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Study on Collapse Optimization of Weak Axis Moment Connections

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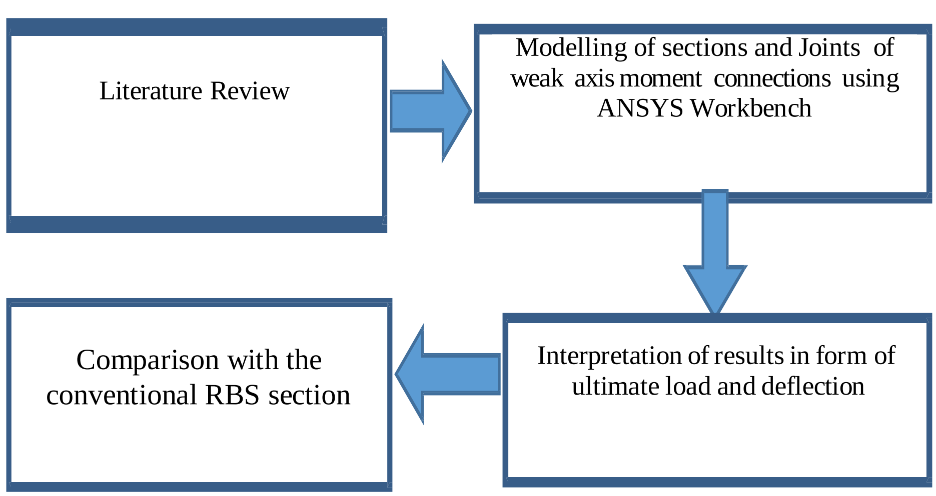
***Abstract:** 3D Weak axis moment connections are the connections between the beam with the web of an I section. But these connections are weaker as they are connected to the web which are thinner portions of the I section compared to flanges. This can lead to buckling of flanges. A new reduced beam section (RBS) connection, consisting of radius cuts in the beam flanges and circular openings in the beam webs, is proposed to allow for more ductile connections. RBS connections may increase structural deflection and crack width in the steel frame structure under large deformations. Therefore, it is extremely important to consider the bearing capacity and progressive collapse resistance of steel frame structures with RBS connections. Progressive collapse analysis of weak axis moment connections without any improvisation is taken for analysis and their collapse location and collapse resistance studied. To enhance weak joint connection design and to delay collapse time, we introduce reduced beam sections. Curved cell reduced beam sections are modeled and analysis is performed for various thickness of cell and by changing diameter. Thus, an effective size was obtained by combining the results with the conventional and the effective location of weak axis is improved.*
***Keywords:** Reduced beam section, weak axis moment connection, curved cell RBS*

I. INTRODUCTION

Steel frame structures with ordinary weld connections often suffer from brittle fractures; design of steel connections has a great effect on the seismic performance of the whole steel structural system. Moment Resisting Frames (MRF) are efficient framing systems under seismic loads. MRF systems provide high ductility and high energy dissipation. However, they perform very low elastic stiffness and cause high labour work. RBS beam approach, another strategy introduces openings in beam webs to form a plastic hinge away from the connections to make beams more ductile. In a beam column joint, when the beams are connected to the flange of an I section then they are called strong axis moment connections. They are so called because when the beams are connected on to the web, they are more thinner sections than flange and the load transferred from the beam is getting directed to a much thinner section which results in buckling.

II. METHODOLOGY



III. VALIDATION

Validation is based on Journal Huiyun Qiao, Yu Chen, Jinpeng Wang, Canwen Chen (2020) Experimental study on beam-to-column connections with reduced beam section against progressive collapse. Table 3.1 lists the mean values of the material properties measured in this study. Cyclic Loading analysis is performed here.

Table 3.1: Material properties

Element	Fy (N/mm^2)	Fu (N/mm^2)
Column flange (t=10mm)	248.6	456.3
Column web (t=8mm)	263.9	454.5
Beam flange (t=9mm)	290.1	485.5
Beam web (t=6mm)	299.8	483.4

Considering an elastic modulus of 210 GPa, the corresponding elastic strain of 1440 µm/m was used as the reference strain gauge value. Fig 3 a gives an overview of finite element model of RBS sectioned beam column connection.

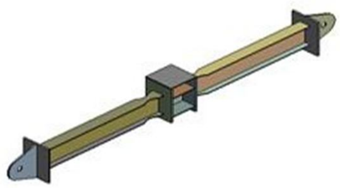


Fig 3 a: Beam column connection- RBS section

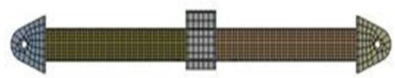


Fig 3 b: Meshed RBS section

The element size is about 12 mm near the beam-to-column connection and 27 mm away from the connection area.

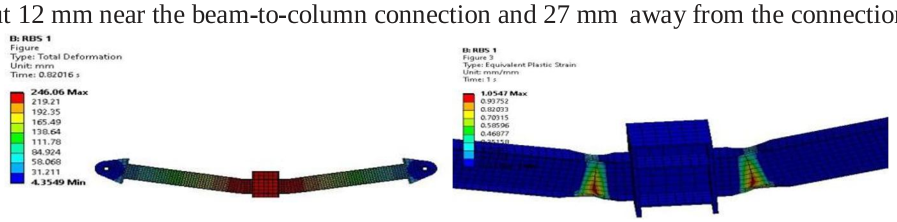


Fig 3 c: Total deformation diagram and Equivalent plastic strain diagram

And from the analysis performed in ANSYS WORKBENCH 2022 the maximum load of 225.3kN with a maximum deflection of 246.06mm was obtained. Therefore, we can conclude that an error of 3.82% was there for maximum load value and 3.95% error was there for maximum deflection value obtained in analysis when compared to the result obtained in reference journal.

