Cyclic Behavior Of Special Shaped Reduced Beam Section Connections On Non Prismatic Corrugated Beams And CFST Columns

Niveda B. S.[1] and Mr. Sajan Jose[2]

Abstract— This paper presents the study of cyclic behavior of joints composed of non-prismatic corrugated steel beams and CFST columns with reduced beam sections. As per recent studies, steel moment frames with weld connections are very brittle in earthquakes. The main damage in such structures is reported on the weld regions due to formation of plastic hinge which resulted in ultimate collapse. The best method to reduce the stress concentration in weld region could be the use of reduced beam section (RBS). RBS moves plastic hinge formation at suitable distance from the joint such that both column and joint remain protected during an earthquake. Three connections with different shape of reducing beam flange have been modelled using ANSYS 16.1 and compared with each other during cyclic behaviour with a story drift of 0.03 radians. The obtained result of this study showed that using circular RBS, stress on column is greatly reduced with an average maximum load carrying capacity. It also shows better hysteresis behavior. Plastic strain is also more on the RBS region.

Index Terms— CFST columns, hysteresis behavior, Non prismatic corrugated steel beams, plastic hinge; plastic strain, Reduced Beam Section, Seismic behavior

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1 INTRODUCTION

Steel moment resisting frames are widely used forseismic loading. In steel moment resisting frames (SMRFs), the beam to column connection is fully welded and have been widely used over many years in those areas of the USA that are prone to seismic activity. During the 1994 Northridge and 1995 Kobe Earthquakes, it was observed that the joints had failed through brittle cracking of the welds weld that connected the bottom flange of the beam and the column flange plate. The unexpected damage invalidated the then-existing design and construction procedures.

The best solution to overcome this problem is Reduced Beam Section by weakening a portion of beam flange at a short distance from column flange. This leads in formation of plastic hinges on the beam span away from column face, resulting in the reduction of stress concentration at the interface of beam and column. Because of reducing beam section within a sensitive zone, the beam becomes more prone to buckling.

A concrete-filled steel tube (CFST) column has many advantages compared with steel or reinforced concrete system.One of the main advantages is that local buckling of steel tube is delayed by the restraint of concrete.

It prevents concrete spalling and maintains tube’s stiffness after concrete cracking and compressive strength can be further increased. The strength of concrete is increased by the confining effect provided from the steel tube. The steel tube which acts as formwork for the concrete core supports a considerable amount of construction loads during construction. The CFST combine the merits of steel and concrete and its properties are favourable in terms of compression, tension, bending, shear and torsion.

Non-Prismatic beam is defined as the beam whose cross section is not constant along its entire length. Depth of the beam varies depending upon the moment it has to resist on a particular section.These beams are aesthetically more appealing than the Prismatic beams due to their varying depth. Tapering saves large amount of steel, which saves money on material cost. Less steel results in less weight in shipping, which saves money. It also means less load on the foundation, which saves money, especially in seismic zones, where weight also increases the seismic load.

Beams composed of thin sinusoidal corrugated web I sections are produced in recent years. These elements are beam sections formed by welding of 1.5 to 3.0 mm thick sine form web to hot-rolled flat flange plates. Cold-shaping method is used to produce corrugated sine form of the web. Relatively higher strength and rigidity can be provided with less material with these kind of sections compared to the thick straight web I sections.

To learn the cyclic behavior of different RBS shapes, in this paper nonlinear finite element analysis of connections with

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circular RBS, rectangular RBS and trapezoidal RBS on non prismatic corrugated beams and CFST columns are conducted using ANSYS software.

2 METHODOLOGY

Reduced Beam sections are widely used in European countries. But studies are mainly focused on prismatic thick beams. This method can be adopted in India for better seismic performance.In this paper special type of beam known as non prismatic corrugated beam is used. Column used is CFST column. Different RBS shapes such as circular RBS, rectangular RBS and trapezoidal RBS are studied. Beam column joints are modeled using ANSYS 16.1 and compared with each other during cyclic behavior with a story drift of 0.03 radians. This type of connections have more advantages in Indian profile as they are economical and provide better performance as compared to conventional type of beam column joints.

