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BEAM-TO-COLUMN CONNECTIONS ANALYTICAL STUDY USING REDUCED BEAM SECTIONS

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Abstract: Plastic hinges and increased steel connection ductility were used to mitigate the brittle fracture risk associated with steel frame structures using conventional weld connections. Without having to cut the beam flange or web, a new reduced beam section (RBS) connection was built by increasing the beam's rigidity. RBS joints have the potential to crack and produce structural displacement in a steel frame structure when subjected to significant deformation. Since steel frame constructions with RBS connections are susceptible to delayed collapse, it is crucial to consider their bearing capability and resistance. Increasing the component's ductility and moment capacity will stop it from collapsing, which is the aim of this project. The objectives of this study are to establish the effective size web RBS (thickness and diameters) of the tubular and to guarantee successful modifications to the web RBS and without RBS of the accordion. These RBS models should be compared to those without RBS. In this scenario, pushdown analysis is used. Repositioning the plastic hinge on the beam will distribute the weight evenly and lessen the chance of a sudden failure of the column. Thus, there is a lower chance of an unplanned collapse of the building. If the weight shifts, the beam will break, but the column section of the beam can be altered without damaging it. This study's main objective is to employ RBS to prevent the building from collapsing too soon.

Index Terms - Tubular Web RBS, Accordion Web RBS, Without RBS

1. INTRODUCTION

Reduced beam sections are frequently used in the construction of steel moment frames in seismic zones (RBS). These are the most common and cost-effective types of sections that are produced when some of the beam flanges are cut close to the column face. By creating a plastic hinge within the beam, the Reduced beam sections in the Steel Moment Frames enhance the structural earthquake performance.

Brittle fracture has been seen at the beam-to-column connections of steel moment frames using conventional weld connections. In order to improve the engineering performance and ductility of the steel connections, new tactics were required. One such strategy was to weaken the beam section at a reasonable distance from the column face. Reduced beam sections (RBS) connections, wherein segments of the beam flanges have been cut near the beam-to-column connections, have been commonly employed in steel moment frames. The yielding zone can be shifted from the column face to the beam span in RBS connections, preventing early damage from occurring at the beam-column weld joints. A third strategy entails creating openings in beams that can improve building spatial efficiency and enable access to pipes in order to make beams more ductile. Engineers cut web apertures in steel frames for unique pipelines needed for air-conditioning, heating, and water supply systems. Analytical investigations have been done on steel web opening beams.

Connections with flange- or web reduction may change their mechanical properties when significant deformation takes place. The web-reduction causes a discontinuous force transmission path, increasing the force concentration on the beam web. The ability to withstand progressive collapse can be used to indirectly assess the bearing capacity, deflection, and cracking of beams with reduced flanges and webs in order to prevent cracks.

In this project the main aim is to study how the collapse analysis occurs in the beam-to-column section by using a reduced beam section (RBS). Instead of drilling a hole in the web placing RBs and cutting the beam's flange, this investigation is being conducted using tubular web RBs and accordion web RBS.

The majority of research used seismic analysis, whereas this one uses collapse analysis. How does collapse analysis work? When a structure has an unexpected accident, the loads acting on it are immediately distributed to the column from the beam, causing the structure to abruptly collapse. Collapse analysis is the term for this. Use a reduced beam section (RBS) instead of cutting the web and flange of the beam-to-column to prevent this rapid collapse.

Utilizing ANSYS software workbench 2022 R2, the analytical research of collapse analysis is carried out in this project. The Ansys was divided into many components, and static analysis was used for structural construction.

1.1 OBJECTIVE OF THE PROJECT

- To investigate how the tubular web RBS collapses by altering its effective size (thickness and diameters)
- To investigate the collapse mechanism by varying the RBS's effective size (thickness and diameters)

2. SPECIMEN DESIGN

The interaction between the beam and column was modelled in ANSYS Workbench R2 2022. The beam-column specimen that was used for validation features a column web that is 250mm long and 14mm thick. The column's flange measures 250 mm in length and 9 mm in thickness. The beam flange is 200mm long and 5.5mm thick, while the beam web is 100mm long and 8mm thick. The maximum yield strength for bi-linear materials is 290.1 MPa, young's modulus is 2x105 MPa and the poisons ratio is 0.3. ANSYS needs to specify that the stress-strain graph is multi-line. Therefore, the multilinear beam's ultimate tensile strength is 485.5 MPa, and the flange's yield strength is 290.1 MPa. The beam web's ultimate tensile strength is 483.4 MPa, whereas its yield strength is 299.8 MPa. The column flange has a yield strength of 248.6Mpa and an ultimate tensile strength of 456.3Mpa. A column web has a yield strength of 253.9 MPa and an ultimate tensile strength of 454.5 MPa.

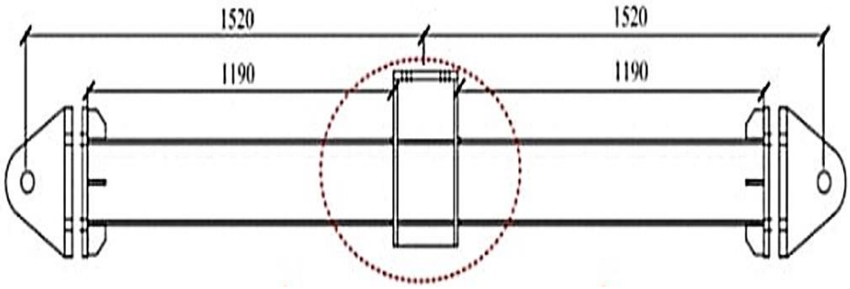


Fig -1: Details of the Specimen

3. MATERIAL PROPERTIES

Table-1: Dimensions Beam-to-Column

Element	t_w (mm)	t_f (mm)	L_w (mm)	L_f (mm)
Beam	8	5.5	100	200
Column	14	9	250	250

Table-2: Properties Beam-to-Column

Steel – Fe_{345}	Young's Modulus 2×10^5 Mpa	Yield Strength 290.1 Mpa	Poisson's Ratio 0.3	Multi-Linear Property

Element	Yield Strength (MPa) (Fy)	Ultimate Strength (MPa) (Fu)
Beam Flange	290.00	485.00
Beam Web	299.00	483.00
Column Flange	248.00	456.3
Column Web	263.9	454.5

Table-3: Dimensions RBS as per IS Code

Element	Diameter (mm)	Thickness (mm)	Distance from Column A (mm)
Tubular Web RBS	60.3	2.9	75
	60.3	4.5	75
	76.1	3.2	75
	76.1	4.5	75
	88.9	3.2	75
	88.9	4.8	75
Accordion Web RBS	60.3	2.9	75
	60.3	4.5	75
	76.1	3.2	75
	76.1	4.5	75
	88.9	3.2	75
	88.9	4.8	75

4. MODELLING OF BEAM-COLOUMN

The aforementioned characteristics, along with the placement of the accordion RBS and tubular RBS pipes, represent the beam-column. It is modelled using the ANSYS R2 20222 version software. has numerous linear qualities.

5. ANALYSIS

ANSYS software is used to create six models for each portion of this investigation. The three dimensional Beam-Column model was created using ANSYS workbench R2 2020. utilising RBS connections in this paper. Reducing the flexural strength of the beam at the RBS region and forcing a plastic hinge to form in a location away from the connection is known as a reduced beam section (RBS), also known as a dogbone connection, and it is a type of connection used in welded steel moment frames. Software called ANSYS Workbench R2 2022 was used to create these models. 16 models in total, 6 with tubular web RBS and 6 with Accordion web RBS, are prepared for the study.

5.1 TUBULAR WEB RBS

Where the beam plastic hinge should be, a piece of the web is replaced with a tube to generate the TW-RBS versions. The tube is positioned in the two portions of the beam that are turned around and have various diameters and thicknesses to examine the percentage of increased load. By comparing the maximum deflection and load of the various models, ascertain the proportion of the additional load that will take longer to collapse. Six models for the tubular web RBS have been produced by the ANSYS R2 2022 programme. While the TW-RBS pipe used in place of the beam section has a varying diameter and thickness, all of the models have a similar geometric design. The steel tube section's diameter and thickness are determined using the IS code. The equation of, allows for the determination of the tube's diameter.

$$D = 2 \times (e - a) \qquad - (1)$$

Where,

D = Diameter of pipe
e = Distance from the column to center of the tubular pipe
a = Distance from the column to tubular pipe starting end
b = Diameter of tubular pipe

Allowed range of $e = 0.5d < e < d = 9 < e < 18$ as per IS 1161: 1998 - (2)
Allowed range of $a = 0.5bf < a < 0.75bf = 4.5 < a < 6.83$ as per IS 1161: 1998 - (3)

The RBS dimension is fix by the depth of beam. First fix with any size and adjust with dimension. So fix diameter as per standard size and adjust "e" and "a" with the range. Therefore, the "d" should not more than I section. The beam – column size and properties are same and the difference is the diameter and thickness of the tubular pipes of 6 models are different.

