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Strengthening of RC Beam-Column Joints Using Steel Plates and Shear Connectors

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Abstract: The role of a beam-column joint is very vital in RCC framed structures. Most of the structural collapses due to earthquakes have been initiated by the failure of the beam-column joints and therefore understanding the behavior of beam-column joints is important. The beam column joint is a crucial area where loads from the beam and columns are transferred. It becomes the most critical part of the structure when poor detailing ,unsafe design adopted in the region ,overuse or lack of maintenence.
Large numbers of retrofitting techniques are being adopted worldwide to strengthen the beam-column joint.
Analytical modelling of interior and exterior beam-column joint has been modelled by using finite element analysis software ANSYS to validate the performance. In the proposed technique beam column joint were modeled using steel plate and steel plate with shear connectors. For structural safety, especially for reinforced concrete beam–column joints, strength of the joints has to be increased. The test results show that the performance of the joints was improved by using the proposed method.
Keywords: ANSYS, Steel plate, Beam-Column joint, Shear connector, Structural collapse

I. INTRODUCTION

Most of the damages to existing reinforced concrete infrastructure are due to inadequate design, overuse and/or poor maintenance. Hence strengthening/retrofitting of such structures has become one of the most demanding construction activities. As far as RCC framed structures are concerned, the beam-column joints are crucial elements which are prone to failure. Arun Raj Ebanesar [3] They shows that experimental and analytical investigation improvement in seismic performance was found in the beam column joint by providing wire mesh and steel plate, which absorbs the lateral input energy more than the conventional joint. This method can be effectively used as new earthquake resistant construction. Sasmal and Voggu [20] Studied the quality of RC beam-columnjoints is considered by two variety of internal beam-column joints. The shear strength of the joints is tested analytically using the method of soft strut and tie.It is reflected by the analysis that subsequentenergy dissipation per cycle drift offers a lot better perspective than the cumulative energy dissipation. The proposed technique Strengthening of Beam-Column joint using steel plates and shear connectors is introduced. Internal strengthening of beam column joint processing with parametric study. From the parametric study an optimum dimension for steel plates is obtained. The results proving that the joint performance improved by increased load carrying capacity of the joint and the failure location that also moved from the joint.

II. OBJECTIVE

To perform nonlinear FEA of beam column joint with internal strengthening using steel plate under various parametric study subjected to monotonic loading.
1) Effect of plate length
2) Effect of plate Height
3) Effect of plate Thickness
4) No of plates (Single,Double)

III.METHODOLOGY

The main goal of this project is to strengthen the Beam-Column joint using steel plate and shear connectors under various parameters and to investigate the performance of the joint by internal and exteernal strengthening. The study's primary goal is to use the ANSYS WORKBENCH software to analyse and compare the performance and determine the ultimate load, deflection and the failure location.

A. Modelling of Structure

The Beam-Column joint specimen was modeled using ANSYS Workbench. The proposed conventional model is shown in fig 1. A monotonic displacement was applied to the beam to analyse the performance of joint and to identify the failure location. The grade of concrete in the frame members was M25 with the specified characteristic compressive strength of 25 MPa and the grade of reinforcement is Thermo-mechanically Treated(TMT) bars with the specified yield strength of 415 MPa. Modulus of Elasticity of concrete E_c = 15000MPa, Characteristic strength of concrete f_{ck} = 25MPa, Poisson's Ratio = 0.2, Modulus of Elasticity of steel E_s = 210000MPa. All columns of the study are chosen to be size 200mmx300mm and height 2300mm. whereas, the size of the beam sections is considered as 200mmx300mm and height 900mm. The design for shear reinforcement in beam and column sections was carried out as per IS 456:2000 design provisions. The FEM model of specimens is shown in Fig 1 to 2.

TABLE I

MODEL	DIMENSION(mm)	HEIGHT(mm)
Beam	200x300	900
Column	200x300	2300

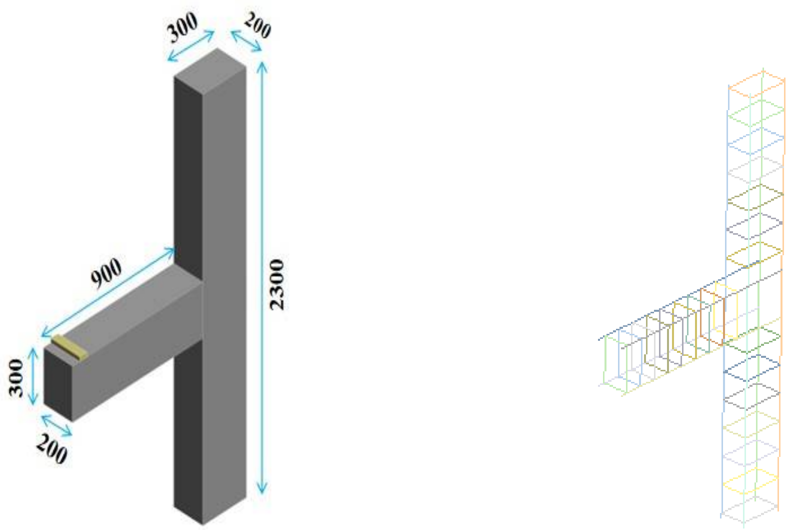


Fig -1(a) Fig -1(b)

Fig-1 : Modelled Beam-Column Joint a) geometry ; b) reinforcement details in model of conventional specimen(without steel plate for strengthening)

TABLE III

Plate length (mm)		Plate Height (mm)	Plate Thickness (mm)	No. of Steel Plates	Steel Volume Constant (mm)
250	-	-	-	-	-
300	250+50				
350	250+100	100	5	1	
400	250+150	150	10	2	150x100x5
450	250+200	200	15	2	300x100x2.5

