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Behavior of Reduced Beam Section Moment Connection with Varying Thickness of Continuity Plate

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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 with continuity plate (CP) and to learn usefulness of those connections for Indian sections. Analytical work of reduced beam section moment connections by providing continuity plates of varying thickness under monotonic drift is presented in this paper. The model is created with finite element method (FEM) and analyzed by ANSYS workbench 16.0 software. Observations were noted for the connections with varying thickness of continuity plates and without continuity plates respectively. Similarity of the results is observed between the, the connections with CP having same thickness of beam flange and with CP having half the thickness of beam flange.

Keywords: *Moment connection, reduced beam section, welded connections, continuity plate.*

1.0 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.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.The reduced beam section protects a welded Steel moment resisting frame connection detail by forcing the plastic hinge in a beam to form away from the column face. Recommendations for design and detailing of RBS connection are given in Federal Emergency Management Agency (FEMA) 350–351, 355-D [1–3] and ANSI/AISC 341-10 [4], American Institute of Steel Construction (AISC) ANSI /AISC 358-5 [5], ANSI/AISC 360-10 [6] provisions.

Continuity plates are an integral part of nearly all pre-qualified steel moment connections including RBS. The steel plate stiffeners which are welded on each side of the column web at the level of both top and bottom flanges of beam in order to provide a load path from beam flange to column flange are known as “continuity plates”. The use of continuity plates / stiffeners which depends upon the thickness of column flange is recommended in all cases unless tests show a given connection can work without them. Generally continuity plates are provided as per the thickness requirement given by AISC seismic provisions [5].

To establish a design procedure for using the RBS beam-to-column moment connection without CP, Adam S M &Revelry L D [7, 8, 9, and 10] tested such connections. They observed that heavier shallow columns are able to satisfy the requirement for prequalified use without continuity plates, while lighter and deeper column specimens at a point of instability as defined by column flange twisting and lateral torsional buckling. It was observed that, elimination of continuity plates in RBS moment connections can provide material and labor cost reductions for steel moment frame construction.

Use of RBS connection is found to be advantageous due to, a) shear force in the panel zone is reduced; b) force demand in column continuity plate is reduced; and c) strong-column - weak-beam requirement is satisfied. As force demand in column continuity plate is reduced continuity plates with less thickness than the beam flange may be used. Therefore this study was conducted to understand behavior of RBS connections with varying thickness of continuity plates and without continuity plates respectively by FEM for Indian profiles.

2.0 Geometrical details of reduced beam section models.

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. Sections with 350 MPa grade, Young's modulus $2x10^5$ and Poisson's ratio as 0.3 are considered. Height of column considered is 2000 mm and length of beam from mid length of the column is 2200 mm. Table 2 shows the calculations of radius cut as per AISC formulae. Six sections between WPB 200 to WPB 300 used as a column and twelve sections of NPB 200 to NPB 300 used as beam that is for each column two different beams are connected for analysis. The combinations of sections are as given in Table 1 below;

Table 1: Geometrical properties of sections

	Column section			Beam section		
Model No.	(D x B)	t_w (mm)	t_f (mm)	(D x B)	t_w (mm)	t_f (mm)
RBS 01	209 x 209	13.0	19.5	222.0x 112	6.6	10.2
RBS 02	209 x 209	13.0	19.5	240.0 x 120	6.2	9.80
RBS 03	240 x 226	15.5	26.0	258.0 x 146	6.1	9.20
RBS 04	240 x 226	15.5	26.0	262.0 x 147	6.6	11.2
RBS 05	268 x 262	12.5	21.5	242.0 x 122	7.0	10.8
RBS 06	268 x 262	12.5	21.5	270.0 x 135	6.6	10.2
RBS 07	278 x 265	15.5	26.5	313.0 x 166	6.6	11.2
RBS 08	278 x 265	15.5	26.5	327.0 x 160	6.5	10.0
RBS 09	280 x 263	17.3	27.6	300.0 x 150	7.1	10.7
RBS 10	280 x 263	17.3	27.6	304.0 x 152	8.0	12.7
RBS 11	340 x 330	15.0	21.5	357.6 x 170	6.6	11.5
RBS 12	340 x 330	15.0	21.5	397.0 x 180	7.0	12.0

Radius cut RBS is shown in Figure 1. According to AISC 358-05 [5] cut dimensions a $\cong$ (0.5 to 0.75) bf, b $\cong$ (0.65 to 0.85) d_b and $0.1b_f$ c $\leq 0.25b_f$ are considered. Fifty percent beam flange reduction was considered Table 2. Each RBS connection is studied with; 1. Without continuity plates, 2. Continuity plates with half thickness of beam flange & 3. Continuity plates with same thickness of beam flange, Table 3 shows the same.