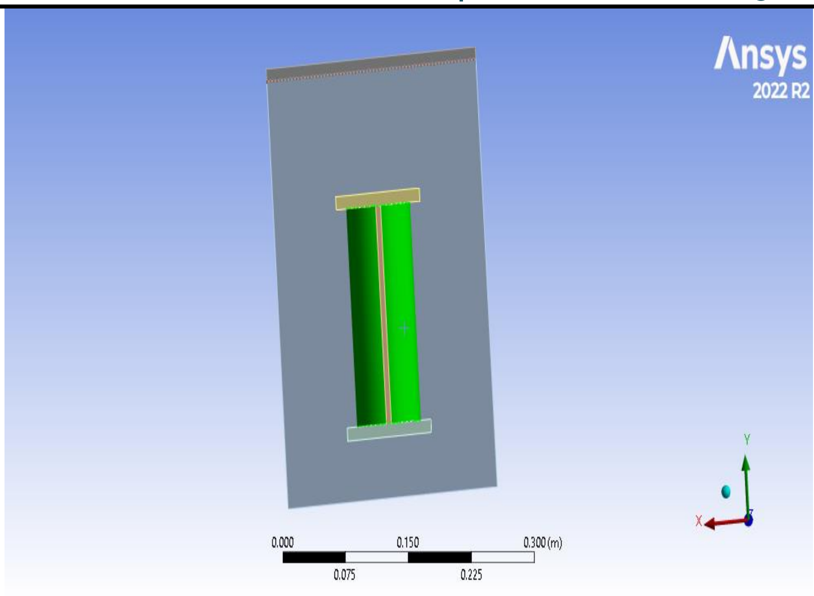
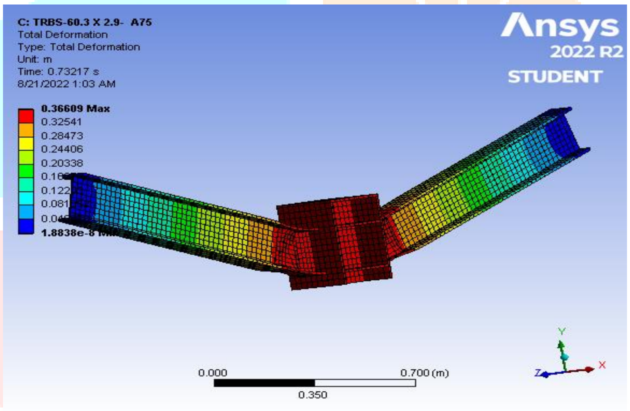


Fig -2: Model of Tubular Web RBS

5.1.1 DEFORMATION OF SPECIMENS

This image depicts the greatest beam deflection at a distance of 75mm from the column and a diameter and thickness of TW-RBS are 60.3mm x 2.9mm, 60.3mm x 4.5mm, 76.1mm x 3.2mm, 76.1mm x 4.5mm, 88.9mm x 3.2mm, 88.9mm x 4.8mm respectively. The highly deflection acting area is indicated by the red hue in the picture. The colors display the various deflection ranges.



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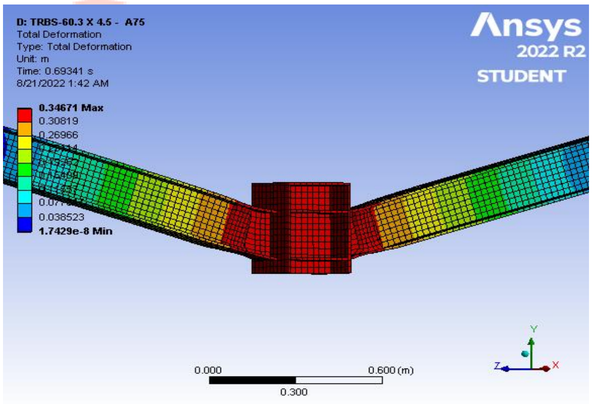

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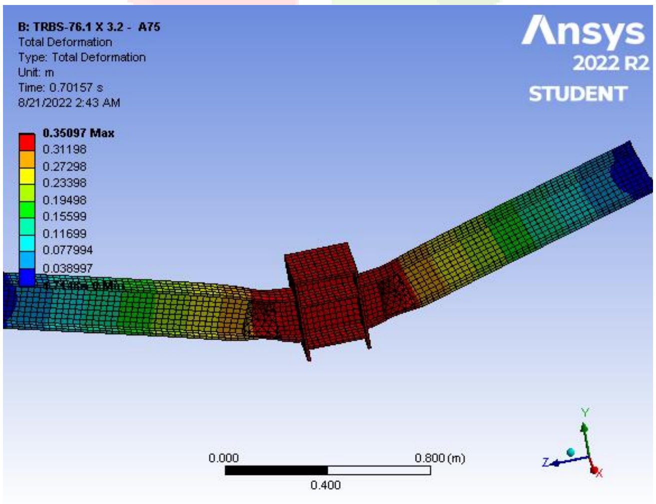

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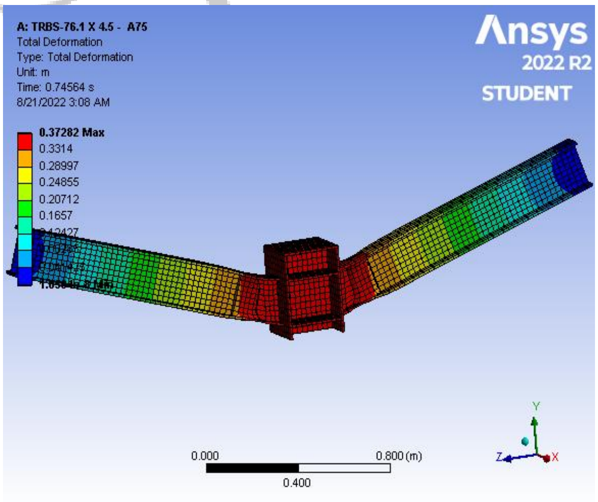

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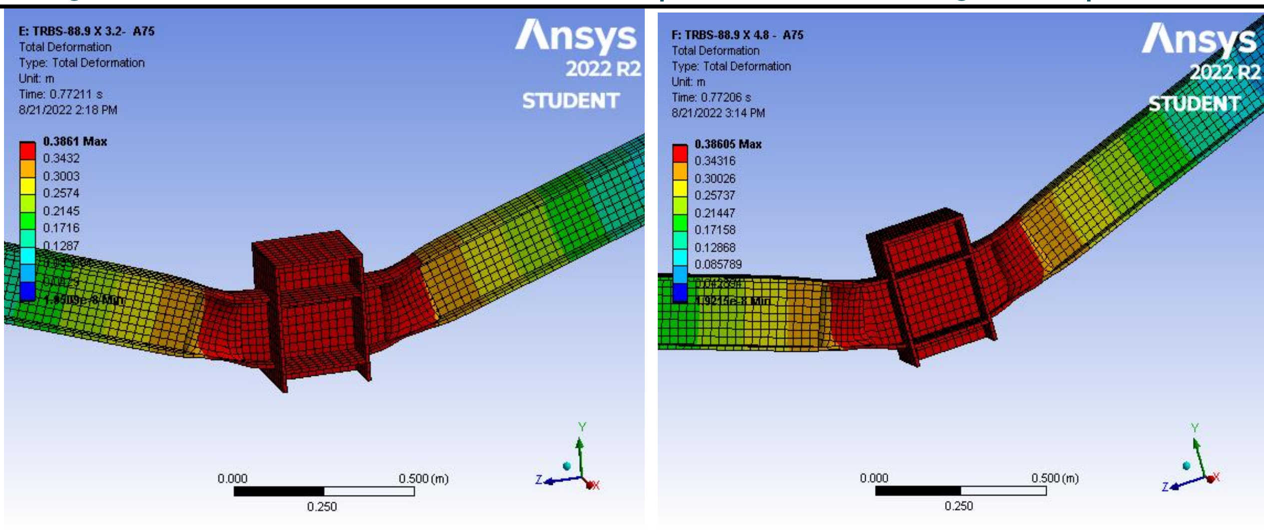
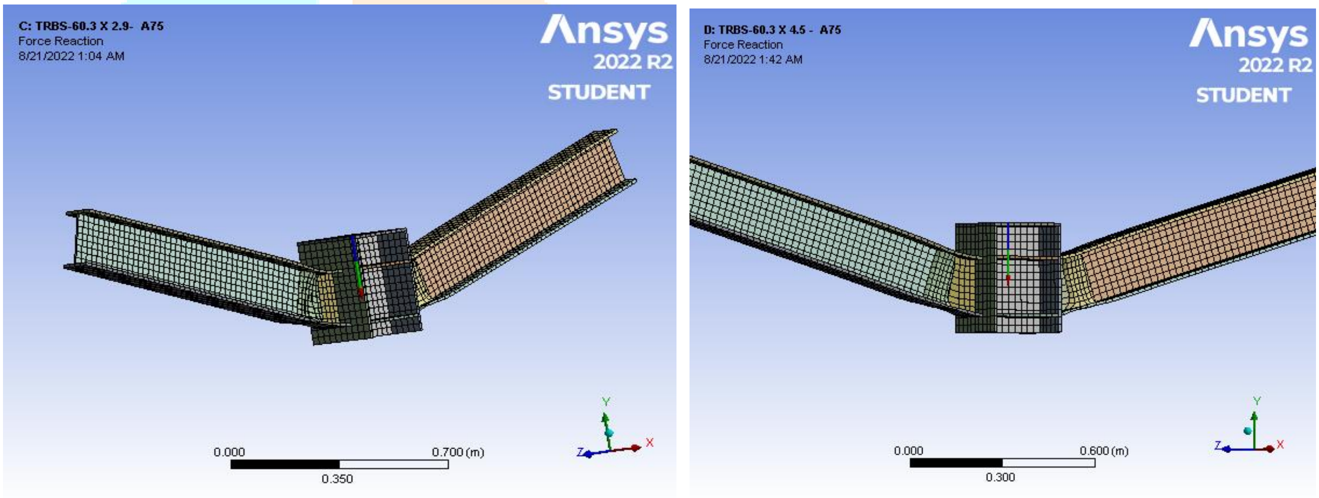


(e) (f)

Fig -3: Total Deformation TW-RBS (a) 60.3mm x 2.9mm; (b) 60.3mm x 4.5mm; (c) 76.1mm x 3.2mm; (d) 76.1mm x 4.5mm; (e) 88.9mm x 3.2mm; (f) 88.9mm x 4.8mm

5.1.2 Force Reactions of Specimens

This image demonstrates how the force reaction that acts on it occurs when the load is applied to the top of the column and is distributed evenly over the beam that the plastic hinge manufactured using the TW-RBS.



