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Non Linear Finite Element Analysis for Beam Column Connection with Reduced Beam Section

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Abstract- **Reduced beam section (RBS) connection is investigated and is widely used in US, Japan and Europe. However, very limited study is conducted with respect to Indian profiles. This study is conducted to give advantageous factors related to RBS connections in inclined beam column connection and to learn usefulness of those connections for Indian sections. External load leads to shear and flexural forces on the inclined columns and beam in different way from those on the conventional vertical columns, failure mode, resistant strength, and ductility capacity of the inclined column-beam joints may be different than those of the perpendicular beam-column joints. Analytical work of reduced beam section on moment resisting frame connections by providing round and trapezoidal cut at the web and flange of the beam. The model is created with finite element method (FEM) and analyzed by ANSY workbench 16.0 software. Cyclic loading were applied to each beam column connection and loaded carrying capacity of each specimen were noted. The beam column section are designed as per IS 12778-2004 and IS 12779-1989**.

I INTRODUCTION

During the 1994 Northridge earthquake, moment connections in steel moment resisting frames (SMRF) suffered unexpected brittle failures in and near the heat-affected zones. A lot of damage of lives and property was observed during this earthquake. Many industrial steel buildings were severely damaged during this disaster. A number of various studies have been carried out in order to improve the seismic performance of the conventional welded connections since then. Two key concepts have been developed for better performance of connections: strengthening the connection and weakening the beam flange connected to column, in order to avoid damages of the respective column. Both strategies force the plastic hinge away from the face of the column, and problems related to potential fragility of groove welds under triaxial stress conditions are avoided.

The first approach provides a beam-to-column connection stronger than the beam itself, through reinforcing a short portion of the beam near the column by using cover plates, ribs, haunches or side plates. The second approach however, referred as Reduced Beam Section (RBS), is based on the selective removal of beam material adjacent to the connection, either from the web or from the flanges as shown in the Figure 1. Reduced beam section moment resisting connections are among the most economical and practical rigid steel connections developed in the aftermath of the 1994 Northridge, earthquake.

As RBS connection is studied and used widely in US, Japan and Europe, however its study is quite limited with respect to Indian profiles and so not found mentioned in any Indian Standards for steel design IS800-2007, IS808-1989, IS1852-1985, IS 2062-1999, IS8500-1991, IS12778-2004 & IS12779-1989. It can be adopted in India for better performance in strong and intermediate earthquakes.

Fig.1. Reduced beam section in a beam column joint

II METHODOLOGY

- Conduct Literature review on RBS in structures
- Modelling of RBS in beam column joint by altering geometry.
- Analysing using ANSYS WORKBENCH 16.1
- Deformation and ultimate load carrying capacity is determined using software
- Comparison of results
- Conclusion

III MODELLING OF COLUMNS

Beam column joint having size 1000x1000mm were used as test specimen for finite element modelling. Hot rolled parallel flange I sections are used for this study as per Indian Standard (IS) 12778 and 8500. These sections are classified into three types as, narrow parallel flange beams (NPB), wide parallel flange beams (WPB) and parallel flange bearing pile sections (PBP). NPB sections are generally used for beam and WPB sections are used for columns. Specimen details are given in the table 1 and mechanical properties of the section is shown in the table 2.

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Table 1. Specimen details of beam column joint

Description	Beam	Column
Element	NPB200	WPB150
Depth	200mm	162mm
Web thickness	5.6mm	8mm
Flange width	100mm	154mm
Flange thickness	8.5mm	11.5mm

Table 2. Material properties of steel

Section	WPB150	NPB200
Yield strength (MPa)	334	330
Tensile strength (MPa)	486	484

Round and trapezoidal are the two type of geometry are proposed for reduced section. The proposed geometry having same cross sectional area of 2718.046 meter square and cut were provided with in flange and web of the beam and result were compared. Fig 2 shows typical geometry of reduced section and table 3 shows the geometric details of reduced section. An element SOLID45 from ANSYS element library was used for the 3-D finite element modelling of the RBS moment connection. The fundamental assumptions made to idealize steel mechanical properties are including: Young's modulus of 20000 MPa, Poisson's ratio of 0.3.

