

EVALUATING THE DESIGN OF BEAM-COLUMN JOINT USED IN MULTI-STOREY STEEL FRAME STRUCTURE

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Abstract: In last many decades' researcher and academician are working towards the enhancement of strength of the multi-storey structure. So in the same order, here in this work different design of beam-column was proposed and analysed. In this work total seven different cases of beam-column joint were proposed and evaluate the different performance parameters. It calculates the value of total deformation, equivalent stress, elastic strain and other parameters for each case of analysis. It also shows the distribution of different parameters throughout the beam and column joint in each case of analysis. In this work, Ansys static structure is used to perform numerical analysis of column-beam joint. Through analysis it is found that, case-6 shows the optimum design of joint. with case-6, the total deformation is minimum, whereas the equivalent stress is also low as compared to other cases of joint. So, it is concluded that case-6 shows the most optimum case of joint in beam-column joint.

Keywords: beam-column joint, FEM analysis, deformation, failure behavior, stress-strain analysis

1. Introduction

The idea of a gradual collapse-resilient structure first appeared in 1968, when parts of a Ronam point residential building collapsed. Since then, many structural engineers and university researchers have been committed to mitigating the effects of the gradual collapse of building structures. Significant changes were made to the design philosophy of the main buildings after the uneven collapse of the Murrah Federal Building in 1995 due to the 1996 bombing and collapse of the Khobar Tower. However, after the collapse of the World Trade Center building by terrorists. In the September 2001 attacks, several government agencies and local agencies worked on developing specific design guidelines for the design of advanced structures that could withstand collapse. Amongst these strategies, the U.S. General Service Administration (GSA, 2013) [1] and Unified Facilities Criteria (UFC) published by Department of Defense (DoD), United States of America (UFC, 2013) [2] describes detailed methodologies to resist the progressive collapse of building structures. Progressive collapse is defined as "the propagation of the first regional failure from one element to another, leading to the collapse of the whole structure or its disproportionate part" (ASCE / SEI 7-05, 2006) [3]. This is the reaction failure of the chain of building elements to a degree disproportionate to the damage that was initially localized and is also referred to as disproportionate collapse (NISTIR, 2007) [4]. Sequential collapse is the permanent failure of a load-bearing structure - due to the initial destruction of the base to the components of the individual structure and leading to the collapse of the entire building or an important part of the building. The definition of gradual collapse, defined by various standards, covers the impact of the "card house" when the damage extends beyond the local area to a level disproportionate to the initial cause. It resembles a continuous decline of the cycle in a circular position when initially pressed.

Multi-storey structures are used for different applications like offices, parking, public places and many other. In this steel frame structure is the most commonly used structure. The performance of the structure depends on the different process parameters like load bearing capacity required, material used for structure, design of beam and column and many others. Out of these, beam-column joint is one of the major parameters on which the performance of the structure depends. If suppose any column get buckle, then suddenly load get transfer in to beam and if the joint in between column and beam is not proper then failure occurs and this leads to progressive failure of multi-storey building structure. So, in order to restrict the progressive failure of the multi-storey building, despite making the proper design of column and beam it is very necessary to have an optimum design of column-beam joint. So, in order to identify the different parameters and analysing the failure behaviours of joints, in this work FEM analysis of multi-storey steel frame column-beam joint was performed.

2. Development of solid model

The solid model of steel frame beam-column joint was made on the basis of geometrical parameters that was considered by Meng et.al [64]. The geometrical parameters of column and beam is mention in the below table. The design parameters of beam and column as considered by Meng et al. is shown in the below figure

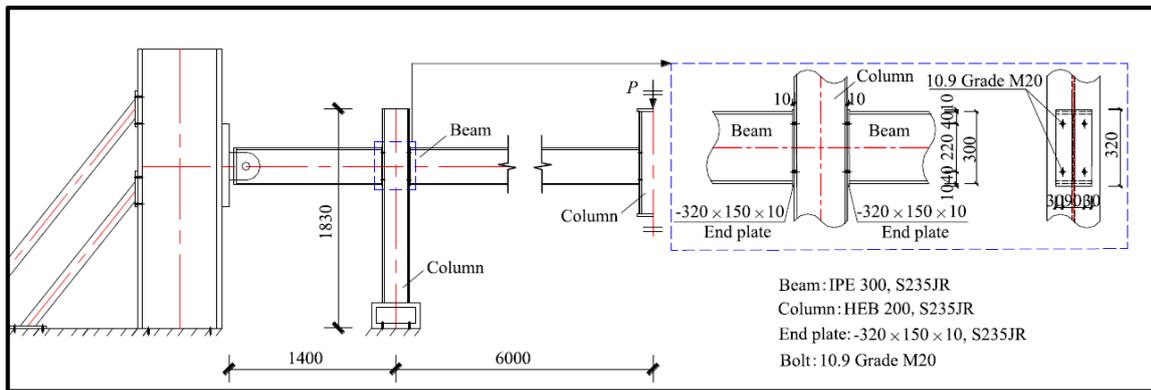
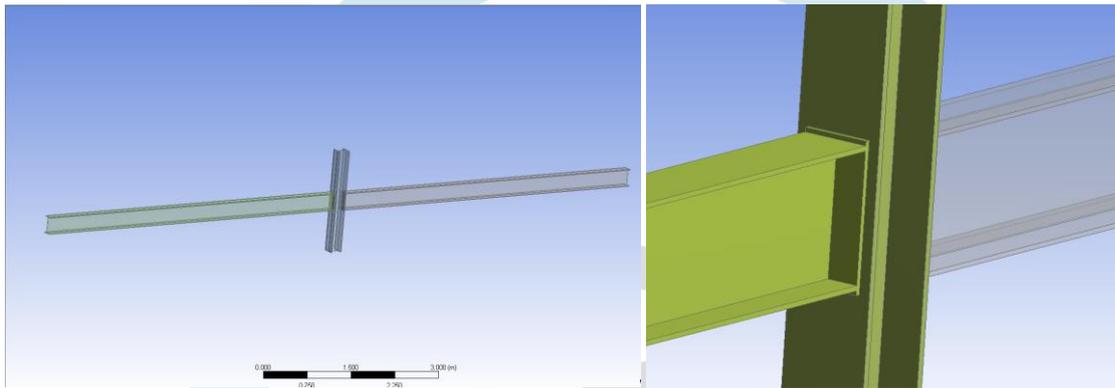