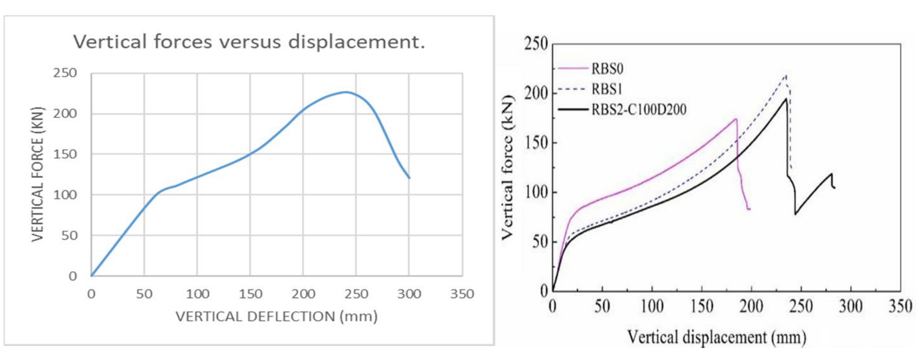


Fig 3 d: Comparison of graph obtained from analytical study and experimental study from journal

Table3.2: Comparison of FEA result with reference journal

	Load (kN)	Deflection (mm)
Reference journal	217	236.7
Finite element analysis	225.3	246.06
Percentage error	3.82	3.95

IV. MODELLING AND ANALYSIS OF RBS SECTION

A. Modelling

In order to model the Reduced Beam Sections using ANSYS. Progressive collapse analysis is performed, we have initially set breadth and depth range of webs and flanges.

Column flange (t=10mm)
Column web (t=8mm)
Beam flange (t=9mm)
Beam web (t=6mm)

We initially do the modelling of normal connections and then that of the normal RBS connections and finally the modelling of circular plate RBS connections. Progressive collapse study is done. In normal connection circular plate RBS (NC CP), b_f = 100mm; d_b = 200mm.

$$0.5\,bf \le a \le 0.75\,bf$$

$$0.65db \le b \le 0.85db$$

$$0.1\,bf \le c \le 0.25\,bf$$

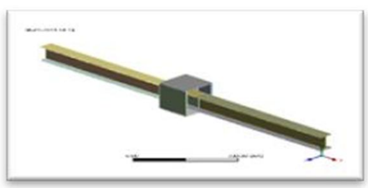


Fig 4 a: Model of normal beam column connection

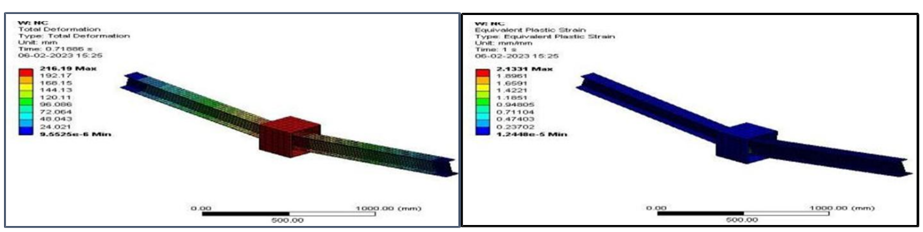


Fig 4 b: Total deformation and equivalent plastic strain of normal connection

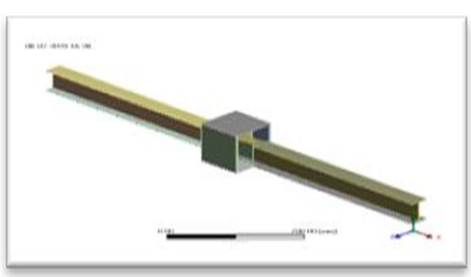


Fig 4 c: Model of RBS connection

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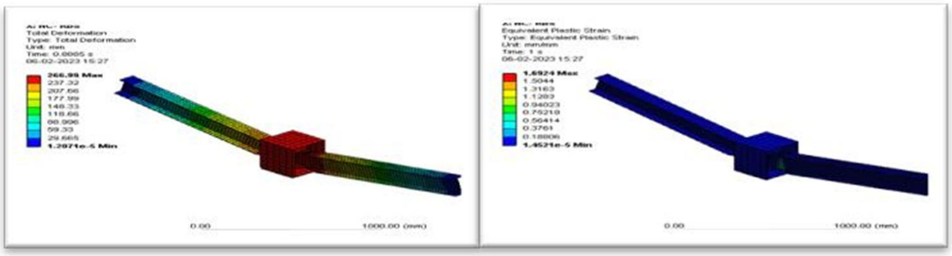


