Analytical Study of New Type of Reduced Beam Section under Cyclic Behaviour

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Abstract-- Recent earthquakes have shown that steel frame (SF) with welded connections are so brittle. According to the studies conducted, great damages were due to the cracking of the weld between the beam flange and the column face and inducing concentrated stresses in this area. A new method is investigated to reduce the stress concentration at the column panel zone could be the use of Reduced Beam Section (RBS). It transfer the plastic hinge formation at a certain distance away from the column face. Various shapes cutouts are possible (constant, tapered or radius cut) to reduce the cross sectional area of the beam flange and thus reduce the stress concentration. In this paper a new type of reduced beam sections have been modeled using ANSYS15 software by reducing the beam flange in different pattern and is compared each other under cyclic behavior and best method is selected which have more advantage than radius cut geometry. The obtained result of the study showed that using varied voids, RBS is more ductile and dissipate energy more compared to other connections.

Index Terms- cyclic behavior, Ductility, Finite Element Analysis , RBS profiles , Reduced Beam Section, Steel Moment Frames, Steel Structures,

1 Introduction

The RBS connection is one of the most popular and most economical type amongst post Northridge and Kobe connections. Number of analytical and experimental studies have been performed on RBS moment connection to enrich poor moment connections for existing steel moment frame. In RBS the beam flange is trimmed away in the region adjacent to beam-to-column connections at a certain distance away from the column face to reduce the stress concentration developed in the column panel zone. 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 of the Indian Standard for steel designs. The RBSs were more economical and have the highest rotation capacity compared with other ordinary steel moment connections. Considering the advantages of RBS moment connections and lack of knowledge of the performance of this connection with respect to Indian profiles led to a study on this topic.

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2 Methodology

The RBS moment connection is studied and widely used in European countries. This method can be adopted in India for better performance of steel structures in seismic prone areas. Design of such type of connections were not presented and used in India. Recently an Experimental and analytical study were carried out with RBS (radius arc cut geometry) in Indian profiles. And the analytical study in that paper is validated.

In this paper a new type of reduced beam section is introduced under cyclic behavior which have more advantage than radius cut geometry in Indian profiles.

3 Geometry Details of RBS

In RBS, the main dimensions that must be chosen by the designers are (fig.1): "a" the distance from the face of the column to the start of the RBS "b" the length of the RBS "c" depth of the RBS at the minimum section. These dimensions should be kept as small as possible, otherwise the plastic hinge will develop back to the face of the column.

In this study the beam flange is reduced by providing holes in different pattern such as same voids and varying voids in different ways. The area of reduction is kept constant even if the diameter of voids varies.

The fig.1 shows that the sample top view of the ordinary welded connection (OWC) and connections with different patterns selected for this study such as reduction of flange with radius cut geometry (RBS), with voids of same diameter (RBS SV), with voids of varying diameter (RBS VV).

Height of the column (WPB150) considered was 975 mm and length of the beam (NPB200) from the Centre of the column was 1000 mm. Other, geometrical details are mentioned in Table.1 selected from the Indian standards.

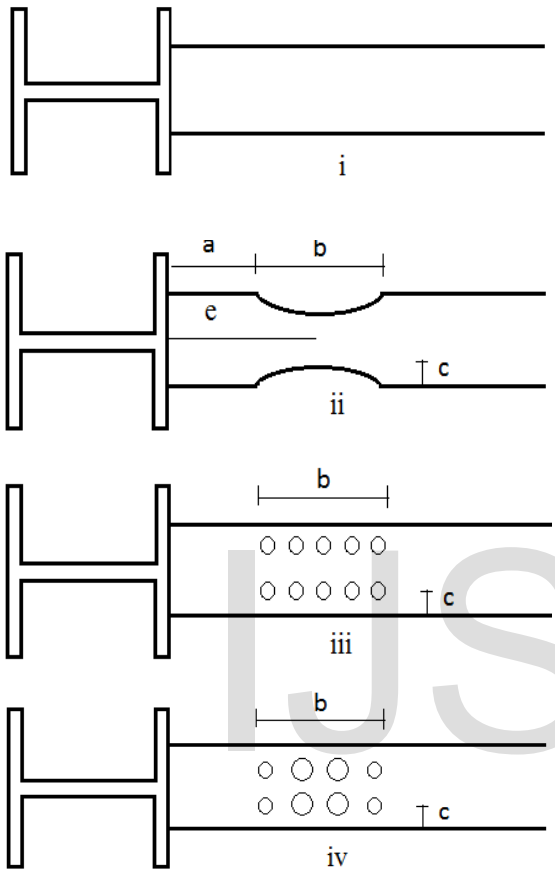

Fig.1 Typical top view geometry details of i) OWC ii) RBS1 iii) RBS SV iv) RBS VV

TABLE I
SPECIFICATION OF MODEL

Member	Depth d(mm)	Web thickness tw (mm)	Flange width tf(mm)	Flange thickness tf (mm)
Column	162	8	154	11.5
Beam	200	5.6	100	8.5

4 Numerical Study

The ANSYS finite element software was used to model the specimens for nonlinear analysis.