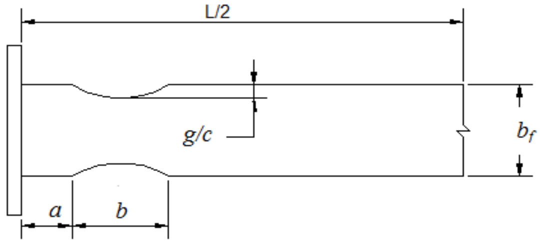


Figure 1: Radius cut section
Source: (Swati Kulkarni, 2013 [13])

Table 2: Geometrical details of reduced beam section

Model No	a mm	b mm	c mm
RBS 01	188.70	67.20	28.00
RBS 02	204.00	72.00	30.00
RBS 03	219.30	87.60	36.50
RBS 04	222.70	88.20	36.75
RBS 05	205.70	79.80	33.25
RBS 06	229.50	81.00	33.75
RBS 07	266.05	99.60	41.50
RBS 08	277.95	96.00	40.00
RBS 09	255.00	90.00	37.50
RBS 10	258.40	91.20	38.00
RBS 11	303.96	102.0	42.80
RBS 12	337.45	108.0	45.00

Table 3: Details of RBS connection

Model No.	Without continuity plate	C.P. (Full thickness.) mm	C.P. (Half thickness.) mm
RBS 01	Y	Yes (10.20)	Yes (5.10)
RBS 02	Y	Yes (09.80)	Yes (4.90)
RBS 03	Y	Yes (10.80)	Yes (5.40)
RBS 04	Y	Yes (10.20)	Yes (5.10)
RBS 05	Y	Yes (10.80)	Yes (5.40)
RBS 06	Y	Yes (10.20)	Yes (5.10)
RBS 07	Y	Yes (11.20)	Yes (5.60)
RBS 08	Y	Yes(10.00)	Yes (5.00)
RBS 09	Y	Yes(10.70)	Yes(5.35)
RBS10	Y	Yes(12.70)	Yes(6.35)
RBS 11	Y	Yes(11.50)	Yes(5.75)
RBS 12	Y	Yes(12.00)	Yes(6.00)

3.0 Finite element modelling

RBS special moment frame connection is considered for the study. The ANSYS 16.0 Workbench structural analysis software is used for the finite element analysis. SOLID45 element from ANSYS element library is used for the 3-D finite element modeling of the reduced beam section moment connection. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities. In this modeling both ends of column are considered as hinged. In the ANSYS model, the beam to column element connection is also configured as being fully restrained. In the finite element analysis, for monotonic loading, beam tip displacement of 0.04 drift angle was applied and von Mises stress are studied.

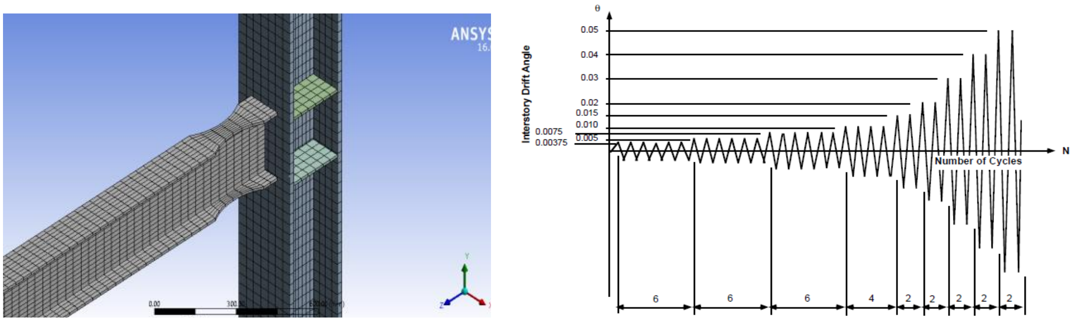


Figure 2: (a) Finite element Meshing, (b)Reference diagram for drift angle.

