Seismic Enhancement of RBS with Pretension Bolt in Steel Moment Resisting Frame.

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Abstract - *Reduced beam section design provides a more predictable and reliable behavior at the beam column connection during seismic event. RBS enhances the ductility of the beam and it made the column safe from overall collapse of a structure but it reduced the load bearing capacity of beam considerably.to overcome the lack of moment capability of beam this study aims to implement a pretensioning bolt with plate welded across the RBS. The main objective of this paper is to evaluate the performance of reduced beam section(RBS) with various design modification, specifically focusing on strengthening methods involving bolts and plates. The study aims to determine whether the diameter of bolts used in these strengthened RBS designs influences the load bearing capacity of the beam.*

Key Words: Reduced beam section, load bearing capacity, collapse, beam, column, bolts.

1.INTRODUCTION.

A moment resisting frame (MRF) is a structural system commonly used in buildings to resist lateral loads, such as those generated by wind or earthquakes. It consists of beams and columns connected together to form a rigid frame that can transfer and distribute these loads throughout the structure. MRFs are highly efficient in terms of material usage and construction costs. They can provide a high strength-to-weight ratio, allowing for lighter and more economical designs compared to other structural systems they offer flexibility in architectural design by providing open floor plans with minimal obstructions. The absence of diagonal bracing allows for more usable space and better utilization of the building. MRFs can provide an aesthetically pleasing appearance due to their clean and unobstructed structural lines. This makes them suitable for modern architectural designs. MRFs typically have redundant load paths, meaning that if one member fails, the load can be redistributed to other members. This enhances the overall robustness and resilience of the structure. robustness and resilience of the structure.

Lateral stability is a crucial aspect in the design and performance of moment resisting frames (MRFs) during seismic events. Seismic stability joints are commonly used in MRFs to enhance their lateral stability and ensure their ability to withstand strong earthquake forces. Seismic stability joints are designed to provide controlled yielding and energy dissipation during seismic events. These joints are typically located at specific levels along the height of the MRF, such as at beam-column connections or at the base of the structure. The performance of seismic stability joints is critical in ensuring the overall stability and safety of MRFs during earthquakes. These joints must be designed to have sufficient strength and ductility to withstand the anticipated seismic forces without failure. Additionally, their behaviour under cyclic loading conditions should be carefully considered to ensure that they can sustain multiple seismic events without significant degradation in performance. Several factors need to be considered in the design and evaluation of seismic stability joints. These include the selection of appropriate joint types, such as fuse elements or energy dissipating devices, as well as the determination of their capacity and behaviour under different loading conditions. The detailing of these joints is also crucial to ensure proper load transfer and avoid potential weak points or failure modes

During 1994 Northridge, CA earthquake, the beam flange-column flange weldments in steel MRF failed at much lower than anticipated load and drift levels. Thus structural engineers introduced RBS, which appears to the most economical new design method. The RBS protects the welded connection by forcing the plastic hinge in a beam to form away from the column face. Traditionally it's a strong column weak beam combination Reduced Beam Sections (RBS) design provides a more predictable and reliable behaviour at the beam-column connection during seismic events. The purpose of an RBS is to enhance the ductility of the beam. By reducing the beam section's width and depth at the ends, the plastic hinge formation can be controlled and confined within the reduced section. This allows for controlled yielding and energy dissipation during seismic events or other loading conditions, improving the overall ductility of the beam. Providing reduced beam sections on beams instead of the beam-column interface allows for improved ductility, maintains the flexural capacity of the beam, preserves the column's design integrity, and facilitates construction processes. The disadvantage faced in RBS is that it reduced the moment capacity.

1.1 Pretension Bolt

A pretension bolt often referred to as preloaded bolt. It's a type of fastener which is tightened to a particular tension before it is subjected to an external load. This tensioning ensures the bolt can effectively handle applied loads during service, which improves performances and reliability. Pretension bolts are commonly used in structural applications such as in the construction of building, bridges and other infrastructures.