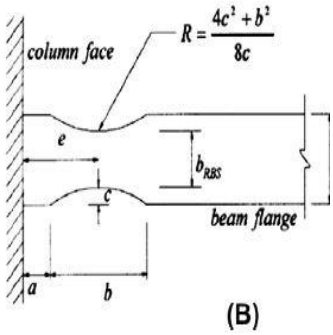

Fig.2. Typical geometry of round reduced section

Table 3. Material properties of steel

Section	a (mm)	b (mm)	C (mm)	R (mm)	Area (mm^2)
Round	60	160	25	140.5	2718.046
Trapezoidal	60	160	25	-	2718.046

For beam column connection, both end of column is fixed and beam towards the column face is fixed by welding and other end makes free. Reverse cyclic load for a fixed deformation of 50mm are applied on the free end of the beam and all are done in ANSYS Workbench 16.1. Description of models is given in the table 4.

Table 4 Model description

Model	Details
Model A	Control specimen
Model B	Specimen with round RBS at flange
Model C	Specimen with trapezoidal RBS at flange
Model D	Specimen with round RBS at web
Model E	Specimen with trapezoidal RBS at web

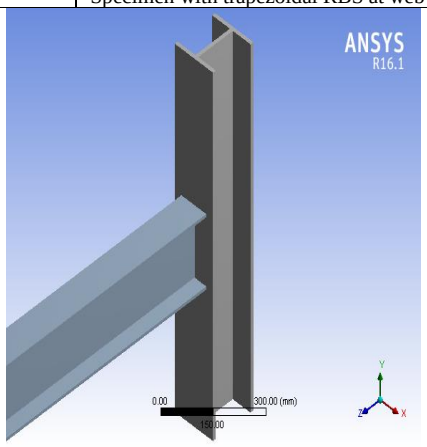

Fig 3 (Model A)

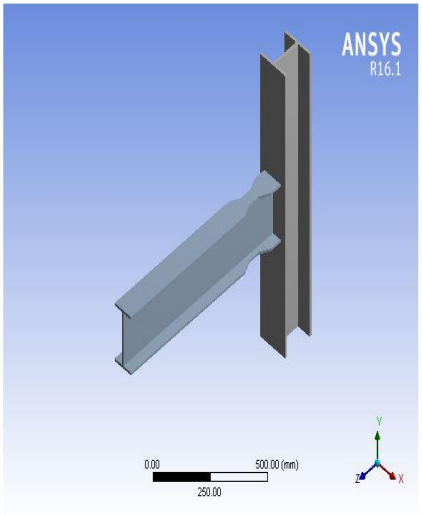

Fig 4 (Model B)

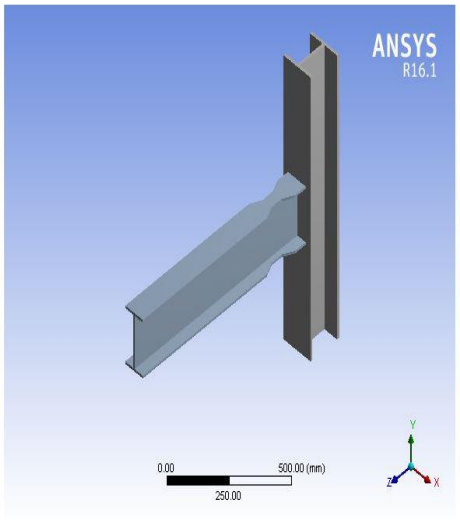

Fig 5 (Model C)

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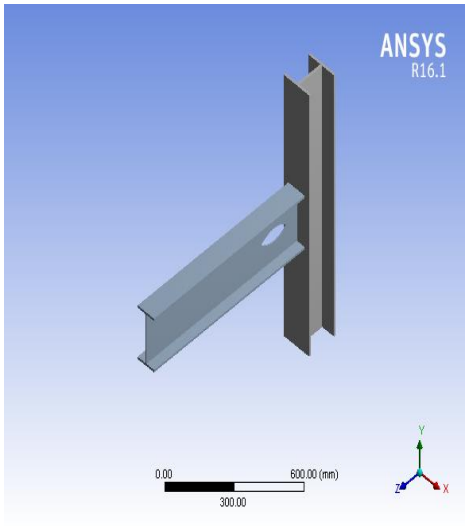

Fig 6 (Model D)

