International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 6, September-October 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Analysis of High Rise Building Connection for Square Hollow Beam and Column Using Fem Software Abaqus

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ABSTRACT

Most of the steel structures in India are made of conventional steel sections (such as angle, channel and beam sections). However, new hollow steel sections (such as square and rectangular hollow sections) are gaining popularity in recent steel constructions due to a number of advantages such as its higher strength to weight ratio, better fire resistance properties, higher radius of gyration, lesser surface area, etc. This type of hollow sections can save cost up to 30 to 50% over the conventional steel sections (Tata Steel brochure, 2012-17). But unlike the conventional steel sections these hollow sections do not have standard connection details available in design code or in published literature. To overcome this problem the objective of the present study was identified to develop a suitable and economic connection detail between two square hollow sections which should be capable of transmitting forces smoothly and easy to be fabricated. To achieve the above objective, a square hollow beam to square hollow column connection was selected and modeled in commercial finite element software ABAQUS. This model was analyzed for nonlinear static (pushover) analysis considering a number of connection details. Following four alternative scheme of connection details were selected for this study: (i) using end-plate, (ii) using angle section, (iii) using channel sections, and (iv) using collar plates. The base model (rectangular hollow beam welded to one face of the rectangular hollow column) is also studied for reference. The performance of the selected connection details are compared and the best performing connection details is recommended for rectangular hollow beam-to- rectangular hollow column joints. The result shows that the load carrying capacity of the joint and the maximum deformation capacity is highly sensitive to the type of connection used. Also, the location of formation of plastic hinges in the structure (which can beat joint or at beam) depends highly on the type of connection used.

KEYWORDS: *hollow sections, nonlinear (pushover) analysis, capacity curve, plastic hinge, deformation, Connection*

How to cite this paper: Udit Dubey | Kapil Mandloi | Renu Tiwari "Analysis of High Rise Building Connection for Square Hollow Beam and Column Using Fem Software Abaqus" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-6, October 2021, pp.1727-1733, URL: www.ijtsrd.com/papers/ijtsrd47704.pdf

IJTSRD47704

I. INTRODUCTION

Connecting technology plays an important role in the performance of hollow section structures. A distinction has to be made between CHS and RHS connected members, because the behavior of joints, e.g. local behavior of members is different. A particular case is represented by beam-to- column joints in building frame with Concrete Filled Hollow Section (CFHS) columns. Both welded and or bolted connections can be used in such a case .For beam-to-column joints of hollow section frames(e.g. RHS columns and beams or hollow section columns and I or H section beams),blind bolting technology is available. These section summaries the main aspects concerning the behavior and design of hollow section connections loaded predominantly statically. This means they can also be used for seismic resistant buildings, since seismic motions are not considered as generating fatigue phenomena. European standard [p

Re N 1993-1-8: 2003],application rules to determine the static resistances of uni-planar and multi-planar joints in lattice structures composed of circular, square or rectangular hollow sections, and of uni-planar joints in lattice structures composed of combinations of hollow sections with open sections.

Most of the steel structures in India are made of conventional steel sections (such as angle, channel and beam sections) and were designed by conventional working stress methods. However, new hollow steel sections (such as square and rectangular hollow sections) are gaining popularity in recent steel constructions due to a number of advantages. Not only the hollow sections make the entire structure light weighted as they possess high strength to weight ratio, also they have higher efficiencies in resisting forces in comparison to conventional steel sections. The hollow sections also have better fire resistance properties. Higher radius of gyration, lesser surface area of the sections result savings in transportation, fabrication and painting costs. According to a recent study (Tata Steel Hollow section brochure), up to 30 to 50% saving in cost can be achieved by using hollow steel sections over the conventional steel sections. The steel industry in India started producing such hollow sections and making them available to the builders in regular basis. Fig. 1 presents photograph of typical rectangular hollow section (RHS) available in India. This development has brought attention of researcher to the connection Design which is a very important aspect of steel design and construction. Unlike the conventional steel sections these hollow sections do not have standard connection details available in design code or in published literature. The application of hollow sections is notrising up as suitable connection configurations (for shear force and bending moment) have not been developed between the sections.

