The study of behaviour of partially restrained connection's under the effect of seismic load for top and seat angle connection

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***Abstract*—Generally, beam to column connections are analysed as rigid or pinned connection. The moment will greatly reduce for rigid connection as there will be negative and positive moment in the beams which will result in economy of the section and for pinned connection the moment is higher compared to rigid connection and results in higher section. But considering the detailing of beam to column connection, various connection details are available.**

This paper is presented considering top and bottom seat angle with bolted connection. It is to be noted that most of the cases there is a gap of approx. 5mm between column and beam connection details. Hence rotation of the joint is possible when there is load acting on the beam, full force transfer may not takes place at the joint. Many researcher have tried to give formulae for stiffness for these partially restrained connection and this paper has tried to analyze the steel frames for pinned, rigid and partially restrained connection with the calculation of relative stiffness of joint. The analyses is carried out using Staad-Pro Software for pinned , rigid and Semi-rigid connection and results are compared and presented in this paper.

Keywords—Semi-rigid connection, relative stiffness

I. INTRODUCTION

The actual moment transfer from beam to column is still unknown as far as connection type is considered. For long time the joint is idealized as rigid or pinned connection. Hence in pinned connection there is no moment transfer to column whereas in rigid connection there will be moment transfer to column. But these two connection yield, the two extreme values and many researchers have tried to explain the actual behavior of these two connection by analytical and experimental results.

Many researcher shown that it undesirable to design the frame as rigid or pinned connection, as it will lead to uneconomical design. Experimental and analytical results shows that there is variation of internal force transfer from beam to column depend upon the bending stiffness of the joint, thickness and location of bolts etc. These parameters affect the behavior of the frame and decrease the negative end moment and increase mid span moment on beam. Hence researchers were concluded to consider the semi-rigid connection should be taken into considered for analyses and design of steel frames[1].

Kartal et al.[2] perfomed analytical model for pinned, semi-rigid and rigid connection using "SEMIFEM" and Ansys and verified the results using FORTRAN language using moment curvation relation and justified that semi rigid connection shall be used in the design of beam-column joint. Wang Yan et al [1] proposed the initial stiffness of semi rigid connections is related to bending stiffness of joints, thickness and location of bolts. Pirmoz et al [3] had done experimental and FEM models for combined moment and axial tension force. Conclude that when the axial tension loading develops in the connection of the semi-rigid frame during seismic excitation or at the construction process then it will affect the moment-rotation response.

II. STRUCTURAL PROPERTIES OF CONNECTION[4]

The main structural properties of the connection are as follows:

A. *Stiffness of connection or connection flexibility*

The member stiffness in the connection is defined as a safe design with regards to both lack in movement and weakness in material and also prevention of separation in the connection.

The stiffness of connection will the affect the deformation in structure and also the stiffness of the attached members and it will be the more affected in case of non-braced frame structure for the deflection and it also affect the stability of the structure.

If the connection is assumed to be rigid then the analysis of the structure should be the done in such a way that it should neglect the deformation.

If the connections are assumed to be the pinned connection then they should have sufficient of Flexibility to accommodate rotations at the joint without the causing bending moment which may lead to permanent failure of connection.

There are various factors which create difficulties in getting values of joint stiffness, i.e Screw hole size, Contacting surface finish, washers etc.

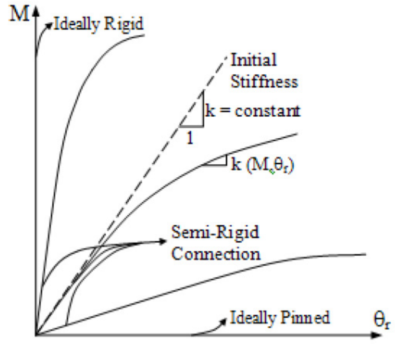

Fig 1 : Structural Connections moment-rotation

B. Strength

Strength is defined as the capacity to resist force or pressure or in other words the strength can be defined as the when the load is applied on the structure it should not fail it should be capable of taking of the applied load on the structure. The strength is again classified as Plastic deformation, Compressive Strength , Tensile Strength , Weakness in material, Impact Strength.