2. STUDY THE BEHAVIOUR OF DIFFERENT DIMENSION OF RBS IN BEAM COLUMN CONNECTION WITH AND WITHOUT PRETENSION BOLT

The analytical study consists of 5 models with and without

Strengthening of RBS and the values of each models are compared. Additionally, critical aspect of this study is ensuring that the plastic hinge formation remains within the RBS region of the beam and doesnot relocate due to modification The cut value of RBS are calculated as per AISC-358 specification

R = radius of cut = $(4c^2+b^2)/(8c)$ (1)

$0.5bf \le a \le 0.75bf$ (2)

$0.65d \le b \le 0.85d$ (3)

$0.20b \le c \le 0.25d$ (4)

Where bf= flange breadth of beam, d=depth of beam

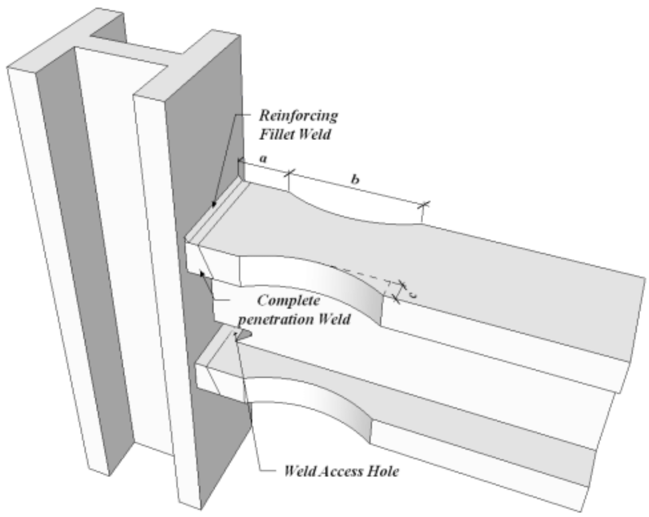

Fig -1: RBS Connection

Table -1: Different models with design parameters.

MODELS	DESIGN PARAMETERS
Model 1	a=50 b=130 c=10
Model 2	a=75 b=175 c=25
Model 3	a=62.5 b=150 c=17.5
Model 4	a=75 b=130 c=10
Model 5	a=50 b=175 c=25

Here the both ends of columns are fixed and the end of beam is free so that the cyclic load is given at the tip of beam in downwards direction. The height of column and the length of beam is 975mm and 1000mm

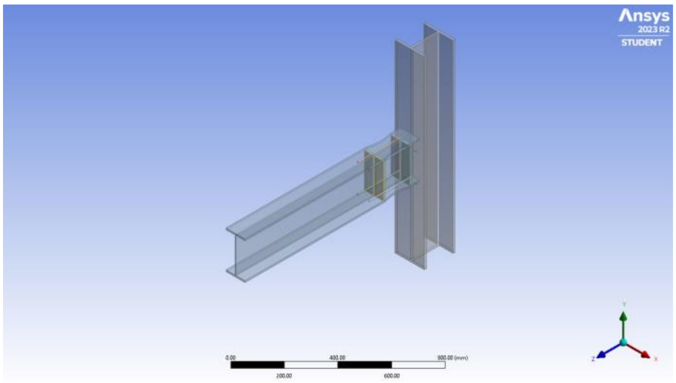

Fig -2: Geometry of strengthened RBS model

The RBS region is strengthened with the help of 4 bolts and a plate across the plastic hinge region. Bolts provide additional shear and tensile resistance, helping to transfer load and improve the overall rigidity of the connection. Plates are added to reinforce the reduced section providing additional cross –sectional area and stiffness