Fig 4 d: Total deformation and equivalent plastic strain of RBS connection

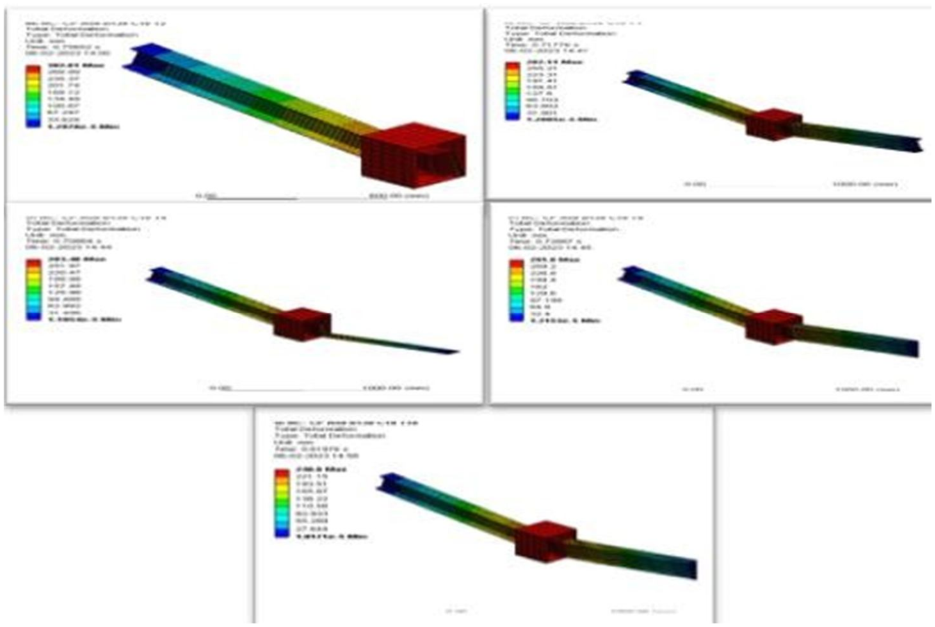


Fig 4 e: Total deformation diagram of NC CP A50 B130 C10 connection by varying thickness 2,4,6,8 and 10mm

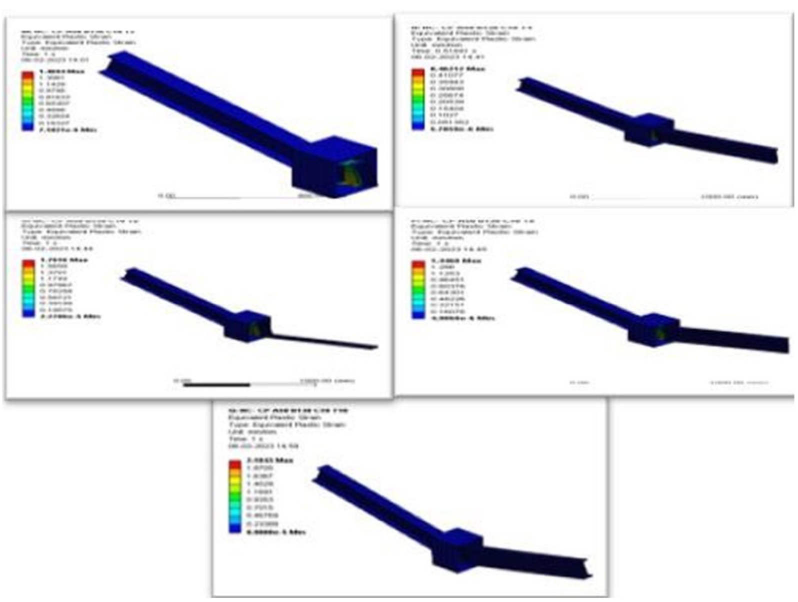


Fig 4 f: Equivalent plastic strain diagram of NC CP A50 B130 C10 connection by varying thickness 2,4,6,8 and 10mm

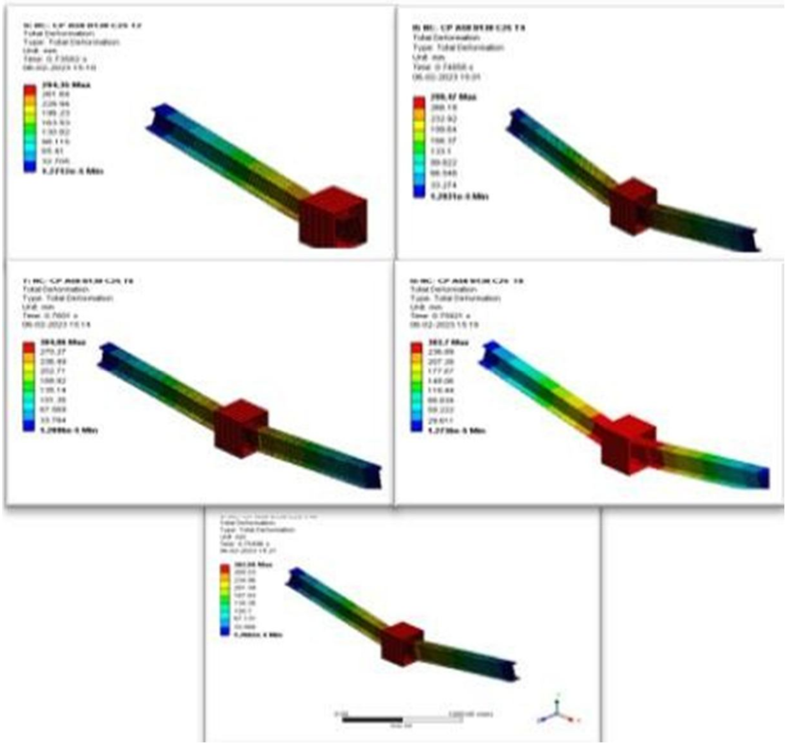


Fig 4 g: Total deformation diagram of NC CP A50 B130 C25 connection by varying thickness 2,4,6,8 and 10mm