C. Ductility or Deformation capacity

It means property of material which change the shape of the body due to the applied load i.e reduction in total area or bending without any cracking or breaking and also the ductility can be said that it is opposite of the brittleness.

Ductility in connection is explained with the help of graph shown below and specified with the nonlinear behavior of the stress and strain nature. When the calculation is worked out then non-linearity can be eliminated so as to perform linearity in all the kind of loads applied.

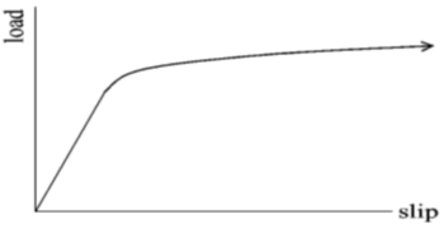

Figure 2: Load v/s Slip

Increase of max. load carrying capacity of structure which says that if the ductile capacity of the attached sections is higher than the max. load carrying capacity then it will affect the structure and if it is less than ultimate load carrying capacity than the structure act stable.

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III. STRUCTURAL PROPERTIES OF CONNECTION

According to Wang Yan , Liu Xiuli ,Li jianfen the paper says that it is concerned with the initial stiffness of semi-rigid connections under linear assumption ie; the fixed end moments of the semi rigid beams and also it says that the real action of the beam to column connections depends upon overall performance of steel structure under the load.

The Initial stiffness of the PR connections mainly depends on the following relations;

- Bending stiffness of the joint.
- Thickness of the bolt.
- Location of the bolt.

The initial stiffness of the connection as per Wang el.al, 2004 is given in the table

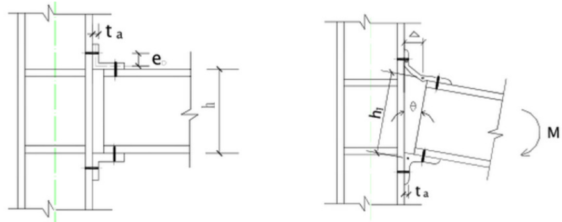

Figure 3:- Typical top and seat angle connection, Deflection configuration at elastic condition.

Initial stiffness of semi rigid connection.

$$R_{ki} = \frac{3EI_a}{1 + \frac{0.78t_c^2}{e_o^2}} \frac{h_1^2}{e_o^3}$$

IV. MODELLING AND LOADING IN STAAD.PRO SOFTWARE

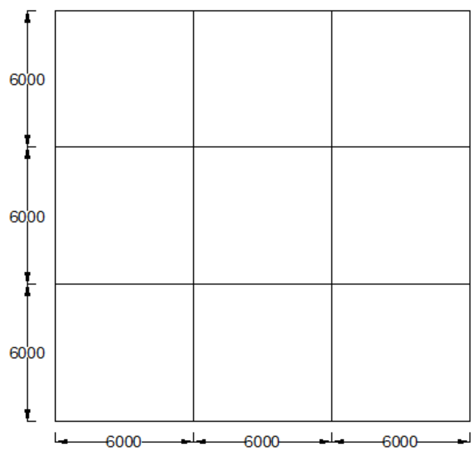

Figure 4 :- Plan for model

A. Modelling

For the analysis of G+3 model is prepared, as shown in the plan above and 3-d Model is shown below. This model is analyzed in the STAAD-PRO software. To get stability against the earthquake loads, the bracings at end frames is provided. Otherwise for pinned connection, all columns will behave as cantilever and the frame is unstable. Firstly tentative column and beam size were fixed with all loads. After analyses, depending upon the force generated on structural element, the sizes and connection details were done and incorporated in the Staad-Pro software.

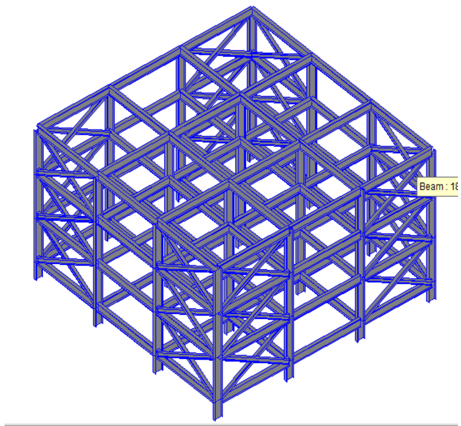

Figure 5 :- 3D model for analyses

Three models were done, First model is with rigid connection, second model is pinned connection with moment release at beam ends and third model is done with calculation of initial stiffness Rki depend upon the top and seated connection and that value is incorporated in the model to study the behavior of semi rigid connection. Aanlyses is done for the three models to compare the results.