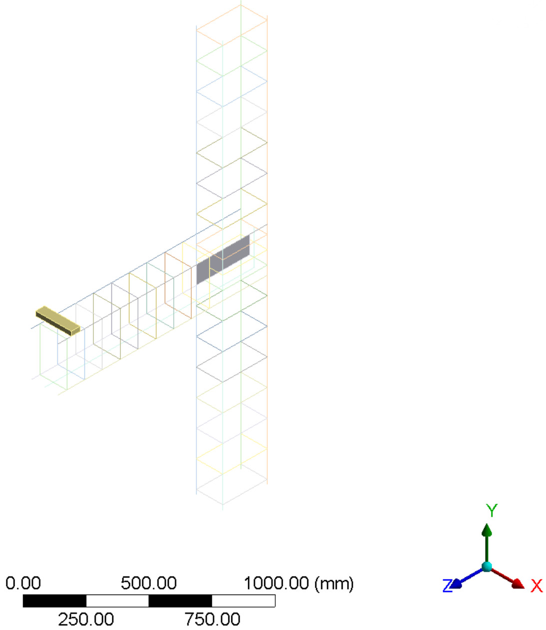


Fig-2 : Modelled Beam-Column Joint (steel plate is connected internally)

B. Boundary conditions and loading

The bottom and top end of the support is fixed . Loading plate is located at the end of beam. Load on the beam was applied monotonically. Corresponding deflection and load where noting for analysing the performance of joint under various parameters. The procedure was continued till failure of beam occurs.

IV. RESULT AND DISCUSSION

The model is subjected to nonlinear static analysis under monotonic loading with various parameters and Figure 3 to 13 represents the total deformation and plastic strain of the models.

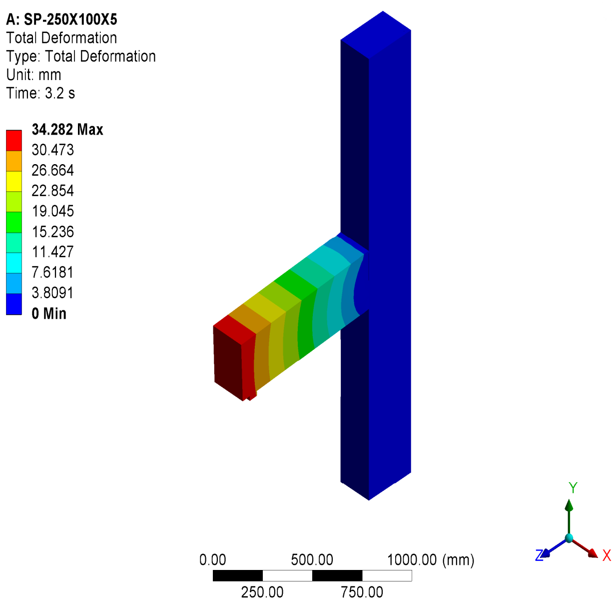


Fig 3- (a)

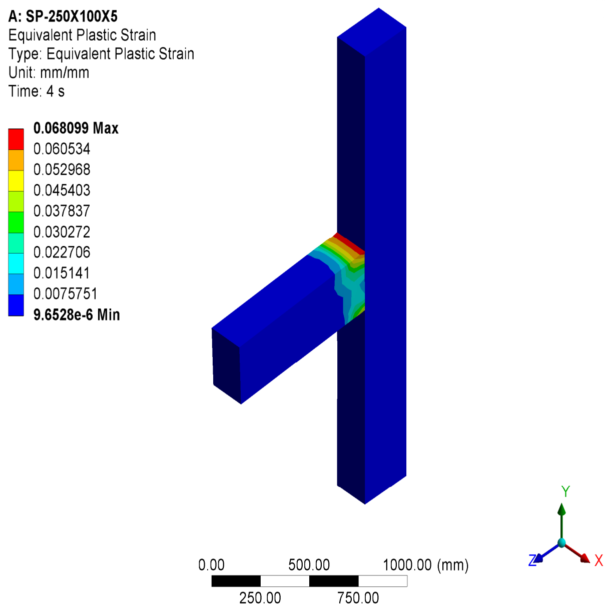


Fig 4- (a)

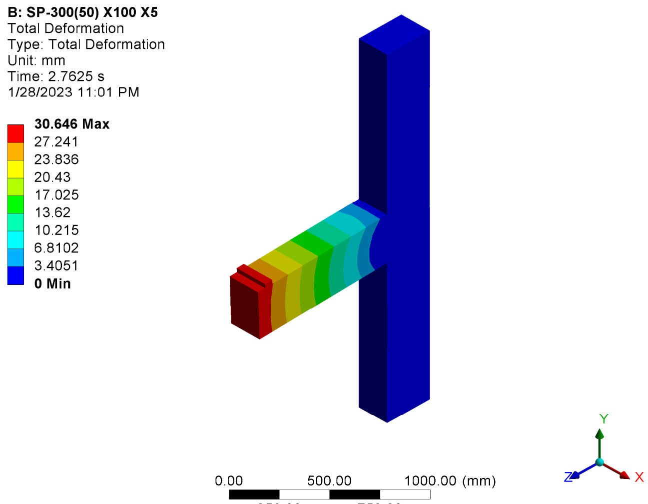
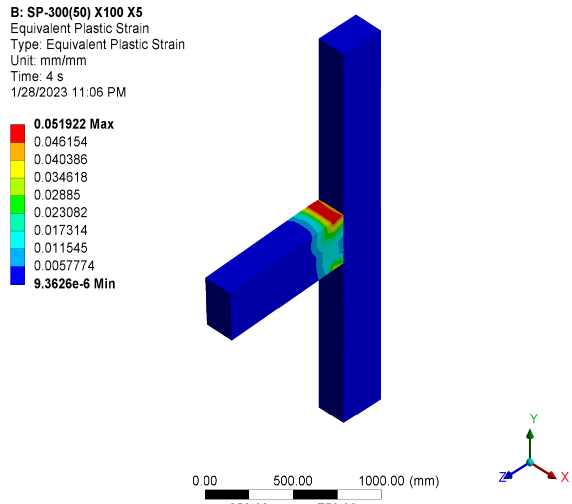


Fig 3- (b)