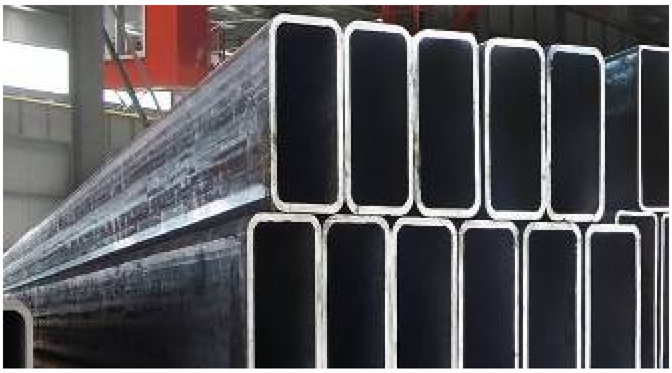


FIG.1.1: TYPICAL RECTANGULAR HOLLOW SECTION (RHS) AVAILABLE IN INDIA

Sufficient research works have been done on the connections between conventional beams and columns (especially I-beam, I-column), but very little information are available on the seismic connections between hollow beams to hollow columns. Direct extensions from connections detailing between the conventional sections are also not feasible as there are certain differences in geometry between hollow and conventional sections. As the thickness of the walls in hollow box sections are usually very small (4-8 mm) the possibility of local failure is very high if connection is designed without proper analysis. According to the current practice ,full penetration of welds are used in joints involving smaller hollow sections and for large hollow sections diaphragms are inserted in columns at beam flange level. However this is not fully capable of resisting the fracture under seismic loading and also involves a lot of fabrication works resulting the hike in cost of the structure. The use of bolts can be an alternative as it would give considerable tolerances in fabrication but for tightening of nuts the access on the inside for the conventional bolts cannot be provided everywhere. To overcome these problems a suitable and economic connection detail should be designed between two hollow sections which should be easy to fabricate and should be capable enough to resist loading. It is known that the Northridge (1994) and Kobe (1995) earthquakes showed deficiencies in the seismic performance of steel buildings, mainly in the behavior of their connections, initiating a search for new alternatives in configurations of steel structural systems and connections with capacity to achieve an acceptable level of performance.

II. OBJECTIVES OF RESEARCH WORK:

Based on the literature review presented above the main objective of the present study is identified as to develop improved beam-to-column connection detail for square hollow beam to square hollow column ensuring smooth flow of forces.

1. To establish limit state capacities of each storey of framed building for various 4 performance levels.
2. To develop probabilistic seismic demand model (PSDM) and fragility curves for benchmark OGS framed buildings designed with various schemes of MF.
3. To develop reliability index for OGS framed buildings designed with various schemes of MF.
4. To propose appropriate schemes of MF for the design of OGS buildings based on the reliability indices achieved by the benchmark frames.

III. LITRATURE RIVEW

Kumar (2013) studied on the behaviour of OGS buildings with different MFs proposed by different

International codes in a probabilistic frame work using fragility curves (2000 SACFEMA method) and reported that application of MF only in the ground storey may not provide the required performance, rather it leads to more damage to the adjacent storeys. There are many literatures available (Kaushik et al., 2009; Tian and Symans, 2012; Sahoo and Rai, 2013 and many others) on the various techniques of retrofitting OGS buildings.

Prof. Dr. Eduardo et al (2016) studied the connection concept is a key point in the design of steel structures which affects fabrication, erection procedures and the final costs. Welding processes have been extensively used for tubular trussed girders by combining shop welding with bolted flange solutions to facilitate straightforward connection procedures during erection. The present research addresses the behavior of innovative beam-to-column bolted connections for steel rectangular hollow sections (RHS) which combine simplicity in fabrication and erection, favorable aesthetics for the case of visible structures and structural effectiveness. Four cruciform prototypes were tested under a static non-reversible bending moment with different bolted conditions:

1. NON-FRICTION
2. FRICTION CONNECTION

The experimental results show that the proposed geometry with friction connections is able to develop a rigid elastic moment–rotation response up to usual loading conditions.

Eduardo Nuñez C.1et al (2017) was study to propose a new moment connection, EP-HSS ("End-plate to Hollow Structural Section"), using a wide flange beam and HSS column through a configuration that is out of the range of prequalification established in the ANSI/AISC 358-10Specification, as an alternative to the traditional configuration of steel moment frames established in current codes. From an analytical, numerical (FEM)and experimental study, based on qualification protocols established in the ANSI/AISC341-10Specification,theresultsshowed that the EP-HSS allows the development of inelastic action only on the beam, avoids stress concentration in the column and develops a high energy dissipation capacity, ensuring satisfactory performance under seismic actions without brittle failure mechanisms, satisfying the requirements and protocols established in the AISC (American Institute of Steel Construction) Specifications for seismic zones.

