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Experimental Investigation on the Behavior of Reinforced Concrete Columns to Steel Beams Connections (RCS)

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ABSTRACT: Advantages such as high ductility, reduction of dead load and higher energy dissipation of the structures made with steel beams and concrete columns compared to conventional reinforced concrete structures have resulted in the widespread use of these structures. On the other hand, the provisions of different codes of RCS connections lead to complex details and implementation. In this paper, the behavior of steel beam to circular concrete column connections was experimentally studied. Five real scale external RCS connections were made and tested. Variable parameters of the specimens were included the tie spacing around and inside the connections, confinement around the connection region with CFRP sheets and concrete type. The aim of the study was to propose a connection with simple details and desirable behavior. The results indicated that the proposed connection can appropriately transfer the moment from the steel beam to the concrete column in addition to having simple implementation. Also, the confinement of the connection region with CFRP sheets increased the ductility and energy dissipation of the RCS.

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1. INTRODUCTION

RCS structures are classified into two types of continuous beams and continuous columns. Experiments have shown that RCS structures with continuous beams have higher ductility compared to those with continuous columns [1]. Sheikh et al. [2] tested seventeen 2/3 scale interior RCS connections. Tests showed that joint strength significantly increases through details that mobilized concrete shear mechanisms in the joint. Kanno [3] tested 19 RCS connections at Cornell University. The main variables included joint failure modes, use of high strength concrete in the connection, joint aspect ratio and effect of column axial load. An analytical and experimental program was also conducted by Parra and Wight [4]. Parra et al. [5] proposed a deformation-based capacity approach for designing RCS connections in high seismic risk zones to control joint distortions and damage. Cheng and Chen [6] tested six RCS joints and the effect of different parameters such as slab connection, transverse reinforcement in joints and loading protocol were considered in their research. Alizadeh et al. [7] tested two interior RCS connections designed based on the strong column–weak-beam criterion. Both specimens were tested under quasi-static reversed cyclic loading. The specimens were modeled by a finite element method. In another study, Alizadeh et al. [8] tested two interior connections. The joint of the first specimen was designed according to ASCE 1994 guidelines [9], while the second specimen had a new proposed joint detail. Self-consolidating concrete was used in both specimens.

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2. RESEARCH SIGNIFICANCE

The main reason for failure in the RCS connections is the concrete crushing at the upper and lower parts of the steel beam due to the beam rotation in the connections. ASCE 1994 design committee has offered different methods to prevent this failure mode. The suggested methods make the connection implementation complicated due to cutting the required plates and welding them in the connection region. In the case of circular columns in RCS connections, the steel band plate at the upper and lower parts of the steel beam can be replaced by fiber-reinforced polymer (FRP) sheets. Concrete confinement due to FRP sheets can prevent concrete crushing around the connection region. In this experimental study, five full-scale specimens were constructed and tested. The details of the specimens are shown in Table 1.

3. PROPERTIES OF MATERIALS

The compressive strength of the normal and fiber concrete used in columns was 40.5 and 43.7 MPa, respectively. The yield stress of the steel beam was 356 MPa. The yield stress of the reinforcements was 408 MPa. The volume ratio of the steel fibers used in the mixture of fiber concrete was 1%. In all tests, the cyclic load was applied to the end of the steel beam. In addition, a 100 kN axial compression load was applied to the

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Table 1. Details of specimens

Specimen No.	Specimen details
1	Semi-circular transverse reinforcement with 25 mm spacing was used in and around the connection region.
2	Circular transverse reinforcement with 25 mm spacing was used in and around the connection region.
3	Circular transverse reinforcement with 75 mm spacing was used in and around the connection region. The upper and lower parts of the connection are confined with CFRP Sheets.
4	Circular transverse reinforcement with 75 mm spacing was used in and around the connection region. The upper and lower parts of the connection were confined with CFRP sheets and steel fiber concrete was used in this specimen.
5	Circular transverse reinforcement with 75 mm spacing was used in and around the connection region. The upper, lower and the joint parts of the connection were confined with CFRP sheets.

Table 2. Test results and comparison of the test results with calculated capacities

Specimen No.	Load test capacity of the connection P_n (kN)	Bending test capacity of the connection M_{RCS} (kN.m)	calculated bending capacity of the steel beam M_{beam} (kN.m)	calculated bending capacity of the column M_{column}(kN.m)	$\frac{M_{RCS}}{M_{beam}}$	$\frac{M_{RCS}}{M_{column}}$
1	84.00	121.8	135.4	150.4	0.89	0.81
2	91.00	131.9	135.4	150.4	0.97	0.87
3	96.00	139.2	135.4	150.4	1.02	0.91
4	98.00	142.1	135.4	150.4	1.04	0.93
5	100.00	146.1	135.4	150.4	1.07	0.96

column using a hydraulic jack. The loading began at 0.05% drift. Drifts of 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5 and 5% were applied to the specimens, consequently. The results of the study are shown in Table 2. The load versus drift relationships of the specimens are shown in Figure 1. Based on the test results, the following conclusions are drawn:

4. CONCLUSIONS

1. The ratios of the connection bending capacity to the bending plastic moment of the steel beam were 0.89 and 0.97 for the first and second specimens, respectively. These valves show that the connections failed before beam failure. It can be concluded that the provisions of the ASCE 1994 design guidelines to prevent concrete compressive failure around the connection region may not be satisfactory.

2. The ratio of the connection bending capacity to the bending plastic moment of the beam was 1.02 for the specimens having columns confined with CFRP sheets (third specimen). This value shows that the bending capacity of the connection was more than that of the steel beam. Therefore, it can be

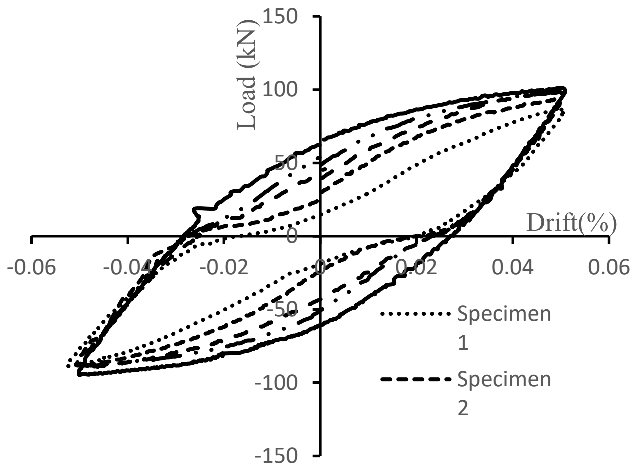

Figure 1. Load versus drift relationship

concluded that using CFRP sheets was a suitable method to prevent concrete crushing around RCS connection region.

3. Comparison of the hysteresis loops of the third, fourth and fifth specimens show that the use of either fiber concrete or CFRP sheets in the RCS connection increased the strength and energy dissipation capacity of the connections.

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