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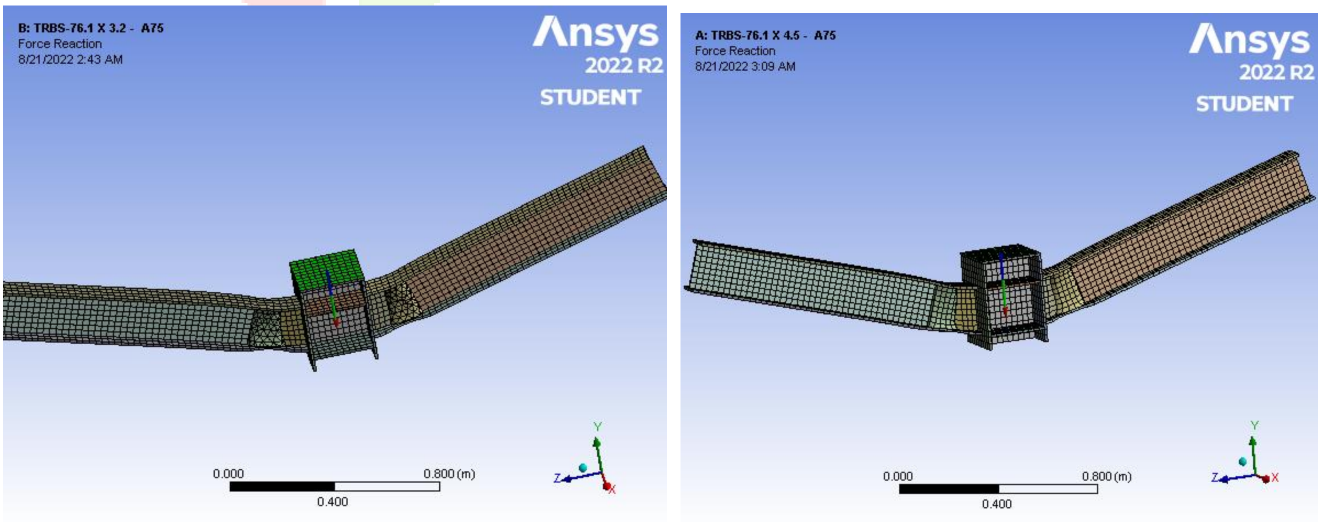

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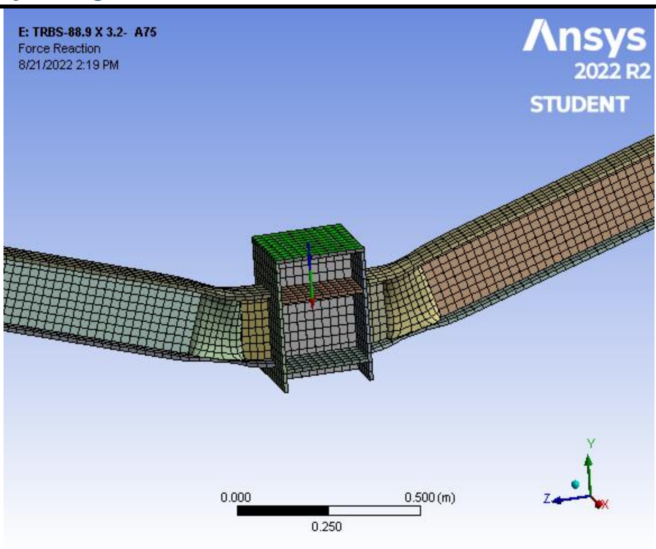

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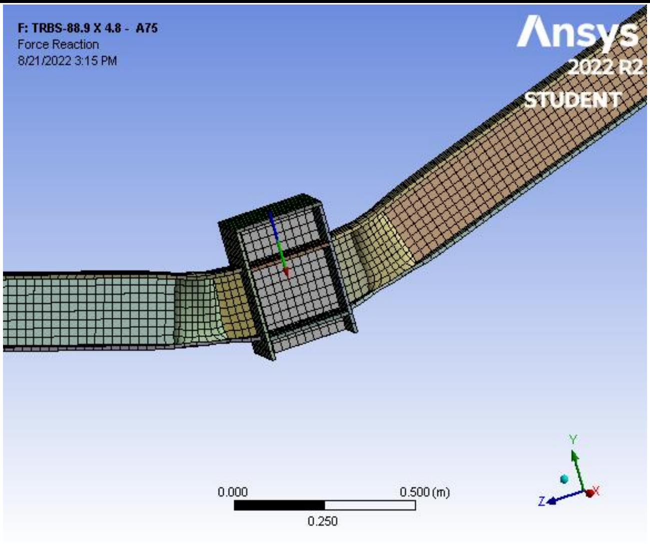
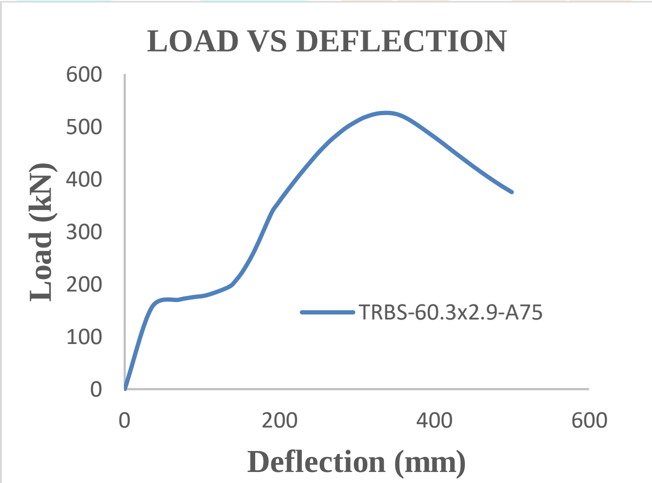


(f)

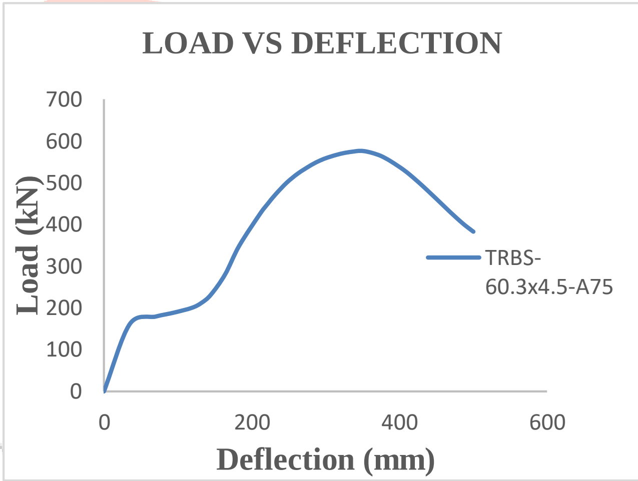
Fig -4: Force Reaction TW-RBS (a) 60.3mm x 2.9mm; (b) 60.3mm x 4.5mm; (c) 76.1mm x 3.2mm; (d) 76.1mm x 4.5mm; (e) 88.9mm x 3.2mm; (f) 88.9mm x 4.8mm

5.1.3 GRAPHS OBTAINED FROM MODELES

These images demonstrate how the force reaction that acts on it occurs when the load is applied to the top of the column and is distributed evenly over the beam that the plastic hinge manufactured using the TW-RBS.