2.1 Equivalent plastic strain of strengthened RBS models

The equivalent plastic strain of all models are listed below

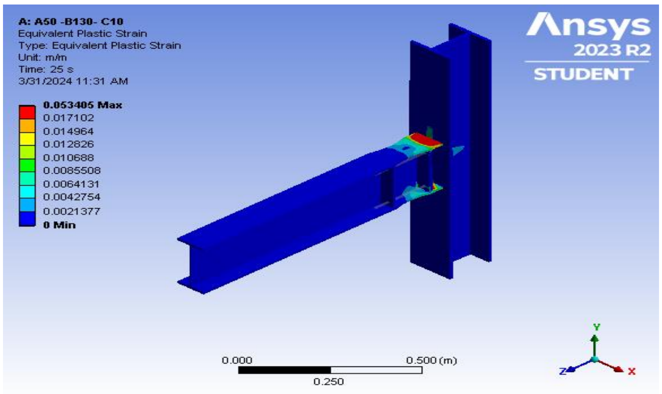

Fig -3: Equivalent plastic strain of Model 1

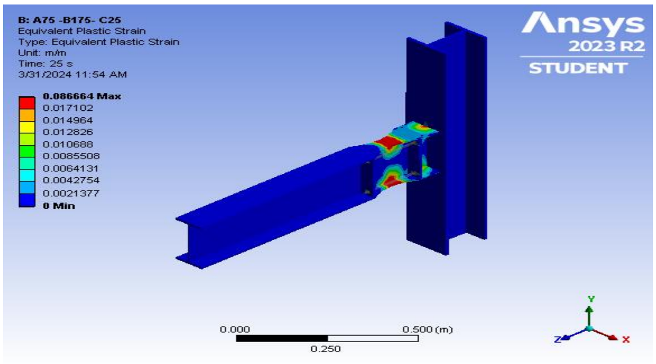

Fig -4: Equivalent plastic strain of Model 2

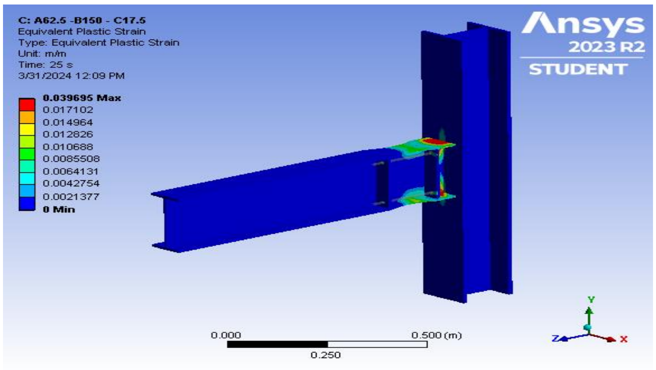

Fig -5: Equivalent plastic strain of Model 3

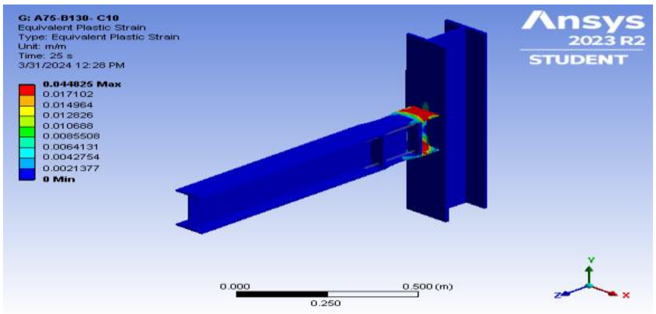

Fig -6: Equivalent plastic strain of Model 4

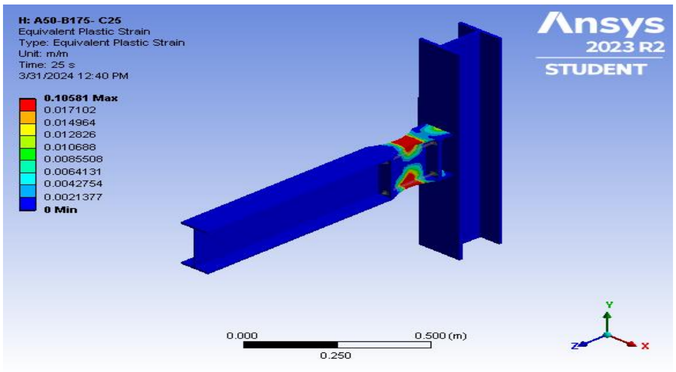

Fig -7: Equivalent plastic strain of Model 5

2.2 Result

Table -1: Analysis of Models

Model	Max Load bearing (kN)	Drift (%)
Model 1	84.42	3
Model 2	75.90	3
Model 3	81.11	3
Model 4	81.06	3
Model 5	73.76	3

