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STUDY OF STEEL MOMENT RESISTING FRAME WITH REDUCED BEAM SECTION

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Abstract —*This paper present some detailed information about reduced beam section used in moment resisting frame. Guidelines about the cut, that is to be introduced in the flange of the beam section ,are obtained from FEMA 350.Time history analysis and dynamic analysis are carried out in this paper. A G+15 storey steel building is modeled using RBS as a component in one building and regular beam section as a component of the other in STAAD PRO V8i. Displacement, storey drift , time period and base shear of both the buildings are compared as the result.*

Keywords*- Reduced beam section, Time history analysis, FEMA 350, Staad pro. v8i ,SMRF*

I. INTRODUCTION

During the 1994 Northridge earthquake, the bolted web-welded flange moment connections in steel moment-resisting frames suffered unexpected brittle failures in and near the heat-affected zones[1] .A lot of damage of lives and property was observed during this earthquake. Many industrial steel buildings were severely damaged during this havoc. Many modifications have been proposed for post Northridge earthquake new construction and retrofit of steel moment frames [1]. Many of the recommendations in [9] have since found their way into the Seismic Provisions for Structural Steel Buildings published by the American Institute of Steel Construction (AISC)[2]. The most commonly observed damage occurred in or near the welded joint of the bottom flange of a girder to the supporting flange of column. However the typology and technology of the RBS beam to column connection, as well as its behavior under cyclic loading conditions were investigated in USA after the Northridge earthquake. The Reduced Beam Section (RBS) is one of the ways to weaken the beam framing to the column. Reduced beam section connections provide similar benefits to reinforced connections, but are more efficient and economical because they do not require the extra field welding and material associated with reinforced connections. RBS connections also have a number of advantages in design practice. Compared to reinforced connections, their use leads to reduced demands for continuity plates, panel zone reinforcement, and strong column–weak-beam requirements [2]. All of the connections approved in for Steel Moment Resisting Frames combined improvements in welding along with detailing that induce the beam plastic hinge to form a short distance away from the beam-to-column interface. The type of detailing that shifts the plastic hinges away from the connection region generally falls into two main categories, reinforcement detailing and reduced beam section detailing.

II. LITERATURE REVIEW

A. J.shen, T. Kitjasateanphun, W. Srivanich,"SEISMIC PERFORMANCE OF STEEL MOMENT FRAMES WITH REDUCED BEAM SECTIONS", Engineering Structures 22, pp 968-983,2000

They have investigated the seismic performance of Steel MR Frames with RBS and addressed the design issues related to it. Non-linear static and time history analysis of eight frames with different no. of stories and different RBS configurations were conducted. It was found that Flange Reduction rate and eccentricity decide the strength demand. The strength and stiffness (drift) requirements are, in most cases, were satisfied.
They also carried seismic analysis of some frames and they considered the following things

- Realistic model for RBS calibrated by the test and the finite-element simulations
- Panel zone effect as opposed to the center-line assumption
- P-Delta effect

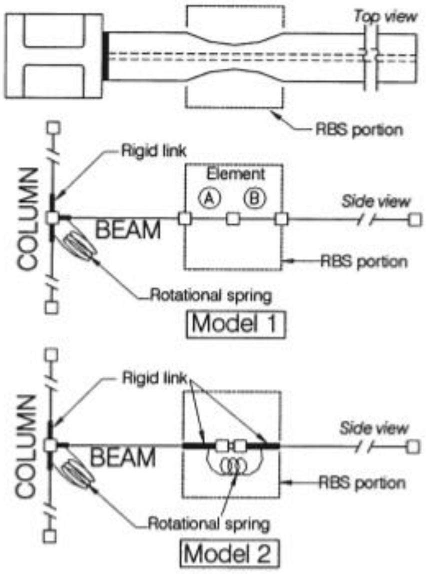

Figure 1. Analytical model of RBS connection

Two steel moment resisting frames one of three storey and another of ten stories were modelled in accordance with AISC Load and Resistance Factor Design (LRFD) specifications and 1994 Uniform Building Code .Three corresponding RBS frames designated as e1,e2 and e3 frame are generated from the SMRFs by introducing different RBS details as follows

- The RBS portion is of circular-cut type;
- The length of RBS is equal to 3db/4;
- The e1 and e2 frame have RBS with the same beam flange reduction of 40% but different eccentricity (e) of db/4 and 3db/4;
- The e3 frame has the RBS with 60% beam-flange reduction and db/2 eccentricity.