Fig.1 Parameters of beam, column and endplate

Fig.2 Solid model of column-beam joint



3. Meshing

After developing the solid model, for performing the numerical analysis of joint it is necessary to do meshing of the geometry. During mesh discretization of complete solid model in to number of elements was done. the independence of number of elements was done by doing the mesh with different number of nodes and elements. In this work four different set of number of nodes and elements was considered and calculated the value of total deformation. Through analysis it is found that with 44500 number of elements the value of total deformation is coming close to the required value. With higher number of elements, no any significant changes were found with the results.

4. Boundary condition

Different boundary conditions were applied at different components of the column-beam joint structure. For Validating the FEM analysis of joint as considered by Meng et.al same boundary conditions were considered by them. Both the ends of the beam will remain fixed as shown in the figure. The load applied on the column is 1625 kN, which is also shown in the below figure. In order to validate the numerical FEM analysis of column-beam joint as considered by Meng et al. [64], value of total deformation was calculated. After applying the different boundary conditions at different components of the beam, solution was done. The performance parameters of initial joint are shown in the below figures.

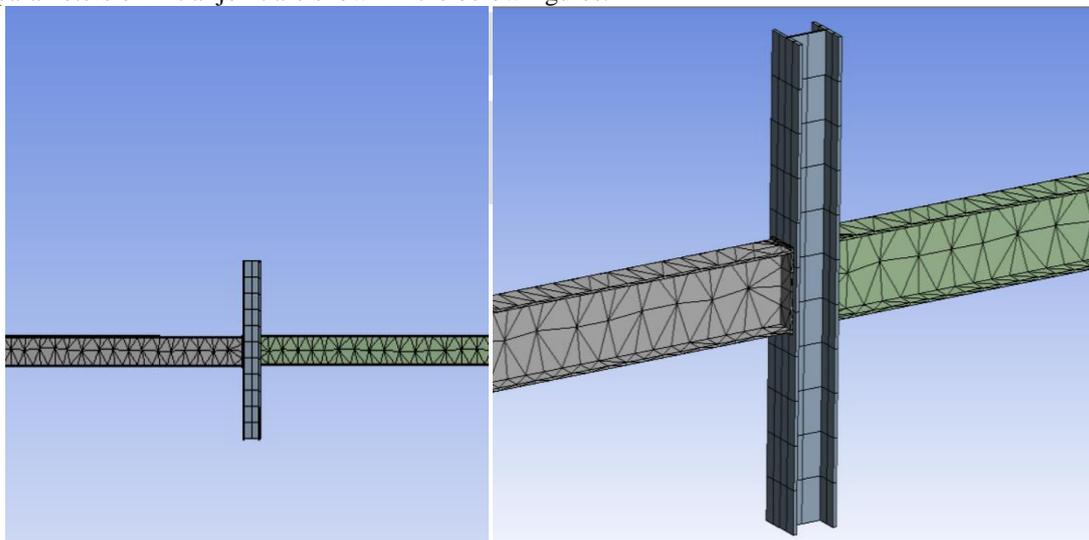


Fig.3 Meshing of solid model of column-beam joint considered for FEM analysis

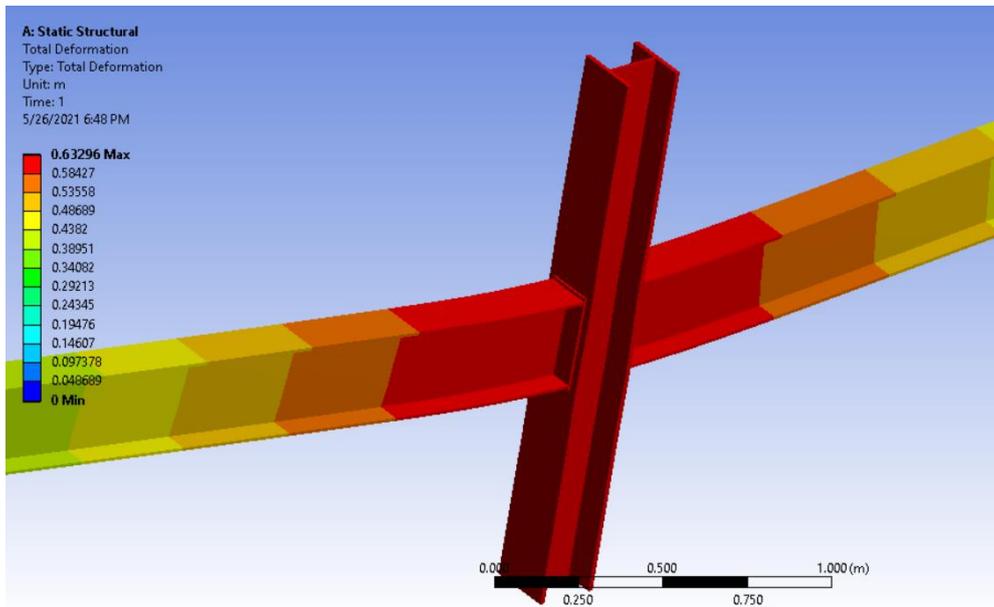


Fig.4 Total deformation of the joint

From figure it is found that the total deformation of the joint after applying the given load conditions is near about 633 mm. through contours plots it is also seen that the maximum deformation is at the joint, which means the maximum load or stress is coming to the center that is at the joint. After finding the value of total deformation for this case, it is then compared with the total deformation calculated by Meng et al. [64]. The value of total deformation calculated by Meng et al is shown in the below figure.