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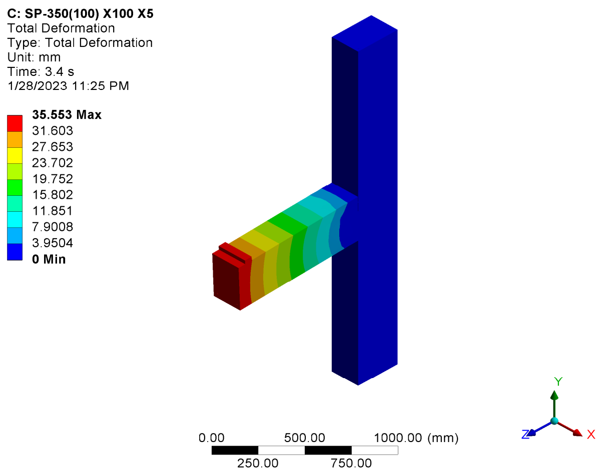

Fig 3- (c)

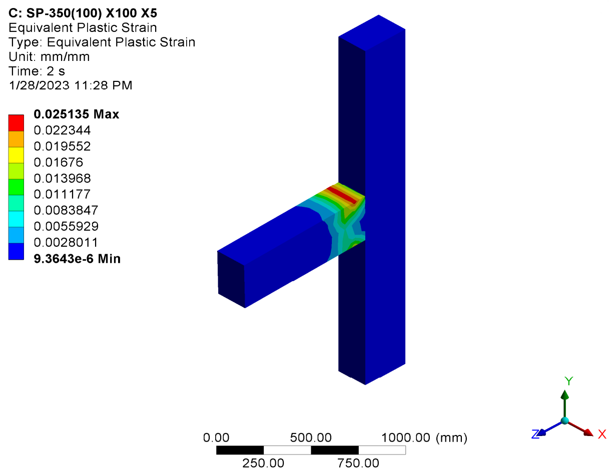

Fig 4- (c)

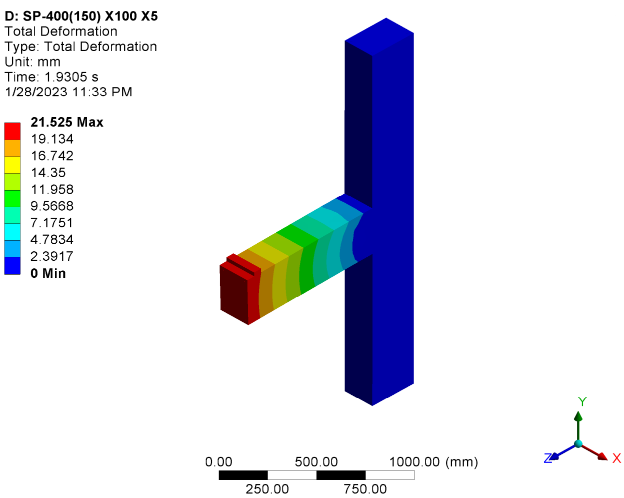

Fig 3- (d)

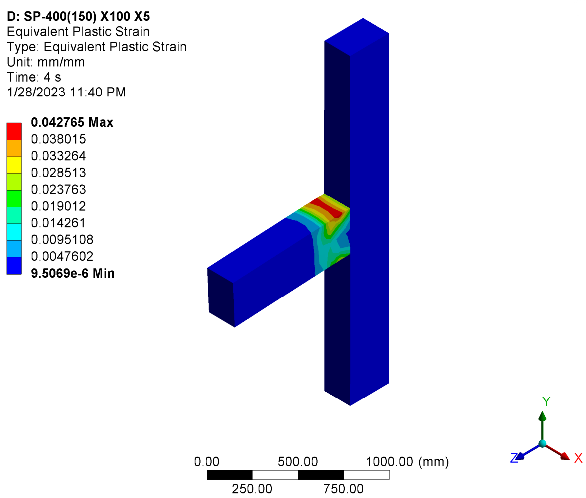

Fig 4- (d)

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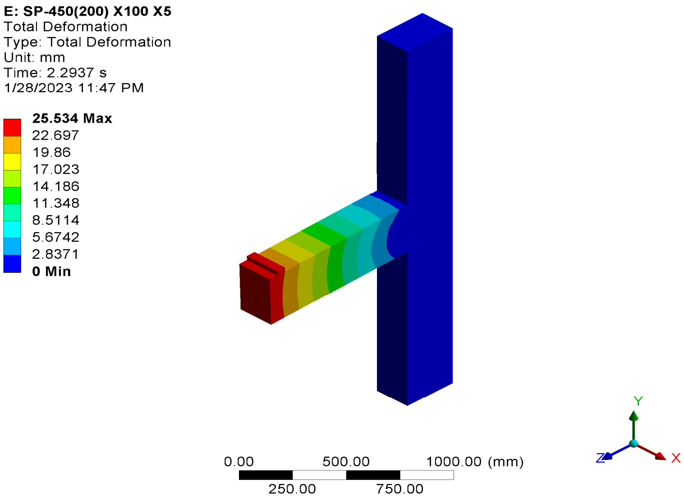

Fig 3- (e)

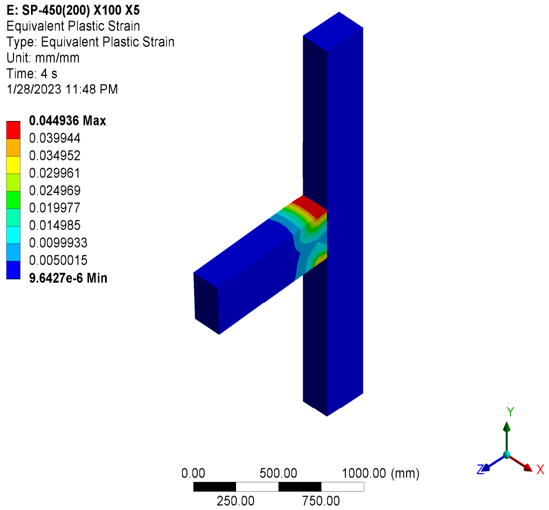

Fig 4- (e)

Fig-3 & 4 : Total Deformation and Plastic strain of Beam - Column Joint with steel plate having length 250, 300, 350, 400 & 450mm, height 100mm and thickness 5mm a) Plate length 250 ; b) Plate length 300mm ; c) Plate length 350mm ; d) Plate length 400mm ; e) Plate length 450mm.

