456:2000 is found to be maximum for a given load. The deflection of the beam-column joint specimen detailed as per code IS 13920:1993 is less than that of the specimen detailed as per code IS 456:2000. The deflection of the beam-column joint specimen retrofitted with fiber reinforced polymer sheets is the least for a given load.