3 GEOMETRICAL DETAILS

In RBS, the dimensions are chosen as per FEMA 350 and geometrical details of RBS are shown in figure 1.

- a = 0.50 to 0.75 b_f (150 to 225)
- b = 0.65 to 0.85 d_f (455 to 595)
- $0.2\, b_f \le c \le 0.25\, b_f$ ($60 \le c \le 75$)

Where,

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.

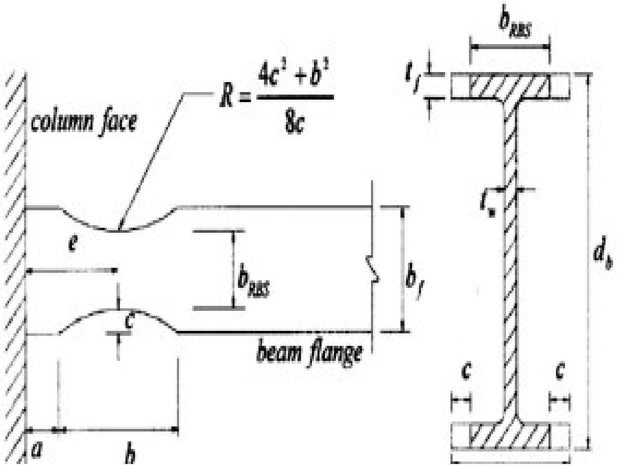


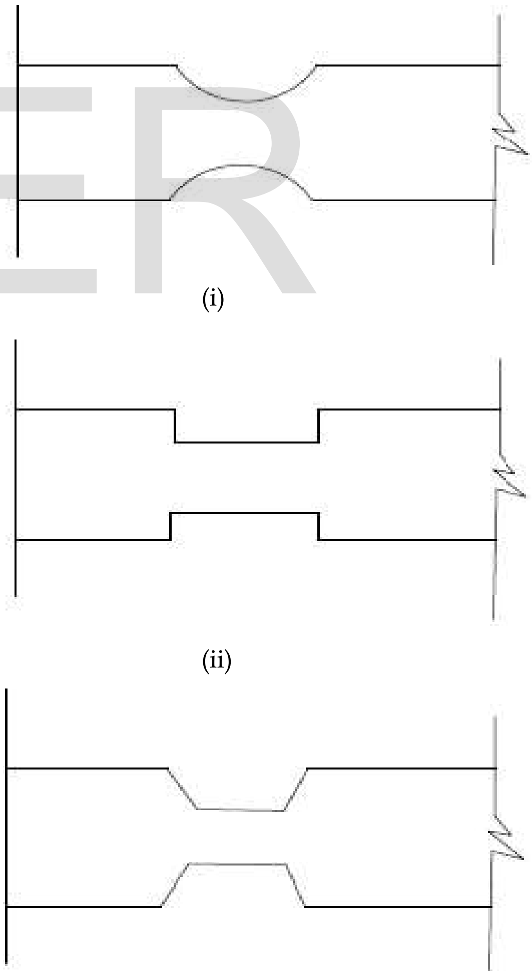
Fig 1. Geometrical details of RBS [6]

These dimensions should 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 different shapes such as circular RBS, rectangular RBS and trapezoidal RBS. The area of reduction is kept constant in all shapes with slight variations in dimensions within the range. The fig.2 shows that the sample top view of the different RBS shapes such as (i) circular RBS, (ii) rectangular RBS, (iii) trapezoidal RBS.

The column used is CFST square box column with a dimension of 550x550x10 mm. The height of the column considered is 3000 mm. Other properties of CFST column is given in table 1.

Steel beam used is having a length of 3600 mm, depth of 700 mm, width of 300 mm, web thickness of 13 mm and flange thickness of 24 mm. Other properties of steel beam is given in table 2.