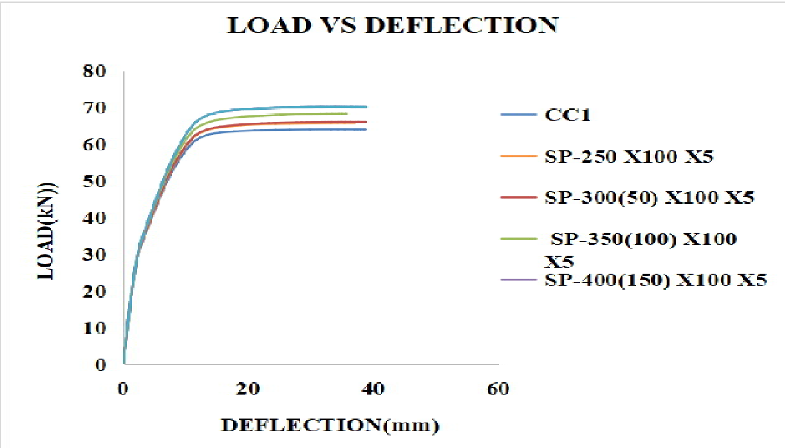

Chart 1 -: Load - Deflection Curve

MODEL	DEF(mm)	LOAD(KN)	LOAD(N)	% INCR IN L OAD
CC1	34.313	63.981	63981	1
SP-250 X100 X5	34.282	65.741	65741	2.750
SP-300(50) X100 X5	30.646	66.001	66001	3.157
SP-350(100) X100 X5	35.553	68.308	68308	6.762
SP-400(150) X100 X5	21.525	69.65	69650	8.860
SP-450(200) X100 X5	25.534	69.931	69931	9.299

Table 3 : Analysis result of models having various plate length

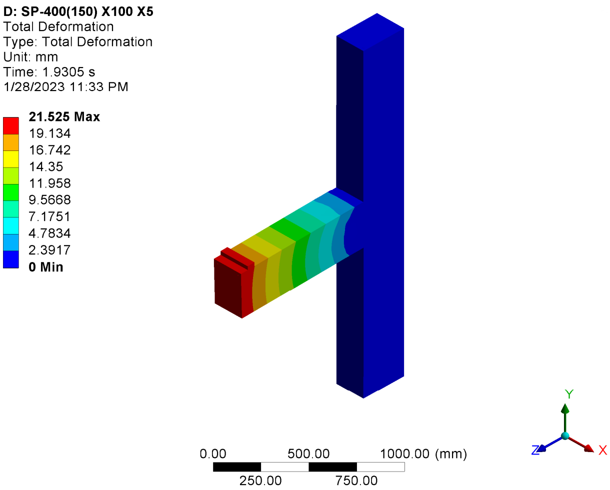

Fig 5- (a)

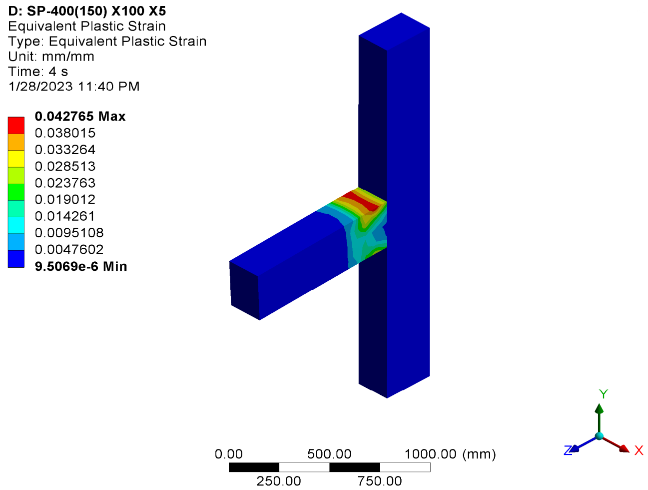

Fig 6- (a)

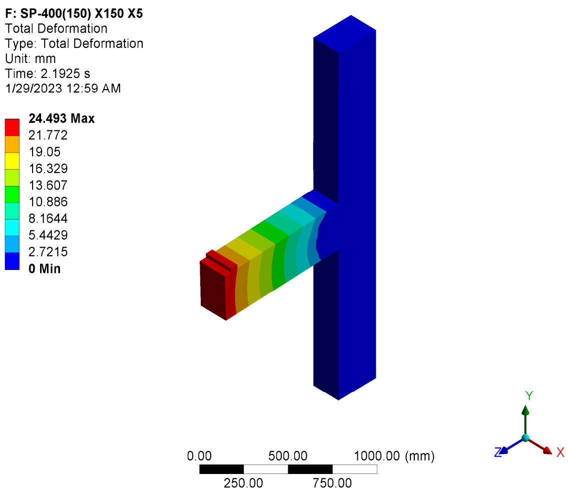

Fig 5- (b)

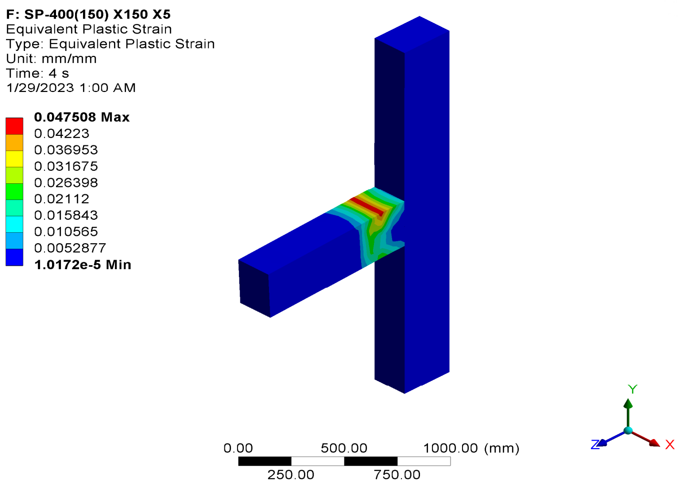

Fig 6- (b)