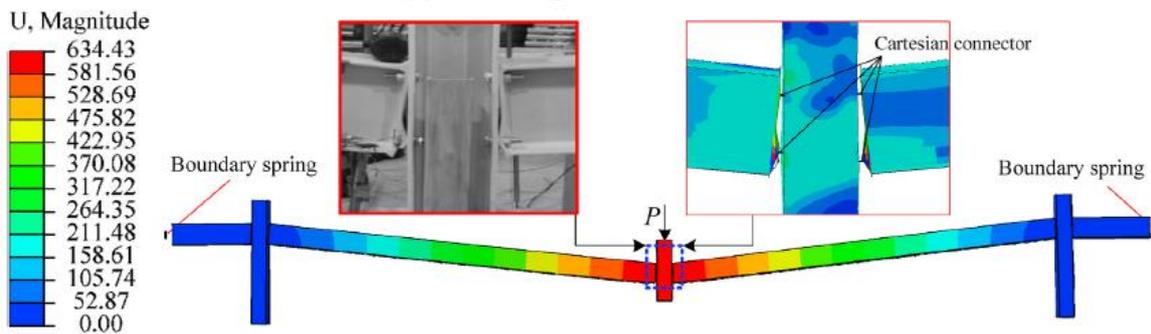


Fig.5 Total deformation calculated by Meng et al.

Table.1 Comparison of value of total deformation

Deformation calculated by Meng et al.	Deformation calculated through FEM analysis in present work	Error (%)
634.43 (mm)	632.96 (mm)	0.23

From above table it is concluded that the value of total deformation calculated through FEM analysis in the present work is coming very near to the value calculated by Meng. et al. Hence it can say that the performed numerical analysis of multi-storey steel frame column-beam joint is correct. In order to analyse the further parameters of joint von-miss's stress, strain, Maximum principal stress and minimum principal stress was also calculated for each type of joint.

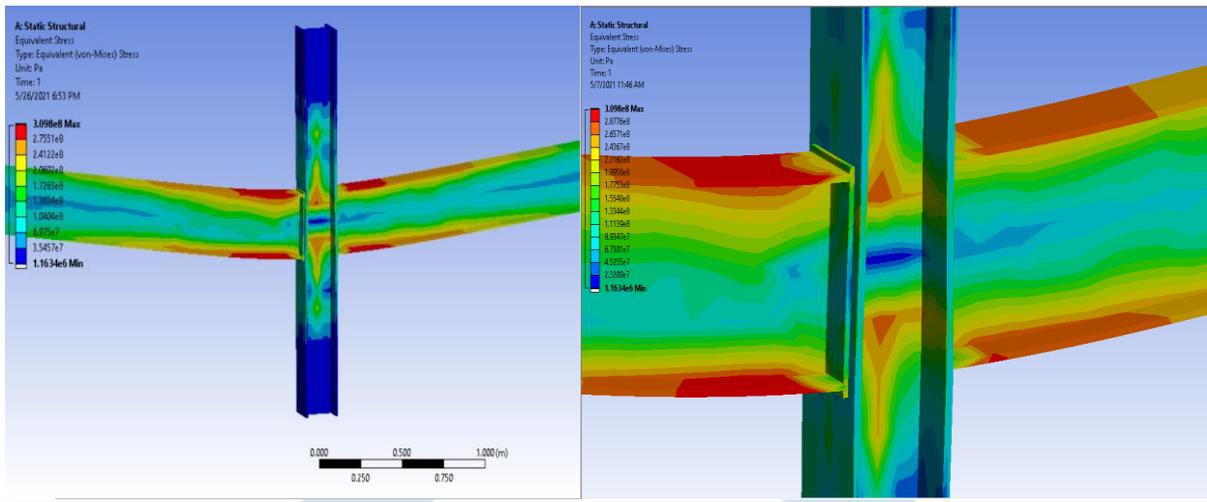


Fig.6 Value of equivalent stress for case-1

From figure it is found that the value of maximum equivalent stress at joint is near about 309 MPa. Figure also shows that the maximum stress is acting at the centre of the column, in which most specifically maximum stress is acting at the column-beam joint. Due to the use of endplates the stress concentration shifter little bit side from the end joint point, which helps in increase the strength of the joint.