Non prismatic beam with a tapering ratio 1.5 is used in this study. Corrugations used are sinusoidal corrugations with a thickness of 3 mm. Length and height of one wave is 150 mm and 43 mm respectively



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(ii)

(iii)

Fig 2. Different RBS shapes of (i) circular RBS (ii) Rectangular RBS (iii) Trapezoidal RBS

Table 1 : Properties of CFST column

Concrete	Steel
Grade – M30	Grade – Fe 345
Poisson's Ratio – 0.15	Poisson's Ratio – 0.3
Yield strength – 3.83 Mpa	Yield strength – 345 Mpa
Density – 7860 kg/m^3	Density – 7860 kg/m^3
Young's modulus – 27386 Mpa	Young's modulus – 20000 Mpa
Multi linear property	Bi linear property

Table 2 : Properties of steel beam

Grade	Fe 345
Poisson's Ratio	0.3
Yield strength	345 Mpa
Density	7860 kg/m^3
Young's modulus	20000 Mpa

4 FINITE ELEMENT ANALYSIS

The ANSYS16.1 software was used to model the specimens for nonlinear analysis. SOLID 186 from ANSYS library was used for 3-D finite element modelling of the RBS moment connection. 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.A displacement control loading was applied on the tip of the beam by imposing cyclic displacement based on AISC loading protocol. Cyclic behavior of different shapes of RBS is compared by keeping the story drift as 0.03 radians. Specifications of different shapes of RBS are given in table 3. FE models of RBS with different RBS are shown in fig 3.

Table 3 : Dimensions of RBS

RBS SHAPES	DIMENSIONS
Circular RBS	a = 180 mm b = 525 mm c = 75 mm
Rectangular RBS	l = 455 mm b = 60 mm
Trapezoidal RBS	L1 = 525 mm L2 = 375 mm h = 60 mm

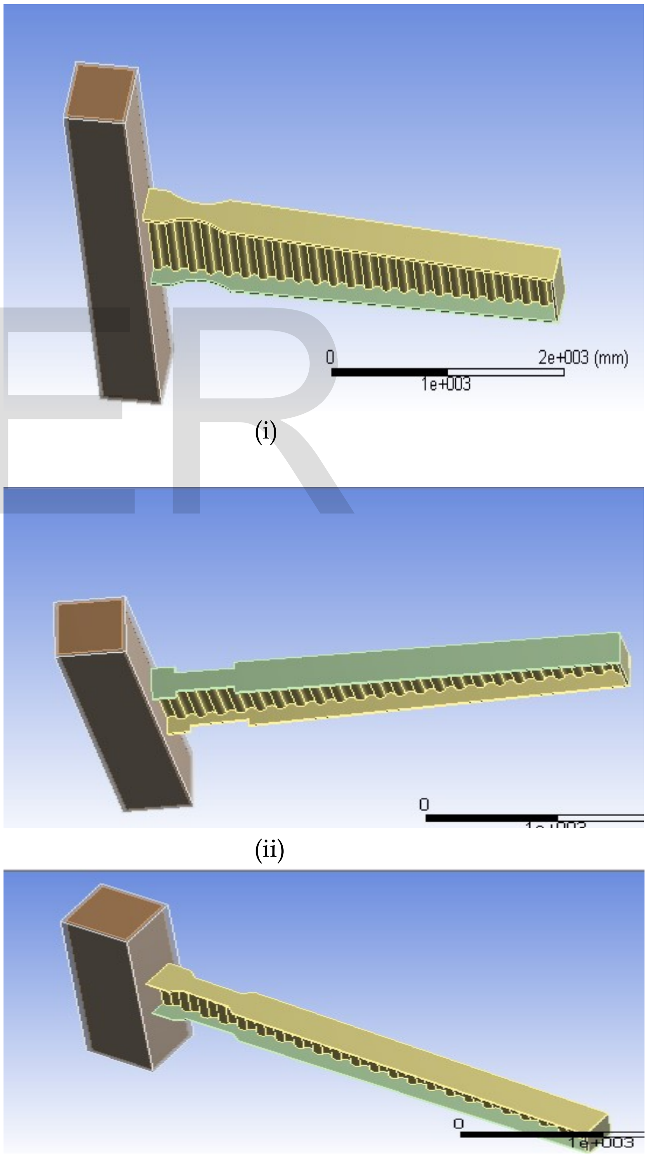

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Fig 3. FE models of RBS shapes (i) Circular RBS (ii) Rectangular RBS (iii) Trapezoidal RBS