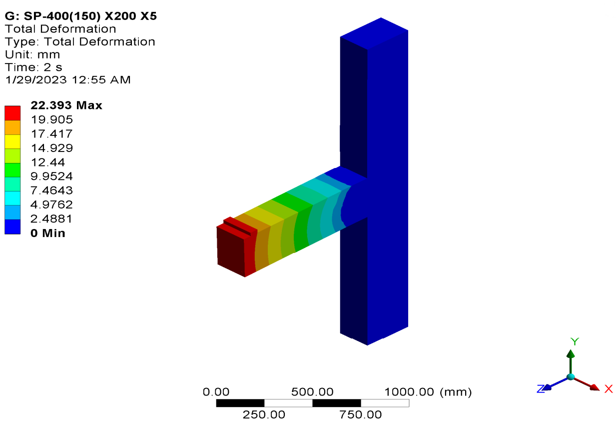

Fig 5- (c)

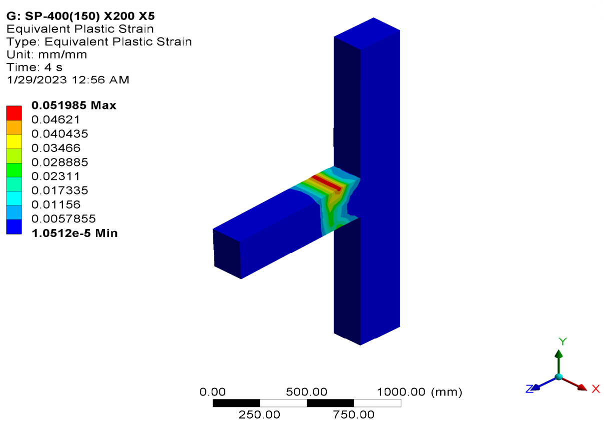

Fig 6- (c)

Fig-5 & 6 : Total Deformation and Plastic strain of Beam - Column Joint with steel plate having height 100 ,150 & 200mm, length 400mm and thickness 5mm a) Plate Height 100 ; b) Plate Height 150mm ; c) Plate Height 200mm.

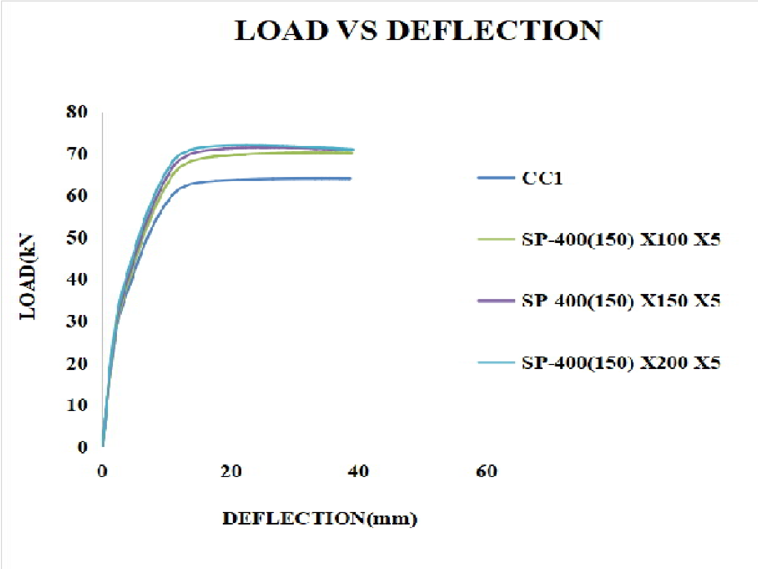

Chart 2 -: Load - Deflection Curve

MODEL	DEF(mm)	LOAD(KN)	LOAD(N)	% INCR IN LOAD
CC1	34.313	63.981	63981	1
SP-400(150) X100 X5	21.525	69.65	69650	8.860
SP-400(150) X150 X5	24.493	71.296	71296	11.433
SP-400(150) X200 X5	22.393	71.863	71863	12.319

Table 4 : Analysis result of models having various plate height

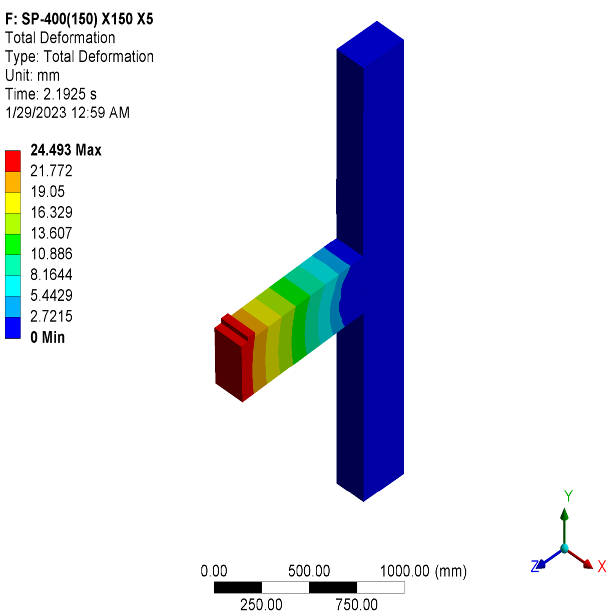

Fig 7- (a)