The frames are from three- and ten-story steel buildings with 3 bays by 4 bays. All bays are 9.1 m wide and story height is 4.2 m at first story and 3.5 m at others. The buildings consist of special moment-resisting frames at the perimeter in one direction and the braced frames in the perpendicular direction.

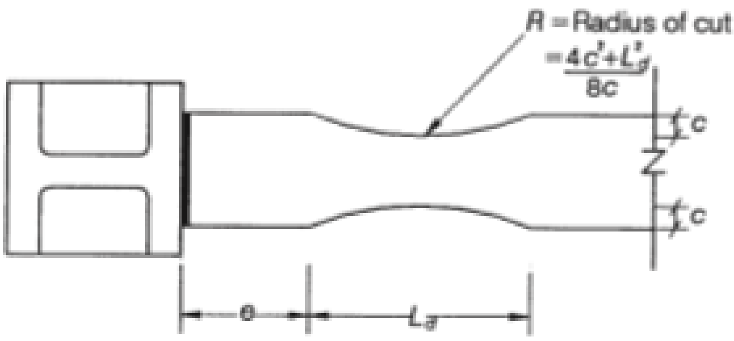

Figure 2. Profile detail of RBS in RBS frame

Table 1. Profile detail of RBS

Frame	Beam flange reduction from original section	e	L_d
e1	40%	$d_b/4$	$3d_b/4$
e2		$3d_b/4$	
e3	60%	$d_b/2$	

d_b=beam depth; e=eccentricity; L_d=RBS length

Various models were made of three storey and ten storey building using different frames. Plastic hinge rotation of each frame subjected to EI Centro rotation and newtonhall trotation are obtained and resulted. From this results of distribution of plastic hinge the plastic deformation pattern in the RBS, beam end (or column face), and panel zone is closely related to the flange reduction rate and location of the RBS. In other words, the pattern can be predetermined by design. The column face has little or no plastic deformation in e1 frames or e3 frames, but considerable amount of plastic rotation in e2. The plastic rotation in three components (beam end, RBS and panel zone) is interrelated, and a change in one of them usually causes an alteration in the other(s). For instance, e3 frames have lowest stress at the column face, but largest plastic rotation in the RBS (twice as much as that in e1 frames).Compared to the performance of the RBS and column face, the deformation in the panel zone is not as sensitive to the RBS configuration.

B. Jun Jin, Sherif El-Tawil,"SEISMIC PERFORMANCE OF STEEL FRAMES WITH REDUCED BEAM SECTION CONNECTIONS" , Journal of Constructional Steel Research 61,pp 452-471 ,2005

They investigated the behaviour of RBS frames by subjecting a 4-, 8- and 16-storey steel MR frame to a suite of earthquake records. The analysis was done using a computer program. Pushover analysis and suites of transient analysis were conducted on the three frames. Results confirm that RBS frames are capable of economically providing good seismic performance in regions of high seismic risk. Several specific conclusions were also derived.
In this paper experimental behaviour of RBS is carried out. The investigations mainly focused on three kinds of connections: tapered cut, radius cut, and straight cut RBS connections. Test results show that tapered cut and radius cut connections provide better performance than constant cut connections. Lateral torsional buckling was observed which directly led to twisting of column. This problem was overcome by introducing slab which acted as bracing between the beams. Fractures observed, were eliminated by grinding flanges in the reduced section region to a specified minimum smoothness.
Three different models are designed, modelled and subjected to a suite of earthquake records. Perimeter moment resisting frames are selected as the lateral load structural system for all three buildings. The floor plan, elevations, and design details for the buildings are shown in Fig 3.