B. Loading

Assuming the structure as a residential structure hence the following loads are to be considered:-

Following data to be assumed :

Thickness of slab as 100mm

Thickness of wall as 230mm

Height of floor as 3000mm

Density of brick as 19 kN/m^3

Density of concrete as 25 kN/m^3

Self weight of framed structure is considered as per actual sections modelled in Staad.Pro software and wall loads are provided with deduction of beam depth. Live load considered is 2 kN/m^3.

Seismic parameters considered in the model as follows.Inputs are as per IS1893-2002 (part 1)

a) Type of city considered is Vijayapur, Karnataka
b) zone (z) = 0.16
c) Importance factor(Important building) = 1
d) Type of soil/ rock considered as Medium soil
e) Structure type Steel frame structure
f) Damping ratio as 5%.

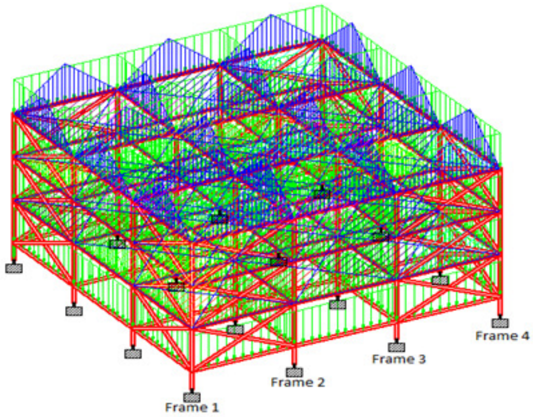

Figure 6 :- Loading on Model

C. Fixing member sizes

Staad pro model with end moment release for beams is analysed to get maximum moment and shear force for the beam element. As per the analyses result the middle frames get the maximum value of moment is 244 kN-m and shear force of 135 kN. Using these values the sections are calculated as per IS800-2007 for input in the model. The section arrived as per calculation for top and seatedangle connections were Beam with ISWB 550, column ISWB 600 and bracing with pinned connection with ISHB 250.