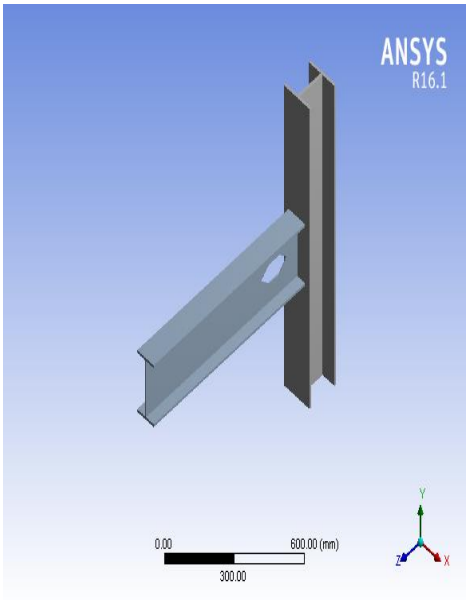

Fig 7 (Model E)

IV ANALYSIS

Deformed shape of beam column joint with different reduced section at the beam is analyzed using ANSYS 16.1 WORK BENCH and it is compared with specimen with out reduced beam.

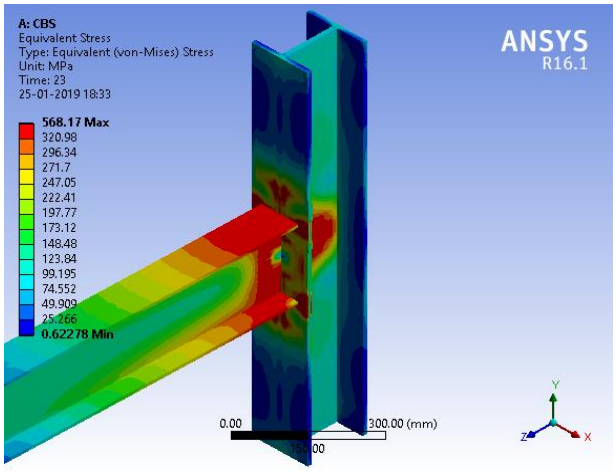

Fig 8 Deformed shape of Model A

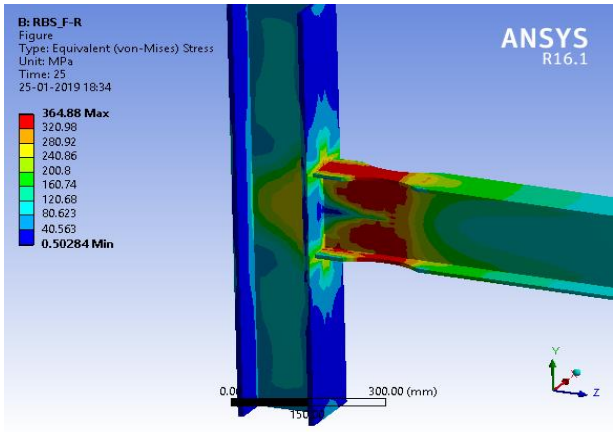

Fig 9 Deformed shape of Model B

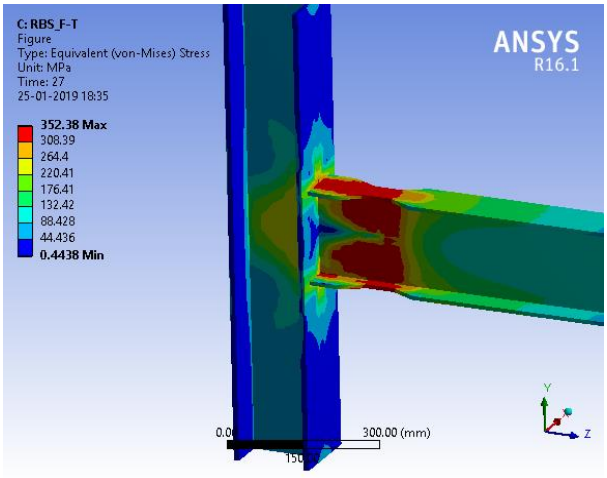

Fig 10 Deformed shape of Model C

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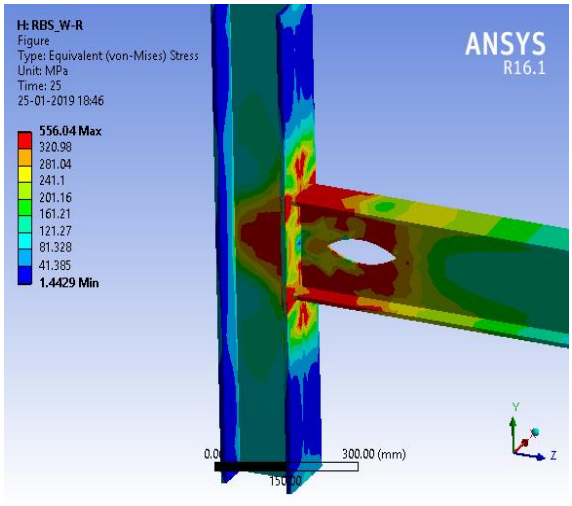