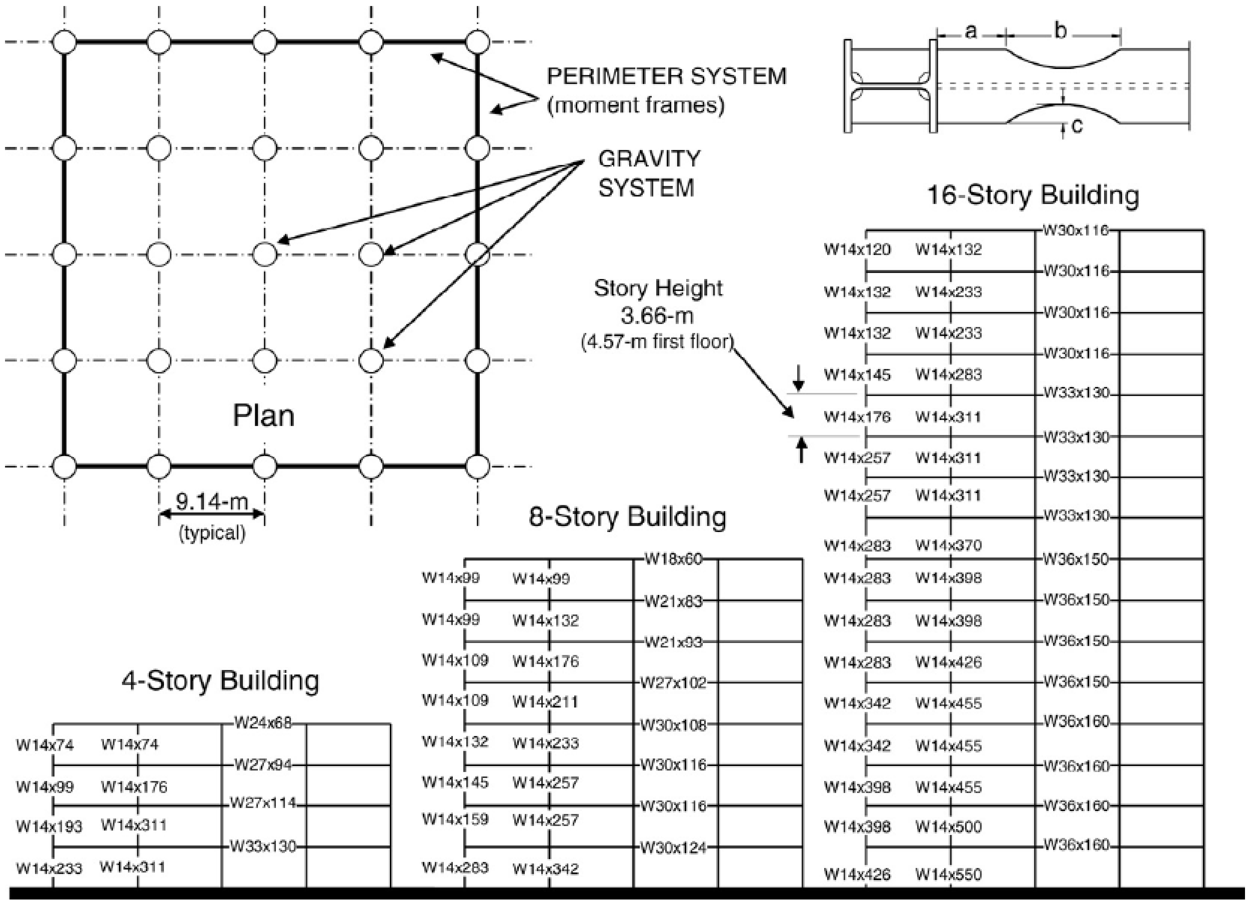

Figure 3. Design details of buildings

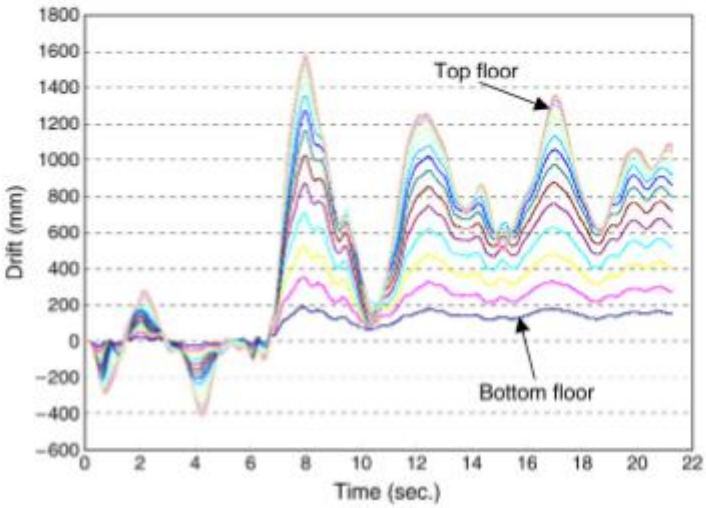

Figure 4. Drift history of the 16-story building—record LA3

The frames are analysed using the computer program DYNAMIX developed by El-Tawil and Deierlein and modified by Jin.The program features inelastic beam–column, rotational spring, and panel zone elements that can be used to represent steel frames. Two types of analysis is carried out i.e., Pushover Analysis and Dynamic Analysis .Although use of pushover analysis for evaluating