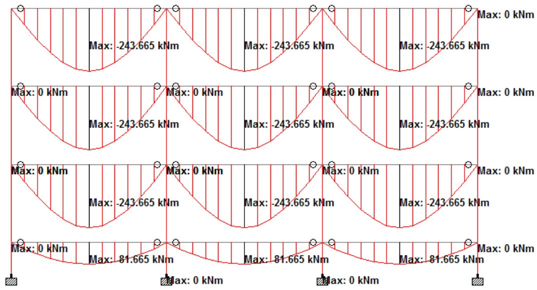

Figure7 :- Bending moment diagram for Pinned connection

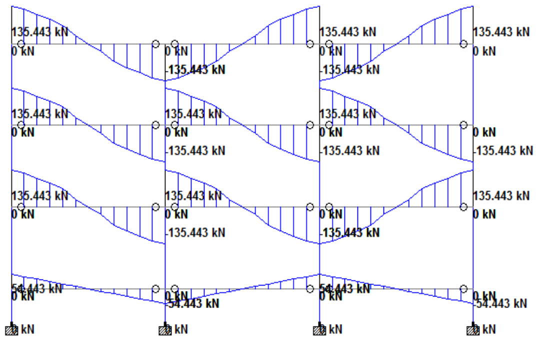

Figure 8 :- Shear force diagram for Pinned connection

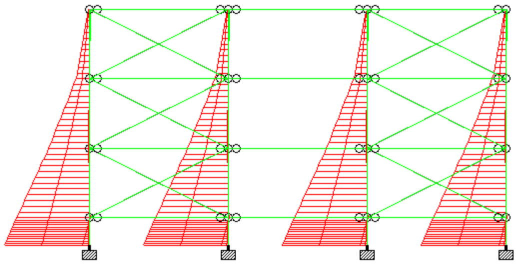

Figure 9 :- Cantilever behaviour of column under earthquake loads

D. Initial stiffness of the beam to column semi-rigid connection

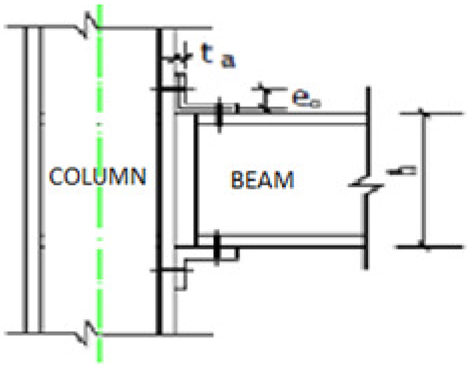

Figure 10 :- Top and seat angle

Design of connection is done as per IS800-2007 and the following details were provided. ISA 200X200X25 mm is provided for top and bottom seat angle. 6 Number of bolts are provided for the connection.

BEAM SECTION ISWB550

- Beam section (d_w) = 550 mm
- Thickness of web (t_w) = 10.5 mm
- Flange Width (b_f) = 250 mm
- Flange Thk. (t_f) = 17.6 mm
- Moment of inertia (Ia) = $7.49X10^8$ N/mm^4

SEAT ANGLE DETAILS

- Angle thickness , (ta) = 25 mm
- Length of angle provided, (le) = 250 mm
- Moment of inertia (Ia) = (le× ta^3)/12

  =$3.226X10^5$ mm^4
- Pitch of the bolt (e_o) =60 mm
- Centerline distance of web (h) = 575 mm
- Young's modulus (E) =$2.05X10^5$ N/mm^2

$$R_{ki} = \frac{3EI_a h^2}{e_o(e_o^2 + 0.78t_a^2)}$$

R_{ki} = 3559.93 kN.m/deg.

V. ANALYSIS AND RESULT

Analyses is carried out in Staad Pro software with basic load cases Deadload(DL), Live loads (LL) and Earthquake loads (EQ) and for the analyses the following load combinations were adopted.

1.5(DL+LL)
1.2(DL+LL+EQ+X)
1.2(DL+LL+EQ+Z)
1.2(DL+LL+EQ-X)
1.2(DL+LL+EQ-Z)
1.5(DL+EQ+X)
1.5(DL+EQ+Z)
1.5(DL+EQ-X)
1.5(DL+EQ-Z)
0.9DL+1.5EQ+X
0.9DL+1.5EQ+Z
0.9DL+1.5EQ-X
0.9DL+1.5EQ-Z

Three models were done in software as follows

1. Pinned connections
2. Rigid connections
3. Semi-rigid connections

To study the comparison between the three models, frame 3 is used as we get maximum moment and shear force. The results were compared between the ground floor(GL), First floor(FF), Second floor (SF) and Third floor/terrace (TF).

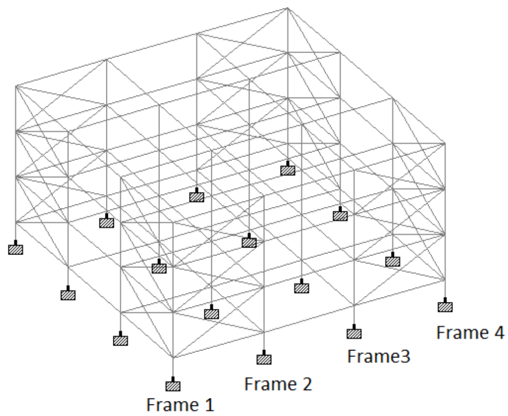

Figure 11 :- Frame 1 to 4 considered in the model

The following table shows the comparison of beam end moment for the following connections.

Table 1: Comparison of beam end moment for different type of connections for top and seat angle.