The fundamental assumptions made to idealize steel mechanical properties are including: Young's modulus of 2x 105 MPa , Poisson's ratio of 0.3. SOLID from ANSYS library was used for 3-D finite element modelling of the RBS moment connection. Multi-linear stress strain curve are input directly as element material property for cyclic analysis (fig.2) the column was assumed as fixed connected at both the ends and at the joint beam to column element connection is configured as fully restrained.

Studies were done in beam column joint with ordinary rigid connection (ORC), and various type of reduced flange sections. Such as radius cut geometry, providing same holes and varied holes on the flange of the beam which is proposed as a new method.

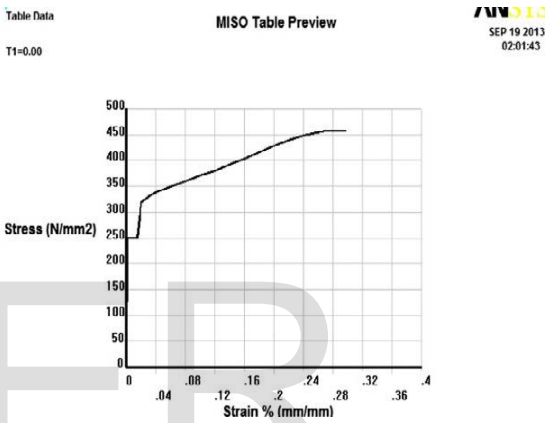

Fig.2 Material property

A displacement control loading was applied on the tip of the beam by imposing cyclic displacement based on SAC loading protocol fig.3

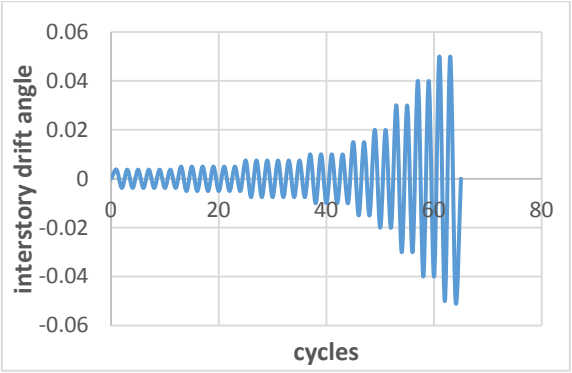

Fig.3 SAC loading protocol

The beam flange reduction by two methods including radial cutting and circular cutting. Specifications of the model is summarized in the table 2.

TABLE II

MODELS STUDIED

Model	Reduced Parameter (mm)
OWC	-
RBS	a =60 b =160 c =25 e =140
RBS- SV	Five circles with d=25 mm of same dia
RBS1-VV	Six circles that increases gradually d= 8 & 20 & 34 & 34 & 20 & 8 on right and left
RBS2-VV	Seven circles that increases gradually d= 20 & 25 & 28 & 28 & 25 & 20 on right and left
RBS3-VV	Five circles that increases gradually d= 20 & 25 & 34 & 25& 20 on right and left
RBS4-VV	Six circles that increases gradually d= 15 & 20 & 30 & 30 & 20 & 15 on right and left

5 RESULT

5.1 Stress Distribution

The Von Mises Stress distribution of 25 models were analyzed and out of that 7 models were shown below.

It can been seen that the concentrated stress for all types of RBS model occurs in the region of beam were flange reduction is provided and for ordinary welded connection (OWC) the concentrated stress occur in the panal zone of the column face.