the performance of the 16-story building is not permitted in [8] because of concerns about higher mode effects, it is nevertheless conducted to provide insight into the accuracy of the method and to evaluate the limits imposed by FEMA-350 [8]. Fig.3.8 shows the mean maximum drifts computed from the dynamic analyses and story drifts computed using the code pattern as well as a uniform load pattern, where the lateral story load is proportional to the story mass.

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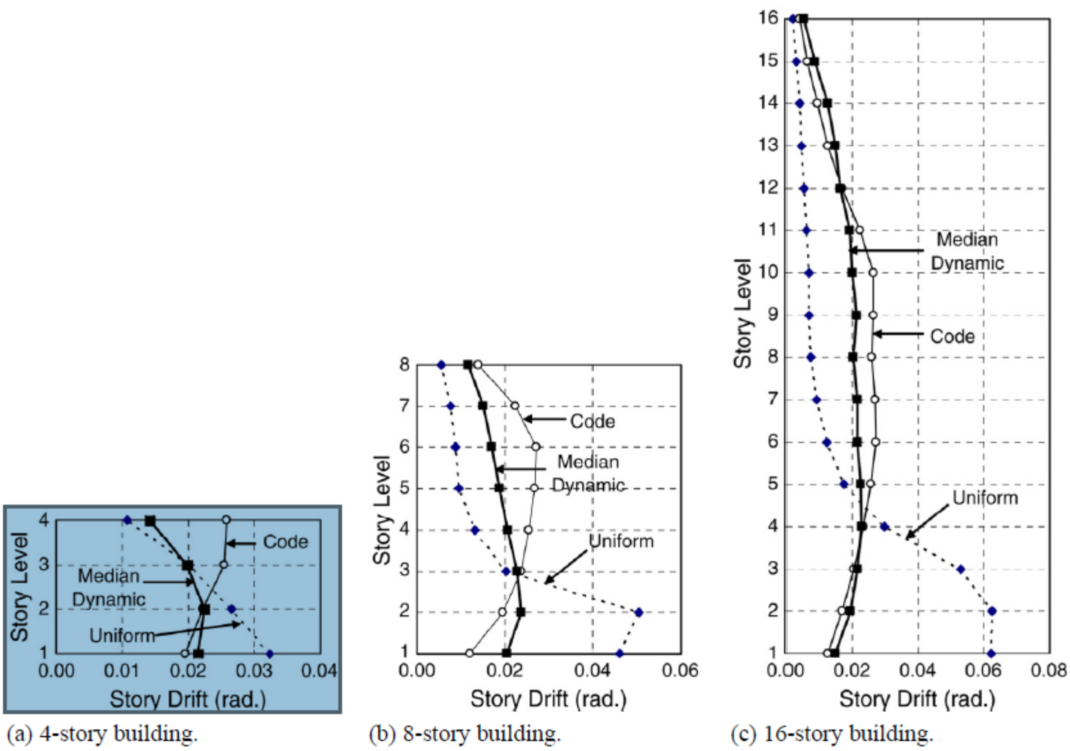