Connections	Stiffness kN.m/deg	Storey	Bending Moment (KN-m)		
			Start	Mid	End
Rigid	Infinite	GL	90.4	-53.1	63.7
		FF	177	-	95

				134	
		SF	171	-131	82.8
		Tf	173	-145	37.5
Pinned	Zero	GL	0	-81.7	0
		FF	0	-244	0
		SF	0	-244	0
		Tf	0	-244	0
Semi-rigid	3559.93	GL	73.5	-57	59.8
		FF	142	-152	91.5
		SF	131	-150	80.2
		Tf	133	-161	37.5

The following table shows the comparison of column moments for exterior and interior columns.

Table 2: Comparison of exterior column moment for different type of connections for top and seat angle.

Connections	Stiffness kN.m/deg	Storey	Bending Moment (KN-m)	
			Top	Bottom
Rigid	Infinite	GL	8.5	-23.5
		FF	-4.99	4.78
		SF	6.79	5.38
		Tf	-8.74	4.56
Pinned	Zero	GL	3.41	-36.8
		FF	0.413	3.42
		SF	2.85	0.38
		Tf	0.044	2.89
Semi-rigid	3559.93	GL	7.19	20.6
		FF	3.12	2.99
		SF	6.16	-3.75
		Tf	-4.93	2.51

Table 3: Comparison of interior column moment for different type of connections for top and seat angle.

Connections	Stiffness kN.m/deg	Storey	Bending Moment (KN-m)	
			Top	Bottom
Rigid	Infinite	GL	13.6	-56.6
		FF	47.8	-66.1
		SF	61.2	-48.2
		Tf	37.5	-19.5
Pinned	Zero	GL	133	158
		FF	71	133
		SF	19.3	71.1
		Tf	0.056	19.3
Semi-rigid	3559.93	GL	27.2	25.3
		FF	39	-69.9
		SF	58.7	-45.4
		Tf	42.1	2.51

A. Beam Behavior for top and seat angle connection

In this analysis and design we considered a G+3 Steel structure (3-D Model) as shown above in analysis. The top & seat connection is analyzed for the following connection and those connection are as follows ; 1. Rigid , 2. Pinned, 3. Semi-Rigid Connections. For analysis of the top&seat angle the intermediate frame is considered and the comparison between the different connection are observed.

The Semi-rigid connection is achieved by releasing the calculated stiffness for the top & seat angle connection at the member end by using STAAD-PRO software and then behavior is checked. After analysis of connection the difference in moments in Rigid and Semi-Rigid condition is 25%.While the difference in moment in pinned and semi-rigid connection (that is mid span moment) is around 60%. Therefore this connection is a kind of flexible connection which will not provide complete restraint for rotation.

In case of rigid type of connection the distribution of moment will be according to relative stiffness of the joint and member. But in semi-rigid type of connection the end moment will be reduced by some percentage and that reduction in end moment will be because the member stiffness gets modified which is based on the type of connection.

After the modification of the end moment in the semi-rigid connection the actual stiffness will be less as compared to rigid connection since the end moment will be reduced but the middle moment will be increased.

In case of pinned connection there will be no moment development at the joint (zero moment at the ends) that is, a pinned connection will not be having moment capacity. When the pinned connection compared with the semi-rigid connection there will be slight development of moment at the end of the member

B. Column Behavior for top&seat angle connection

In case of semi-rigid connection the member stiffness get modified depending upon the type of connection and the distribution of the moment. In case of pinned type of connection due to Dead load and Live Load moment will not develop in the column, only when the seismic forces in any one of the direction act on the structure the moment will be developed in the column and because of seismic forces acting on the structure the moment will be developed at the bottom of the column and it behave like a cantilever beam. In case of rigid type of connection column behave fixed at both the ends so moment will develop at both end of the column.

The difference of moment between Semi-rigid and rigid connection will be around 60% for exterior column and 20% for interior column. The difference of moment between Semi-rigid and pinned connection will be around 14% for exterior column and 80% for interior column.

The following diagram shows the S.F and B.M for the rigid connection.

