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Progressive Collapse Mitigation Study on Box Column and Steel Beam with Corrugated Web RBS

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***Abstract*:- Steel frame constructions using traditional weld connections frequently experience brittle breakdowns. To mitigate this issue,steps were taken to incorporate plastic hinges and improve the ductility of the steel connections.The beam-to-column connection has been identified as a key element for steel frame structures to maintain the structural integrity during progressive collapse phenomenon. In this study box column and steel beam subjected to progressive loading are considered with corrugated web RBS connection, called the curved cell web RBS (CW-RBS) which increases the moment capacity and the time of progressive collapse. In the case of RBS a portion of beam is being cut from the web and flanges so that plastic hinge gets relocated to the portion which is weak and this prevents welding failure at the end of beam and failure in column but this reduces the stiffness of beam. In this case CW-RBS is implemented on the beam that is web of the beam is cut in an area near the column and the cut-out section is replaced by a cell made with two curved corrugated plates,this increases the stiffness which inturn increases the moment capacity and time of progressive collapse. Thus failures on box column completely gets relocated to CW-RBS and makes the box column and joint safe thereby we can prevent this portion from weakening. These are done according to FEMA 350. Modelling and analysis is carried out using ANSYS software .In this study we obtain ultimate load capacity, moment capacity, drift angle.**

Keywords: Progressive Collapse Mitigation, RBS, CW-RBS Corrugated Web RBS

1.INTRODUCTION

Steel frame structures with ordinary weld connections often suffers from brittle fracture situation in which a local failure causes a major collapse, with the magnitude being disproportionate to the initial event. For steel frame structures, the beam-to-column connection has been identified as a crucial component for maintaining structural integrity during the progressive collapse phenomenon.

Progressive collapse refers to a situation in which a local failure causes a major collapse, with the magnitude being disproportionate to the initial event. New strategies were necessary to improve the ductility of the steel connections, such as weakening the beam section at an appropriate distance from the column face. In steel moment frames, reduced beam section (RBS) connections have been widely used, with parts of the beam flanges near the beam to column connections being removed [Fig 1].The yielding zone can be transferred from the column face to the beam span using RBS connectors, and thereby it prevents initial damage from occurring directly at the weld joints of the beams and columns.

In addition to the RBS beam approach, another strategy is to introduce openings in beam webs to form a plastic hinge away from the connections to make beams more ductile . Web-openings in beams can be used to improve the spatial efficiency of buildings and provide access to pipelines. Engineers create web openings for pipelines in steel frame structures, air-conditioning, heating, and water supply systems that require special pipelines. Connections with flange- or web-reduction may change the mechanical characteristics and increase structure deflection when large deformation occurs. It is extremely important to consider the bearing capacity, deflection, and cracking of beams with flange- and web-reductions, which can be indirectly evaluated by the ability to resist progressive collapse.

In this study box column and steel beam are considered with corrugated web RBS connection, called the curved cell web RBS (CW-RBS) which increases the moment capacity and the time of progressive collapse. Modelling and analysis is carried out using ANSYS software.

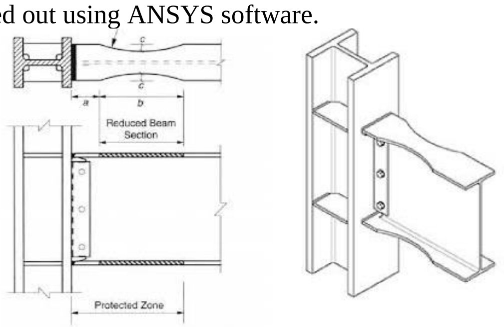

Figure 1. Reduced Beam Section (RBS)

Figure 2. Application of Reduced Beam Section (RBS) Connection

Fig 1 RBS

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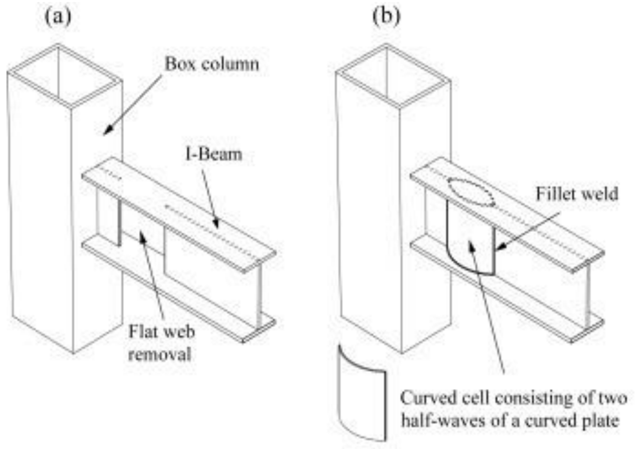