Fig 12 Deformed shape of Model D

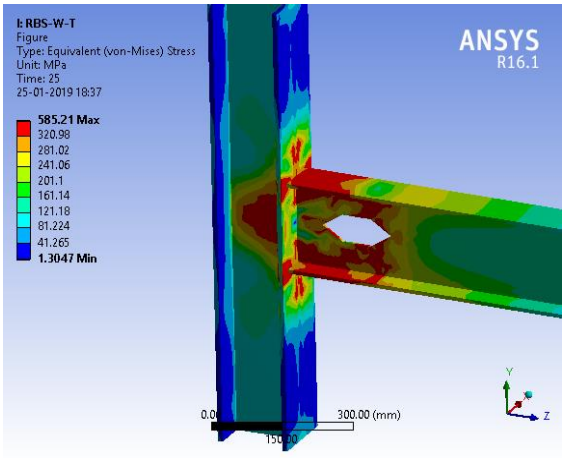

Fig 12 Deformed shape of Model E

V RESULTS AND DISCUSSION

The load-deformation curve of beam column section with reduced beam is shown in the Fig 13. Load carrying capacity is maximum for the model B as compared to the other modes with out RBS.

Equivalent column stress of column at failure were obtained from the ANSYS software is shown in Fig 14.

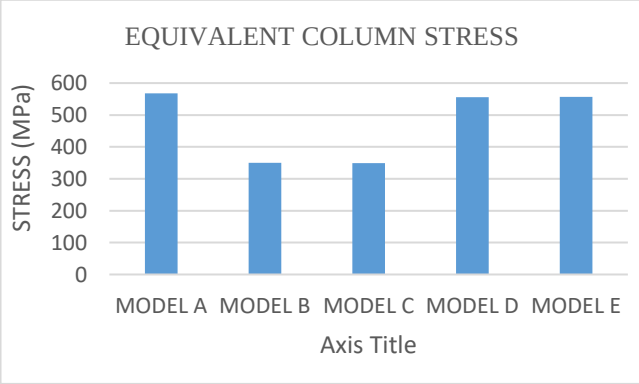

Fig 14 Equivalent column stress of column

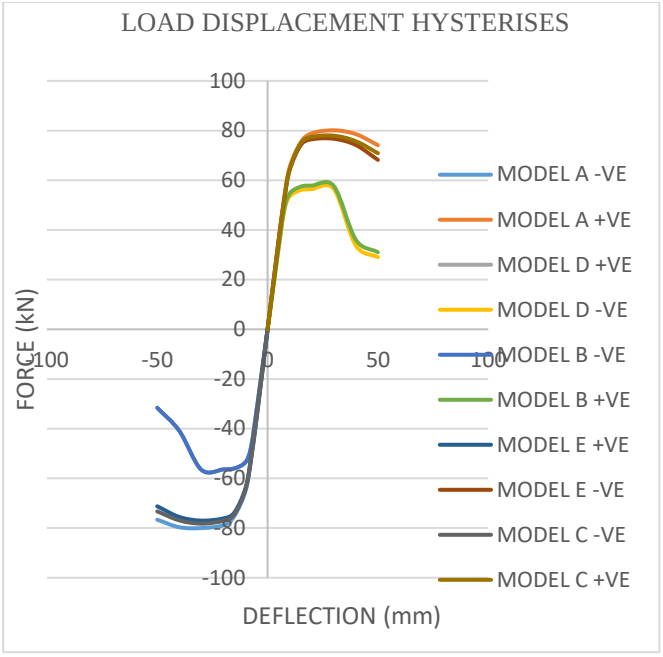

Fig 13. Load-deformation curve of different models

VI CONCLUSION

The main conclusions obtained from the analysis are summarized below:

- The study of reduced beam section on different structural element were done.
- Plastic hinges are formed with in the beam away from the column face.
- The load carrying capacity increased by 20% of beam column joint with round cutting at flange.
- Column stress of beam column joint with round cutting at flange is 62% less than beam column joint with out reduced section

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