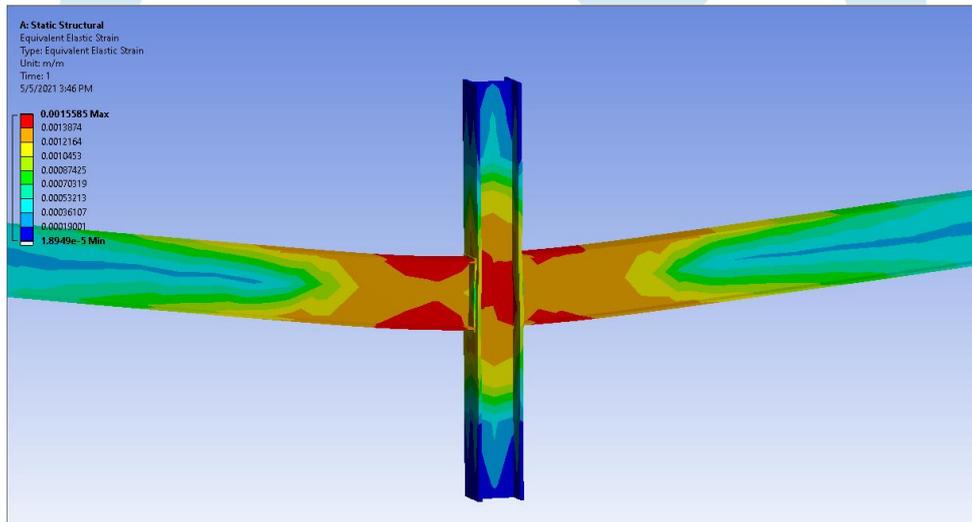


Fig.7 Value of equivalent elastic strain for case-1

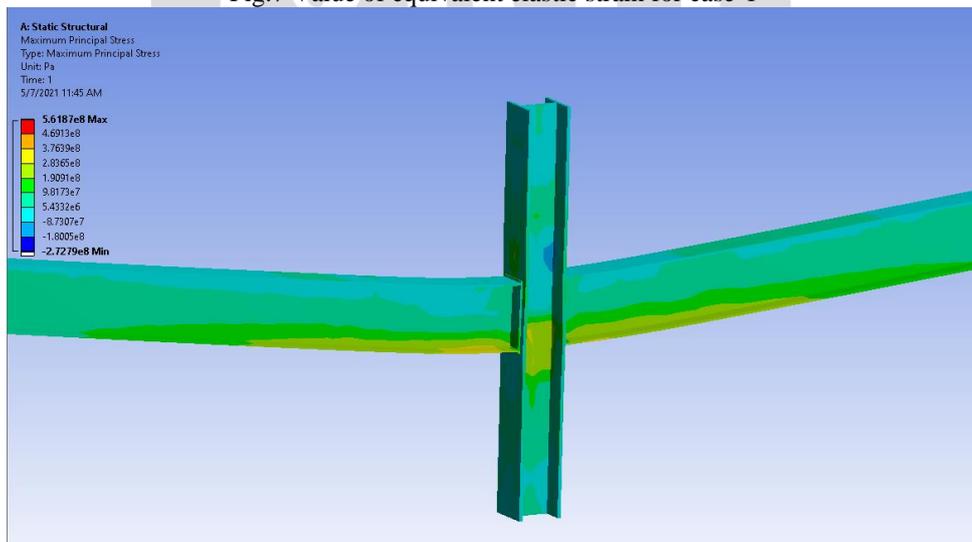


Fig.8 Value of maximum principal stress for case-1

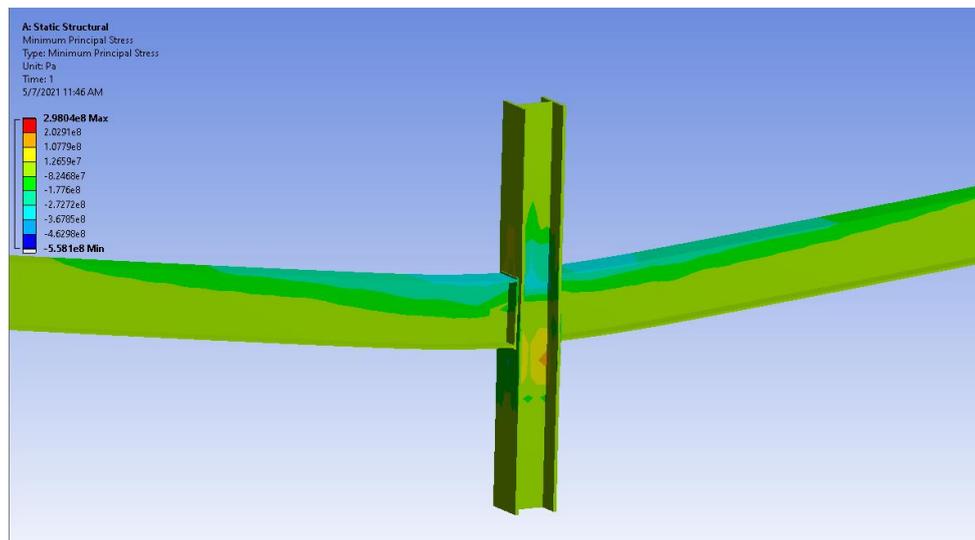


Fig.9 Value of minimum principal stress for case-1

5. Result and Discussion

Beam-column joint play an important role for strengthening the multi-storey steel frame structure. So, in order to further increase the strength of the joint or to analyses the different types of joints during loading conditions, here in this work effect of different types of beam-column joint were analyzed. In this work total seven different types were considered for the FEM analysis, in each case of analysis all performance parameters like equivalent stress, strain, total deformation, maximum principal stress and strain was calculated. Endplate play an important role to restrict the motion of joint and also helps in restricting the progressive failure of the multi-storey structure. So in this work seven new types endplates connections of column and beam was proposed.

Case-1 In this case simple end plate was welded with beam and column as shown in below figure.