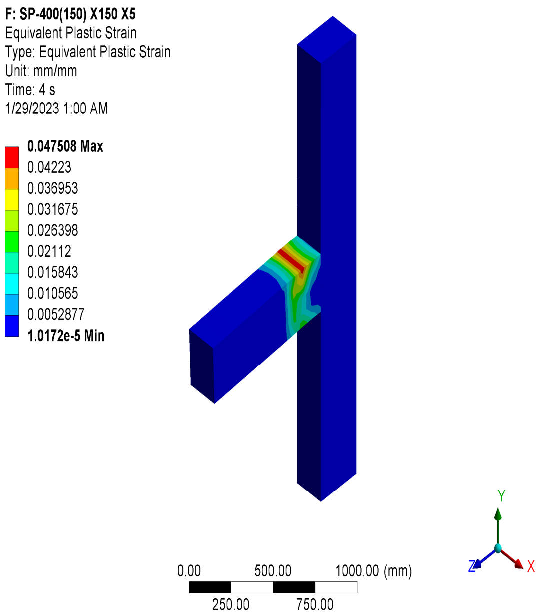

Fig 8- (a)

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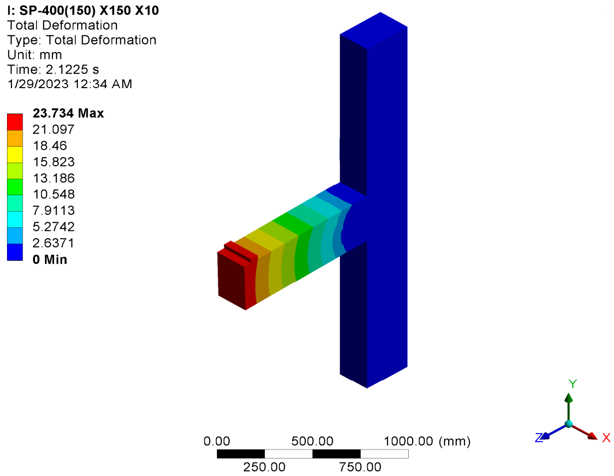

Fig 7- (b)

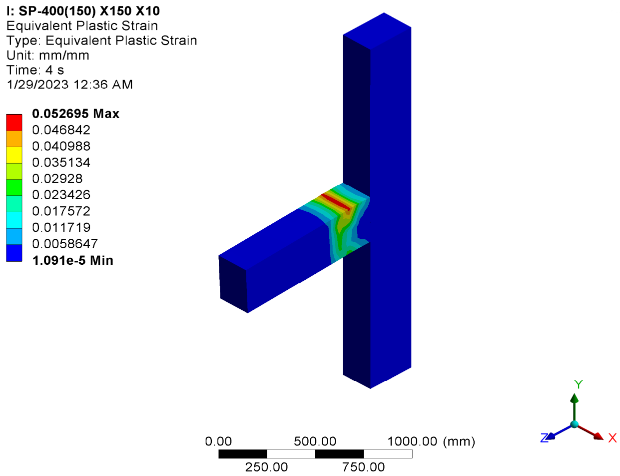

Fig 8- (b)

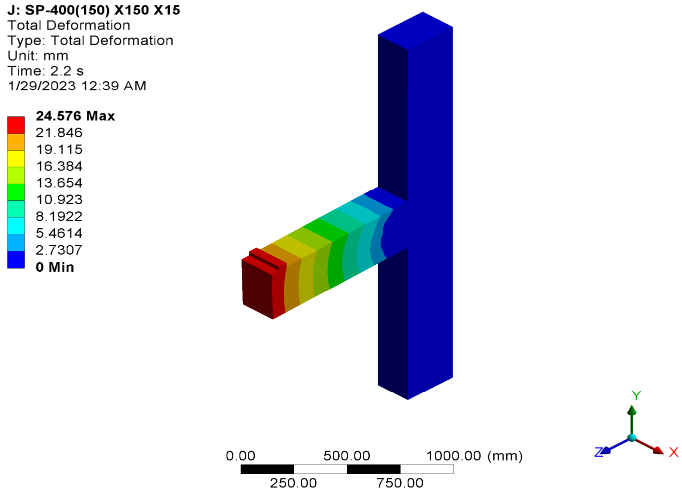

Fig 7- (c)

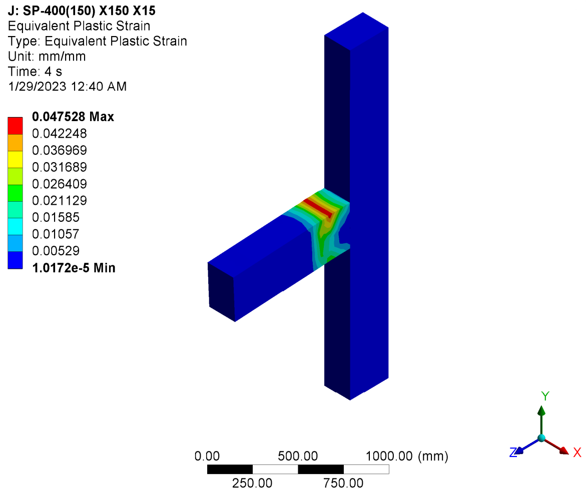

Fig 8- (c)

Fig-7 & 8 : Total Deformation and Plastic strain of Beam - Column Joint with steel plate having thickness 5,10 & 15mm, length 400mm and height 150mm a) Plate thickness 5mm ; b) Plate thicknrss 10mm ; c) Plate thickness 15mm.