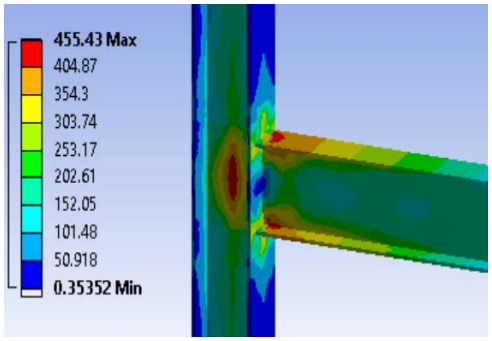

Fig.4 Von Mises Stress distribution of OWC

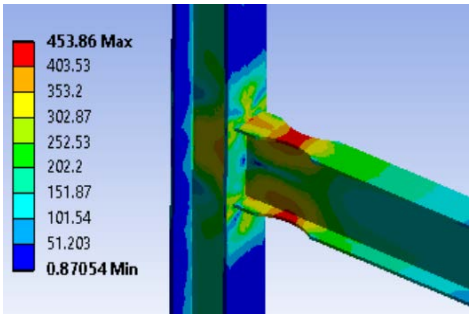

Fig.5 Von Mises Stress distribution of RBS

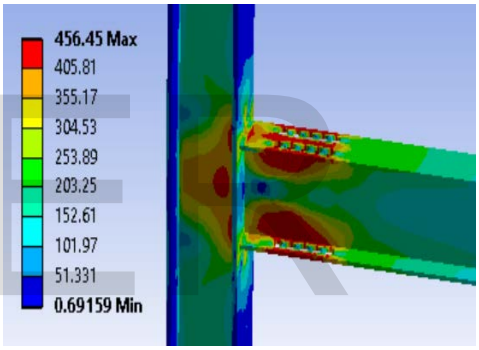

Fig.6 Von Mises Stress distribution of RBS- SV

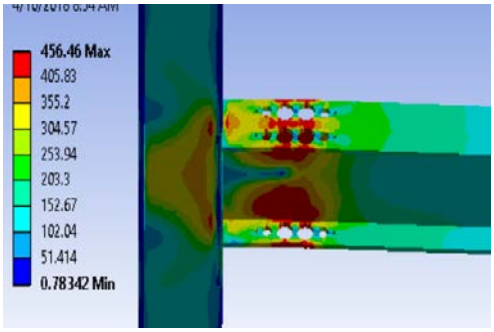

Fig.7 Von Mises Stress distribution of RBS1-VV

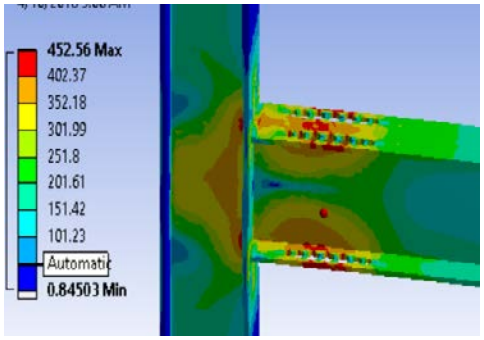

Fig.8 Von Mises Stress distribution of RBS2-VV

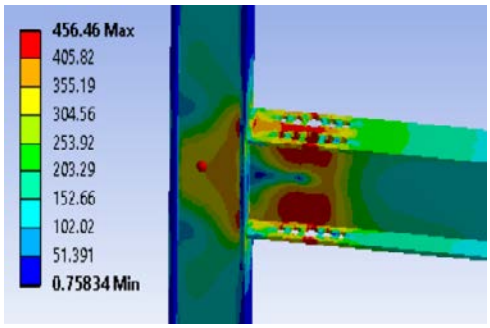

Fig.9 Von Mises Stress distribution of RBS3-VV

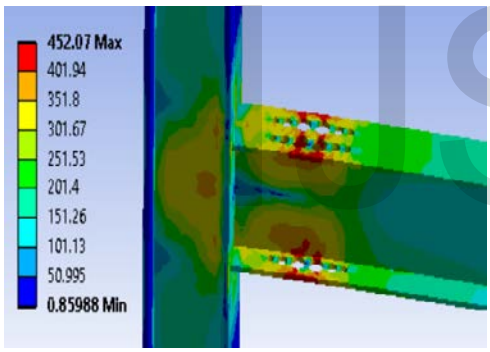

Fig.10 Von Mises Stress distribution of RBS4-VV

It can be seen that the concentrated stress for all types of RBS models occur in beams and for ordinary welded connection (OWC) it occur in the connection.

From the Von Mises stress distribution diagram it can be seen that the RBS4-VV shows excellent transformation of concentrated stress from the column face to reduced section. There occur more yielding without any great damage in between the circular voids. In RBS- SV, Stress can be seen in the column face also and breaking were also observed. So it not applicable. In RBS1-VV, the stress is seen in the vicinity of the weld of beam column joint. So it not a proper design. In RBS2-VV the stress is seen in the vicinity of the weld and in between voids. Also it gets break in between the voids. RBS3-VV, Stress can be seen in the column panel zone. And great damages can be observed in between the voids

5.2 Hysteresis Behavior

The total energy dissipated by each specimen during a complete excursion of 0.05 rad total rotation is show in figures below.