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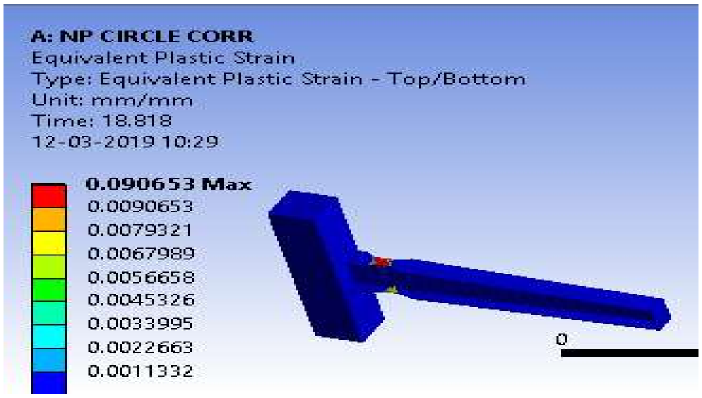
5. RESULTS

5.1 Strain Distribution

Equivalent plastic strain of 3 models are shown in fig 4.

It can be seen that all the strain is concentrated in the RBS region rather than in the joint. This makes the joints safe and prevents from brittle failure.



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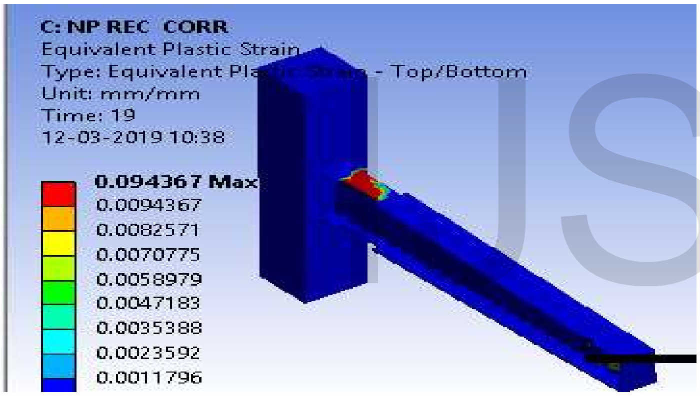

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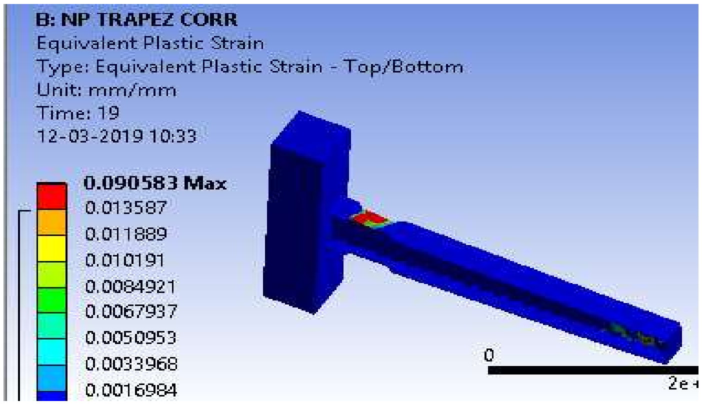

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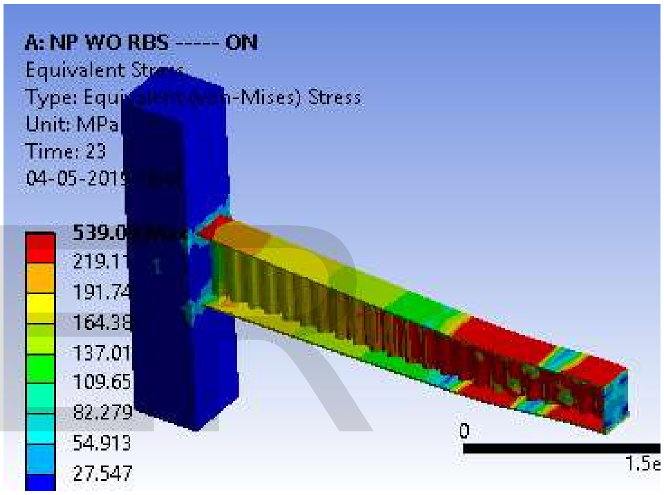
Fig 4. Equivalent plastic strain of (i) Circular RBS (ii) Rectangular RBS (iii) Trapezoidal RBS

5.2 Stress Distribution

Von-Mises stress distribution of 3 models with different shapes of RBS such as circular RBS, rectangular RBS and trapezoidal RBS are shown below.