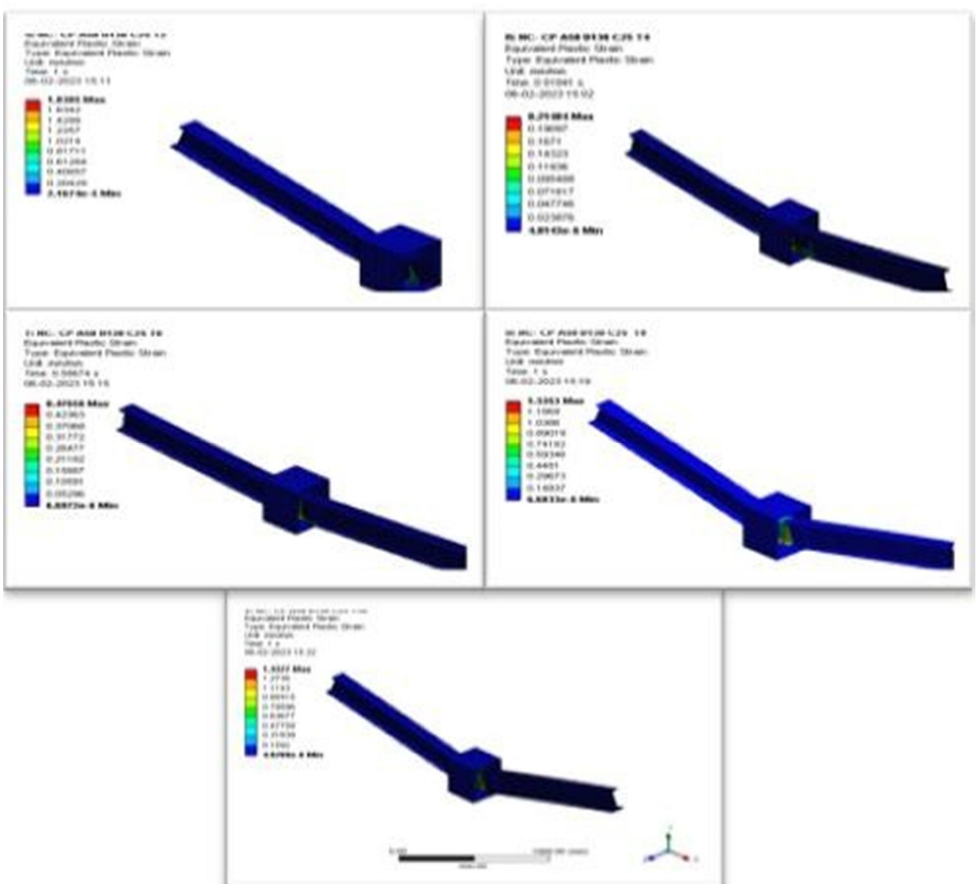


Fig 4 h: Equivalent plastic strain diagram of NC CP A50 B130 C25 connection by varying thickness 2,4,6,8 and 10mm

V. RESULT AND DISCUSSION

From the analysis carried out using ANSYS work bench the ultimate load and the corresponding deformation values are plotted in Table 4.2. And the load deflection curve thus obtained is plotted in Fig 4 q and also the percentage increase in load with respect to the normal RBS connection is also shown in Table 4.2.

Table 4.2: Mechanical properties as crack appeared in beam of NC CP A50 B130 C10 with varying thickness

Models	Deflection (mm)	Load (kN)	% Increase in load
NC RBS	266.99	188.67	-
NC CP A50 B130 C10 T2	302.61	329.7	74.749
NC CP A50 B130 C10 T4	287.11	360.35	90.99486
NC CP A50 B130 C10 T6	283.46	343.09	81.8466
NC CP A50 B130 C10 T8	291.6	350.15	85.58859
NC CP A50 B130 C10 T10	248.8	298.75	58.34525

Then the deflection in mm, load in kN and the percentage increase in load with respect to normal RBS connection varying with thickness in NC CP A50 B130 C10 section is shown through bar charts in Fig 3 r and that of NC CP A50 B130 C25 section is shown in Fig 4 h.

