International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 05 | May-2018 www.irjet.net p-ISSN: 2395-0072

STUDY ON DOUBLE REDUCED STEEL BEAM TO CFST COLUMN CONNECTION UNDER CYCLIC LOADING

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Abstract - Reduced beam section (RBS) is a method for improving the beam column connection ductility. In this method, reducing the area of beam flanges at certain distance away from the connection. Hence move the plastic hinge formation away from connection, and it will be safe. Recently, an advanced version of RBS, Double reduced beam section (DRBS) is developed. In this type, two reduced sections are providing adjuscent to each other. Hence results balanced distribution of equivalent plastic strain, thus widen the plastic hinge formation. In the present study, beam with DRBS connecting to CFST column is evaluated. The comparison of three types of diaphragm connection and parametric studies on ring width of external diaphragm connection and beam configurations are also conducted under cyclic loading.

Key Words: Special moment frame connection, reduced beam section, double reduced beam section, CFST column, External diaphragm connection, Through diaphragm connection, Mixed diaphragm connection.

1. INTRODUCTION

Due to many advantages like high strength, speedy construction, high load carrying capacity, efficiency, availability of material, beauty etc, now the steel structures are very common. In earthquake prone areas, steel is very commonly used as a material of choice for design because it is inherently ductile and flexible.

During the 1994 Northridge earthquake, beam column connections in steel moment resisting frames failed at much lower than anticipated load and drift levels. These failures have led structural engineers to improve upon the connection detailing used prior to the earthquake. For improve the connection, move the plastic hinges region in the beam away from face of the column by either locally strengthening the beam in the region next to the face of the column or weakening the beam that frame into the connection, a small distance from face of the column. Thus the concept of reduced beam section was developed. In this method, beam section is weakened by reducing the area of top and bottom flanges at certain distance away from beam column joint [1]. The design specification for RBS is given in FEMA-350 [2] and AISC – 358 [3].

Double reduced beam section is an advanced form of reduced beam section, (DRBS) was introduced by Mohamad A. Morshedi, Kiarash M. Dolatshahi, Shervin Maleki in 2017 [4].This connection has two reduced beam sections, which are adjuscent to each other. The performance of DRBS is superior to RBS. It widens the plastic hinge formation by reducing the equivalent plastic strain between two reduced beam sections. In this study on moment resisting connection, the behavior of double reduced beam section connecting to CFST column is performed.

Concrete filled steel tubular (CFST) columns are structural members that combine two materials in one member. They have the beneficial merits of steel, such as high tensile strength and ductility, and of concrete, such as the high compressive strength and stiffness. The structures with CFST are widely used in bridges, high rise building, underwater structures etc. CFST columns has numerous advantageous such as it reduces cost and time of construction, combined properties of two materials etc. Rui Li conducted a study on composite joints with reduced beam sections [5].In which the RBS connected to CFST using through diaphragm connection. And found that this connection is suitable.

The behaviour of mixed diaphragm connection is investigated by Ning Wang [6].This study utilize the advantages of mixed diaphragm connection over the diaphragm connections generally used. Daxu Zhang, Shengbin Gao, Jinghai Gong conducted seismic behaviour of steel beam connecting to CFST by external diaphragm connection [7].It was found that this connection is a suitable diaphragm connection. Different research works on steel beam to CFST column led this study to focus on different connection types. Hence in this paper, behaviour of DRBS connection to CFST column using external diaphragm, through diaphragm, and mixed diaphragm connection are examined. Also parametric studies on ring width of external diaphragm connection and on beam configurations are evaluated.

