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Numerical Study on Double Reduced Beam Section Connections under Cyclic Behavior

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Abstract - *Reduced beam section (RBS) moment-resistant connections are one of the most cost-effective and feasible rigid steel connections evolved following the 1994 earthquake in Northridge and California. The primary motive of this connection was to weaken the beam so that smaller forces and moments are transmitted to the connection at a limited distance from the location of the connection. Moreover RBS connections also have a few disadvantages, including local buckling of the web of the beam, decreasing strength of the beam in the face of lateral-torsional buckling, and increasing stress concentration in the cut area of the flange of the beam. A beam-column steel moment connection called "Double Reduced Beam section connection" (DRBS) is adopted in this paper and the connection's seismic performance is evaluated by the use of finite element modeling. The connection consists of two radial cut sections near the face of the column to expand the area of plastic hinge thereby reducing the resulting plastic strain. A parametric study on the influence of cut parameters on the seismic behavior of the connection was conducted. The results showed that, DRBS connections have 52% higher energy absorption while comparing with ordinary beam-column (OBC) connections.*

Key Words: Double Reduced Beam section connection, Plastic hinge, Energy absorption.

1. INTRODUCTION

This Steel moment frames consist of steel columns and beams that are connected by welded connections or bolted connections. During the 1994 Northridge earthquake, severe damage to steel moment frame structures resulted researchers to create alternative connection designs for the connection's used during Northridge earthquake. Previous earthquakes have shown that welded steel moment frame (SMF) is so brittle and susceptible to serious damage. The major damage is the cracks in the weld between the flange of the beam and the face of the column and producing concentrated stress near beam column joint. A logical way to resolve the issue is to reduce the demand for ductility in the welded regions and shift the plastic hinge from the beam column joint. For reliable performance, two main ideas were developed: reinforcing the connection or weakening the beam to minimize damage to the column. Generally, the methods that shifts the plastic hinge at a small distance away from the connection area falls into two major categories such as reinforcement detailing and reduced beam section detailing. In the first type, the beam-column interface provides reinforcement, while in the second; the removal of material from the beam flanges deliberately weakens a region in the beam away from the interface. In RBS, in the region adjacent to the beam-column connection, a portion of the beam flanges are sliced off.

Number of analytical and experimental studies on RBS moment connection has been conducted to enhance poor moment connections for the current steel moment frame. D.T. Pachoumis et.al [2], presents the results of an experimental study of RBS connection with radius cut profile under cyclic behavior. From the experimental and numerical results it is found that the cyclic performance of the RBS connection is satisfactory and the plastic deformation was found in the RBS portion. Also there is no fracture of weld was noticed. Swati Ajay Kulkarni et.al (2014) [4], conducted a study to discover about the benefits and importance of RBS connection for Indian profiles against connection without RBS. It can be observed that the specimen without RBS was poorly performed due to cracks on the bottom flange weld and the specimen with RBS was able to create a rotation of 0.02 radians without any distress in the welds.

In this study double reduced beam sections have been modeled using ANSYS 16 software by trimming the beam flange and is compared with OBC connection under cyclic behavior. The purpose of this paper is to obtain numerical modeling results on four DRBS models. The objectives of this study include: (1) To shift plastic deformations at a particular distance from the beam column junction; (2) To study energy dissipation and stiffness of DRBS connections.

2. NUMERICAL STUDY ON DRBS CONNECTION

The analytical study includes the development of four finite element models to evaluate the performance of connection. The DRBS connection cut parameters follows the AISC-358 specifications. As per AISC-358 the limiting value of the distance from column face to the first radius cut (a) should lie between 0.5-0.75 times the flange width of beam. The length of radius cut should be 0.65-0.85 times the height of the beam and the depth of cut should have a limiting value of

0.1-0.25 times the flange width of beam. The depth of second should greater than or equal to the depth of first cut. Figure 1 show the DRBS model used in the study and Table 1 displays the different models used in this study.