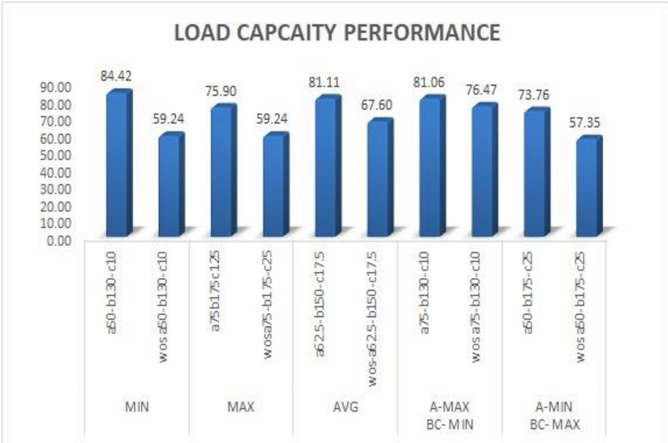

Fig -8: Load capacity performance of model with and without strengthening of RBS

The load bearing capacity varies from one another. But it is observed that the plastic hinge is relocating from the RBS portion which is not acceptable. The model a50-b175-c25 is the best option as there is no plastic hinge relocation from the RBS portion. The load bearing capacity of a50-b175-c25 is 73.76 KN with 26.62 percentage increase in strength than the model a50-b175-c25 without strengthening with a drift value of 3%.

So for further analysis we can take the model a50-b175-c25.

3.STUDY THE BEHAVIOUR OF STRENGTHENED RBS IN BEAM COLUMN CONNECTION WITH DIFFERENT BOLT DIAMETERS

The behavior of model 5 under different diameters of bolt 6mm,8mm,10mm,12mm,14mm,16mm,18mm,20mm.isconsidered for the study.