4.0 Observations

In all thirty fix models are analyzied in ANSYS and stress are observed. Maximum stresses in MPa were noted at panel zone and also at reduced beam section. Table 4 is given below to show the stresses at centre of panel zone and at reduced beam section for different strategies studied.

Table 4:von Mises stresses in MPa the panel zone& at RBS

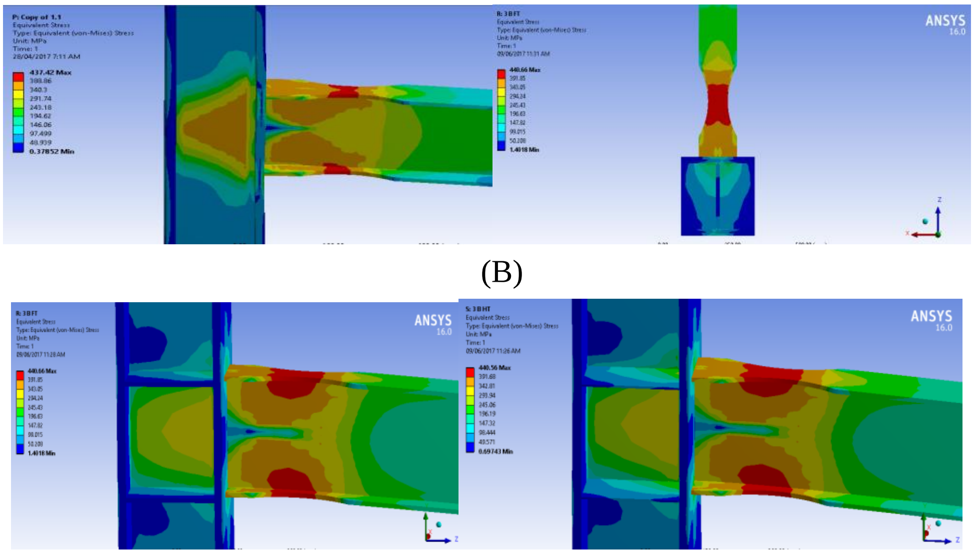
Model no.	Connection without continuity plate		Connection having continuity plate of full thickness		Connectionhaving continuity plate of half thickness	
	PZ	RBS	PZ	RBS	PZ	RBS
RBS 01	362.98	466.52	294.83	441.94	294.83	441.94
RBS 02	373.33	479.89	295.51	442.93	295.51	442.93
RBS 03	388.86	441.46	294.24	442.04	294.24	442.04
RBS 04	373.77	480.33	294.88	442.08	294.88	442.08
RBS 05	392.26	441.28	294.92	442.02	294.92	442.02
RBS 06	391.34	440.10	294.24	440.66	294.24	440.66
RBS 07	362.74	466.33	295.68	443.47	295.68	443.47
RBS 08	357.79	459.64	296.36	443.77	296.36	443.77
RBS 09	344.96	443.24	296.35	443.92	296.35	443.92
RBS10	360.43	463.15	295.96	443.67	295.96	443.67
RBS 11	389.96	441.93	296.47	444.15	296.47	444.15
RBS 12	394.41	443.50	296.05	443.87	296.05	443.87

When subjected to the forces resulting from the motions of the design earthquake: Special moment frames are expected to withstand significant inelastic deformations (drift angle of at least

0.04 radians). Therefore at drift 0.04, observations were noted. It was observed that, in the connection without continuity plate, stresses are above yield in panel zone as well as in the column flange adjacent to beam. Also in some cases local buckling of column flanges was observed.

It was observed that the use of continuity plates in the column panel improved the connection performance. Continuity plate helps to stiffen the column flanges & resist local buckling. Observations for the connections with CP with half thickness of beam flange & with same thickness of beam flange: a) the column panel zone stayed in the elastic range as white wash stayed intact, b) Column flange buckling was not observed, c) Stresses in the RBS area only were above yield limit, d) beam flange buckling was not observed.