METHODOLOGY

To achieve the above objectives the following methodologies have been worked out:

- Select the geometry of a square hollow beam to square hollow column connection
- Model the selected connection in commercial finite element software **ABAQUS**
- Plan for possible alternative connection details for the selected beam-to-column connection.

Analyze the selected beam-to-column connection for nonlinear static analysis considering all the selected connection detail.

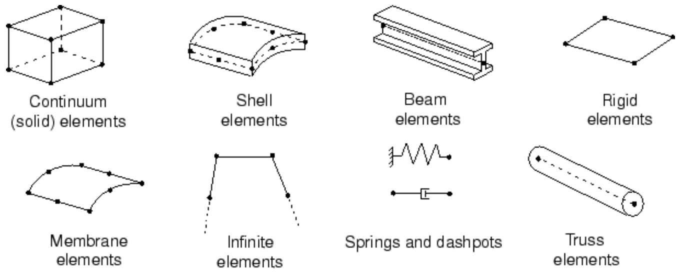


FIG 3.1 ELEMENTS FAMILY (MANUAL TUTORIAL ABAQUS 6.12)

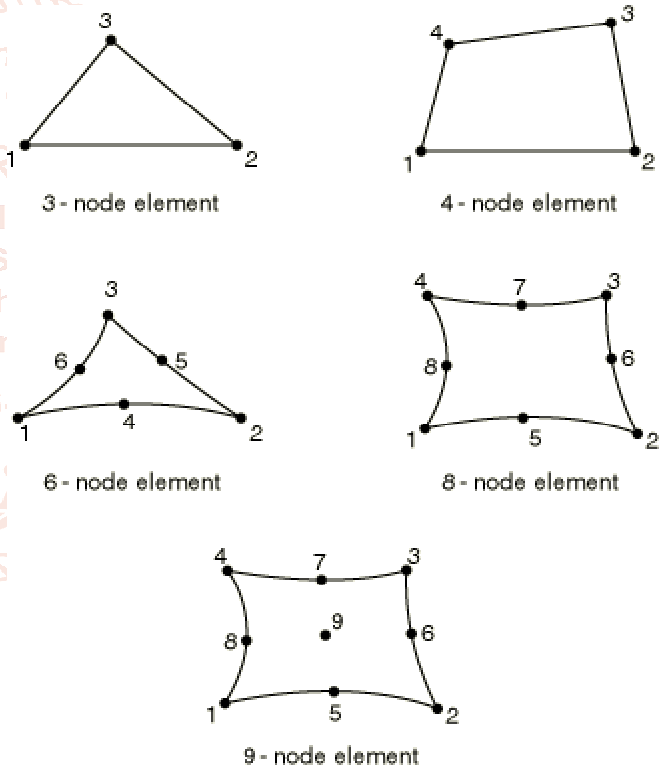


FIG3.2 INTERPOLATION POINTS–NODE ORDERING ON ELEMENTS (MANUAL TUTORIAL ABAQUS6.12)

GEOMETRIC MODELLING

As the elements required for modeling in the FE software have already been discussed in the above, now another important thing required to proceed in this research topic is the modeling of the geometry of the problem. As it has been already stated that the main objective of this work is to design a suitable connection between two box sections, the modeling part should contain box sections and other suitable sections (like angle, plate) to design a beam column connection. This part consists of the different types of proposed connection details modeled with the help of ABAQUS, their physical and FE characteristics, Boundary conditions

Basic Connection

Two exactly similar square hollow sections are modeled with the help of ABAQUS and the connection is done by tie. No welding or bolting is done in this connection. The dimension of both the sections are 200×200×8 mm. Length of both the sections are 3000 mm. Boundary conditions are kept at the column ends as both sides hinged. The connection is shown in the below.