Figure 5. The effect of the lateral load pattern on the pushover response.

Comparisons between pushover analyses using 'code' and uniform lateral load patterns and the median of the transient analyses indicate that the pushover procedure as specified in FEMA-350 can substantially overestimate demands and can thus adversely affect performance evaluations for the three buildings. However, favorable comparisons were achieved between pushover using the code pattern and the median dynamic data for the 16-story building in particular,which suggests that it may be promising to refine pushover methods so that they can be reliably used for performance evaluations of buildings that are taller than permitted by current guidelines.

C. Scott L Jones, Gary T fry, "REDUCED BEAM SECTION WELDED STEEL MOMENT FRAMES", 13TH WORLD CONFERENCE ON EARTHQUAKE, pp 1671,2000

The main aim of this paper is to check whether the connections were able to meet and exceed the plastic joint rotation requirements for special moment frames without the use of the continuity plates.non linear finite element models were created in ANSYS software. Thus reducing material and labor cost can provide an economic benefit to steel moment frame construction.

They performed tests on radius cut RBS details in single-sided beam-column sub assemblage tests after repeated fracture in taper cut RBS specimens.Engelhardt and Gary Fry performed tests on radius cut RBS details in double-sided beam-column sub assemblages to account for higher demands on the panel zone in interior frame joints. All but one of the reported tests that have used a radius cut RBS detail and the new weld detail have performed as expected, with a plastic hinge forming in the RBS to protect the weldment.

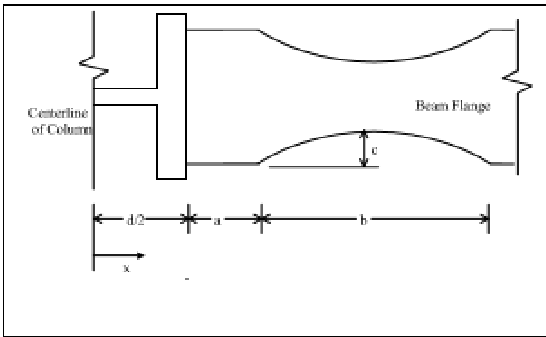

Figure 1. Radius-cut reduced beam section (RBS) detail.

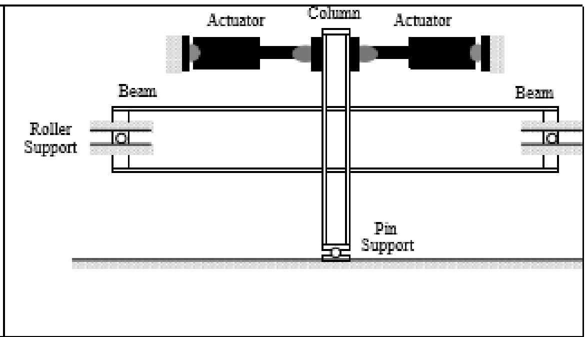

Figure 2. Double-sided moment frame subassemblage test set-up

Figure 6. Single and double side RBS

An elastic-plastic fiber model is presented herein to analyze the column tip load vs. RBS contribution to total story drift curve. Isolation of RBS material behaviour requires that the rest of the material in the frame is treated as rigid forcing all of the deformation into the RBS.The method described herein assumes that the specimen is geometrically perfect i.e, no buckling and the weld material contains no possibility of fracture. These assumptions imply that the model is only accurate in predicting a frame's displacement response to an applied load and vice versa. The fibre model of reduced beam section is described below.