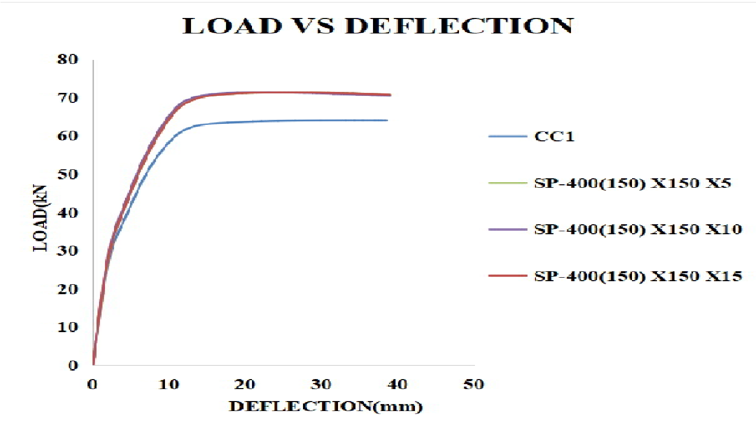

Chart 3 -: Load - Deflection Curve

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MODEL	DEF(mm)	LOAD(KN)	LOAD(N)	% INCR IN LOAD
CC1	34.313	63.981	63981	1
SP-400(150) X150 X5	24.493	71.296	71296	11.433
SP-400(150) X150 X10	23.734	71.307	71307	11.450
SP-400(150) X150 X15	24.576	71.285	71285	11.415

Table 5 : Analysis result of models having various plate thickness

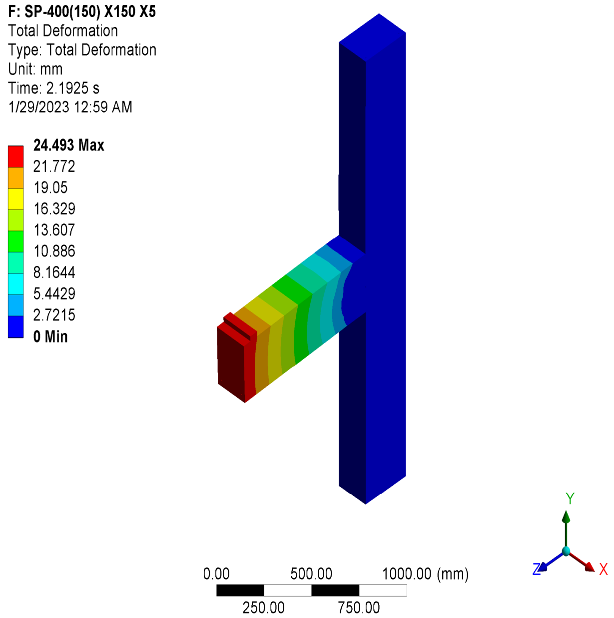

Fig 9- (a)

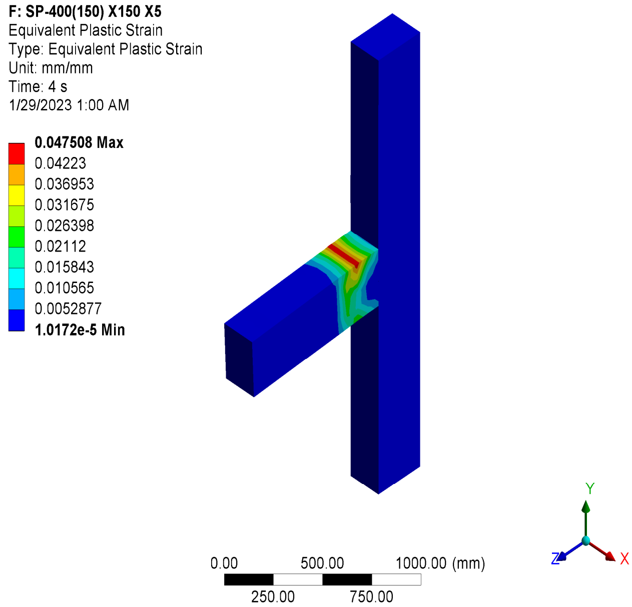

Fig 10- (a)

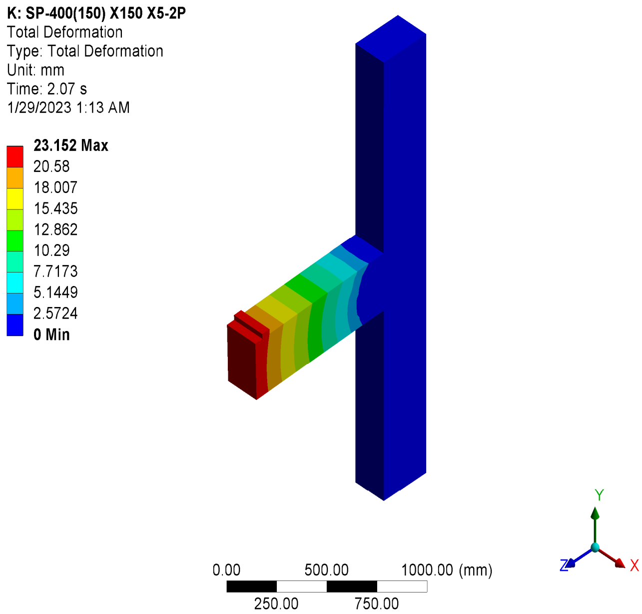

Fig 9- (b)

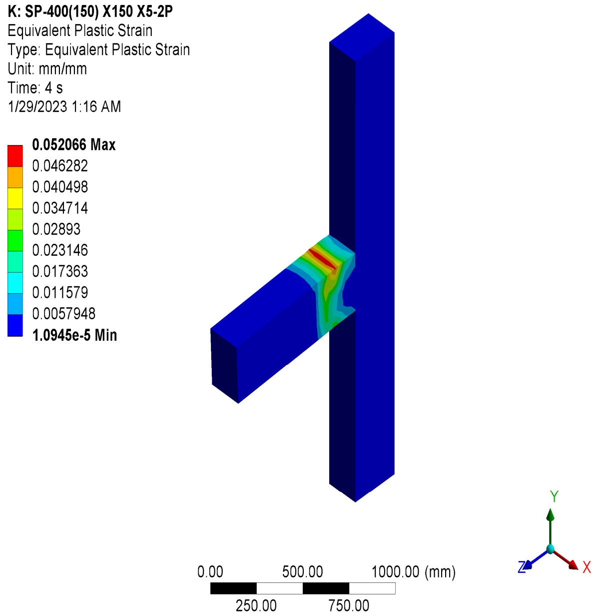

Fig 10- (b)