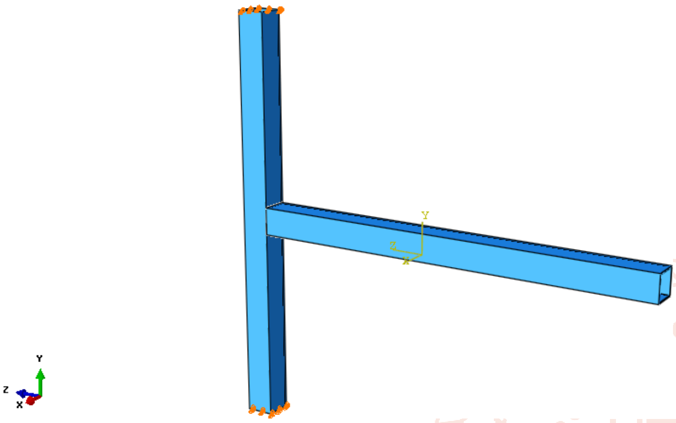
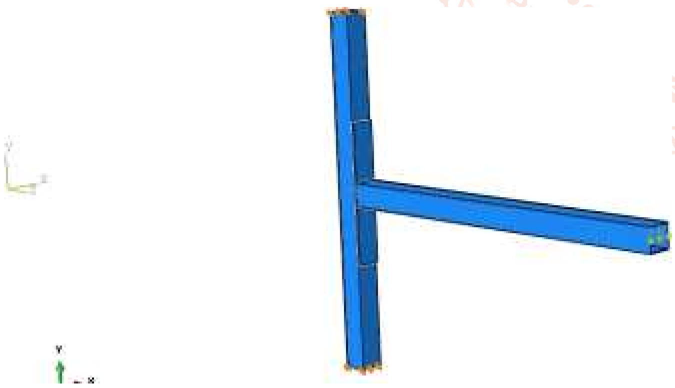


FIG 3.6: BASIC CONNECTION DETAIL

CONNECTION DETAIL USING END-PLATE

An end plate is connected at the beam column joint of the basic connection which is shown above. The thickness of the end plate is 10 mm. The mesh size of the end plate is kept 40mm square. The dimension of the plateis 200×1000×8



CONNECTION DETAIL USING ANGLE SECTION

In this type of connection detail four angle sections are connected with the box sections at the beam column junction. The mesh size of the angle sections are kept as 45 mm square. The dimension of each angle sectionis100×100×10 mm.

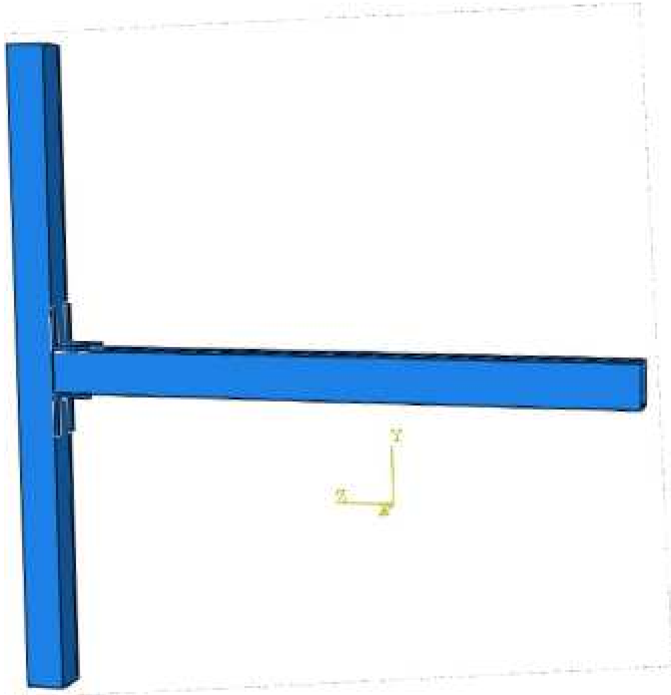


Fig 3.8: Connection detail using angle sections

CONNECTION DETAIL USING CHANNEL SECTIONS

Two channel sections are used in this type of connection detailing. They are basically used for jacketing the column section at beam column junction. The dimension of each channel section is 200×500×6mm. The mesh size of the channel section is 40mm square.