From the figures, it can be seen that stress is concentrated in the RBS region in all the cases with RBS. So failure will occur in the RBS region as plastic hinge is relocated to R BS region from the weld region. This makes the column safe and prevents the weld from failure. But in the case without RBS, stress is concentrated in the weld region and at the free end of the beam which is very dangerous for a building during an earthquake. This resembles the case of buildings during Northridge earthquake. This proves the importance of RBS during an earthquake.



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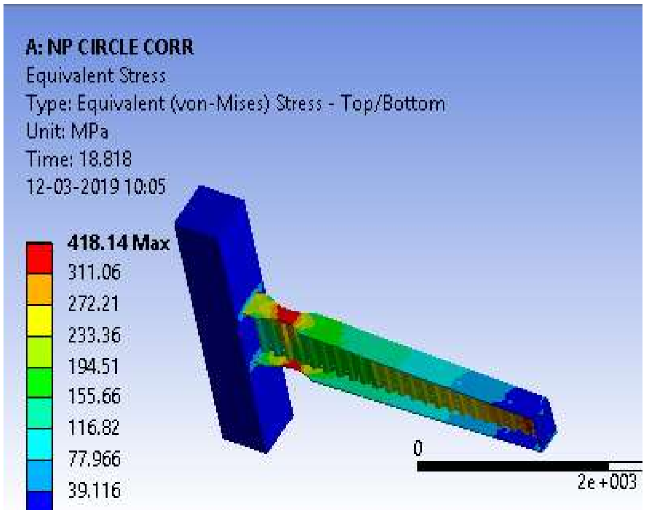

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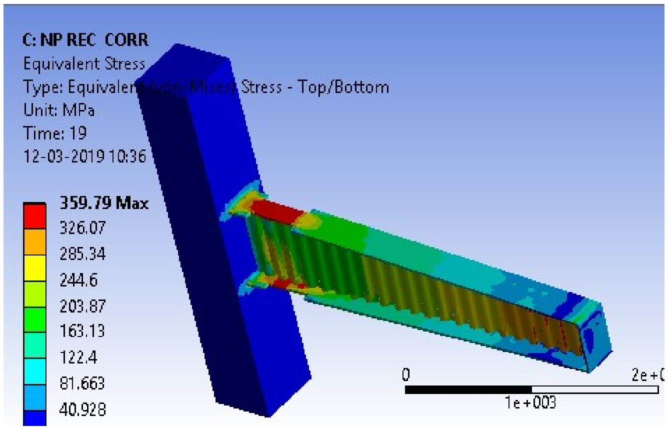

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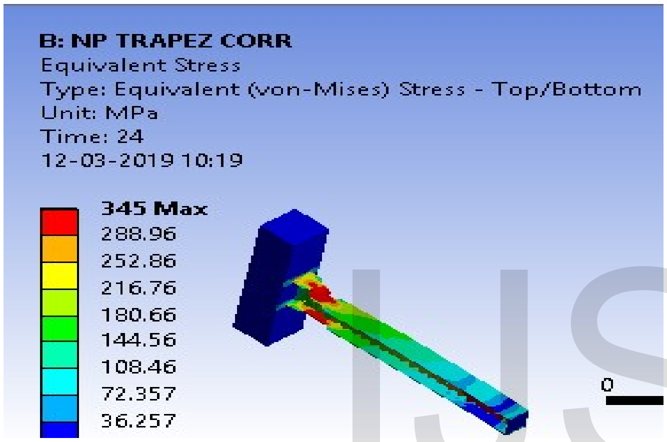