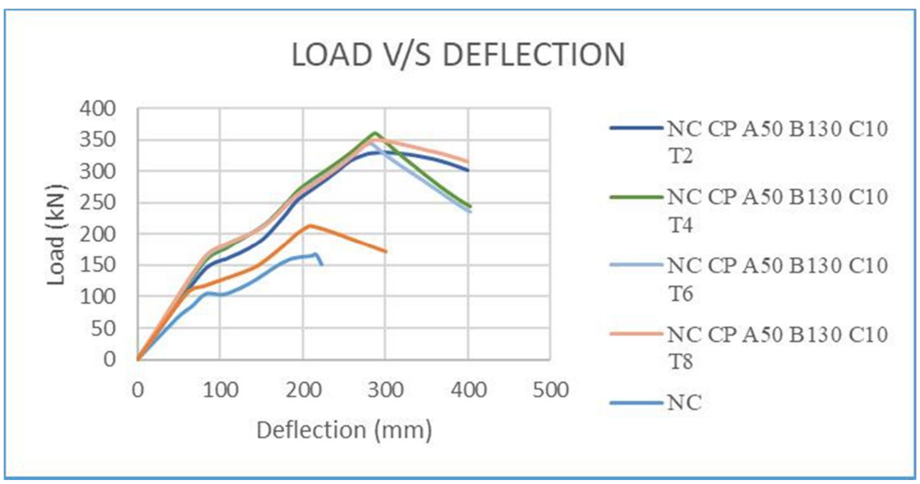
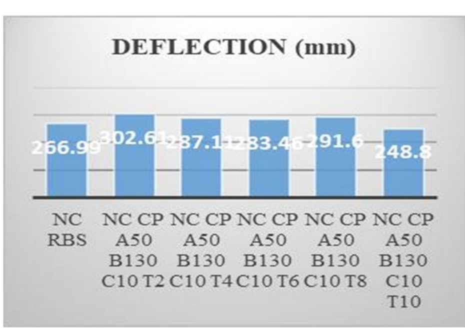
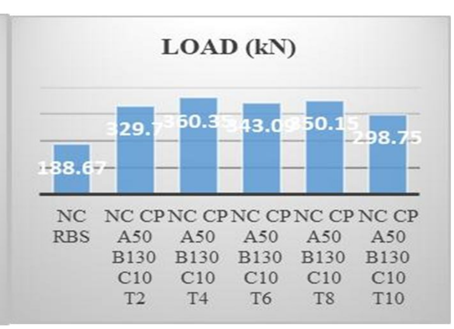


Fig 4 h: Load v/s deflection curve NC CP A50 B130 C10 with varying thickness





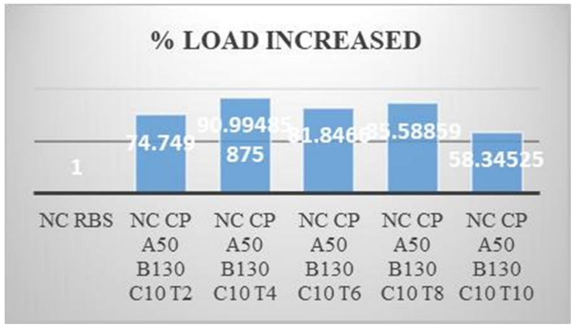


Fig 4 i: Deflection (mm), Load (kN) and % increase in load varying with thickness in NC CP A50 B130 C10 beam

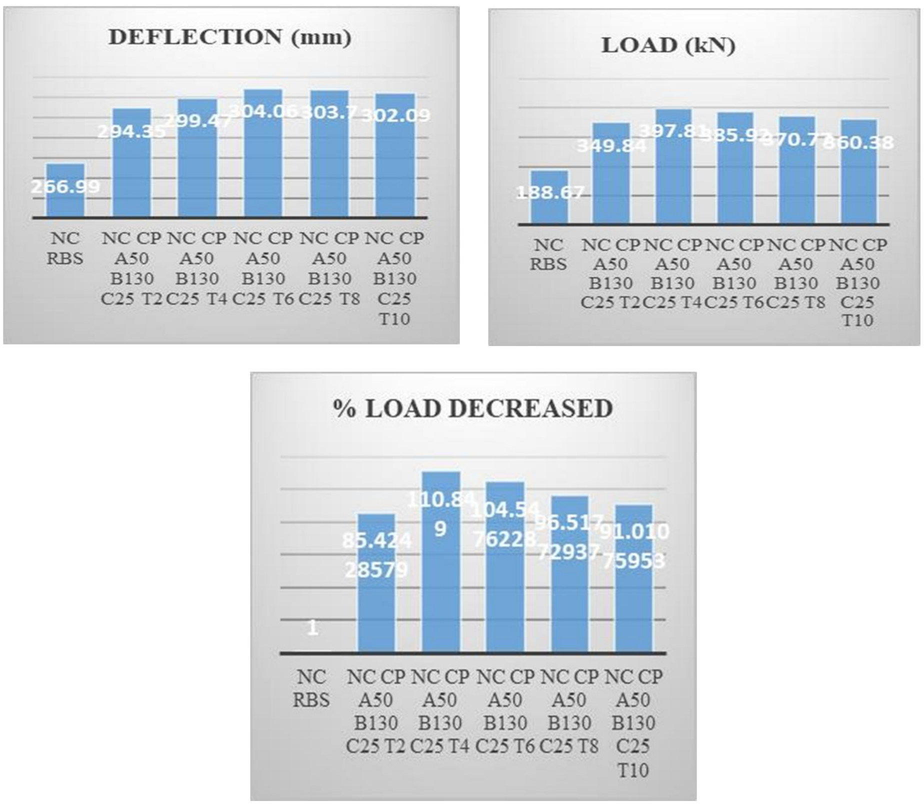


Fig 4 j: Deflection (mm), Load (kN) and % increase in load varying with thickness in NC CP A50 B130 C25 beam

Table 4.3: Mechanical properties as crack appeared in beam of NC CP A50 B130 C25 with varying thickness