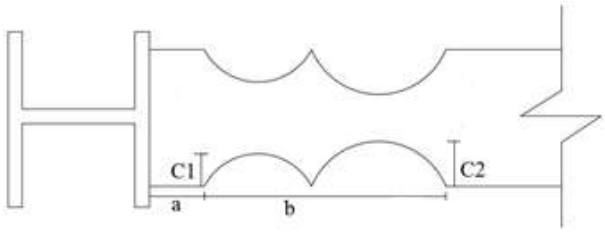

Fig -1: DRBS Connection

Table -1: Different models used in study

Models	Reduce parameters (mm)
OBC	-
DRBS-$C_1$30	a=100,b=280,C_1=30,C_2=40
DRBS-$C_1$40	a=100,b=280,C_1=40,C_2=40
DRBS-$C_2$55	a=100,b=280,C_1=40,C_2=55
DRBS-$C_2$60	a=100,b=280,C_1=40,C_2=60

WPB 290 was used for modelling of column and NPB 330 was used for the modelling of beam. The height of the column and the length of beam is 2500 mm. The column was assumed to be fixed at both ends. . In order to create the plastic deformation in the connection components, a combined hardening rule (Isotropic-Bilinear) with Von Mises criterion was applied. Displacement is applied at the tip of the beam according to SAC loading protocol. (Chart 1)

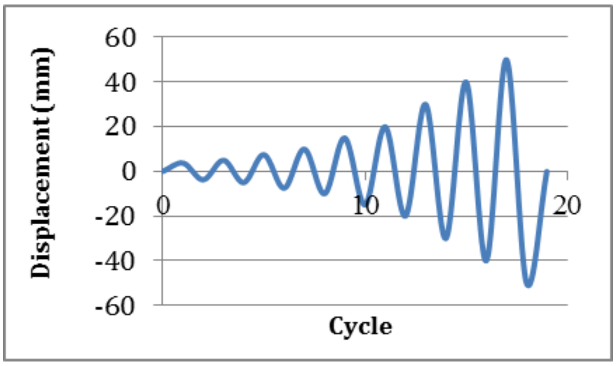

Chart -1: SAC loading protocol

3. RESULT AND DISCUSSIONS

3.1 Equivalent plastic strain of models

The equivalent plastic strain distribution in five models are displayed in Figure 2, 3, 4, 5and 6.