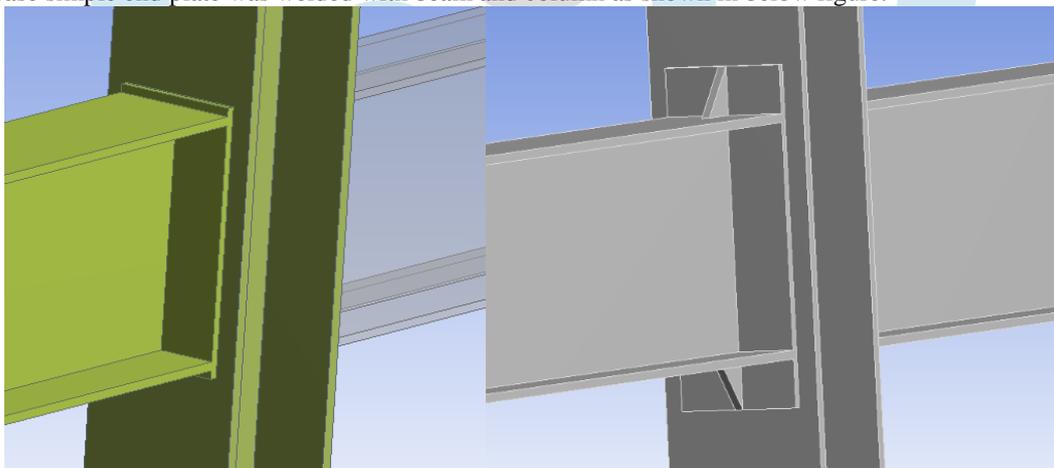


Fig.10 shows the joint connection for case-1 and case-2

Case-2 In this case an additional triangular stiffener is added at the middle of section in in between the endplate and beam.