(a)



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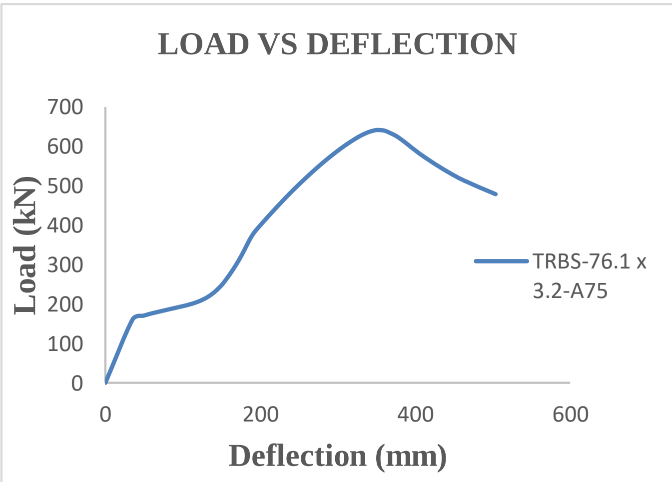

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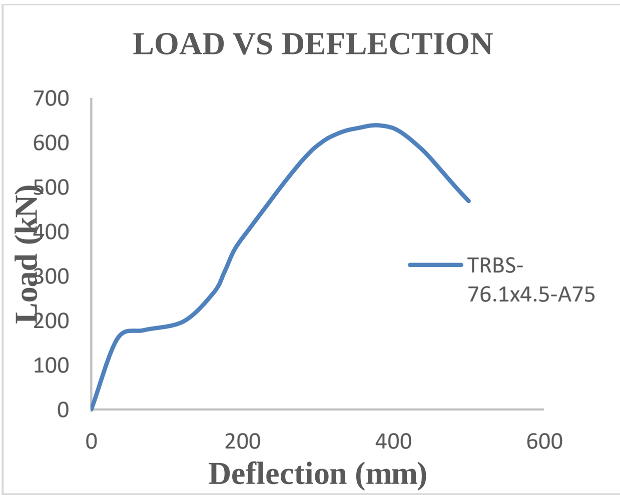

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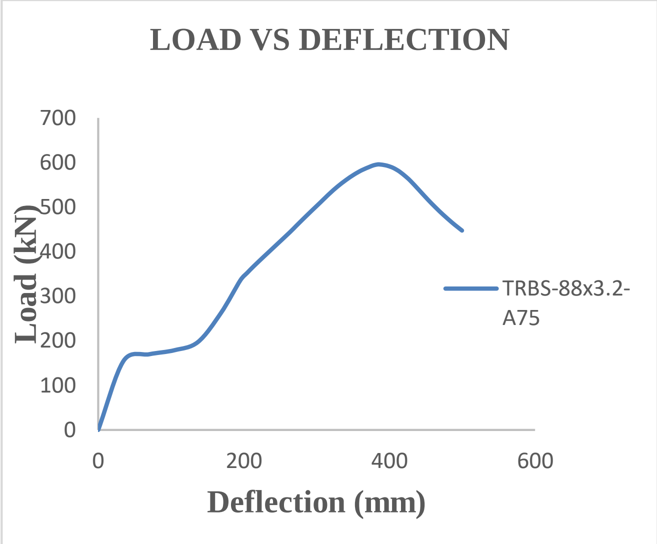

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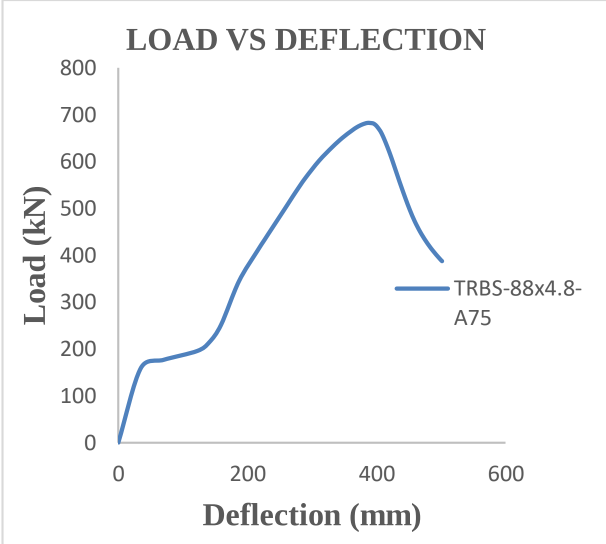


(f)

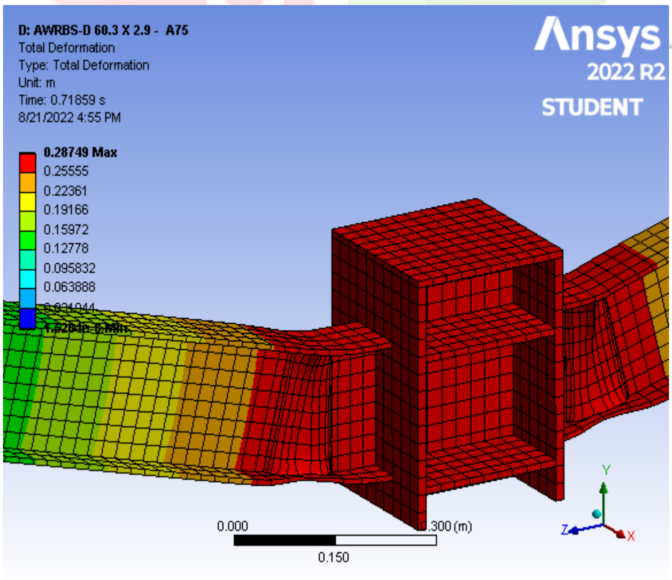
Fig -5: Load VS Deflection Graph TW-RBS (a) 60.3mm x 2.9mm; (b) 60.3mm x 4.5mm; (c) 76.1mm x 3.2mm; (d) 76.1mm x 4.5mm; (e) 88.9mm x 3.2mm; (f) 88.9mm x 4.8mm

5.2 ACCORDION WEB RBS

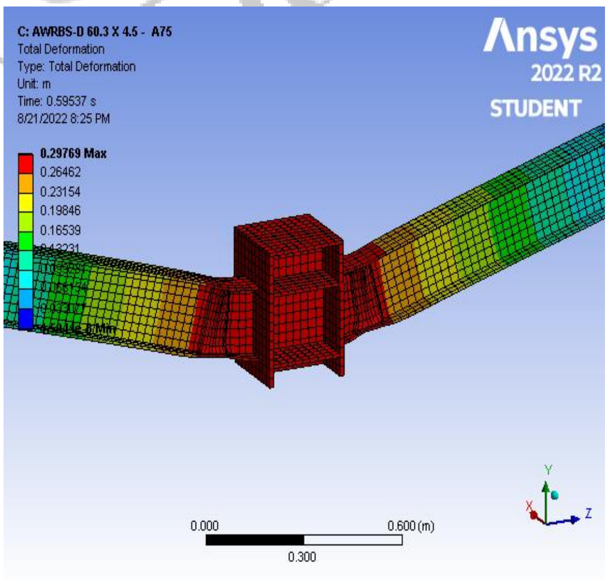
RBS links were developed based on a cutting-edge concept known as "Weakening." According to this idea, the flexural strength of the beam is decreased by decreasing the section at the column face relative to other nearby sections, which causes a plastic hinge to form there. RBS connections are typically described as having a narrower flange in a particular area near the column face. However, the AW-RBS reduces the web contribution to moment strength, leading to a smaller section in the beam. An AW-RBS replaces the flat web where the beam's plastic hinge should be with corrugated plates (in this example, L-shaped folding plates). Although the corrugated web has enough shear strength, its moment strength and flexural stiffness are extremely low. By varying the plate diameter and thickness, six models are created for the accordion web RBS. For the accordion web RBS, six variants are produced by altering the plate diameter and thickness. Along with the plots, the load VS deflection graph is also plotted. The modelling programme ANSYS R2 2020 is used.

5.1.1 DEFORMATION OF SPECIMENS

This image depicts the greatest beam deflection at a distance of 75mm from the column and a diameter and thickness of TW-RBS are 60.3mm x 2.9mm, 60.3mm x 4.5mm, 76.1mm x 3.2mm, 76.1mm x 4.5mm, 88.9mm x 3.2mm, 88.9mm x 4.8mm respectively. The highly deflection acting area is indicated by the red hue in the picture. The colors display the various deflection ranges.



(a)