3.1 Equivalent plastic strain of strengthened RBS models

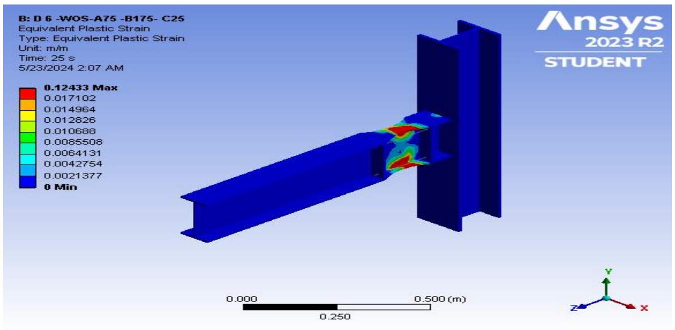

Fig -9: Equivalent plastic strain of Model 5 with 6mm dia

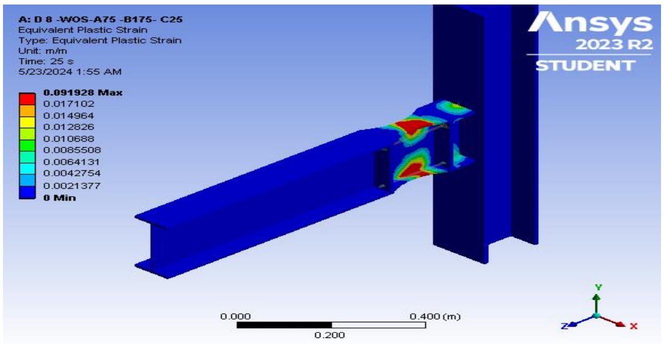

Fig -10: Equivalent plastic strain of Model 5 with 8mm dia

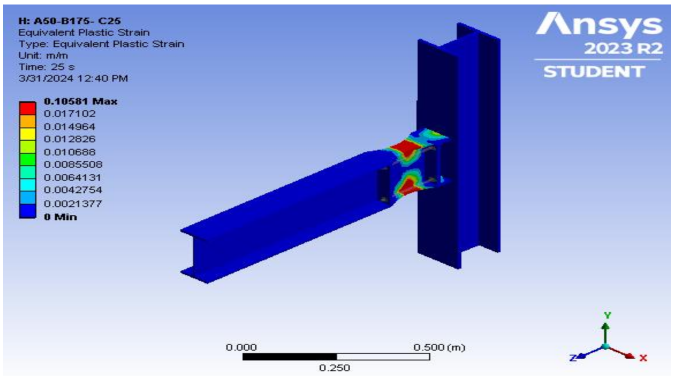

Fig -11: Equivalent plastic strain of Model 5 with 10mm dia

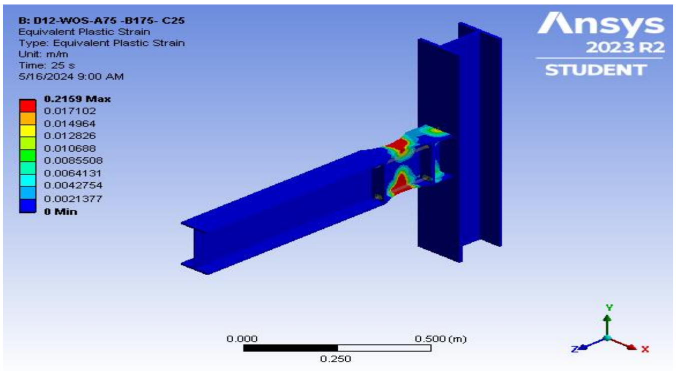

Fig -12: Equivalent plastic strain of Model 5 with 12mm dia

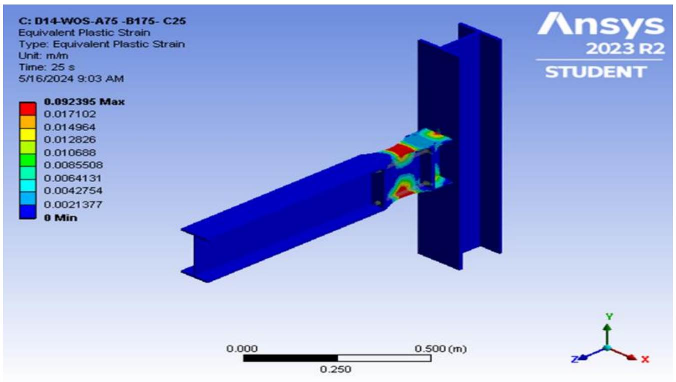

Fig -13: Equivalent plastic strain of Model 5 with 14mm dia

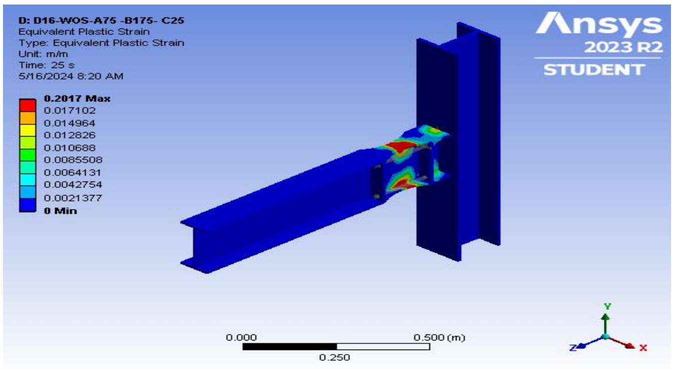

Fig -14: Equivalent plastic strain of Model 5 with 16mm dia

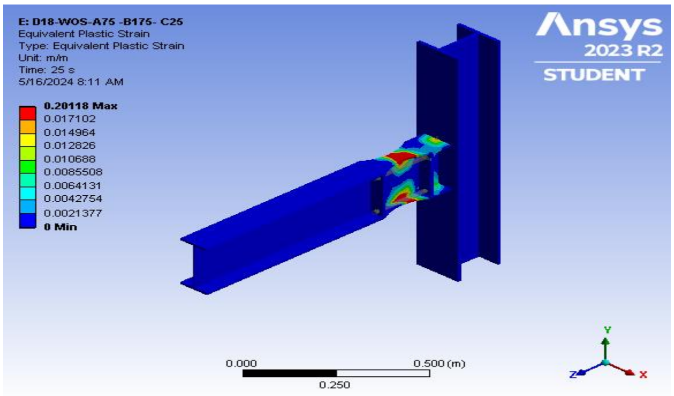

Fig -15: Equivalent plastic strain of Model 5 with 18mm dia

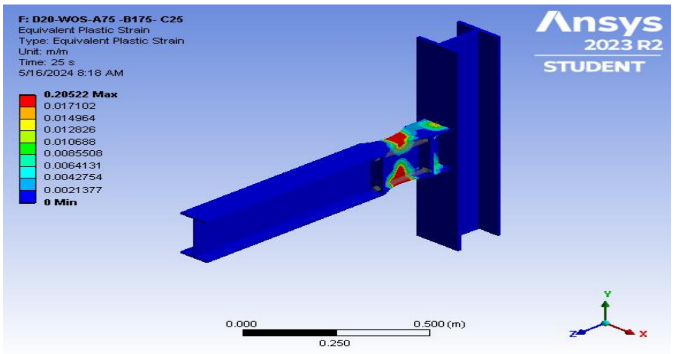

Fig -16: Equivalent plastic strain of Model 5 with 20mm dia

Table: Results of model 5 with various diameters

DIA OF BOLT IN MODEL 5	DEFORMATION (mm)	DRIFT (%)	LOAD (kN)
6	18.7	1	64.31
8	23	2	73.47
10	27	3	73.62
12	23	2	74.28
14	23	2	74.44
16	23	2	74.43
18	23	2	74.44
20	23	2	74.44