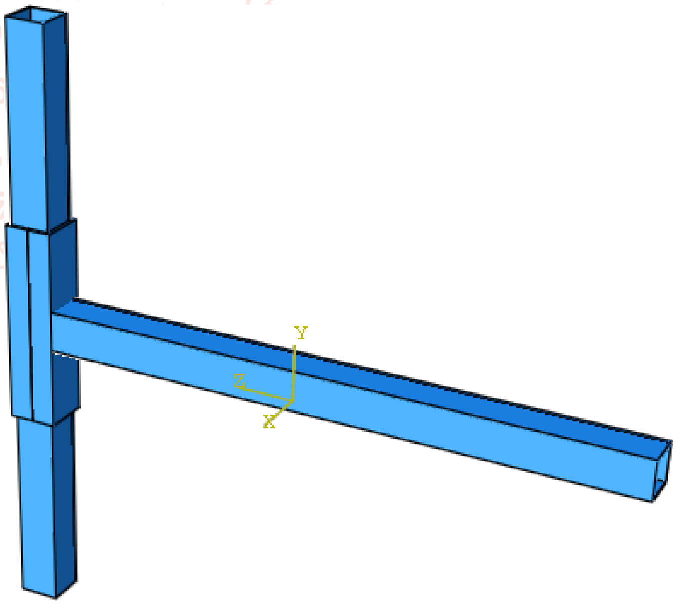


FIG3.9: CONNECTION DETAIL USING CHANNEL SECTIONS

CONNECTION DETAILS USING COLLAR PLATE:

This type of connection consists of two collar plates and twelve triangular plates. The collar plate is made by connecting two 'C' shaped plate of thickness 10 mm welding face to face. The collar plates thus formed is then welded at the column at the upper and lower part of the beam column junction. The triangular plates are the welded between the column face and the collar plates to make a rigid connection. The dimension of the triangular plates are taken as 200×100×8mm.Themeshsizeis taken as 40 mm square

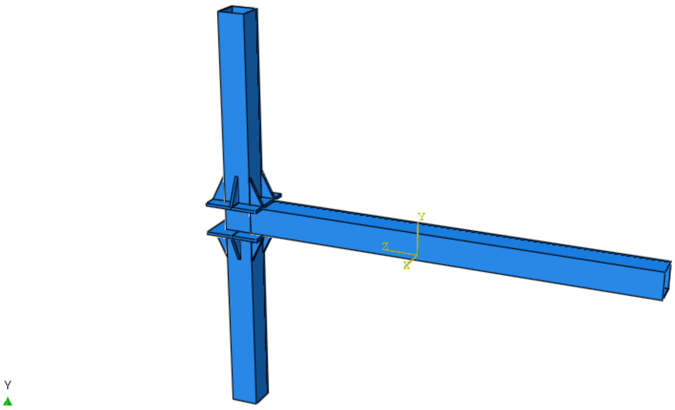


FIG3.10: CONNECTION DETAIL USING COLLAR PLATES

MATERIAL MODELLING

Linear elastic analysis does not reflect the true behavior of structure under ultimate loads, and i t becomes necessary to model the material non-linearity when the structure is subjected to large deformations (due to forces like earthquake). To model the material nonlinearity in the present study stress strain curve of steel is considered as per. Fig. 2.11 presents the stress- strain relation of mild steel used in the present study. The characteristic strength of steel in tension and compression is assumed to be same as 250 MPa. The slope of the strain hardening portion of the curve is after removal of elastic curvature component. This stress strain relationship curve of mild steel has also been used in the research work titled “Use of external t-stiffeners in box-column to I-beam connections” by Ting and Shanmugam in the year1998.