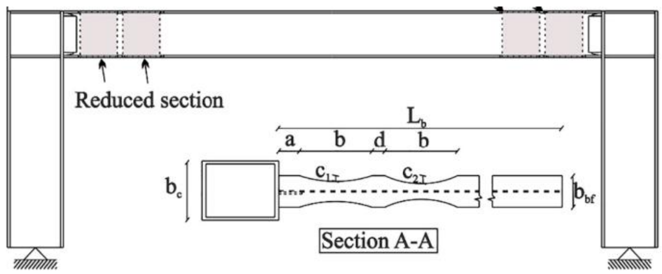

Fig- 1 Radius Cut DRBS Moment Connection

2 DESIGN OF SPECIMEN

A study on CFST column connecting to beam with double reduced beam section by three different connections namely external diaphragm connection, through / penetrated diaphragm connection and a mixed diaphragm connection, in which external diaphragm connected to the top flange and penetrated diaphragm connected to bottom flange of the beam are conducted. Thus comparing the three types of connections. Also, parametric study conducted on external diaphragm connection by changing the width of the ring and changing the configuration of the beam. There were three types of rings according to their width. The width of the ring, which was predicted by the Japanese Code AIJ or the Chinese specification DBJ13-51-2003, was type I, and those with two-thirds and one-third of the width were type II and type III, respectively. The beam configurations considered are one with reduced beam section connection and other with double reduced beam section connection.

CFST column with steel tube of 250 mm diameter and 6 mm thickness were used for the study. Steel tube filled with concrete having 25 N/mm^2 grade. CFST column connected to ISMB 200.Height of column was 1600 mm and length of beam was 1500 mm.

Table-1 Details of DRBS section

BEAM	a	b	C_1	C_2	R_1	R_2
ISMB 200	60 mm	170 mm	22.5 mm	27.5 mm	171.8 mm	145.1 1 mm

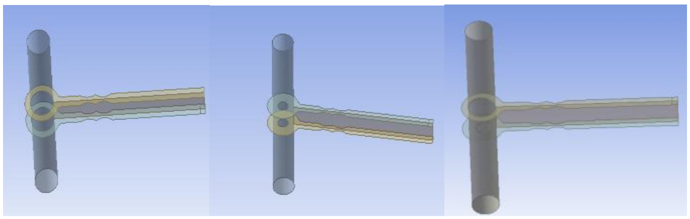

Fig-2 Geometry of External diaphragm, Through diaphragm and Mixed diaphragm connection

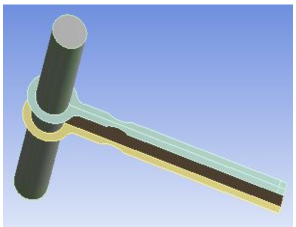

Fig-3 Geometry of RBS specimen with external diaphragm connection

Fixed supports were given at bottom face of column. The AISC seismic loading protocol was used for providing cyclic loading . In addition to cyclic loading, in order to understand the behaviour of CFST column, an axial load of 2546 kN were applied to CFST column.

The axial load carrying capacity of CFST column was calculated based on Euro code 4 (2004).

$$N_u = (1 + \eta_c \frac{t}{D} \frac{f_y}{f_{c'}}) f_{c'} A_c + \eta_a f_y A_s$$

3 FINITE ELEMENT ANALYSIS

The ANSYS Workbench 18.1 was used to model the specimens. The analyses are primarily intended to investigate the overall cyclic behaviour of the DRBS beam connecting to CFST column by different connection methods. The element type used for concrete is SOLID 186, is a higher order 3-D 20-node solid element that exhibits quadratic displacement behaviour. For structural steel, SHELL 181 is used. A tensile test was performed to found out the yield stress and ultimate stress of the steel. The young's modulus of 2 × 10^5 and poisson's ratio of 0.3 were given. The yield stress and ultimate stress of steel was 263 MPa and 610 MPa. M25 grade concrete with young's modulus of 25000 MPa were used.

4 OBSERVATIONS

Overall six specimens were modelled and analysed. Fig 6.8 and 6.9 shows the von-mises stress diagram of different connection specimens. The hysteresis response of each specimen is shown in fig 6.12 – 6.14.

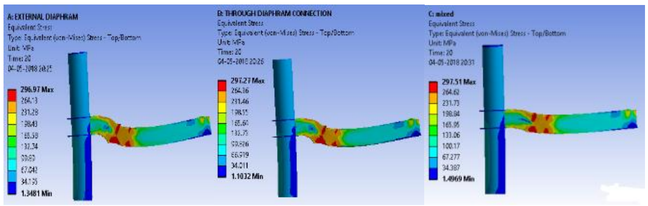

Fig-4 Von-mises stress diagram of external diaphragm, through diaphragm connection and mixed diaphragm connection