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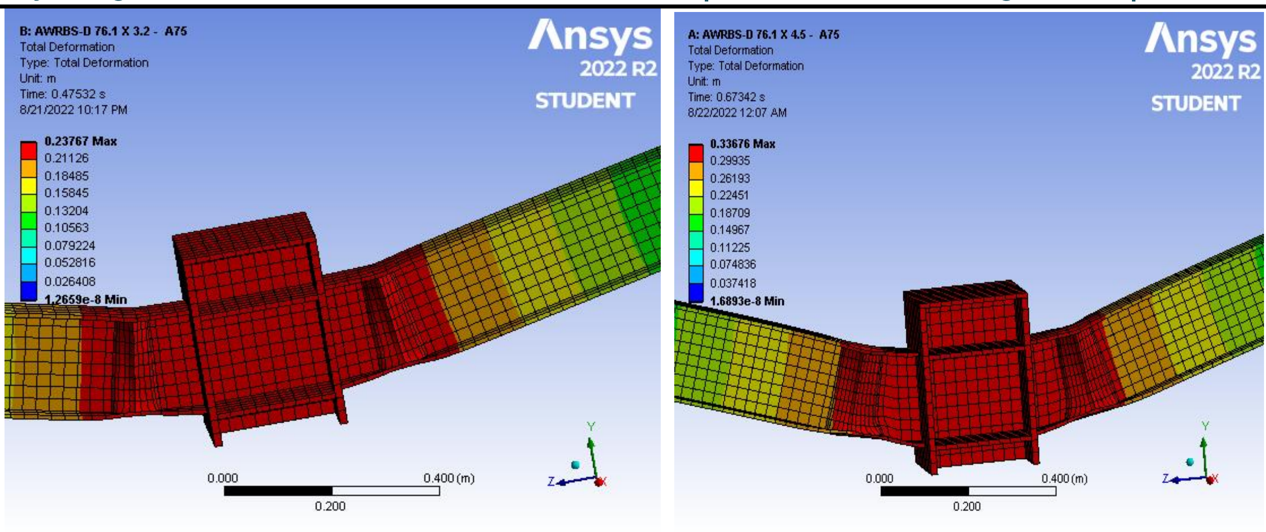
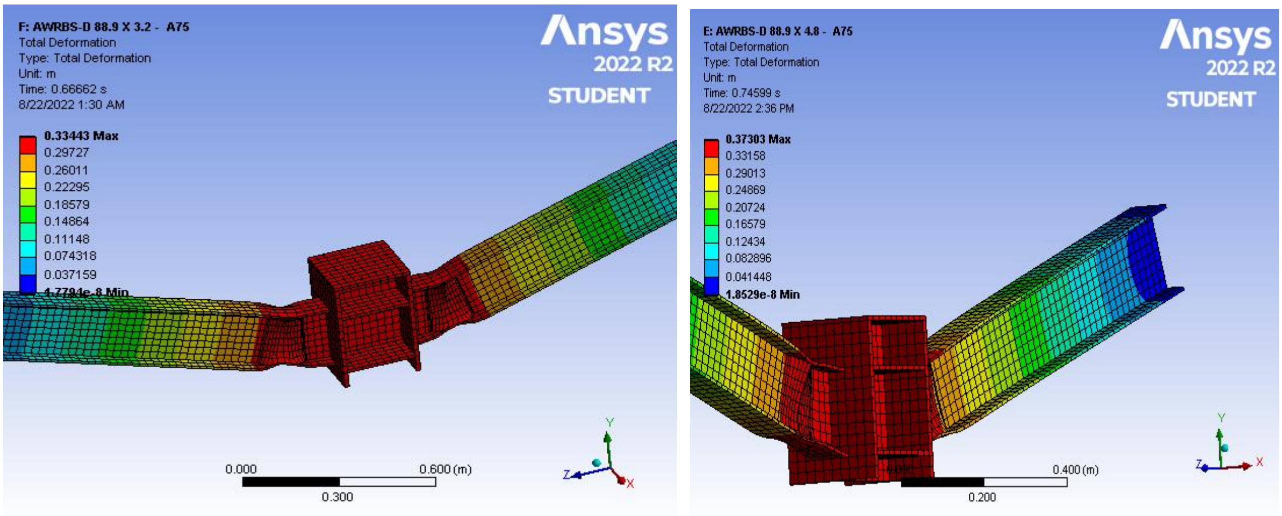


(c) (d)

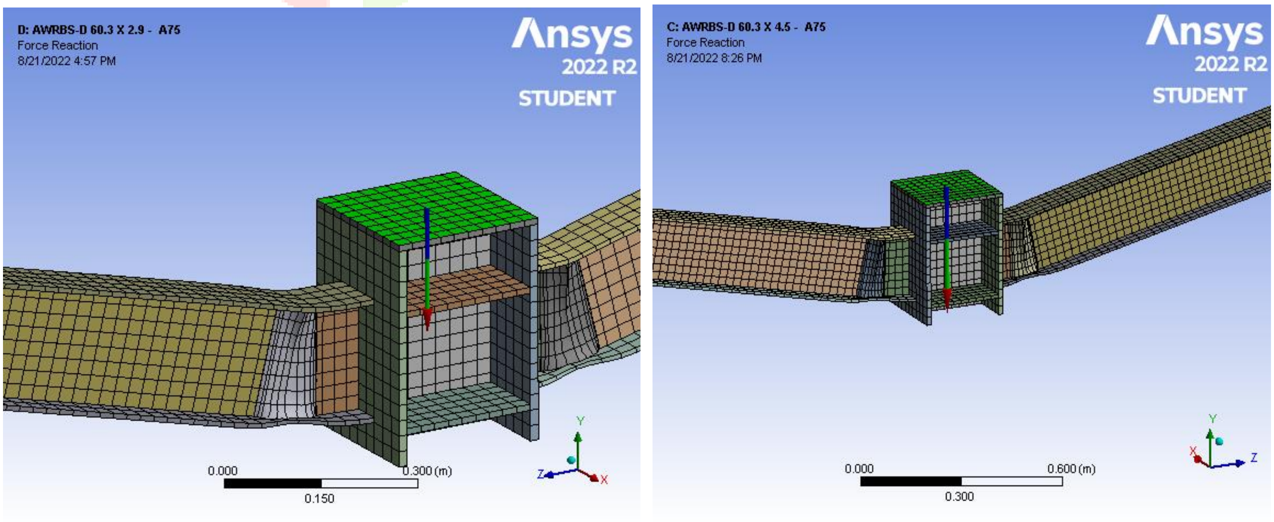


(e) (f)

Fig -6: Total Deformation AW-RBS (a) 60.3mm x 2.9mm; (b) 60.3mm x 4.5mm; (c) 76.1mm x 3.2mm; (d) 76.1mm x 4.5mm; (e) 88.9mm x 3.2mm; (f) 88.9mm x 4.8mm

5.2.2 Force Reactions of Specimens

This image demonstrates how the force reaction that acts on it occurs when the load is applied to the top of the column and is distributed evenly over the beam that the plastic hinge manufactured using the AW-RBS.



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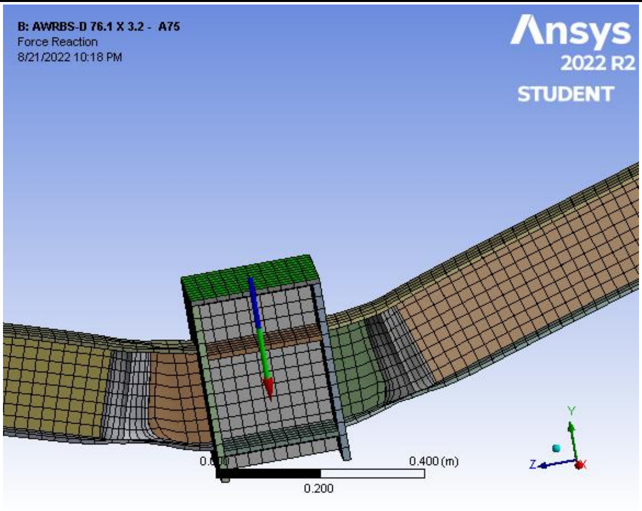

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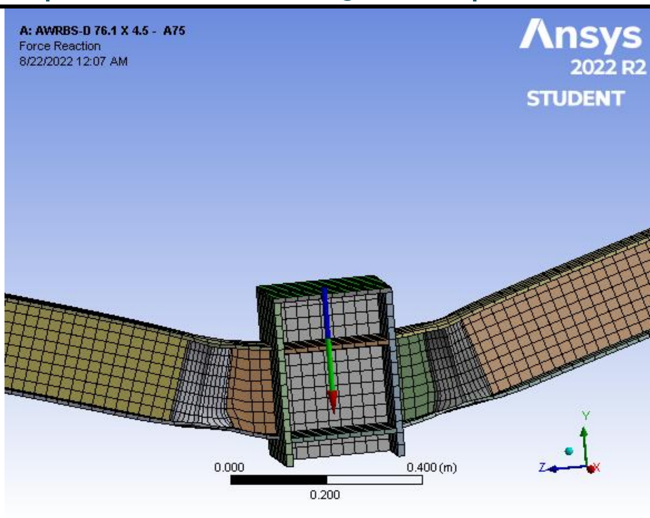

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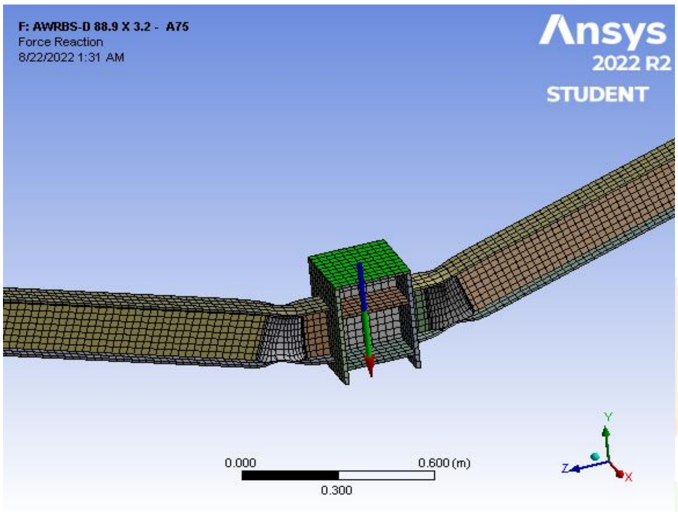