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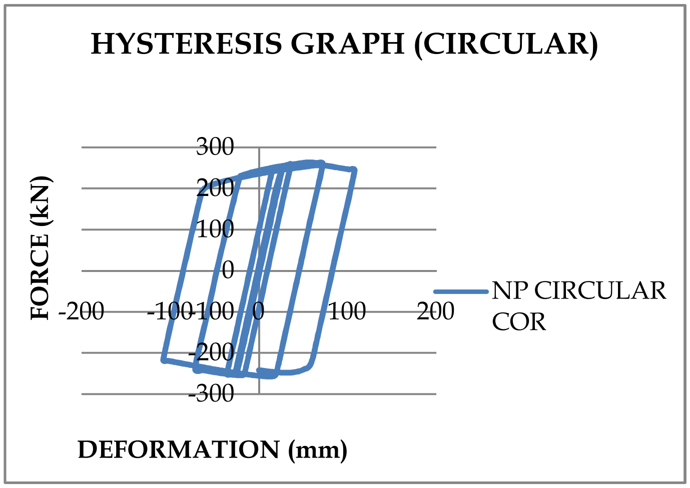
Fig 4. Stress distribution of (i)Non prismatic without RBS (ii) Circular RBS (iii) Rectangular RBS (iv) Trapezoidal RBS

5.3 Hysterisis Behavior

The total energy dissipated by each specimen during a story drift of 0.03 rad is shown in figure below.



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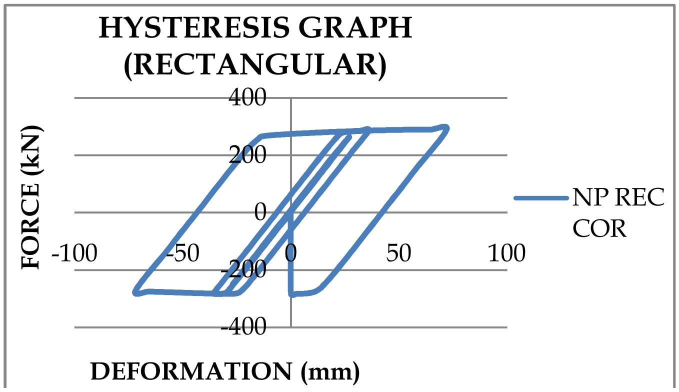

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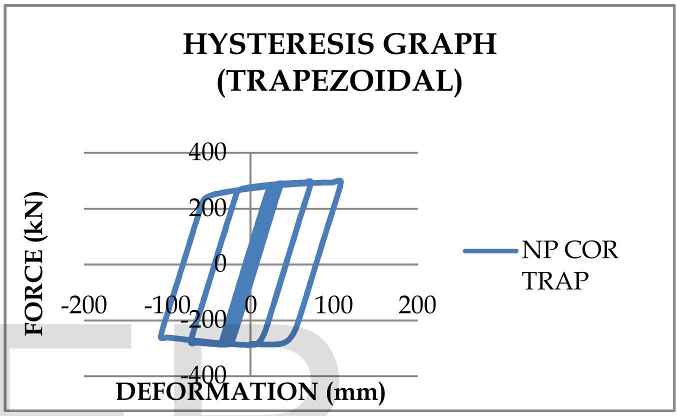

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Fig 4. Hysteresis loops of (i) Circular RBS (ii) Rectangular RBS (iii) Trapezoidal RBS

5.4 Comparison

Comparison of different shapes of RBS in terms of deflection, number of cycles, stress on column and beam are shown in table 4.

Table 4. Comparison of different RBS shapes

Shape	Deflection	Load	Time	Cycle	Stress on column	Stress on beam
Circular RBS	58.8	294.65	18.81	4.70	144.21	418.14
Retangular RBS	71.9	263.68	19	4.75	205.44	356.70
Trapezoidal RBS	71.9	289.32	19	4.75	202.44	359.79

6. CONCLUSIONS

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It can be concluded that Circular RBS exhibit better results. Strain is concentrated in the RBS region in all cases. In terms of load , stress on column and stress on beam, circular RBS is the best compared to other two shapes. As the stress on column is quite less than stress on beam, column remains safe during an earthquake. So it accepts the weak beam- strong column concept. Circular RBS also shows better hysteretic behavior. Stress is concentrated in the RBS region in all cases. But best result is obtained for circular RBS. This study is limited and more extensive study is recommended to understand the behavior of RBS on non prismatic corrugated beams.

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