Fig 2 CWRBS

II.PROPOSED CONNECTION

Corrugated web RBS connection have been proposed in this study.To make this type of RBS connection, the flat web of the beam in the area near the column face must be cut out and replaced by corrugated plates. Since the accordion behaviour of the corrugated web will cause it to have a low stiffness in the longitudinal direction of the beam, this web will play a very small role in the moment capacity of the member. Therefore, replacing the flat web with a corrugated web within a limited distance from the column will reduce the moment capacity of the beam in this area, thus creating an RBS connection. According to studies on beams with corrugated web, there is no interaction between flexural and shear behaviour in these beams, which means the moment capacity can be calculated without considering the corrugated web and only based on the yield capacity of flanges.As mentioned, the most important advantages of corrugated web RBS connection include the increased out-of-plane stiffness and lateral-torsional stability of the beam in the RBS zone and the reduced width-to-thickness ratio of the beam flange, which delays its local buckling. The web of the beam is cut in an area near the column (Fig. 2-a) and the cut-out section is replaced by a cell made with two corrugated plates. In the proposed connection, which is called the curved cell web RBS (CW-RBS) connection, the cell is made with two curved plates as shown in Fig. (2-b). As can be seen, the plates needed to make these cells can be easily prepared by cutting these corrugated plates[5].

III.VALIDATION

A.Description of experimental model

The experimental results obtained from the experiment conducted on various specimens by researches were numerically validated.The dimensions of I beam and I column were I -200 × 100 × 5.5 × 8 (mm) and I-250 × 250 × 9 × 14 (mm).Material properties were taken from the experimental data. Numerical analysis results were compared with experimental results.

B.Finite element analysis

Finite element model (FEM) was established using ANSYS.The numerical analysis results were validated using the experimental results, in terms of the vertical force displacement relationship and the failure modes of the different connections. All components including beams, columns, continuity plates, and corrugated webs were modelled by the use ANSYS. Modulus of elasticity 2x10^5MPa and Poisson’s ratio is 0.3.In FE model the boundary condition and loading criterion are modelled according to those in the experiment.Mesh size of 25mm is selected for analysis.Load –displacement curves are calculated with the FE model and compared with experimental results.The ultimate load and deflection obtained from the experiment is 217kN and 236.7mm and from FEA is 225.3kN and 246.06mm.

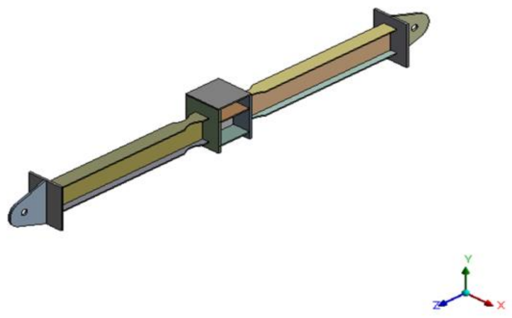

Fig 3. I beam and I column with RBS

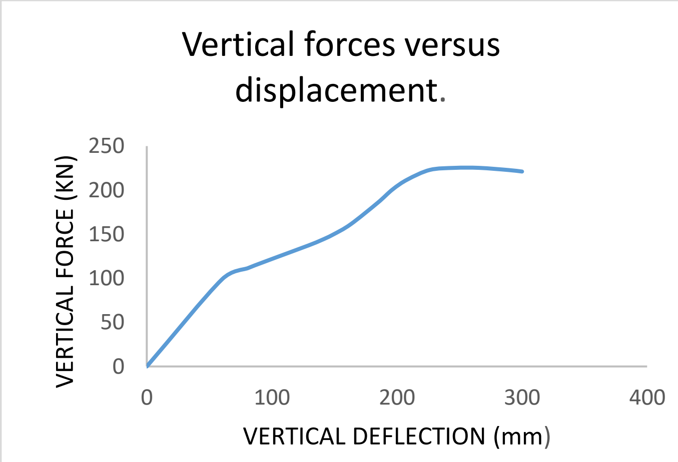

Fig 4. Load deflection curve

Table 1 Comparison of results

	LOAD(kN)	DEFLECTION(mm)
JOURNAL EXP	217	236.7
FEA	225.3	246.06
PERCENTAGE VARIATION	3.82	3.95

PARAMETRIC STUDY

The study was conducted considering various parameters.In that the first one to model and compare the performance of CWRBS(fig.4) with no RBS(fig.1) ,flange cut RBS (fig3)and web cut RBS(fig.2).For this I section beam and box column were chosen.Another study was to vary the thickness with 2.5mm ,5mm and 10mm of CWRBS and fixing a particular thickness which gives the highest performance.