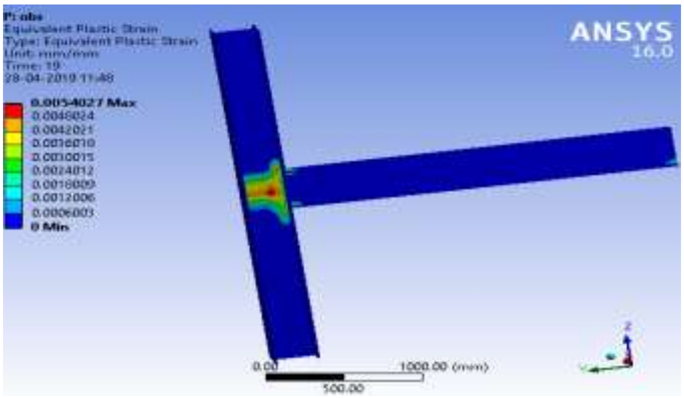

Fig -2: Equivalent strain distribution in OBC

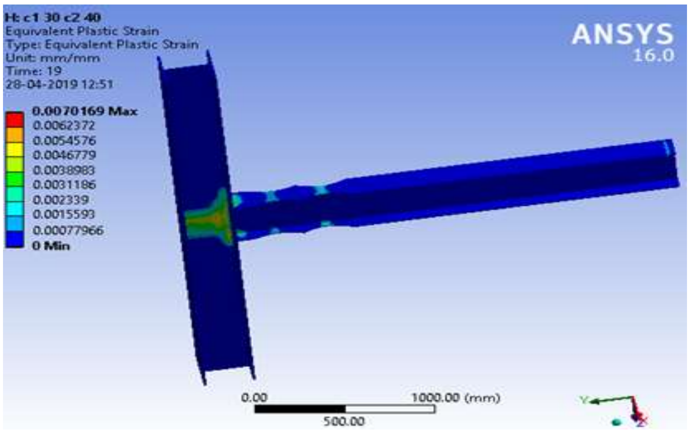

Fig -3: Equivalent strain distribution in DRBS-$C_1$30

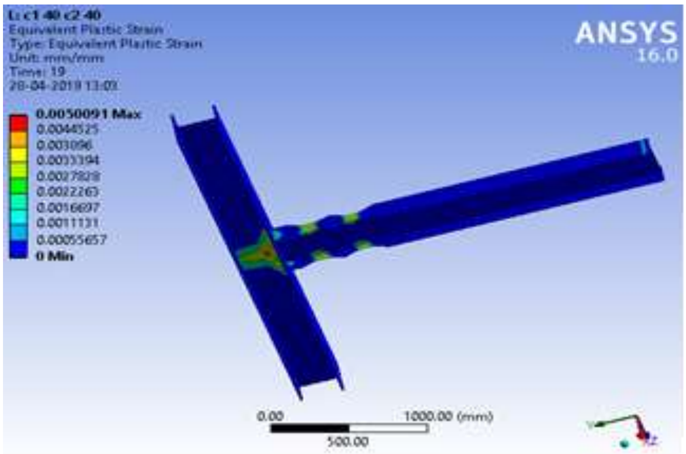

Fig -4: Equivalent strain distribution in DRBS-$C_1$40

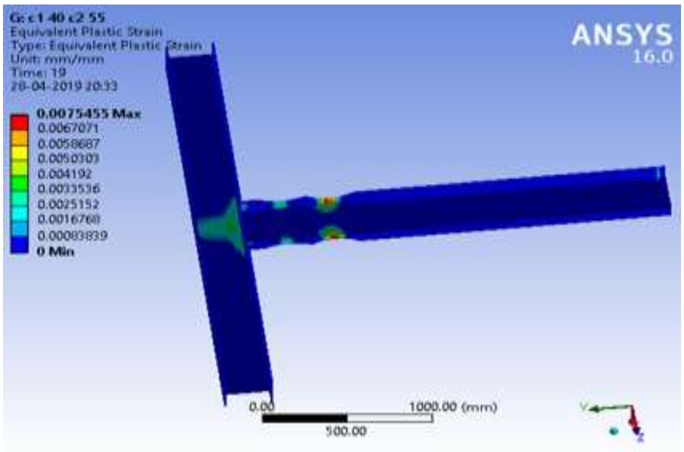

Fig -5: Equivalent strain distribution in DRBS-$C_2$55

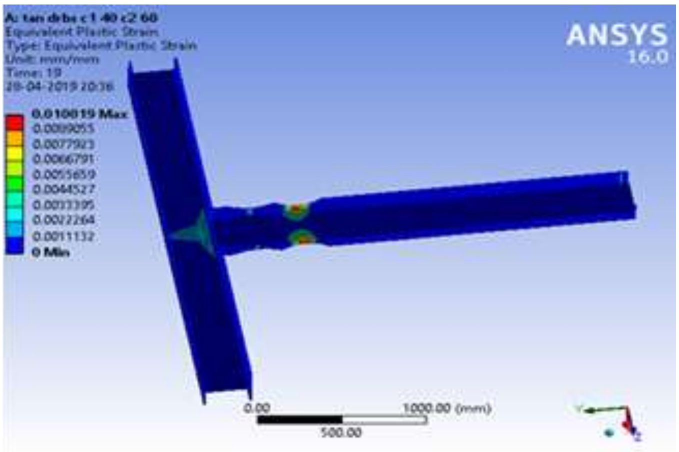

Fig -6: Equivalent strain distribution in DRBS-$C_2$60

Figure 2 shows the equivalent plastic strain distribution of OBC model. From the figure it can be found that plastic strain is concentrated in the face of the column and which inticates that the connection is not strong. In Figure 3 we can see plastic strain distribution in DRBS-C_1 30 model. It can see that a small amount of plastic strain is distributed in the radius cut portion. DRBS-C_1 40 model displayes a balanced strain distribution between two radius cuts and a small amount of plastic strain can found on column face. In DRBS-C_2 55 model the plastic strain is shifted to the second radius cut and only minor amount of strain is present in first radius cut and face of the column. Figure 6 exhibits the plastic strain distribution in DRBS-C_2 60 model. From the figure it can see that plastic strain is completely moved towards the second radius cut and the beam-column joint is safe.

3.2 Hysteretic response

The hysteretic response of three of the models are shown in Chart 2. From the chart it can found that DRBS models have wider hysteresis curves while comparing with OBC conncetion. The area of hysteretic loop increases gradually in accordance with OBC model.