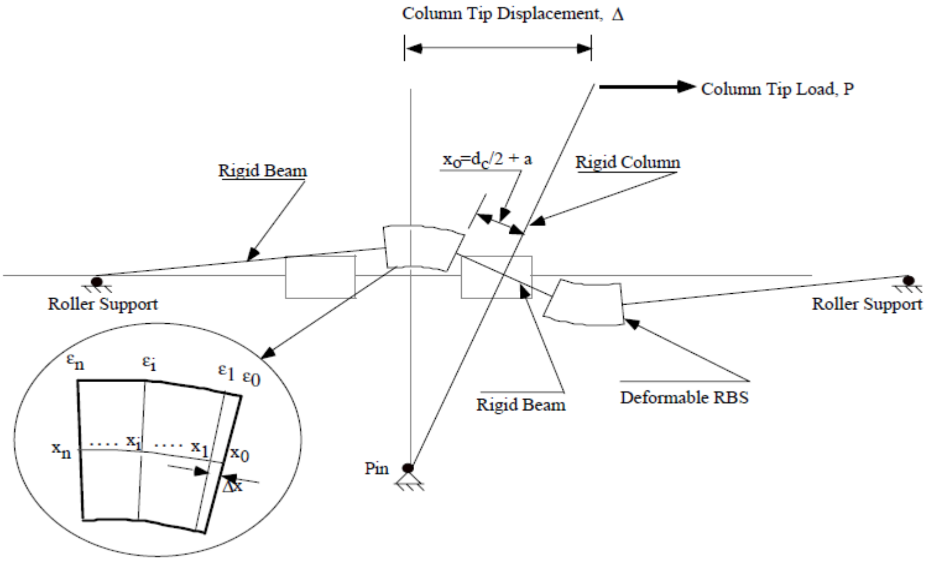

Figure 7. Reduced beam section fibre model

From the above experiment it can be concluded that the full-scale tests showed that all four specimens exceeded the required inter-story drift requirements for use in SMF systems without continuity plates FEMA 350.Finite element modelling can include lateral torsional buckling effects by employing a technique of expanding an eigen value buckling analysis into the nonlinear solution of a finite element model .Finite element modelling can be correlated to full-scale testing and used as a tool for further investigation into the behaviour of the RBS moment connection without continuity plates. Elimination of continuity plates in RBS moment connection scan provide material and labour cost reductions for steel moment frame construction.

D. K.Kildashti, R.Mirghaderi, I.M.Kani,"THE EFFICIENCY OF REDUCED BEAM SECTION CONNECTIONS FOR REDUCING RESIDUAL DRIFTS IN MR FRAMES", Open Journal of Civil Engineering, 2,pp 68-72, 2012

They have taken reduced beam sections as a positive approach to mitigate the huge amount of residual drifts which are greatly amplified by P-Δ effects.A 16-story MR Frame is analyzed and the results are processed to assess the effects of RBS detailing on Drift profile, maximum drift and residual drift.Results show that RBS diminishes both P-delta effect and residual drifts, simultaneously. It also showed that RBS lower the involvement of lower stories which is the main cause of residual drifts.
Several framed structures experiencing plastic deformations during the seismic loading are highly likely to suffer from residual deformations. There are several factors contributing to onset of permanent displacements in structures. Although both certain characteristics inherent in ground motions and component hysteretic behaviours play major part in the variation of residual deformations, the amount of permanent displacements is highly sensitive to P-Δ effects. They also derived results of non-linear dynamic analyses of building with and without RBS subjected to different earthquake suits. They also conceptualised performance of RBS Connection in Reducing Negative aspects of P-Δ. The below shown is a ghraph of residual drifts vs no. of storey.