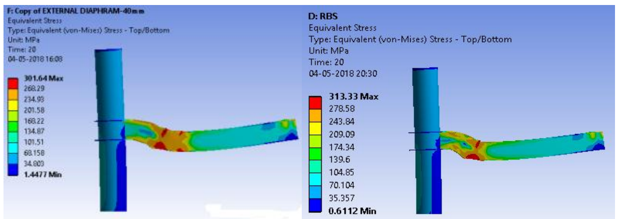

Fig-5 Von mises stress diagram of connection with 40mm and RBS connection

5 RESULTS AND DISCUSSIONS

(i) Different connection types

Analysis results of specimens, which comparing the diaphragm connection type shows that there is not any great difference for different connections. The energy dissipation capacity of external diaphragm connection was observed as 103 kJ and for through diaphragm connection and mixed diaphragm connection, it was found as 93.54 kJ and 103.05 kJ. Hence the energy dissipation capacity of through diaphragm connection was less when compared to other type of connection. External diaphragm and mixed diaphragm has almost similar results. The von-mises stress also found within the limit for the three cases.

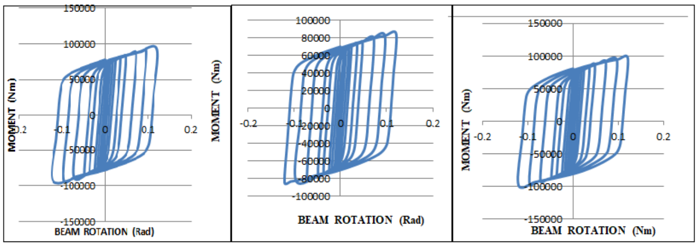

Fig -6 Moment rotation graph of external diaphragm, through diaphragm and mixed diaphragm connection

(ii) Effect of ring width in external diaphragm connection

It was observed that there is only a slight reduction in energy dissipation capacity with reduction of ring width. The energy dissipation of connection with 20mm ring width is 101.6 kJ. For 40mm and 60mm ring width, 102.4 kJ and 103 kJ were observed. The von-mises stress for 60 mm ring width was 296.87 MPa, found less than 20 mm and 40 mm ring width, for which it was 301 MPa. Hence it was observed that there is not any appreciable difference in ring width of external diaphragm connection.

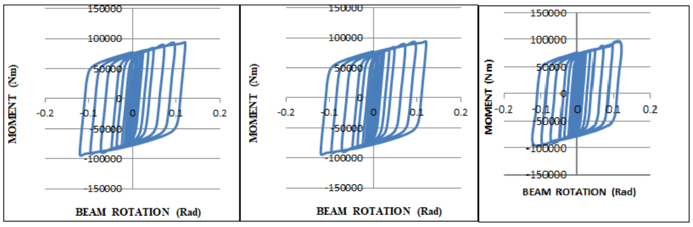

Fig -7 Moment-rotation graph of external diaphragm with 20mm , 40mm , 60mm

(iii) Effect of beam configuration

In order to compare the energy dissipation capacity of RBS and DRBS connection, the specimen with external diaphragm connection having RBS and DRBS were modelled and analysed. Energy dissipation capacity of DRBS connection was found 36% more than RBS connection. For RBS, energy dissipation was 75.25 kJ and for DRBS, it was 103 kJ. The von -mises stress also found higher for RBS connection, it was 313 MPa. Hence it was understood that the performance of beam with DRBS was superior than the RBS connection.

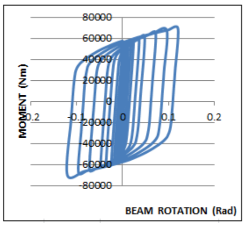

Fig -8 Moment rotation graph of RBS connection

6 CONCLUSIONS

The behaviour of double reduced beam section connecting to CFST column by external diaphragm, through diaphragm and mixed diaphragm connection methods and other parametric studies were also evaluated under cyclic loading. The result is summarized as follows:

- It has been observed that energy dissipation capacity of DRBS connection to CFST using external diaphragm and mixed diaphragm was approximately 12% greater than the through diaphragm connection method. Von-mises stress for each connection was within the limit. All the three connections are good .But external diaphragm and mixed diaphragm connections are slightly better than through diaphragm connection.

- Energy dissipation capacity of DRBS connecting to CFST was found 26% higher than the same specimen with RBS connection.

- Parametric studies on ring width of external diaphragm connection showed that there is not any great difference in energy dissipation capacity. There is only a slight reduction with reduction of ring width.

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