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For conducting the finite element analysis size of beam and column was chosen.The size of the I beam chosen was I Beam -400x225x10x20(mm) and box column 350x350(mm) with 25mm thickness. And for designing RBS,it is designed as per FEMA 350 Cl.3.5.5.1.

All parts of the models, including beam, column, continuity plates, and corrugated plates have a nominal yield stress of 250 MPa, tensile yield strength of 410MPa, and Poisson's ratio of 0.3 and modulus of elasticity of $2x10^5$ MPa .

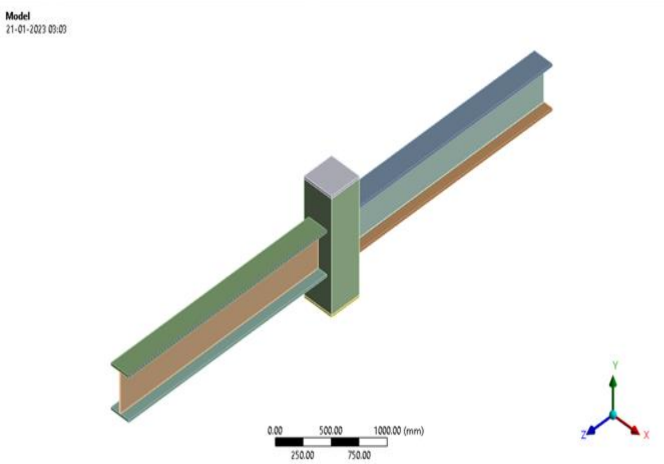

Fig 1. No RBS

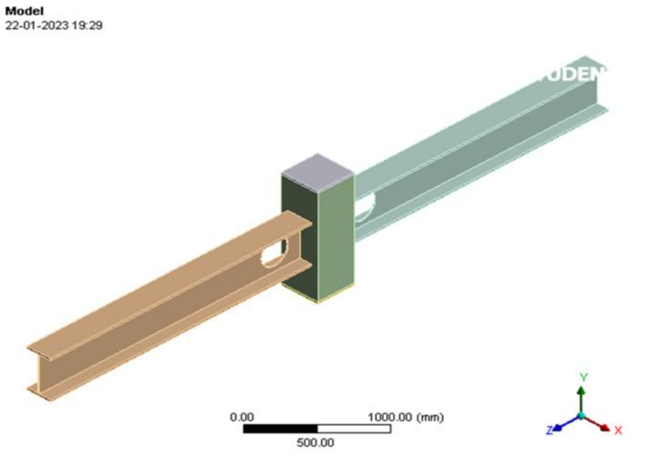