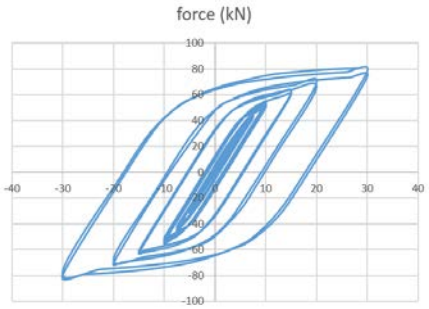

Fig.11 hysteresis loop of OWC

Fig.12 hysteresis loop of RBS

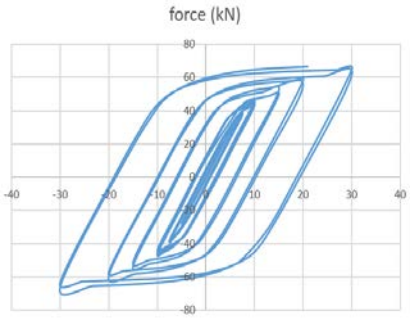

Fig.13 hysteresis loop of RBS-SV

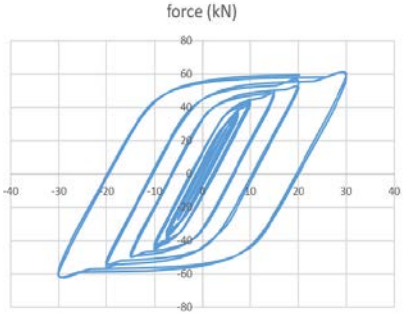

Fig.14 hysteresis loop of RBS1-VV

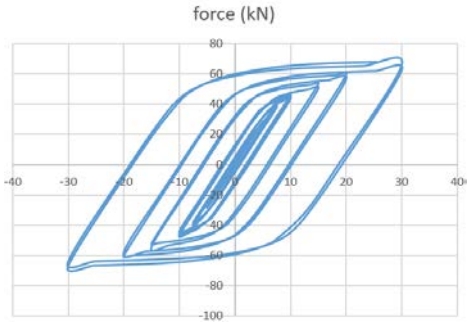

Fig.15 hysteresis loop of RBS2-VV

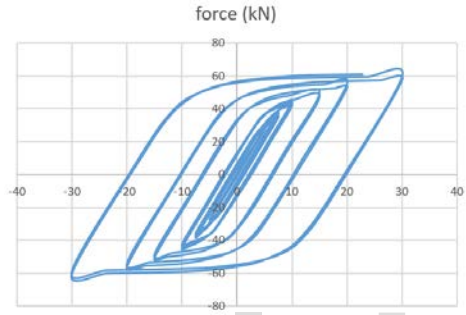

Fig.16 hysteresis loop of RBS3-VV

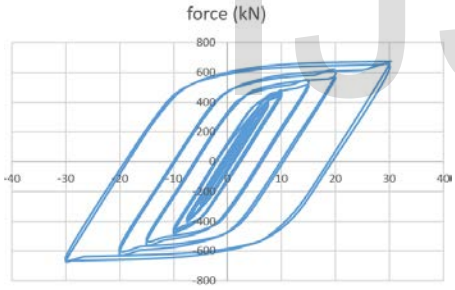

Fig.17 hysteresis loop of RBS3-VV

From the hysteresis behavior of all type of models. The area of hysteretic loops gradually increased and residual deformations were observed with the increase of displacement after yielding. It can be seen that the area of each loops shows slight variations and can be observed that the RBS4-VV slightly dissipate more energy compare to other reduced beam sections. Inelastic deformation occurred mainly in reduced area for connection 'RBS4-VV' creating ductile fuse.

6 Discussion

To achieve the above objectives, a detailed literature review on reduced beam sections were first carried out. From the Von Mises stress distribution diagram it can be seen that the RBS4- VV (varying voids) shows excellent transformation of concentrated stress from the column face to reduced section with more rotation capacity that radius cut geometry and it is more ductile fuse.

7 Conclusion

It can be concluded that the reduced beam section with varying voids (RBS4-VV) shows excellent transformation of concentrated stress from the column face to reduced beam section. It have 0.05 rotation capacity and yielding capacity without any damage in the between the voids. From the hysteresis behavior, the reduced beam section using varied voids dissipate energy more compared to other types of reduction. This study is quite limited and more extensive study is recommended to understand the behaviour of RBS section profiles.

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