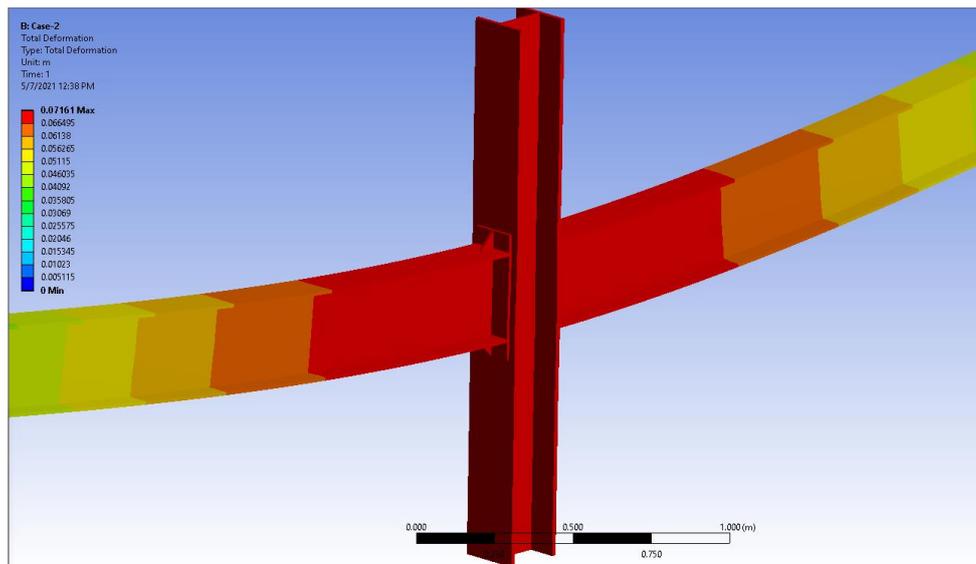


Fig.11 Value of total deformation for case-2

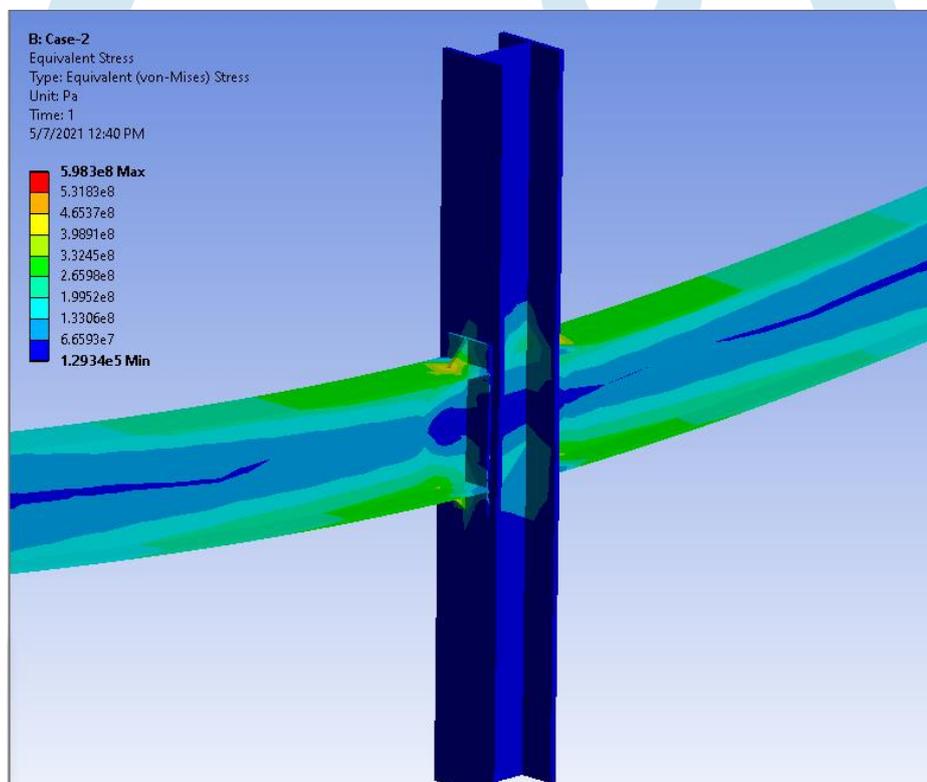


Fig.12 value of equivalent stress for case-2

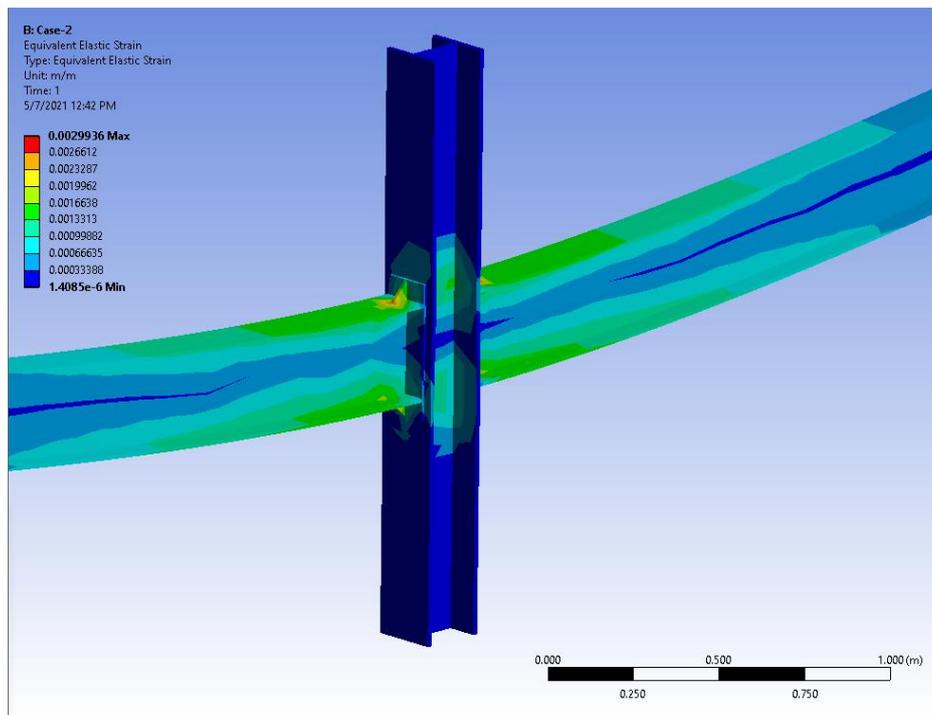


Fig.13 value of equivalent elastic strain for case-2

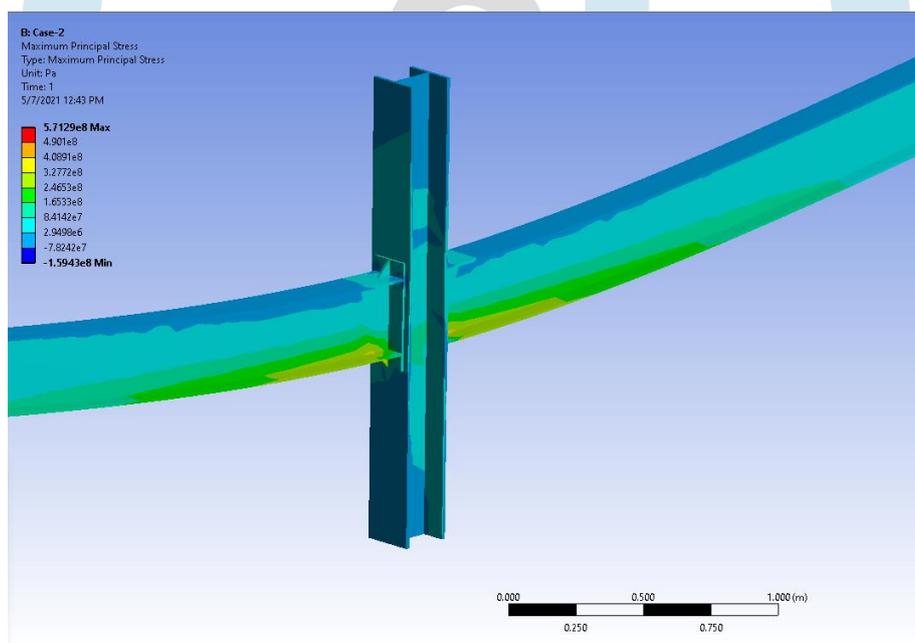


Fig.14 maximum principal stress

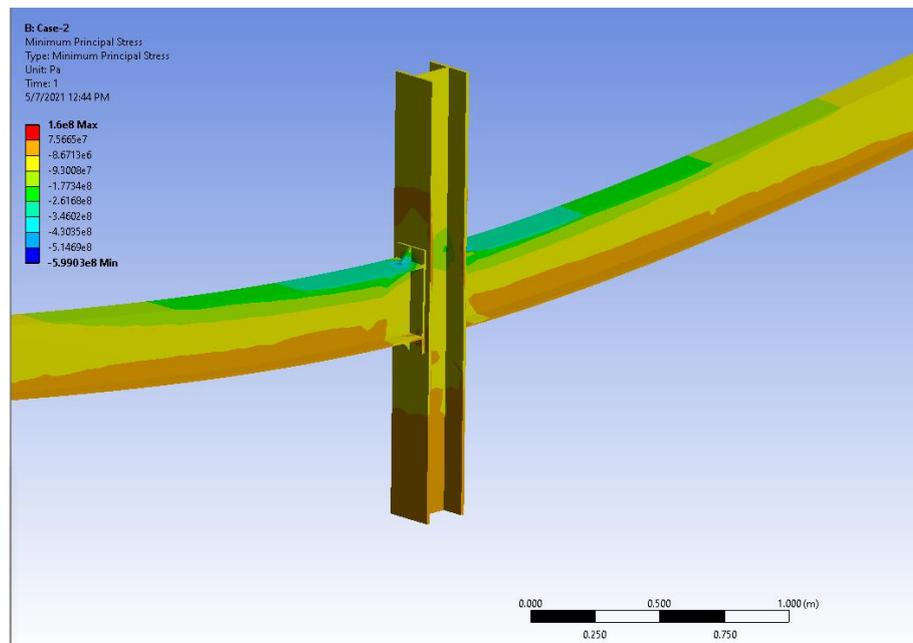


Fig.15 minimum principal stress

Above figures shows the different performance parameters for case-2 beam-column joint. From figure it is found that with triangular stiffener, the total deformation of the joint get reduces to more than 10 time from the case-1 joint. For case second the total deformation is near about 71.6 mm, whereas the equivalent stress is near about 598 MPa which shows the strengthening of case-2 joint as compared to case-1.