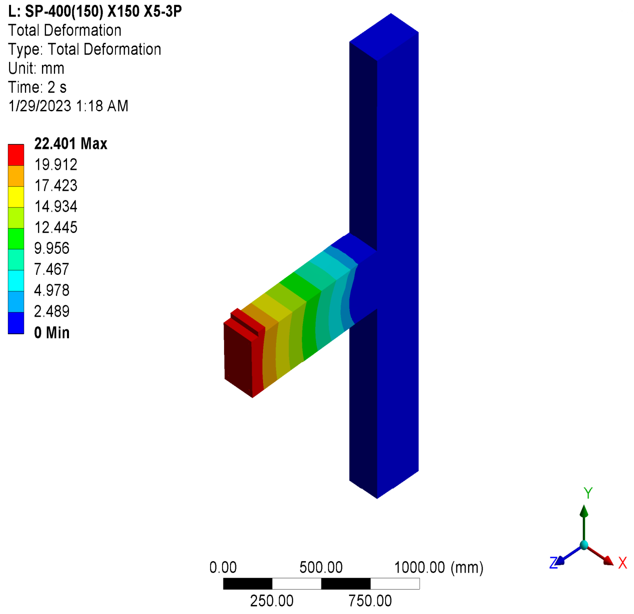

Fig 9- (c)

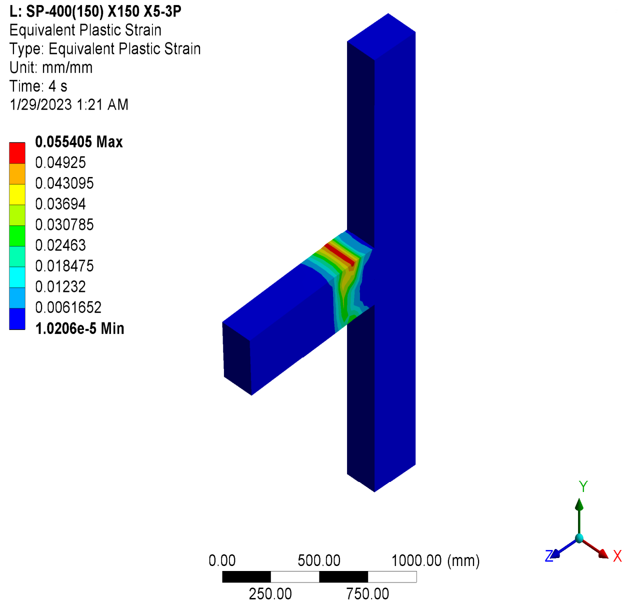

Fig 10- (c)

Fig-9 & 10 : Total Deformation and Plastic strain of Beam - Column Joint with steel plate having thickness 5,10 & 15mm, length 400mm and height 150mm a) Plate thickness 5mm ; b) Plate thicknrss 10mm ; c) Plate thickness 15mm.

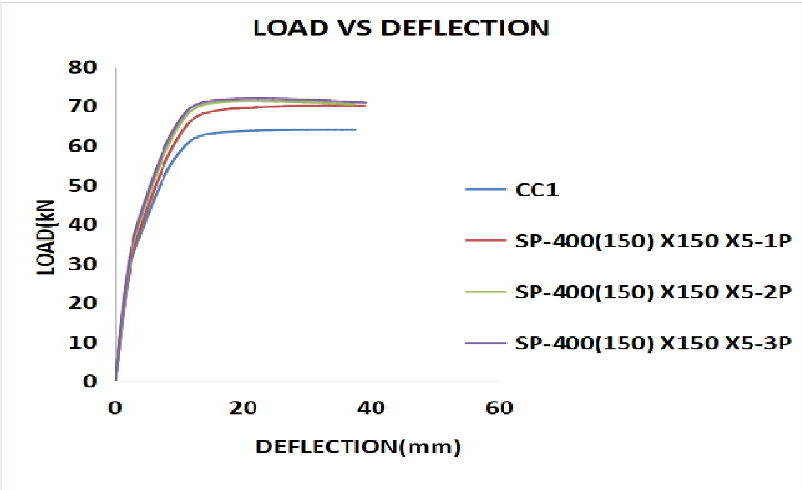

Chart 4 -: Load - Deflection Curve

MODEL	DEF (mm)	LOAD (KN)	LOAD(N)	% INCR IN L OAD
CC1	34.313	63.981	63981	1
SP-400(150) X150 X5-1P	24.493	71.296	71296	11.433
SP-400(150) X150 X5-2P	23.152	71.265	71265	11.384
SP-400(150) X150 X5-3P	22.401	71.868	71868	12.327

Table 6 : Analysis result of models having various plate numbers

V. CONCLUSIONS

A Beam column joint with steel plate is designed. Beam column joint with various length, height, thickness and different number of plates are modelled and they are allowed to testing under monotonic loading.

1) Steel plates having varying length 50mm, 100mm, 150mm and 200mm are studied. From this study it is observed that almost 9.29% of load is increased. Beyond 150mm the load carrying capacity is not very much improved. Hence 150mm is the effective length of steel plate can be used inside for the strengthening of beam-column joint.
2) Steel plates having varying height 100mm, 150mm and 200mm are studied. From this study it is observed that almost 12.4% of load is increased. Beyond 150mm the load carrying capacity is not very much improved. Hence 150mm is the optimum height of steel plate can be used inside for the strengthening of beam-column joint.
3) Steel plates having varying thickness 5mm, 10mm and 15mm are studied. From this study it is observed that almost 11.5% of load is increased. There is no much changes observed in load carrying capacity while doing the parametric study using changing the thickness. So minimum 5mm thickness is recommended for the improvisation of joint strengthening.
4) Placing the plate with different number, it is observed that upto 12% of load is increased. The optimum performance is observed on the plate with two numbers. Beyond two numbers, placing three plates has no significant improvement in performance. Hence the steel plate having 400(150)x150x5 with two number of plates are considered the optimum dimensions for internal strengthening of beam-column joint.
5) From the analysis the optimum dimension of steel plate is **400(150)x150x5**. Two number of steel plates having length 400mm, height 15omm and thickness 5mm is recommended for the Beam-Column joint strengthening.

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