The analysis of model with various diameter started with 6mm, the deformation of beam was 18.7 mm with a load carrying capacity of 64.3kn and drift percentage of 1.at 8mm the deformation of beam was 23mm with load carrying capacity of 73.47 kN and drift percentage of 2.at 10 mm the deformation of beam was 27mm with load bearing capacity of 73.62 kN and drift percentage of 3. at 12mm the deformation of beam was 23mm with load carrying capacity of 74.28 kN and drift percentage of 2. at 14 mm the deformation of beam was 23mm with a load carrying capacity of 74.44 kN and drift percentage of 2. at 16 mm the deformation of beam was 23mm with a load carrying capacity of 74.43 kN and drift percentage of 2. at 16mm the deformation of beam was 23mm with a load carrying capacity of 74.43 kN and drift percentage of 2. at 18mm the deformation of beam was 23mm with a load carrying capacity of 74.44 kN and drift percentage of 2. at 20mm the deformation of beam was 23mm with a load carrying capacity of 74.44 kN and drift percentage of 2.

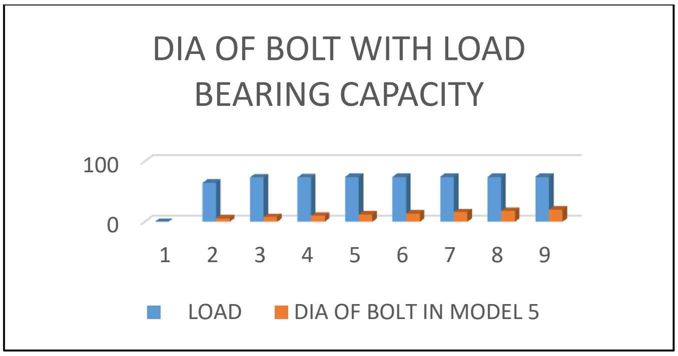

Fig-17: Bar graph of dia of bolt with load bearing capacity

From the above graph it is observed that diameter of bolt dosent have a crucial role in increasing the moment capability. Diameter 8mm,10mm,12mm, is much more capable in bearing the load, but from 14mm onwards the moment capability remains almost same.as we increase the dia it is found that the plastic hinge is relocating from the RBS region to column face and the beam is getting distorted. The load bearing capacity is 74.4 kN throughout after 12mm of bolt diameter.it is because of the beam distortion as the bolt gets restrained. From 12 mm the plastic hinge is relocating from the beam to column and the beam is getting distorted hence it is advisable to use 8 mm to 10 mm dia of bolt to attain maximum moment capacity of beam with strengthened RBS.

4.CONCLUSION

Reducing the beam section, known as a Reduced Beam Section (RBS), is a common technique to enhance the safety of columns from collapse by promoting ductile behavior and controlling the formation of plastic hinges. However, this reduction typically results in a decreased load-bearing capacity. To address this limitation, strengthening the RBS can be implemented to increase its load-bearing capacity while still maintaining the formation of plastic hinges within the RBS portion. One method of strengthening is by using bolts with plates. When bolts with plates are employed, they effectively redistribute the applied loads, providing additional support to the RBS. This redistribution of forces allows the RBS to carry higher loads without compromising its structural integrity. The diameter of the bolts, along with the size and thickness of the plates, plays a critical role in determining the extent of load capacity enhancement. However, it's important to note that increasing the diameter of bolts with plates can only enhance load capacity up to a certain point. Beyond this threshold, the excessive pressure exerted by the bolts and plates may lead to structural failure due to bolt restraint or other failure modes. Therefore, careful analysis and consideration are necessary to optimize the size and placement of bolts with plates to ensure both increased load capacity and structural safety

The conclusions obtained are,

• Indeed, implementing a Reduced Beam Section (RBS) can significantly enhance the safety of a column by improving its ability to withstand seismic or other types of loading. By strategically weakening the beam section near the column, the RBS encourages controlled plastic hinge formation, which helps dissipate energy and prevents sudden, catastrophic collapse during extreme events. This design approach is a fundamental aspect of ensuring structural resilience and safety in buildings and other engineered structures

• Reinforcing the Reduced Beam Section (RBS) with plates and bolts can indeed increase the load-bearing capacity of the structure. By adding plates and bolts, the connection between the beam and the column becomes stronger and more resistant to applied loads. This reinforcement redistributes forces more effectively, allowing the RBS to carry higher loads without compromising its structural integrity. This method helps optimize the performance of the structure, enhancing its ability to withstand various loading conditions while maintaining the benefits of the RBS design in terms of safety and resilience.