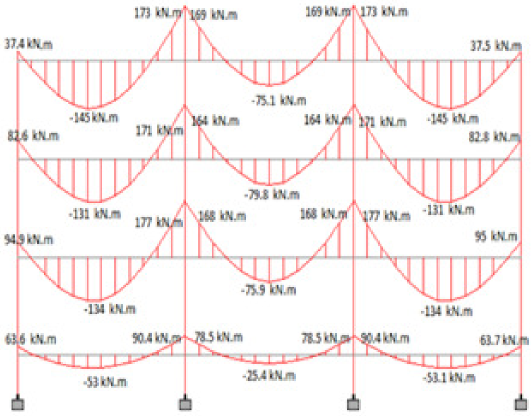

Figure 12 :- Bending moment diagram under rigid connection

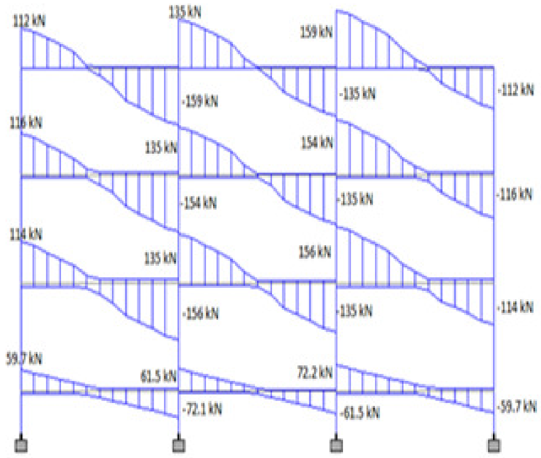

Figure 13 :- Shear force diagram under rigid connection

The following diagram shows the B.M & S.F diagram for semi-rigid connection that is after releasing the calculated stiffness in the software to achieve this type of connection called Semi-Rigid connection and also called as spring action the beam end.

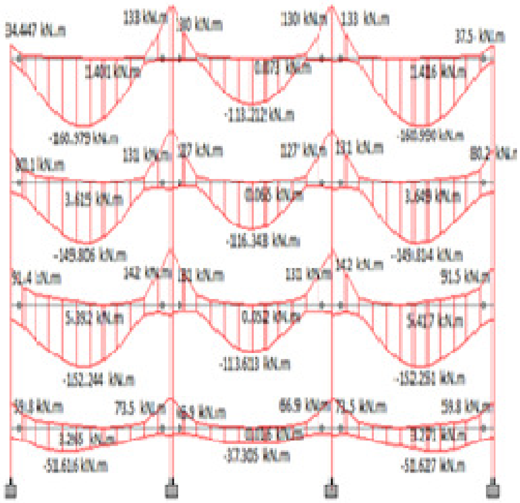

Figure 14 :- Bending moment diagram under Semi-rigid connection

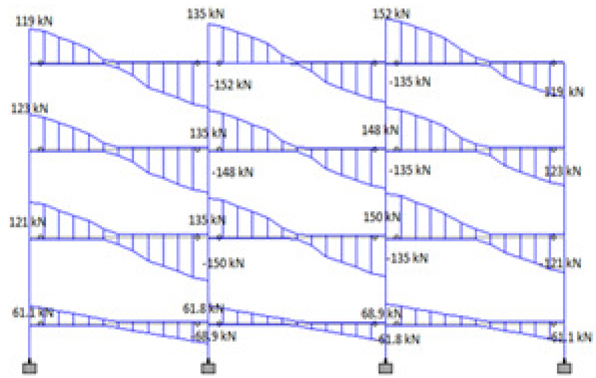

Figure 15 :- Shear force diagram under Semi-rigid connection

VI. CONCLUSION

Generaly structural analyses is carried out using rigid connection and designs are done accordinly. If pinned connections are followed, it results in maximum moment which is not desirable to be used for design. All these connections are idealized for analyses and presently many researcher are of the opinion that the actual stifness shall be used for analyses instead of restricting to rigid or pinned depend upon the type of connection provided.

After analysis of behavior of semi-rigid connection’s under the effect of seismic load,
The mid-span moment for the pinned connection is observed to be 60% more than the semi-rigid connection in case of top & seat angle connection.and also

It is observed that end moments are 25% higher for rigid connection compared with semi-rigid connection for top & seat angle. Hence forth semi-rigid connection s shall be considered in structural design to obtain the optimum results. But the designers should select carefully the degree of connection used in the analyses.

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