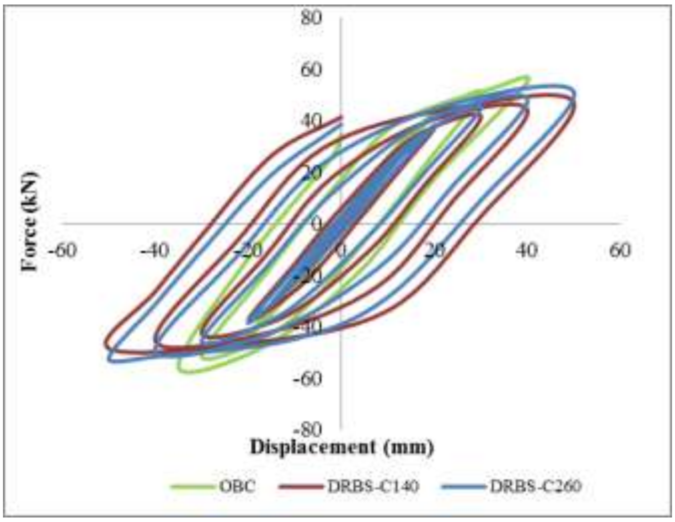

Chart -2: Hysteretic response of OBC, DRBS-$C_1$40, DRBS-$C_2$60

3.3 Energy absorption

The energy absorption can calculate by finding the area under hysteresis curve. Chart 3 displays the energy absorption of all models. From the chart it can found that DRBS-$C_1$40 model have highest energy absorption and it has 52% higher energy absorption while comparing with OBC model. Also, DRBS-$C_1$30 model has 48% energy absorption as compared with OBC model.

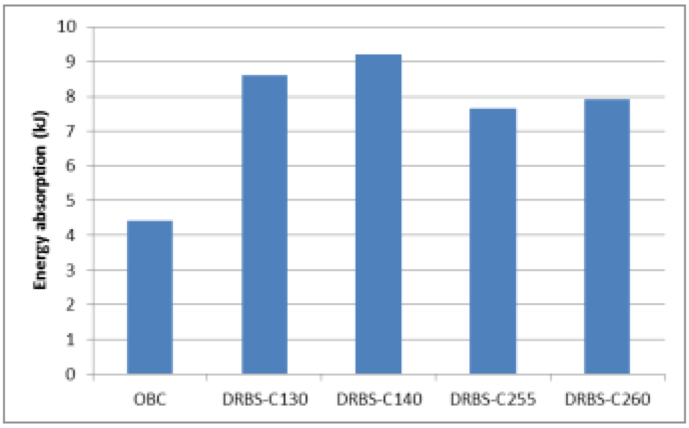

Chart -3: Energy absorption of models

3.4 Stiffness

Stiffness can found out by taking the slope of hysteresis curve. Stiffness can be calculated using the formula

$$\text{Stiffness} = (F\ max - F\ min)/\ (d\ max - d\ min)$$

Chart 4 shows the stiffness of all models in the study. DRBS-C_1 model have highest stiffness than other models. It has 54% increase in stiffness as compared to OBC model.

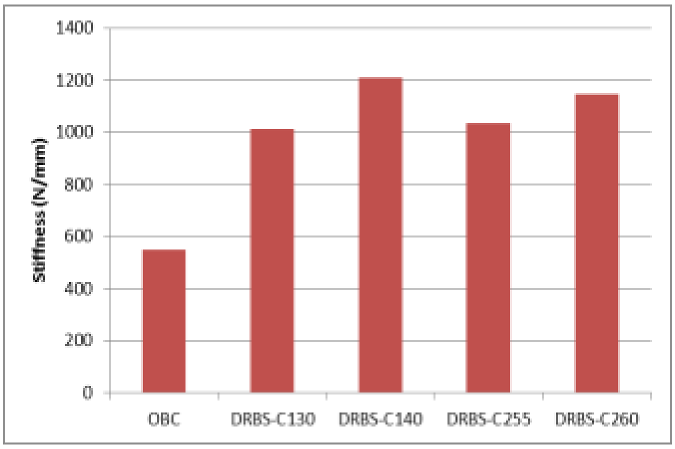

Chart -4: Stiffness of models

3. CONCLUSION

Double reduced beam section has excellent transformation of concentration of stress from column face to the reduced section region. It has significant increase in energy dissipation capacity as compared with ordinary beam column connection. The maximum increase in absorbed energy is 52% while comparing with OBC model. It can found that as the depth of cut is increasing the plastic strain shows a balanced distribution between two radius cuts in DRBS models. From the result obtained from this paper it can be concluded that DRBS shifts the location of plastic hinge at a certain distance from the beam column junction and it makes the beam column joint safe and strong.

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