Fig 2. Web cut RBS

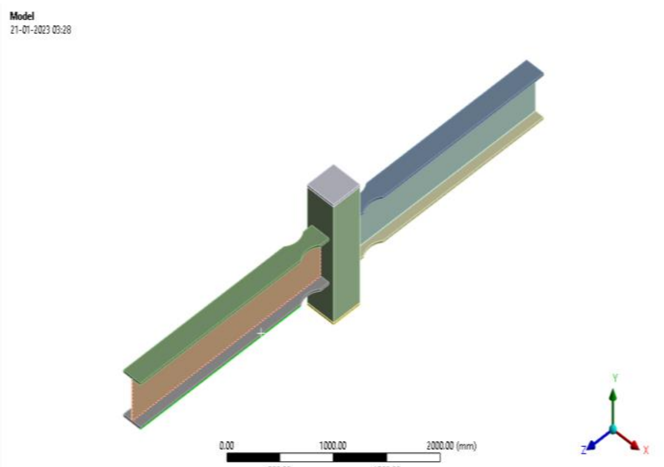

Fig 3. Flange cut RBS

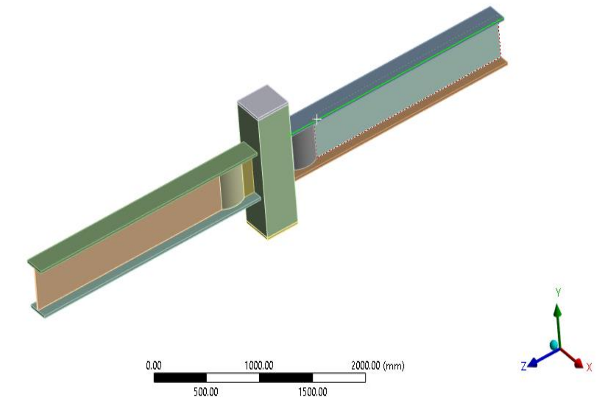

Fig 4. CWRBS

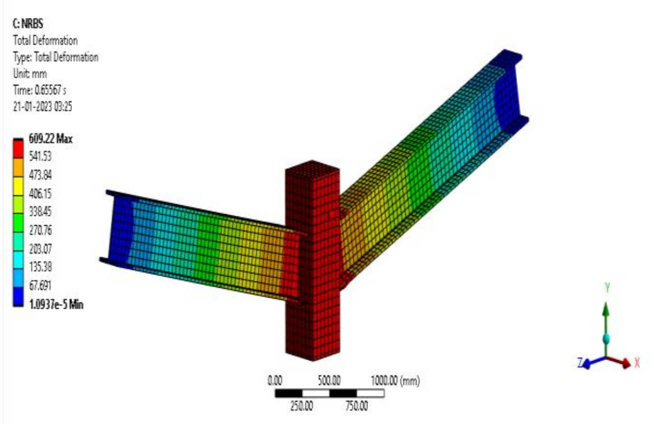

Fig 5. Total deformation of no RBS

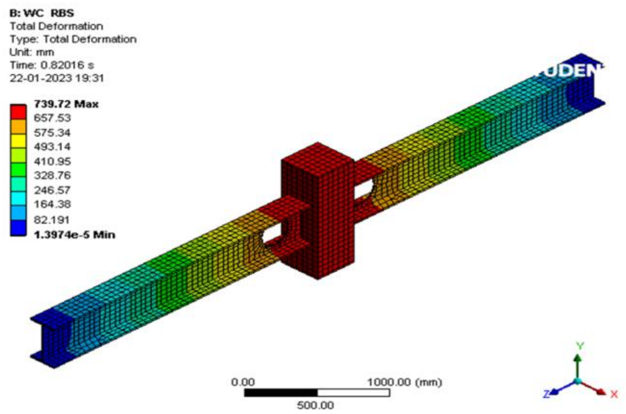

Fig 6 Total deformation of web cut RBS

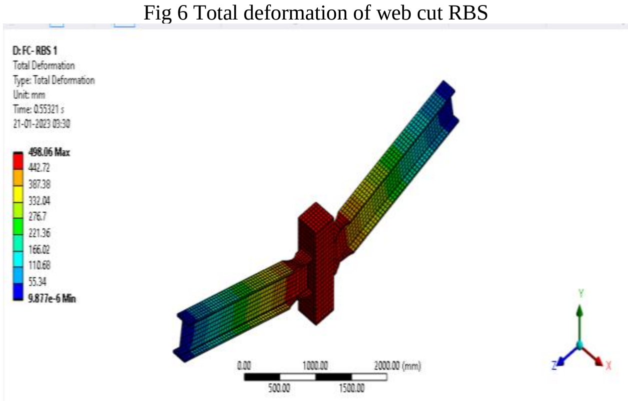

Fig 7 Total deformation of flange cut RBS

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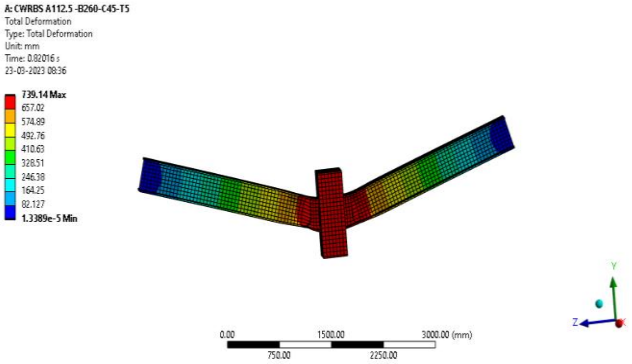

Fig 8 total deformation of CWRBS

Above figures shows the total deformation of no RBS ,web cut RBS,flange cut RBS and CWRBS.