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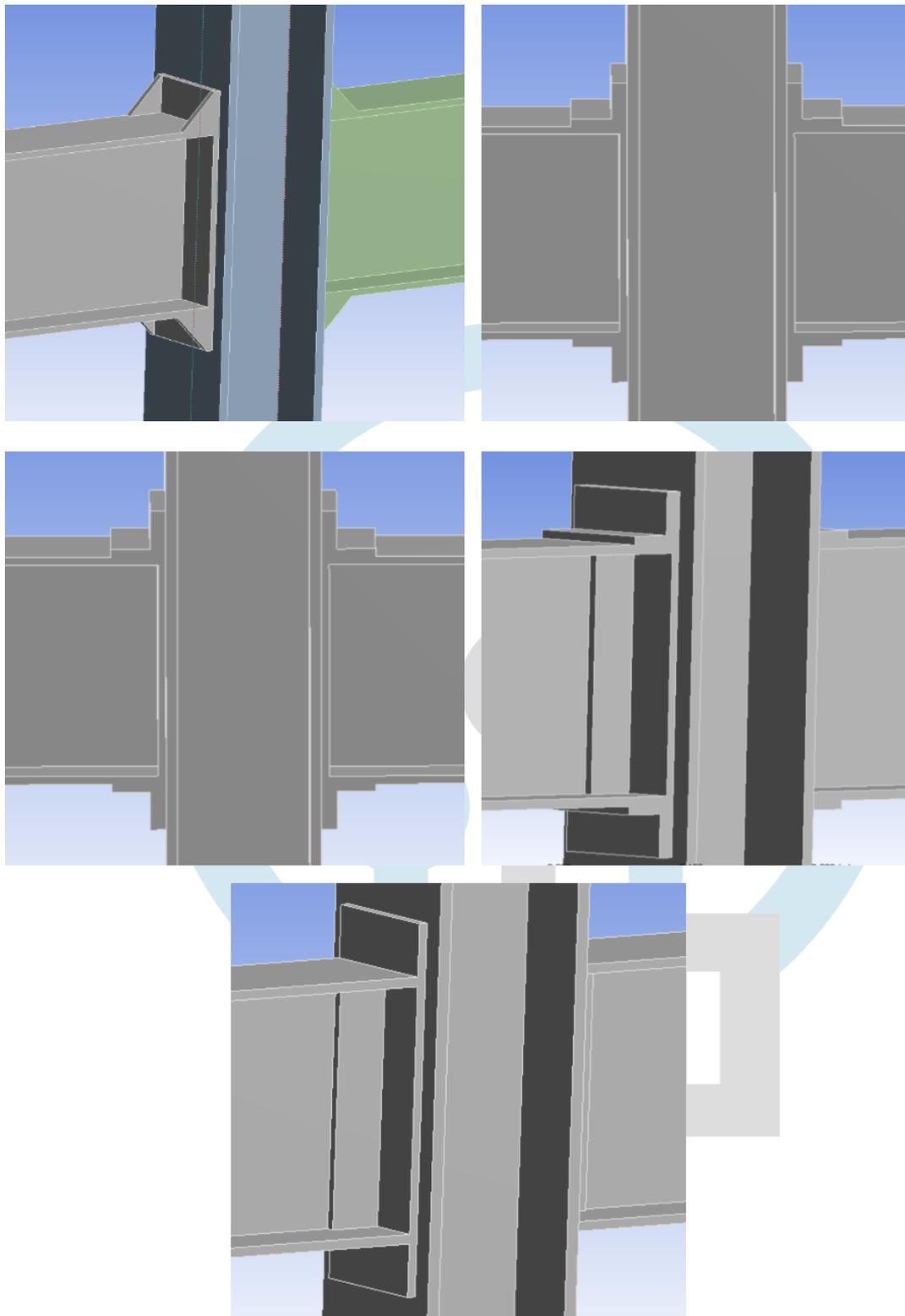


Fig.16 solid model of case-3, 4, 5, 6, 7

6. Comparison of Different Cases of Beam-Column Joints

After calculating the different performance parameters for different joint of the structure comparison was done. through comparison it can analyse the performance of particular joint with respect to particular parameters in each case of joints. The comparison of different parameters is mention in the below section. From figure it is found that the value of total deformation for case-1 is very much high as compared to other, this is mainly use of simple endplate which could not able to resist load acting of the column. Whereas with the use of different other endplate design and support, the total deformation gets significantly reduced. Through contour plots it is also analysed that for case-1 the maximum deformation is at the centre of the column-beam joint. Whereas in other cases it get slightly shifted toward the beam which help in increasing the strength of the joint.