Models	Deflection (mm)	Load (kN)	% decrease in load
NC RBS	266.99	188.67	1
NC CP A50 B130 C25 T2	294.35	349.84	85.42429
NC CP A50 B130 C25 T4	299.47	397.81	110.849
NC CP A50 B130 C25 T6	304.06	385.92	104.5476
NC CP A50 B130 C25 T8	303.7	370.77	96.51773
NC CP A50 B130 C25 T10	302.09	360.38	91.01076

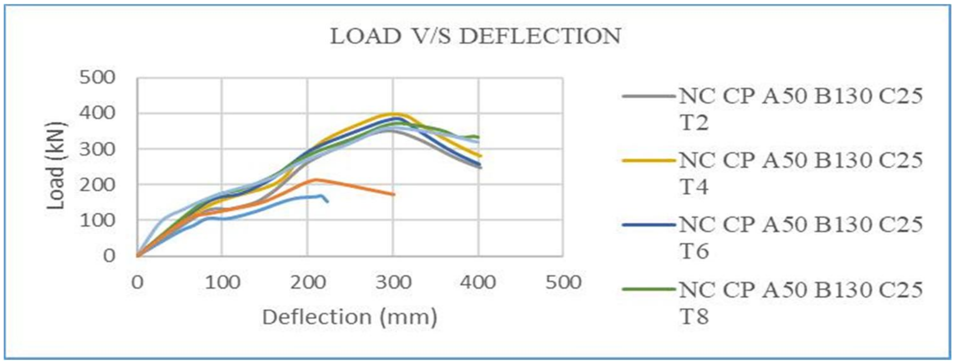


Fig 4 k: Load v/s deflection curve NC CP A50 B130 C25 with varying thickness

In weak connection, the RBS connection can take up 12% more load compared to normal connections. In A50 B130 C10 connections, while varying the thickness the A50 B130 C10 T4 connection is taking more load and is considered as effective section. In A50 B130 C25 connections, while varying the thickness the A50 B130 C25 T4 connection is taking more load and is considered as effective section. From the above cases thickness 4mm provides an effective section, as it takes more load compared to the other cases. Therefore, further cases were made by varying the values of a, b and c by keeping the thickness constant.

VI. MODELLING AND ANALYSIS OF VARIOUS RBS SECTIONS

A. Modelling and Analysis

As we obtained those cases with thickness 4mm provides an effective section, further we consider different combinations of values of a, b and c for the same thickness 4mm.

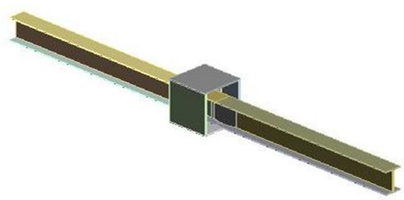


Fig 5 a: Model of NC CP A50 B170 C10 T4 connection

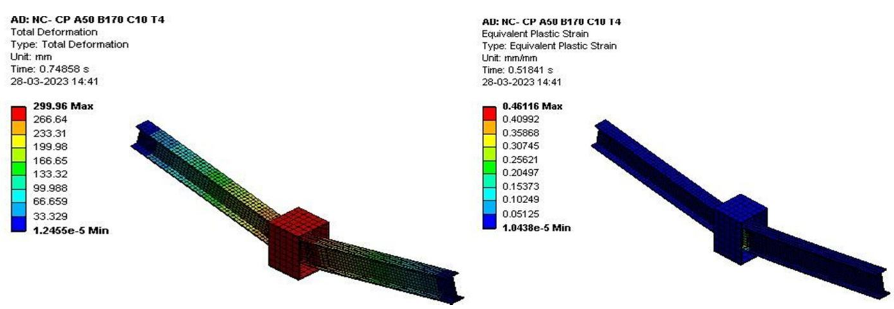


Fig 5 b: Total deformation and equivalent plastic strain of NC CP A50 B170 C10 T4

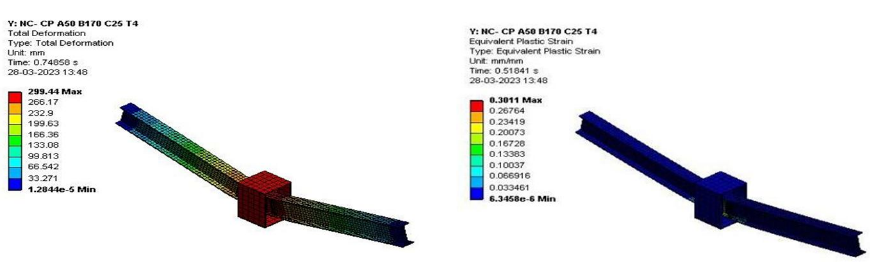


Fig 5 c: Total deformation and equivalent plastic strain of NC CP A50 B170 C25 T4

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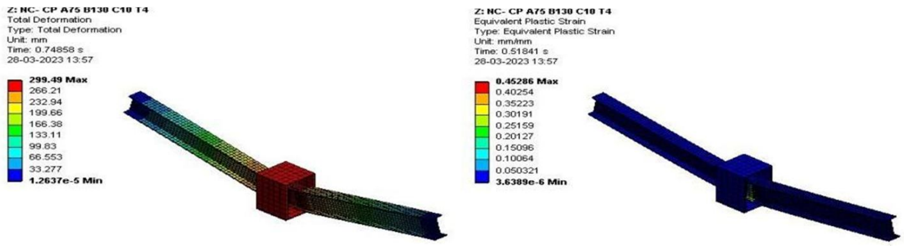