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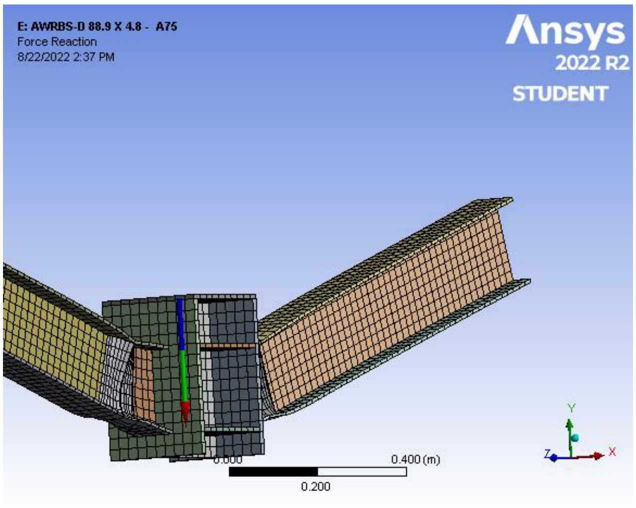
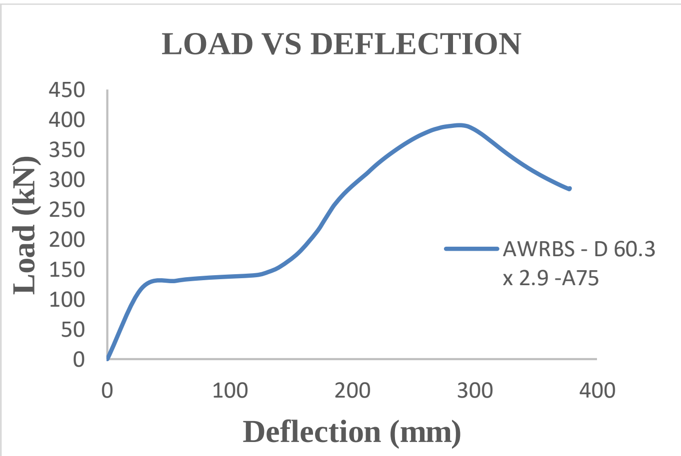


(f)

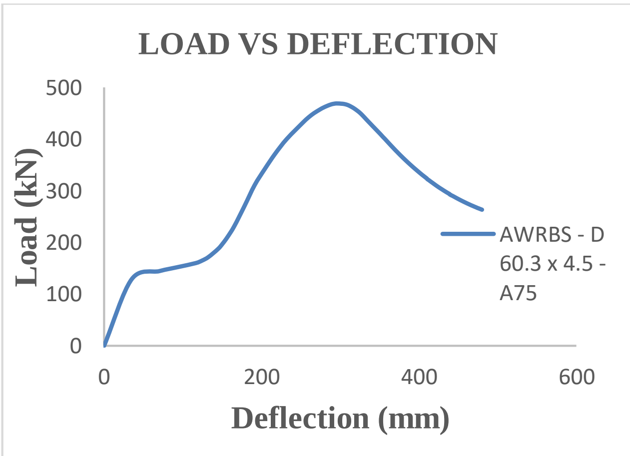
Fig -7: Force Reaction AW-RBS (a) 60.3mm x 2.9mm; (b) 60.3mm x 4.5mm; (c) 76.1mm x 3.2mm; (d) 76.1mm x 4.5mm; (e) 88.9mm x 3.2mm; (f) 88.9mm x 4.8mm

5.2.3 GRAPHS OBTAINED FROM MODELES

These images demonstrate how the force reaction that acts on it occurs when the load is applied to the top of the column and is distributed evenly over the beam that the plastic hinge manufactured using the AW-RBS.



(a)



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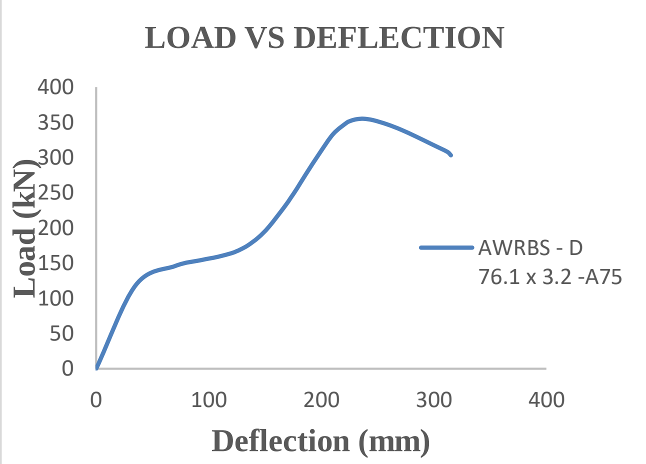

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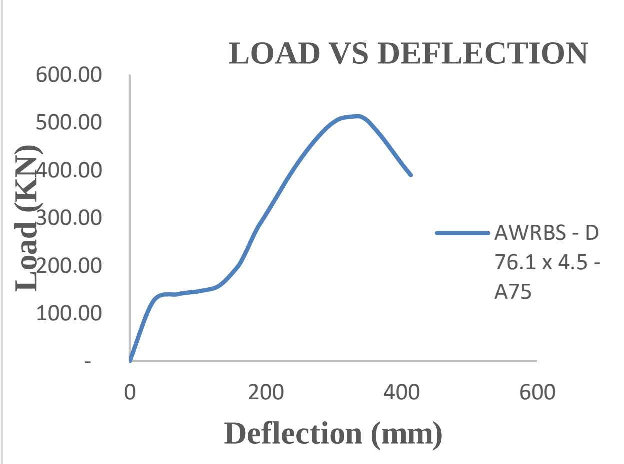

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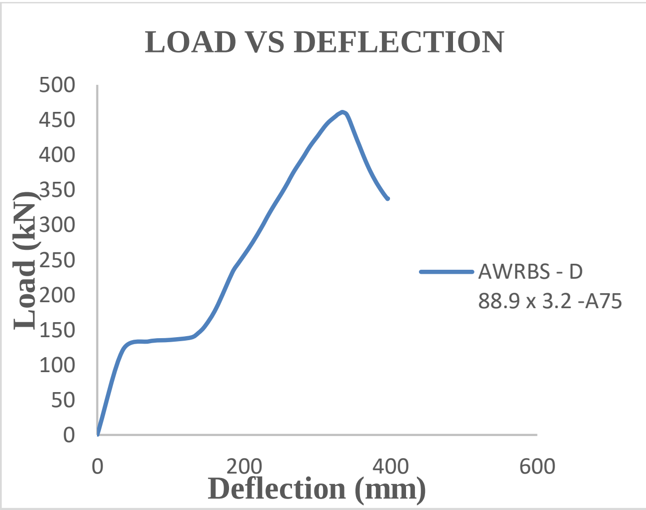

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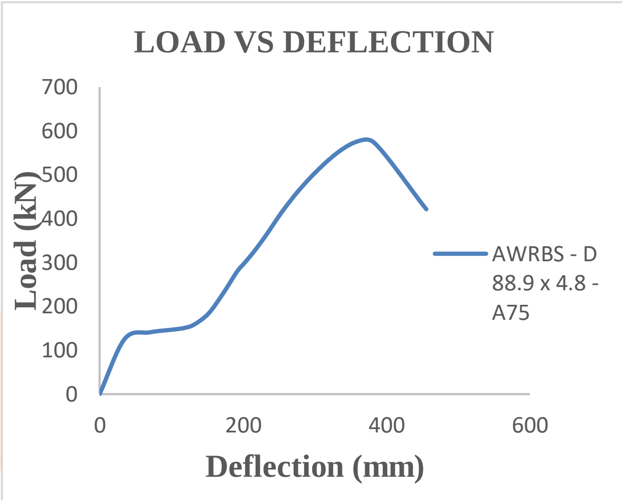

(f)

Fig -8: Load VS Deflection Graph AW-RBS (a) 60.3mm x 2.9mm; (b) 60.3mm x 4.5mm; (c) 76.1mm x 3.2mm; (d) 76.1mm x 4.5mm; (e) 88.9mm x 3.2mm; (f) 88.9mm x 4.8mm

6. RESULTS AND DISCUSSION

Table-4: TWRBS and without RBS

Name	Deflection	Load(Pu)	% of Increase in Load
Without RBS	182.02	252.15	1.00
TRBS-60.3x2.9-A75	336.06	526.28	1.00
TRBS-60.3x4.5-A75	346.72	575.83	9.42
TRBS-76.1 x 3.2-A75	350.97	641.17	21.83
TRBS-76.1x4.5-A75	378.45	638.66	21.35
TRBS-88x3.2-A75	386.06	595.99	13.25
TRBS-88x4.5-A75	386.05	682.89	29.76

Table-5: AWRBS and without RBS

Name	Deflection	Load(Pu)	% of Increase in Load
Without RBS	182.02	252.15	1.00
AWRBS-60.3x2.9-A75	287.49	390.55	1.00
AWRBS-60.3x4.5-A75	295.09	469.02	20.09
AWRBS-76.1 x 3.2-A75	237.76	354.88	(9.13)
AWRBS-76.1x4.5-A75	336.76	512.94	31.34
AWRBS-88.9x3.2-A75	334.43	460.96	18.03
AWRBS-88.9x4.8-A75	373.03	580.1	48.54

The maximum defection values for the six models and the force reaction loads are listed in this table. All of these are compared to a model without RBS. Calculating the percentage of increased load begins with determining the greatest deflection and the load (Pu).