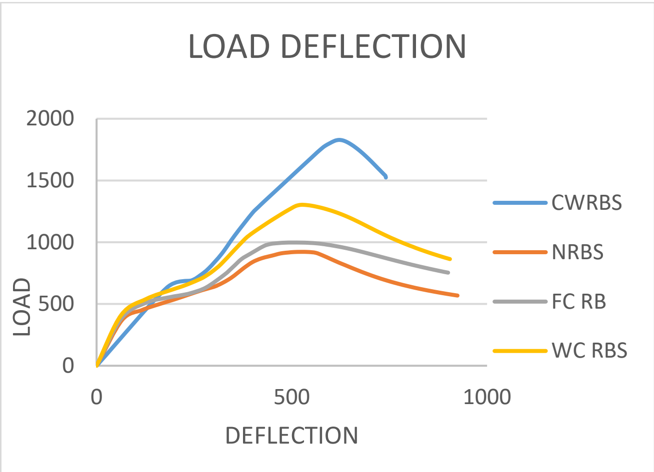

Fig 9 Load deflection curve

Fig 9 is the load and deflection of CWRBS and were compared with no RBS,web cut RBS,flange cut RBS and from the graph it is clear that CWRBS has the highest load carrying capacity compared to other models.

Table 2.Equations from FEMA 350

a	0.50 -0.75bf
b	0.65-0.85db
c	0.20-0.25bf

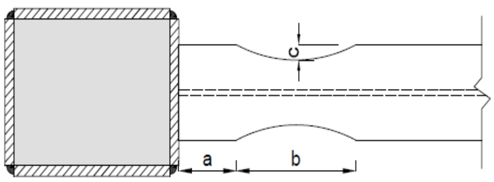

Fig10. Geometric dimensions of the RBS zone

After comparing the performance next is to vary the thickness of the CWRBS and then the thickness is taken as 5mm .FEMA 350 gives the equations for the design of RBS.Here 8 models are modelled by varying the values of a,b and c (fig 10) with their minimum and maximum values by using the equation from FEMA 350 (table.2).
In these equations, bf and db are the width of flange and the depth of the beam, respectively.
After varying all the values CWRBS A168.75-B260-C45-T5 is taken as the effective model among the other 8 models.

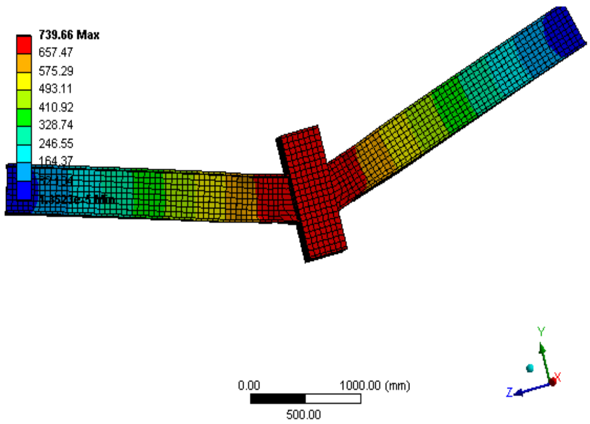

Fig 11. Total deformation

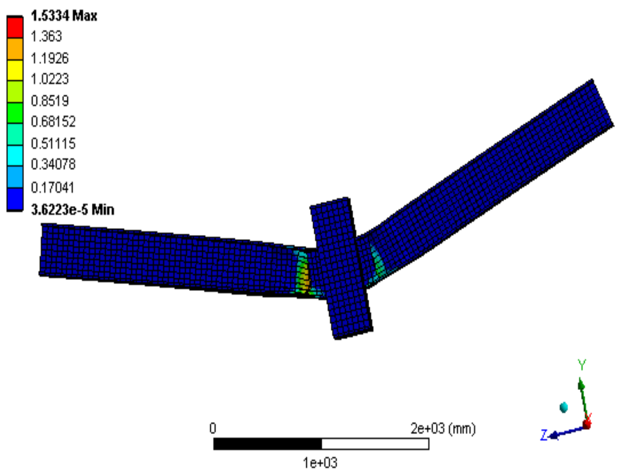

Fig 12.Plastic strain

Fig 11 and 12 shows the total deformation and plastic strain of CWRBS A168.75-B260-C45-T5