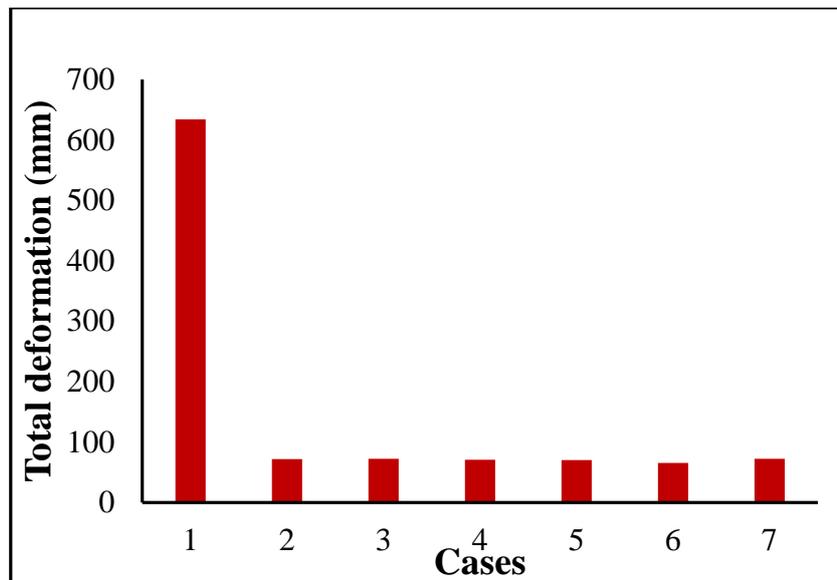


Fig.17 comparison of value of total deformation

Above figure shows the variation of equivalent stress for different cases of joint. From graph it is found that for case-6 the value is minimum as compared to other cases. It also indicates that with the design the reaction force developing at the joint is minimum as compared to other which helps in increasing the strength of the joint and make it capable to with stand at much higher load as compared to other. Comparison of value of elastic strain was done for different cases, from graph it is found that for case-6 the elastic strain is less as compared to other cases. This also indicated the low reaction force developed in the joint. Whereas as case-2 and 7 shows the maximum value of strain which indicated the maximum reaction developed in the joint when load is applied.

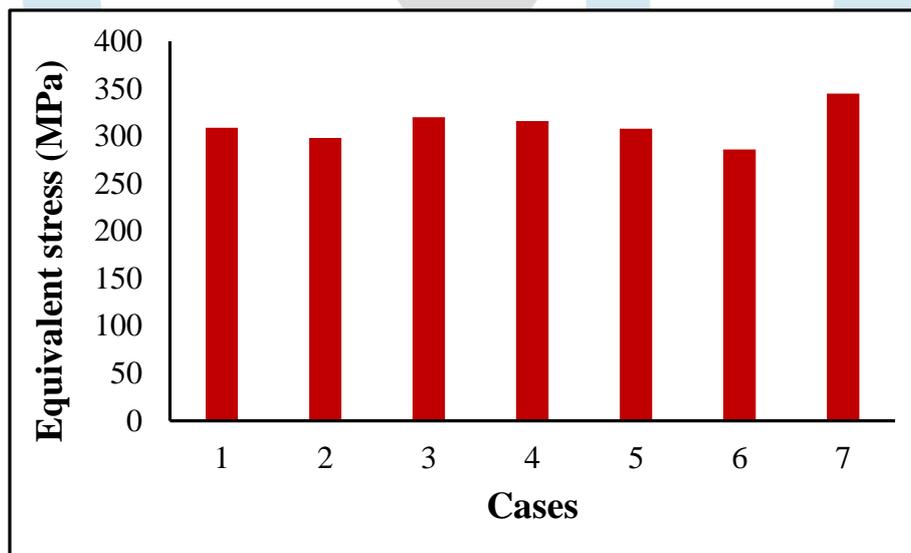


Fig.18 comparison of value of equivalent stress (MPa)

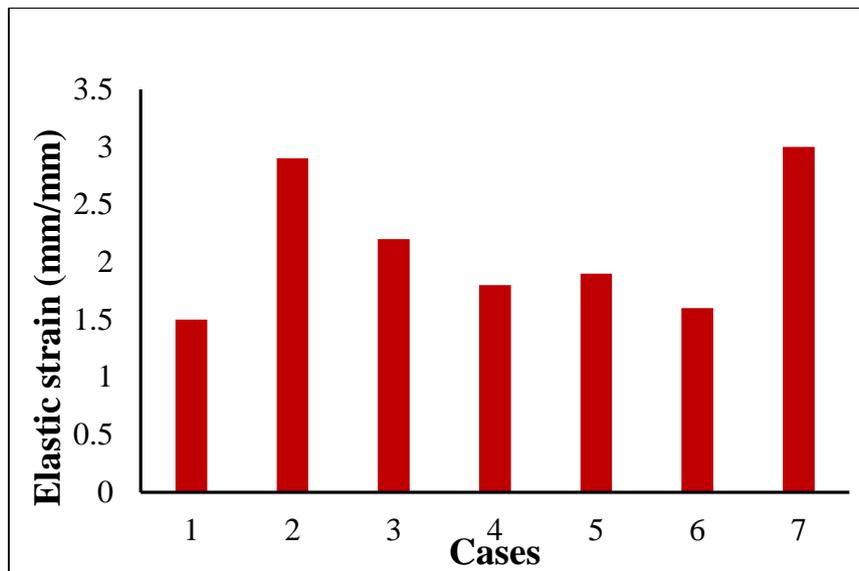


Fig.19 comparison of value of elastic strain for different cases

7. Conclusion

Through Ansys, FEM analysis of beam-column joint was successfully done. Through numerical analysis deformation behaviour of joint with respect to loading conditions was easily analysed. For case-1 as considered in the base paper the deformation is very high and also the stress concentration zone lies to the centre of the beam-column joint. Whereas with the modification in endplate the deformation get reduces and also reduces the equivalent stress value acting on the joint, which help in increasing the capacity of the joint and with stand during loading. Through analysis it is found that with case-6, the value of deformation is least as compare to other cases and also shows the lowest value of equivalent stress as compared to other. In case-6 the stress concentration zone shifted slightly toward the beam rather than lying in the middle of the joint which help in increasing the strength of the joint. The value of elastic strain is also less for case-6 as compare to other which also indicated the lesser reaction force acting in this case, which ultimately strength the joint.

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