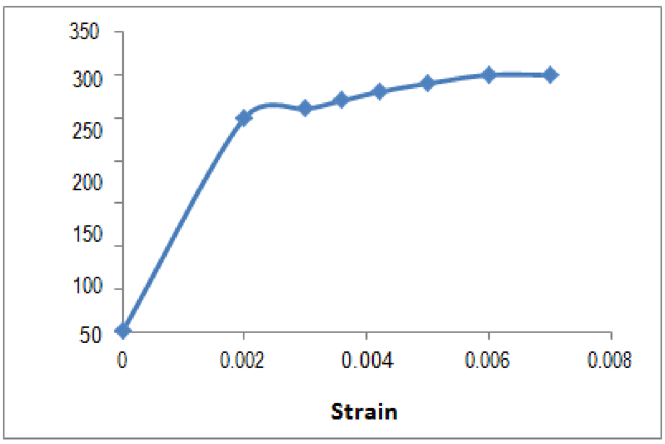


FIG 3.11: STRESS STRAIN CURVE FOR MILD STEEL USED IN PRESENT STUDY

NON LINEAR PUSHOVER ANALYSIS

Pushover analysis is a static, non linear procedure in which the magnitude of the structural loading (or displacement) is incrementally increased in accordance with a certain predefined pattern. In the present study a point load is applied at the tip-end of the beam and the load is incrementally increase using displacement controlled approach. With the increase in the magnitude of the displacement, weak links and failure modes of the beam-to-column joints are found. Local nonlinear effects are modeled through specifying nonlinear stress-strain behavior and the tip end of the beam is pushed until collapse mechanism is formed. At each step, the total shear force reaction at the fixed end of the beam and the displacement of the free tip-end of the beam are plotted (Capacity Curve). Fig. 3.12 presents a sketch showing the pushover analysis procedure (as perATC-40)

IV. RESULT & DISCUSSIONS

As discussed in the previous chapter, the main objective of this research work is to develop a suitable connection between two box sections considering welding connective. To achieve this objective, the first thing to be considered is the parameters required to accomplish this work. From the extensive literature review which has been done for this research work, some inherent difficulties have been found out while designing a suitable connection between two hollow sections. The main difficulty is that the works which have done previously are basically between one hollow section and one conventional section. So direct extensions from that connection details is not feasible due to geometric differences. For this some new parameters should also be considered. So in this chapter firstly a Fe analysis is done for the model consisting two Square Hollow sections with the help of ABAQUS software up to failure. Then analyzing the results the main parameters like flow of forces, location of the formation of plastic hinge are sorted out and then some proposed connection details have been modeled fulfilling the criteria. Then a thorough comparative analysis has been done among the proposed connection details to select the best connection detail for the problem in all aspects.

So this chapter consists of modeling and analysis of the proposed connection details fulfilling the criteria of designing a suitable connection detail and selection of the best possible connection detail among the proposed ones.

BASIC CONNECTION DETAIL

To proceed in the current research work two suitable hollow sections have been chosen from the Indian Steel table. In this case two square hollow sections are chosen which are identical. Dimensions of the sections are 200×200x8 mm. The length of both the sections is taken as 3000 mm. The modeling part and the mesh sizes have been stated in the previous chapter. Then the sections are assembled as abeam column structure. The assembled structure has been shown in figure 4.1. Boundary conditions at both the ends of the column are kept as hinged and load is applied at the tip of the beam.

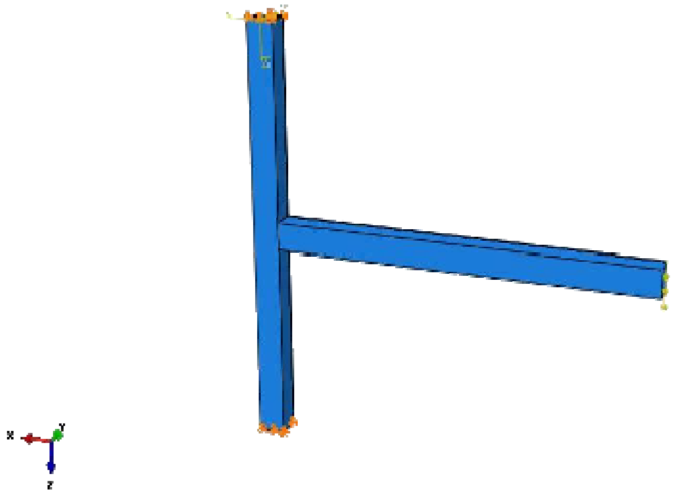


FIG 4.1BASIC CONNECTION DETAIL

Applying the load at the tip of beam the structure is analyzed with the help of ABAQUS software till the failure occurs. After the analysis it is seen that the major stress concentration is found at the beam column joint of the structure which has been shown in figure 4.2 which means that plastic hinge is formed at the column which is not good for a seismic connection. For a seismic connection the formation of plastic hinge should be away from the beam column joint. The other basic observation made from the analysis is that the flow of maximum principle force is from the beam center line to the column web