• Increasing the diameter of bolts in a Reduced Beam Section (RBS) can indeed enhance the load-bearing capacity of the structure up to a certain point. Larger diameter bolts provide greater resistance to applied loads and can effectively transfer forces between the beam and the column. This increased capacity allows the RBS to carry heavier loads without compromising its structural integrity. However, it's essential to consider the limits of bolt diameter increases, as excessively large bolts may lead to structural issues such as excessive pressure on the surrounding material or bolt restraint failure. Therefore, careful analysis and engineering judgment are required to determine the optimal bolt size to maximize load-bearing capacity while ensuring structural safety.

5.REFERENCE

1. Anastasiadis, Anthimos S., Marius Mosoarca, and Victor Gioncu. *"Design aspects of reduced beam sections for IPE and HEA European profiles*." 8th National Conference on Metal Structures, Xanthi. Vol. 29. 2005.

2. Chen, L., and Y. C. Wang. "*Methods of improving survivability of steel beam/column connections in fire*." Journal of Constructional Steel Research 79 (2012): 127-139.

3. Di Benedetto, Sabatino, et al. "*Seismic behaviour of steel Moment Resisting Frames with traditional and innovative connections."* Procedia Structural Integrity 44 (2023): 1901-1908.

4. Indupriya, G., and B. Anupriya. "*Analytical Evaluation of RBS Moment Connection for Indian Profiles Under Seismic Behavior."* International Journal of Sustainable Construction Engineering and Technology 13.3 (2022): 90-106.

5. Loulelis, D., G. D. Hatzigeorgiou, and D. E. Beskos. *"Moment resisting steel frames under repeated earthquakes*." Earthquake and Structures 3.3-4 (2012): 231-248.

6. Moore, Kevin S., James O. Malley, and Michael D. Engelhardt. *Design of reduced beam section (RBS) moment frame connections*. Los Angeles: Steel Committee of California, 1999.

7. Nia, Z. Saneei, M. Ghassemieh, and A. Mazroi. *"WUF-W connection performance to box column subjected to uniaxial and biaxial loading."* Journal of Constructional Steel Research 88 (2013): 90-108.

8. Quayyum, Shahriar, and Tasnim Hassan. *"Seismic performance of a fire-exposed moment-resisting frame*." Journal of Structural Engineering 144.11 (2018): 04018206.

9. Rackauskaite, Egle, et al. "*Computational analysis of thermal and structural failure criteria of a multi-storey steel frame exposed to fire."* Engineering Structures 180 (2019): 524-543.

10. Radzi, Noor Azim Mohd, et al. *"A Review of the Structural Fire Performance Testing Methods for Beam-to-Column Connections*." Advances in Civil Engineering 2021 (2021): 1-18.

11.Saleh, Aboozar, Seyed M. Zahrai, and Seyed R. Mirghaderi. "*Experimental study on innovative tubular web RBS connections in steel MRFs with typical shallow beams."* Structural Engineering and Mechanics, An Int'l Journal 57.5 (2016): 785-808.

12. Swati, Ajay Kulkarni, and Vesmawala Gaurang. "*Study of steel moment connection with and without reduced beam section."* Case Studies in Structural Engineering 1 (2014): 26-31.

13. Taiyari, Farshad, Antonio Formisano, and Federico M. Mazzolani. *"Seismic behaviour assessment of steel moment resisting frames under near-field earthquakes*." International Journal of Steel Structures 19 (2019): 1421-1430.

14. Wilkinson, Sean, Gordon Hurdman, and Adrian Crowther. "*A moment resisting connection for earthquake resistant structures*." Journal of Constructional Steel Research 62.3 (2006): 295-302.

15. Eslami, Mohammadreza, Abbas Rezaeian, and Venkatesh Kodur. "*Behavior of steel column-trees under fire conditions."* Journal of Structural Engineering 144.9 (2018): 04018135.