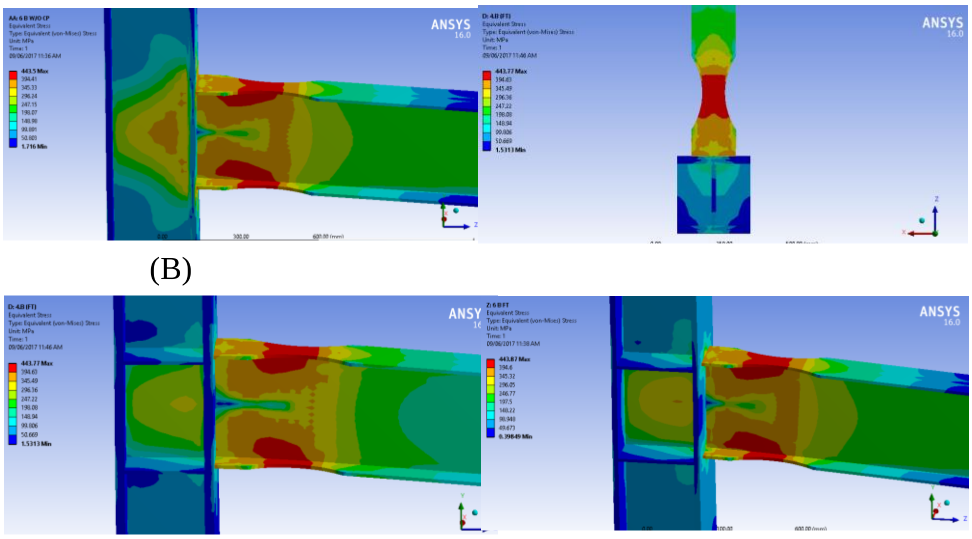
von Mises stress distribution in the models RBS 3, 6 & 11 at 0.04 radians is shown below in Figure3, 4 & 5 respectively.



(A) (B)

(C) (D)

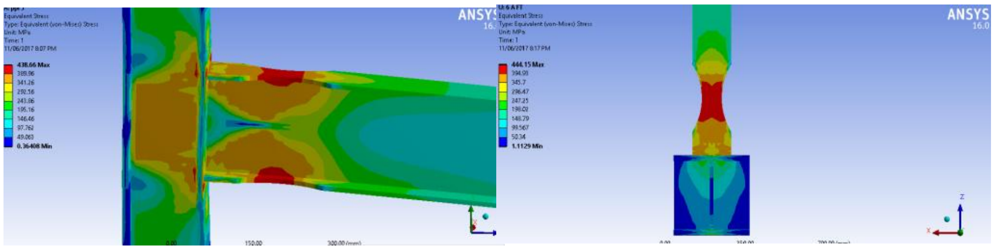
Figure 3: (RBS 03) von Mises stresses in connection at 0.04 radians, A] without CP, B] with CP having full thickness, C] with CP having half thickness.



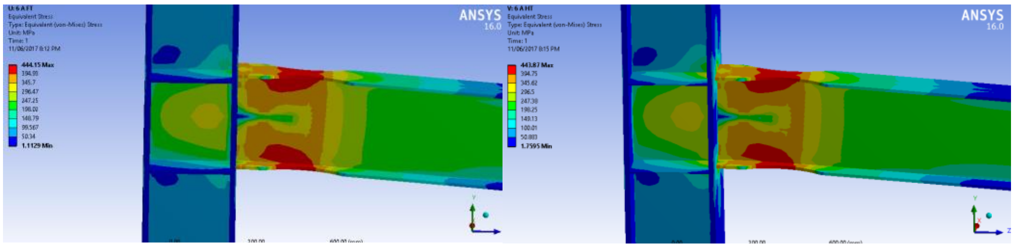
(A) (B)

(C) (D)

Figure 4: (RBS 06) von Mises stresses in connection at 0.04 radians, A] without CP, B] with CP having full thickness, C] with CP having half thickness.



(A) (B)



(C) (D)

Figure 5: (RBS 11) von Mises stresses in connection at 0.04 radians, A] without CP, B] with CP having full thickness, C] with CP having half thickness.

5.0 Conclusions

In this research, behavior of reduced beam section moment connection with varying thickness of continuity plate is studied with respect to Indian profiles. Analysis of thirty six models was in ANSYS software.

Behavior of connections either by using CP of same thickness of beam flange or half of thickness of beam flange was observed similar. It can be suggested that continuity plates with half thickness of beam flange may be used instead of CP with same thickness of beam flange.

FEM analysis was carried out for sections with relatively small size. Connection behavior may differ for large size sections. Experimentation is required for further validation.

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