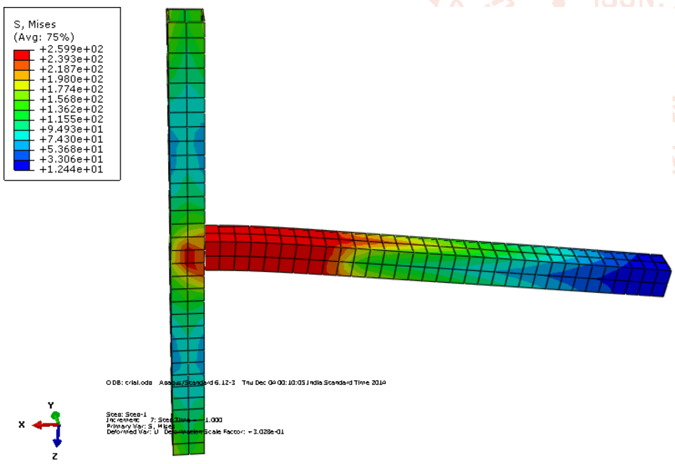


FIG 4.2 STRESS DISTRIBUTION AT FAILURE

PROPOSED CONNECTION DETAILS

As the observations from the analysis of the basic connection detail show that formation of plastic hinge and the path of the force flow is not good for a suitable seismic connection, some new connection details between the existing structures have been proposed to overcome the above mentioned difficulties. The basis of selections of the appropriate connection details are as follows

- The connection detail should reduce stress intensity at the column face and push the location of energy dissipating plastic hinge away from the column face
- t should allow a smooth transfer of beam shear to column webs
- It should be capable of resisting larger deformations without fracture
- Strength and stiffness are to be sufficiently large.

Keeping the above points in mind some alternative connection details have been proposed. The descriptions, analysis and results of those proposed connection details are given in the below.

SCHEME 1: USINGEND-PLATE:

In this type of connection detail a plate of thickness 8 mm is welded at the beam column junction of the structure as shown in figure 4.3. The dimension of the plate provided is 200×1000×8 mm. The main objective of providing the plate between the beam section and the column section is to reduce stress intensity at the column face and push the location of energy dissipating plastic hinge away from the column face.

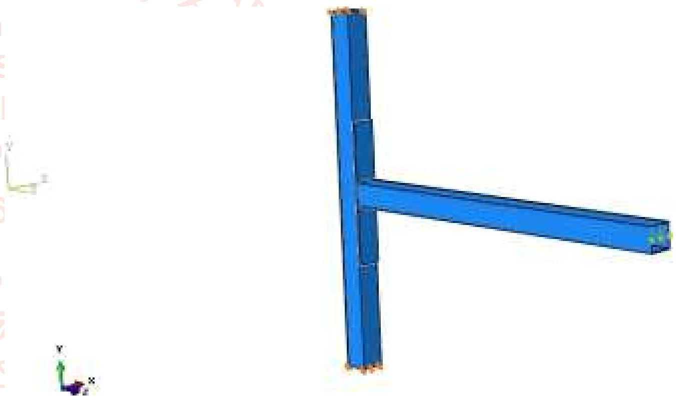


FIG4.3 CONNECTION DETAIL USING END PLATE

The structure is then analyzed by FE software ABAQUS after applying downward deflection at the tip of the beam. Deflection at the tip is gradually increased till it fails. The stress distribution of the structure at failure is shown in figure 4.4.

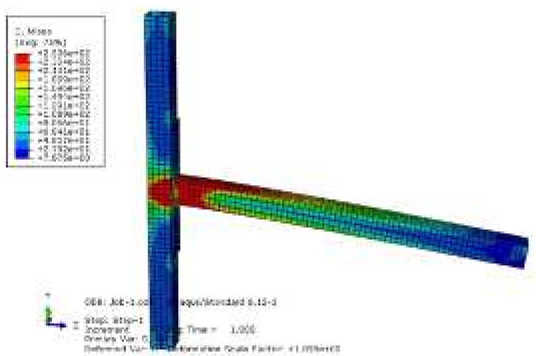


Fig 4.4 STRESS DISTRIBUTION AT FAILURE

The results show that ultimate load carrying capacity of this connection is moderate but the displacement ductility is not up to the mark. The stress distribution also shows that maximum stress is concentrated at column face of the beam column junction. So, the purpose of trying to shift the formation plastic hinge away from the column faces also not satisfied

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