Fig 5 d: Total deformation and equivalent plastic strain of NC CP A75 B130 C10 T4

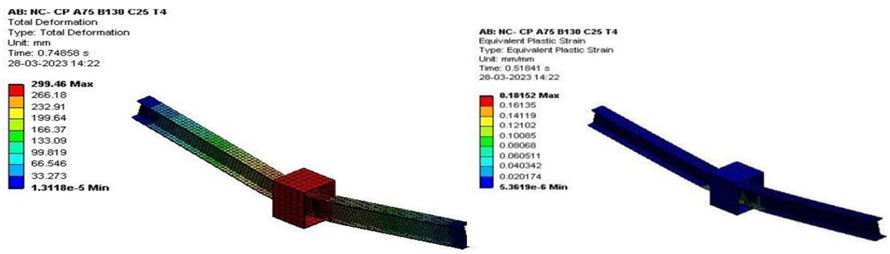

Fig 5 e: Total deformation and equivalent plastic strain of NC CP A75 B130 C25 T4

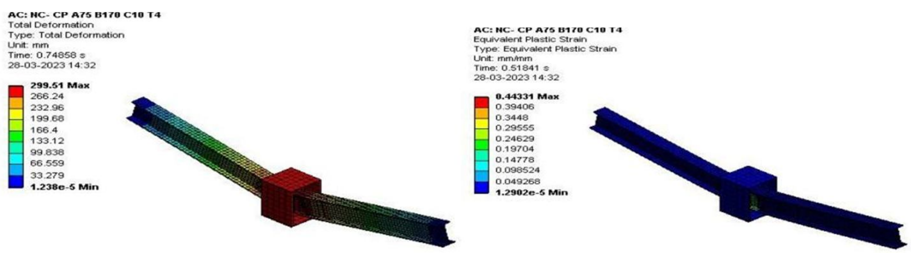

Fig 5 f: Total deformation and equivalent plastic strain of NC CP A75 B170 C10 T4

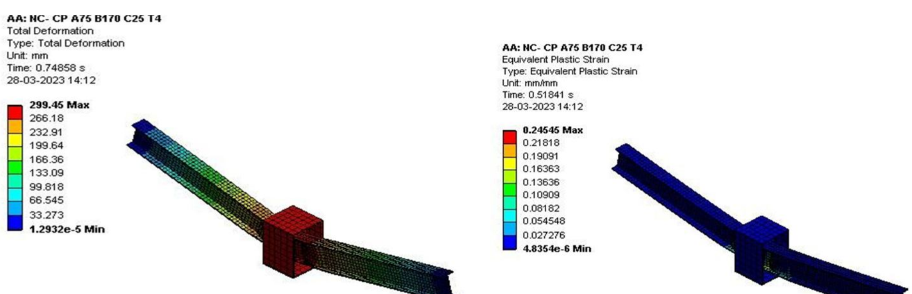

Fig 5 g: Total deformation and equivalent plastic strain of NC CP A75 B170 C25 T4

VII. RESULT AND DISCUSSION

From the analysis carried out using ANSYS work bench the ultimate load and the corresponding deformation values are plotted in Table 5.1. And the load deflection curve thus obtained is plotted in Fig 4 a and also the percentage increase in load with respect to the normal RBS connection is also shown in Table 5.1. Then the deflection in mm, load in kN and the percentage increase in load with respect to normal RBS connection varying with thickness in NC CP A50 B130 C10 section is shown through bar charts in Fig 5 r.

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Table 5.1: Mechanical properties as crack appeared in beam of NC CP sections same thickness

MODELS	DEFLECTION (mm)	LOAD (kN)	% INCREASE IN LOAD
NC RBS	266.99	188.67	1
NC CP A50 B170 C25 T4	306.74	394.8	109.2542535
NC CP A75 B130 C10 T4	283.01	357.52	89.49488525
NC CP A75 B170 C25 T4	298.44	397.87	110.8814332
NC CP A 75 B130 C25 T4	302.37	414.26	119.5685589
NC CP A 75 B170 C10 T4	288.09	372.06	97.20146287
NC CP A 50 B170 C10 T4	269.48	334.75	77.42619388
NC CP A50 B130 C25 T4	299.47	397.81	110.8496316
NC CP A50 B130 C10 T4	287.11	360.35	90.99485875

Fig 5 h: Deflection (mm), Load (kN) and % increase in load with same thickness in NC CP sections

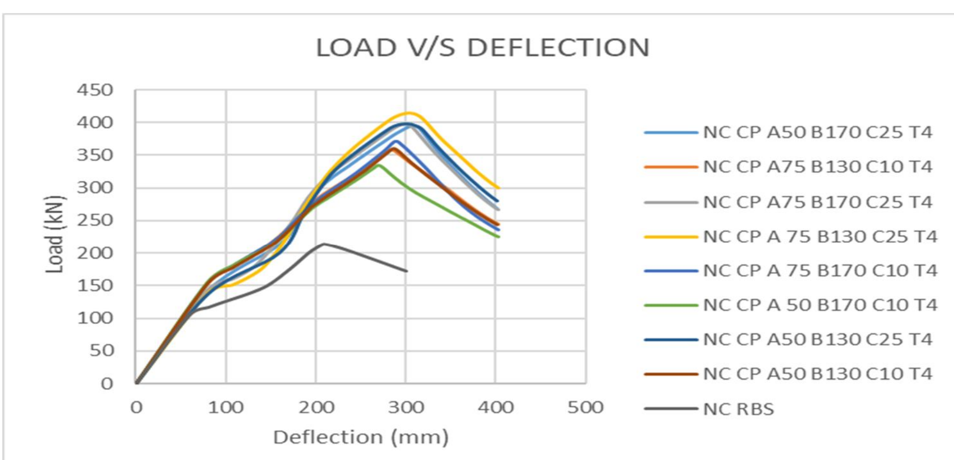

Fig 5 i: Load v/s deflection curve NC CP sections with same thickness

VIII. CONCLUSIONS

From the above analysis done using ANSYS Workbench following conclusions were made:

1) In A50 B130 C10 connections, while varying the thickness the A50 B130 C10 T4 connection is taking more load and is considered as effective section.
2) In A50 B130 C25 connections, while varying the thickness the A50 B130 C25 T4 connection is taking more load and is considered as effective section.
3) From the above cases thickness 4mm provides an effective section, as it takes more load compared to the other cases.
4) When thickness 4mm is made constant and when the other parameters were varied the section NC CP A 75 B130 C25 T4 gave an increase load of 119.56% when compared to normal RBS section. Therefore, the section take up more load when compared with other sections.
5) Other sections also gave increased load carrying capacity when compared with normal RBS section that shows that curved plate RBS seems to be effective compared with Normal RBS.

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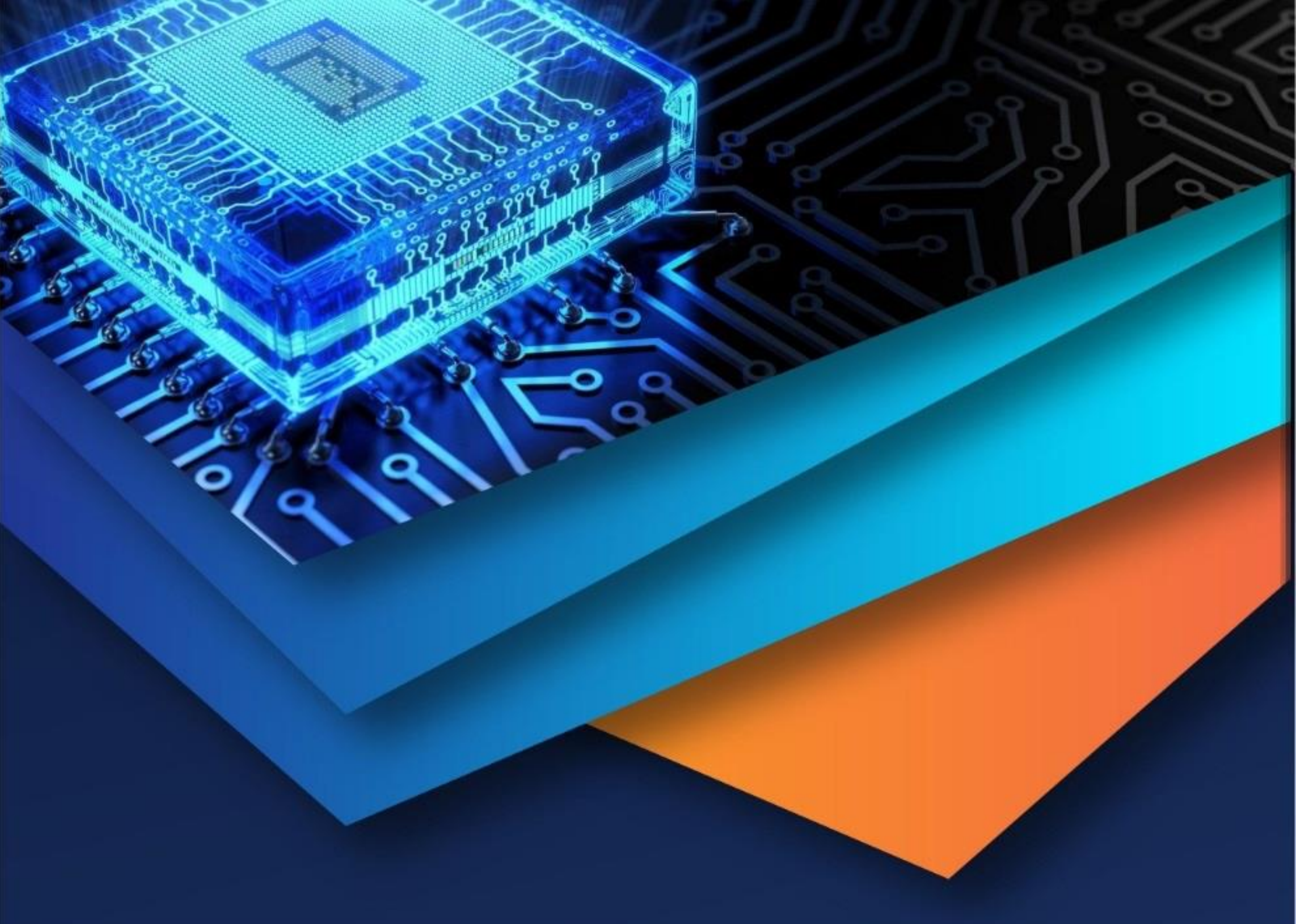

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