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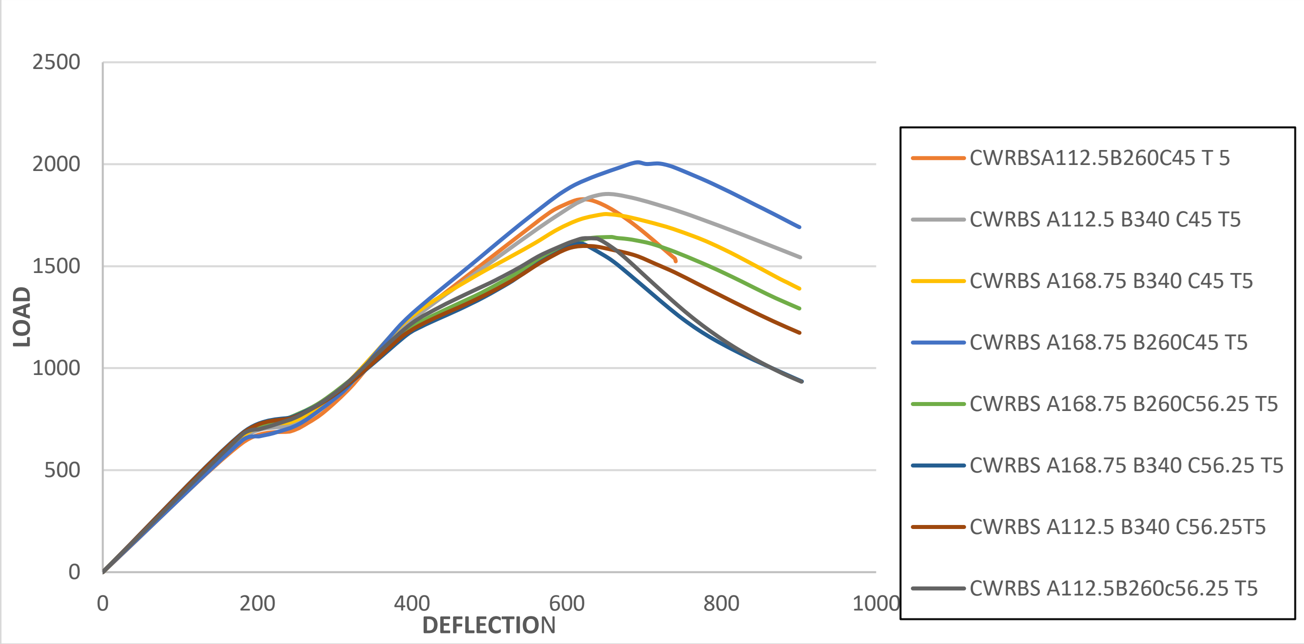

Fig 13.Load deflection curve

Fig 13 shows the load deflection curves of CWRBS of 8 models. Among the 8 models CWRBS A168.75-B260-C45-T5 shows the highest performance.The ultimate load carrying capacity of CWRBS A168.75-B260-C45-T5 was 2003.7kN which is very much higher than no RBS which was 922.06kN .
CWRBS A168.75-B260-C45-T5 has the highest load carrying capacity ,momemt capacity and rotational capacity.

RESULTS AND DISCUSSIONS

The aim of this study is to increases the moment capacity and time of progressive collapse. Thus failures on box column completely gets relocated to CW-RBS and makes the box column and joint safe thereby it can prevent this portion from weakening.

- CWRBS has a higher load carrying capacity than model without RBS Pmax=922.06kN for (No RBS) and Pmax =2003.7kN (CWRBS).
- Moment capacity of CWRBS is higher than model without RBS Mmax=2466.5105kNm (no RBS) Mmax=5359.8975kNm(CWRBS)
- Rotational capacity($^{\theta}$max) is higher for CWRBS when compared to model without RBS for CWRBS ,$^{\theta}$max=0.26865047 and no RBS,$^{\theta}$max=0.19574579
- Stress on column is 392.34 kN/mm^2 and stress on beam is 410 kN/mm^2 which means column hasn't failed but the beam has failed.
- Failures on the column was relocated to RBS zone hence column and the joint was safe.
- Since the failures on column was relocated it prevented welding failure thereby it increased the time of progressive collapse.
- The corrugated web in the RBS zone ensured that the plastic hinges emerged in the RBS zone, thus preventing failure in the beam-column junction.

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