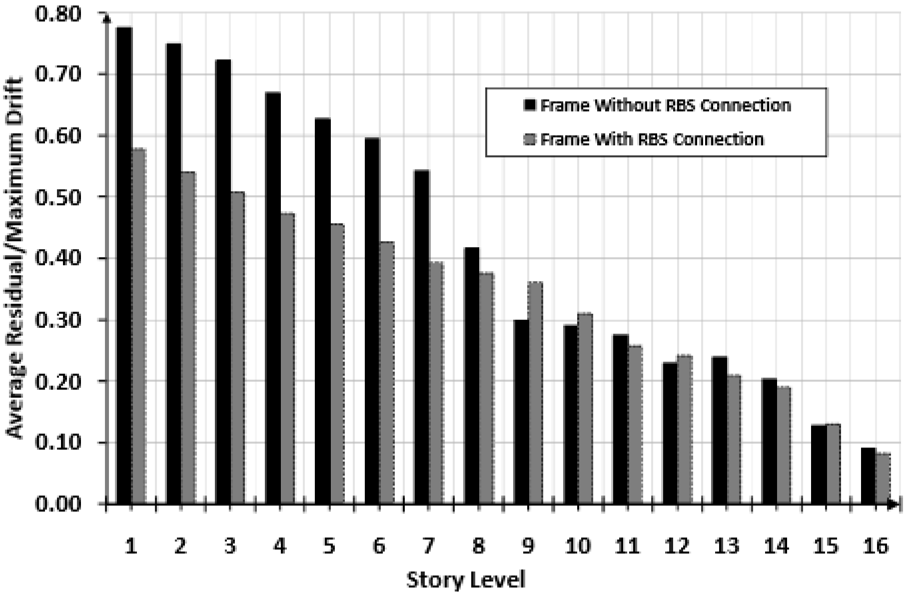

Figure 8. Residual drifts vs no. of storey

E. Swati Ajay Kulkarni, Gaurang Vesmala," STUDY OF STEEL MOMENT CONNECTION WITH AND WITHOUT REDUCED BEAM SECTION", Case Studies in Structural Engineering 1, 26-31,2014

They performed experiment on specimens of Beam-Column assembly of Indian profiles with and without RBS. An FEM model was also created and results were compared with those obtained from the experimental study. It was found that the cyclic performance of RBS moment connection was superior to that without RBS. A reduction in material and labor cost is possible due to elimination of continuity /doubler plates for RBS moment connection. The ANSYS metaphysics finite element software was used to model the specimens for nonlinear analysis. An element SOLID45 from ANSYS element library was used for the 3-D finite element modelling of the RBS moment connection.
250MPa sections grade were considered for this study. Two specimens designated as, connection without RBS as 'WRBS' and with RBS as 'RBS', were studied. RBS connection was designed based on specifications given as per AISC and FEMA codes. For panel zone as well as continuity plates, design shear strength, required shear strength & column web/flange thickness limits were studied..For, specimen WRBS column flange buckling was observed and it became more pronounced with each successive loading cycle. The column panel zone stayed in the upper envelop of elastic state for the specimen as the white wash stayed intact. Column flange or web buckling was not observed. No sign of failure of from welding was observed during the test. The force-displacement hysteretic responses of the connections resulting from the experimental study are compared with those of the finite element analysis.

III. DISCUSSION

For Based on various literature review, it is observed that with the use of reduced beam section plastic hinge formed is away from the beam-column junction. Also by using RBS there is a considerable decrease in residual drift of each storey of the building. This special section uses less amount of steel than the conventional one making the structure lighter. Guidelines about the RBS can be taken from FEMA 350 and AISC.

IV. CONCLUSION

Based on various literature reviews it could be concluding that:

1) The use of RBS firstly decreases the weight and the cost of the building.
2) Plastic hinge will take place away from the face of the column.
3) Involvement of RBS reduces a huge amount of residual drift amplified by P-Δ effects.
4) Elimination of continuity plates in RBS moment connection scan provide material and labour cost reductions for steel moment frame construction.
5) RBS frames are capable of economically providing good seismic performance in regions of high seismic risk.

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