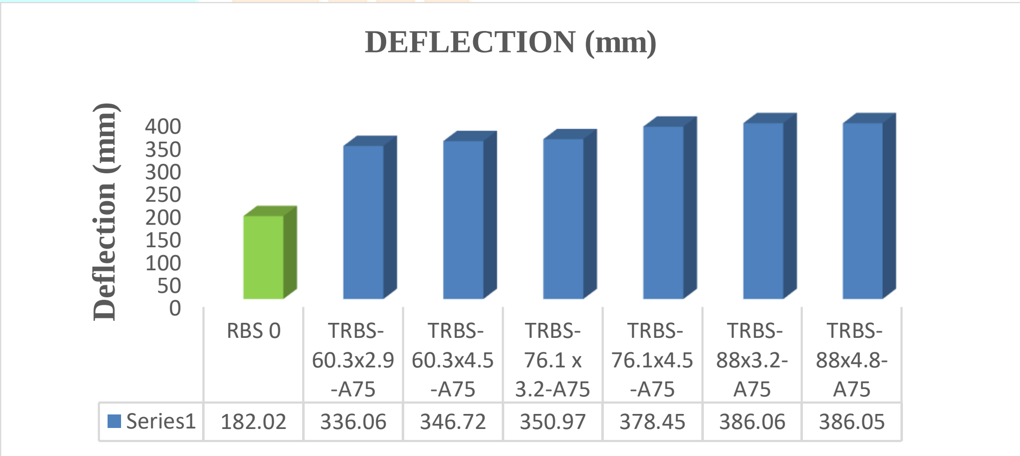

Fig -9: Deflection Line Graph (TWRBS and without RBS)

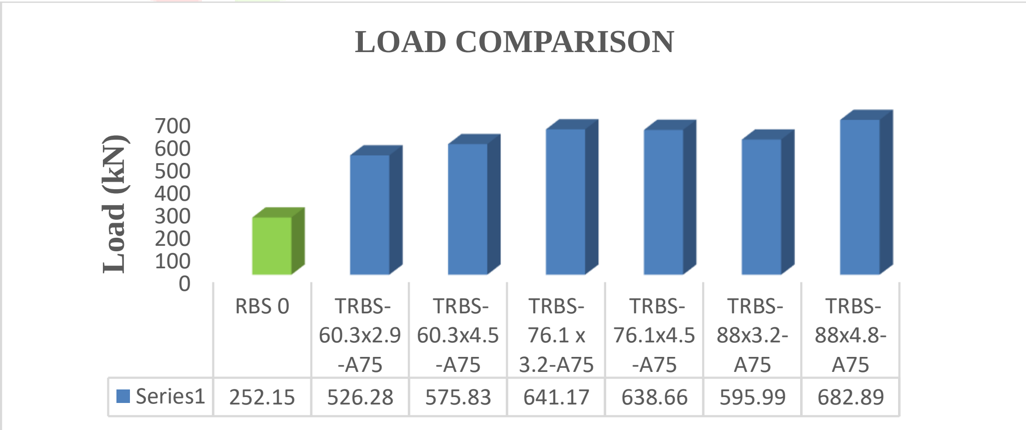

Fig -10: Load Comparison Line Graph (TWRBS and without RBS)

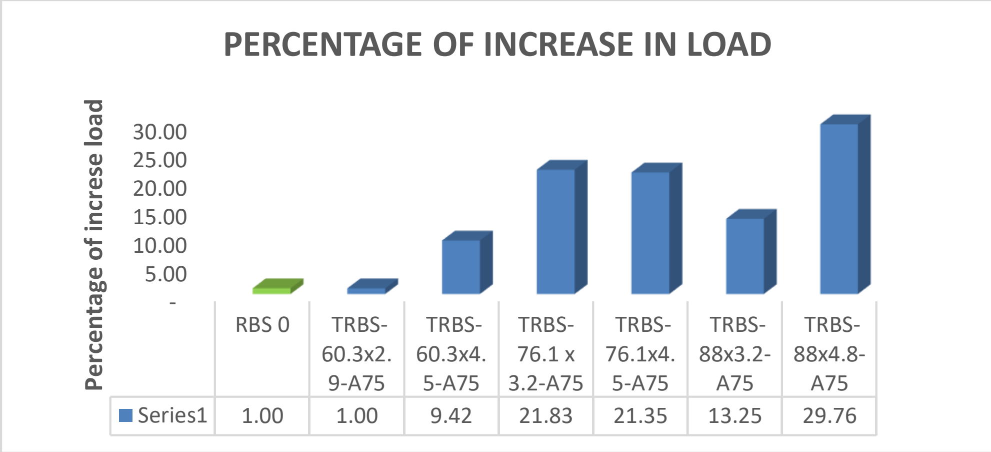

Fig -11: Percentage of Increase in Load Line Graph (TWRBS and without RBS)

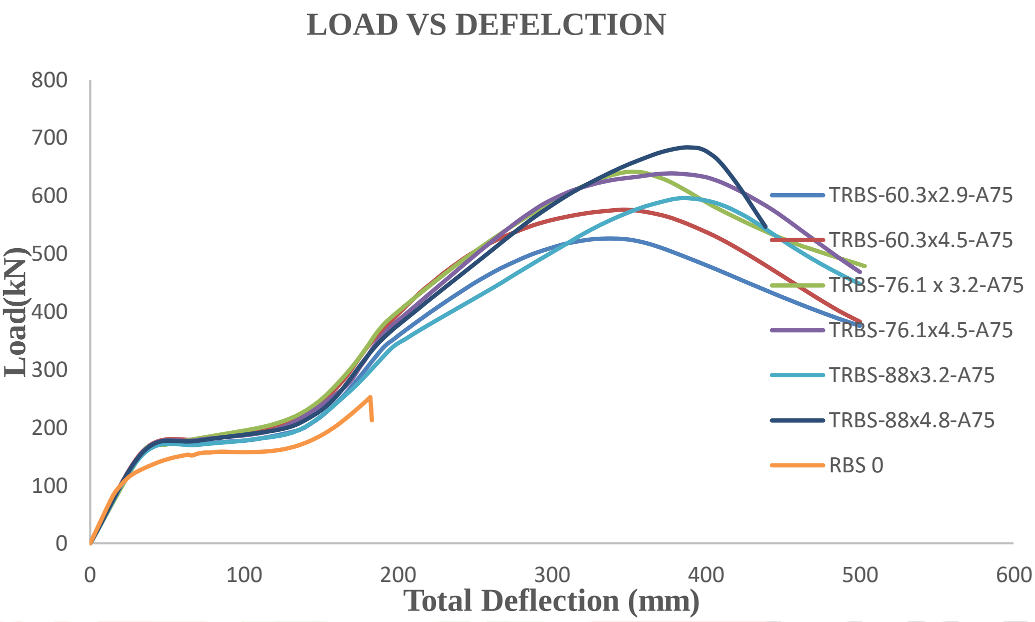

Fig -12: Load VS Deflection Graph (TWRBS and without RBS)

From the graphs,

- TWRBS 60.3 x 2.9 displays the maximum deflection when the maximum load is acting on the column. When the maximum load is 526.28kN, for instance, the maximum deflection is 336.06mm. When that happens, only the section will break; before that, the segment is secure.
- The RBS-free segment of the graph is indicated by the orange area there. When a sudden accident or natural disaster hits the majority of the structure at the load stage of 252.15kN and the maximum deflection required is 182.02mm, the column will suddenly collapse.
- By contrasting these 6 models with and without RBS, it can be seen that when the structure is placed utilising RBS (TW-RBS), it can aid in preventing the sudden collapse. Without RBs, the structure will abruptly collapse when it hits its maximum load point.

If there are no RBS connections in the beam-to-column connections, the column will suddenly collapse when compared to the with and without RBS. In order to mitigate this rapid collapse, the RBS connection is used. TW-RBS - 88 x 4.5 -A75 is the maximum deflection model, which consists of six models with different diameter and thickness. The maximum load is 682.89 kN, and the maximum deflection is 386.05 mm, to put it another way. The deflation changes as the force is applied, and at a peak, the beam is deflected and starts to gradually collapse. Because of this, the reduced beam section supports the weight at a specific location and prevents a sudden collapse. The RBS will quickly collapse if the beam-to-column connection is not used.

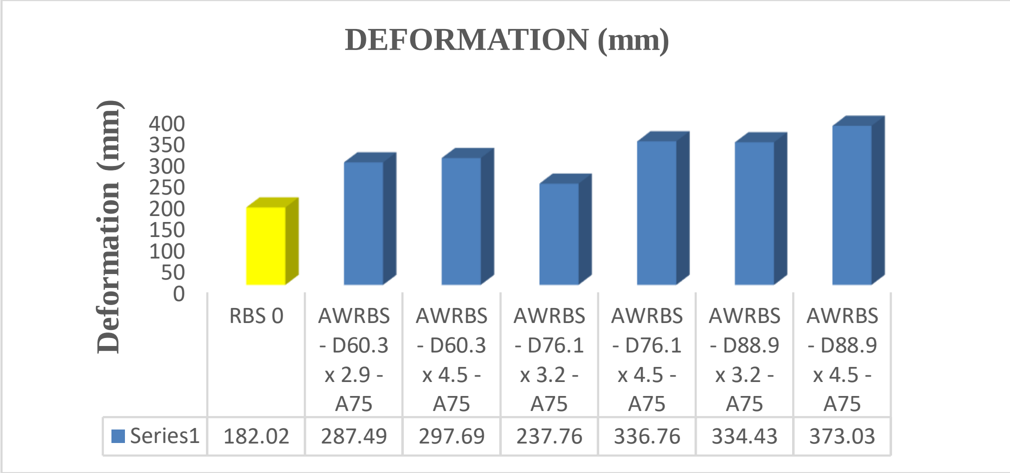

Fig -13: Deflection Line Graph (AWRBS an without RBS)

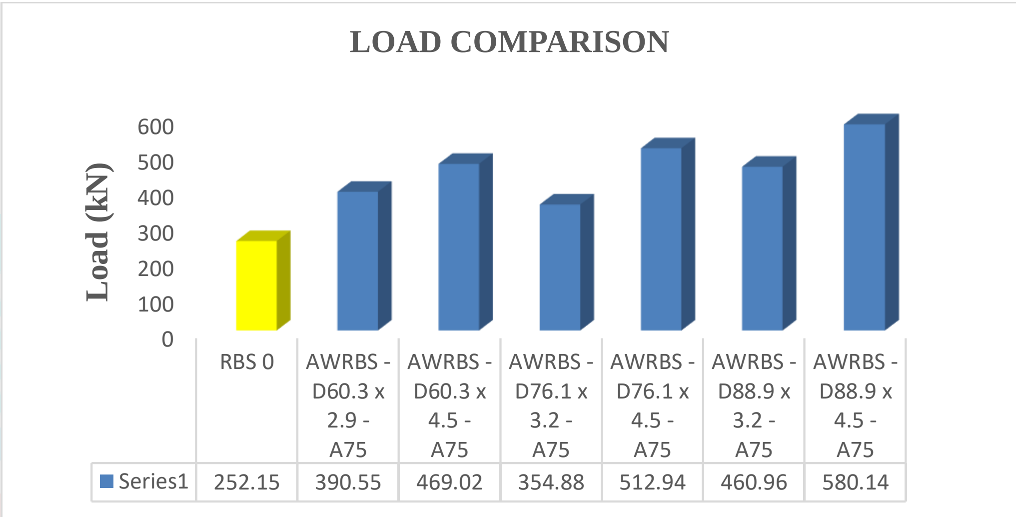

Fig -14: Load Comparison Line Graph (AWRBS and without RBS)

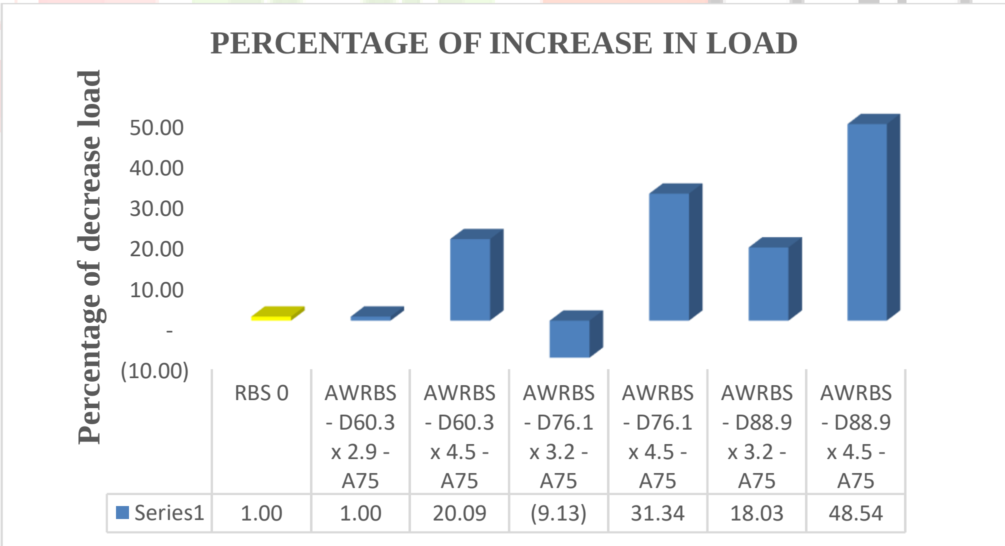

Fig -15: Percentage of Increase in Load Line Graph (AWRBS and without RBS)

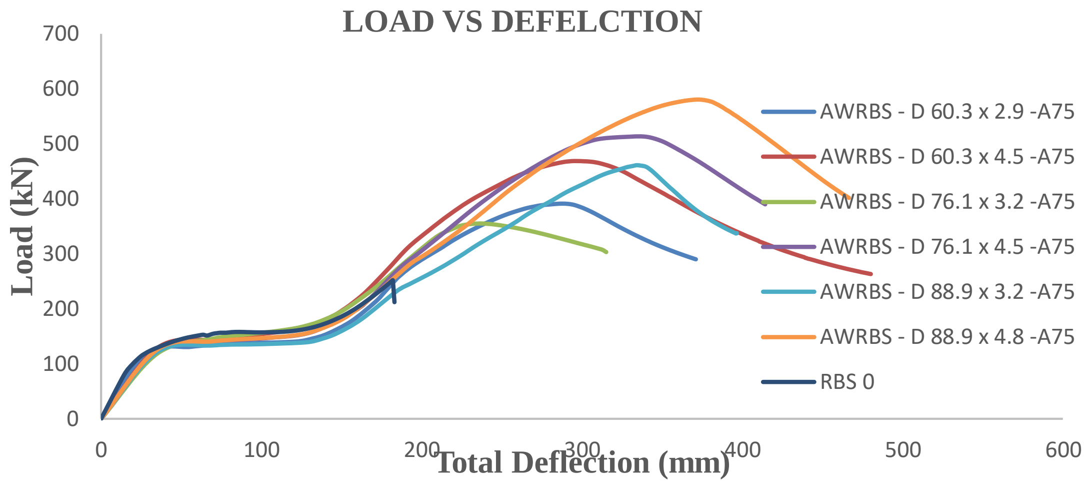

Fig -16: Load VS Deflection Graph (AWRBS and without RBS)

From the graphs,

- AWRBS 60.3 x 2.9 displays the maximum deflection when the maximum load is acting on the column. When the maximum load is 390.55kN, for instance, the maximum deflection is 287.49mm. When that happens, only the section will break; before that, the segment is secure.
- The RBS-free segment of the graph is indicated by the orange area there. When a sudden accident or natural disaster hits the majority of the structure at the load stage of 252.15kN and the maximum deflection required is 182.02mm, the column will suddenly collapse.
- By contrasting these 6 models with and without RBS, it can be seen that when the structure is placed utilising RBS (AW-RBS), it can aid in preventing the unexpected collapse. Without RBs, the structure will abruptly collapse when it hits its maximum load point.

If there are no RBS connections in the beam-to-column connections, the column will suddenly collapse when compared to the with and without RBS. In order to mitigate this rapid collapse, the RBS connection is used. The maximum deflection model, AW-RBS - 88 x 4.8 -A75, consists of six models with different diameter and thickness. The maximum load is 580.14 kN, and the maximum deflection is 373.03 mm, to put it another way. The deflation changes as the force is applied, and at a peak, the beam is deflected and starts to gradually collapse. Because of this, the reduced beam section supports the weight at a specific location and prevents a sudden collapse. The RBS will quickly collapse if the beam-to-column connection is not used.

7. CONCLUSIONS

In this project, various RBS connections are installed in the beam section by varying the thickness and diameter. Six TW-RBS and AW-RBS models are checked, each of them is compared with and without RBS. Using these results as a basis, this study concludes that,

- Due to the stress concentration and material strength loss, the specimen without RBS with brittle failure was unable to resist progressive collapse, and plastic hinge migration was necessary to improve the ductility of the steel connections.
- The stable plastic hinge formed at the beams' reduced region as predicted by the design, and the weld connecting the beam to the column groove did not budge. The outcomes of the numerical simulations showed that the AW-RBS connection with deep beams and columns might potentially surpass the plastic rotation limit for ductile moment connections without significantly causing instability or strength loss.

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REFERENCES

[1] Aboozar Saleh, et.al (2016) – Cyclic testing of tubular web RBS connections in deep beams, *Journal of Constructional Steel Research* Vol 117, 214-226

[2] Alireza Farzampour, *et.al* (2018) – Analysis and design recommendations for corrugated steel plate shear walls with a reduced beam section, *Journal of Thin-walled Structure* Vol 132, 658-666

[3] Ali Imanpour, *et.al* (2019) – Seismic design of the double cell accordion-web reduced beam section connection, *Journal of Engineering Structure* Vol 191, 924-116

[4] Anderi Crisan, *et.al* (2016) – Bending-shear interaction in short coupling steel beams with reduced beam section, *Journal of Constructional Steel Research* Vol 122

[5] Anju K, *et.al* (2014) – Non-Linear finite element analysis for beam-column connection with reduced beam section, *International Journal of Engineering Research and Technology* Vol 8, ISSN: 2278-0181

[6] K. Chen, *et.al* (2020) – Structural behavior of composite moment-resisting joint under the column-removal scenario, *Journal of Structural Engineering* Vol 146, 0401-9226

[7] F. Dinu, *et.al* (2017) – Experimental investigation of beam-to-tubular column moment connections against progressive collapse, *Journal of Engineering Structure* Vol 106, 332-347

[8] N. Fanaie, *et.al* (2019) – An improved and innovative formulation for calculating amplified elastic story drift induced by RBS connection in steel moment frames, *Journal of Steel Structure* Vol 160, 510-527

[9] M. Ferraioli, (2019) – A modal pushdown procedure for progressive collapse analysis of steel frame structures, *Journal of Construction of Steel* Vol 156, 227-241

[10] Huiyun Qiao, *et.al* (2020) – Experimental study on beam-to-column connections with reduced beam section against progressive collapse, *Journal of Constructional Steel Research* Vol 175, 106358