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Behavior of Semi-Rigid Steel Connection for G+ 3 Unsymmetrical Structures under Consideration of Seismic Forces

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Abstract – As the Pinned & Rigid connections will not give real behavior of the structure so partial restrained connection are introduced in the structure by introducing spring stiffness to achieve the approximately real behavior of structure. In this paper analysis and design of top & seat angle connection is presented and beam-column behavior for maximum deflection & joint displacement are compared with different load combination for unsymmetrical structure. The results are taken from Staad-pro v8i and designed values are used to calculate relative spring stiffness of beam-column joint and applied on structure to get the semi-rigid type of connection and results are discussed for all three types of connections called pinned, rigid & semi-rigid connection.

Keywords- Behavior of Beam-Columnjoint Displacement, Maximum Deflection, Relative Stiffness.

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I. INTRODUCTION

Steel structures are simple composite unit having different structural members such as beams, columns are so connected to one another with assumptions that the connections are either pinned or rigid connection. Pinned or Rigid connections are usually assumed for joint and support which provide simplifications in structural analysis and design but they neglect the true behavior of joint. To get true behavior of any joint in the structure the semi-rigid type of connection has to be introduced in the joint by taking spring stiffness of joint in account.

II. LITERATURE STUDY

[2.1] Leong SiongHean, N.H. Ramli Sulong, Mohammed Jameel (1)

To study the effect of axial restraints on the connection behavior at elevated temperature, a finite element model of a top-seat angle connection developed and results shown that an increase in axial restraints has increased connection capacity while the stiffness remains similar for low axial levels.

[2.2] Jared D. Schippers, Daniel J. Ruffley, Dr. Gian A. Rassati, Dr. James A. Swanson(2)

The proposed procedure is used to design three practical examples of top-and-seat angle connections: two fullstrength and one partial-strength. The connections are then are modeled in ABAQUS following a validated modeling approach that has been verified against multiple experimental tests, both quantitatively and mechanistically.

[2.3] Ali Ahmed(3)

To estimate rationally the ultimate moment Mu of connection three simple failure mechanism considering bending & shear deformation effects of prying action on top angle & stiffness of the tension bolts formulation developed.

[2.4] A. Pirmoz, E. Mohammadrezapour (2008)(4)

Studied moment-rotation behavior of this type under combined moment and axial tension force. Several refined 3D finite element models were created and their accuracy is examined comparing by results of previous experimental studies. This study showed that axial tension force reduces connection rotational stiffness and moment capacity.

[2.5] Ali Ahmed &NorimitsuKishi(5)

A method of estimating the ultimate moment capacity has been proposed for top-seat angle connections considering prying force, bolt stiffness & tension angle's bending deformation using the simple mechanism of connection failure.

[2.6] Wang Yan, Liu Xiuli, Li Jianfen[6]

In this paper Initial Stiffness of semirigid connections under linear assumption presented. The fixed end moments of semi-rigid beams under concentrated, uniform and linearly varying loads are obtained. The importance of semi-rigid connection on the internal forces of steel frames is discussed and shown that initial stiffness of semi-rigid connections mainly related to the bending stiffness of joints, thickness and locations of bolts.

III. LOADING CASE APPLIED ON STRUCTURE:

Beam – ISWB 250

Column – ISLC225 FR with 3 mm gap.

Bracing - TUB32322.6

Slab thickness – 175 mm

Load Calculation:

1.Dead load

A]Self weight of member = Applied through software.

B]Floor Load

► Self weight of slab = 0.175*25 = 4.375 kN/m

► Floor finishing & Ceiling finishes = 1.5 kN/m

Total load= 4.375+ 1.5 = 5.875 kN/m >>6 kN/m

2. Live load = 2.5 kN/m

3. Earthquake loads:

Seismic values are applied through software.

As per design results:

Initial Stiffness of the connection=Rki=3*Ia*h1^2/e0(e0^2+.78*ta^2)=544.1718464[6]

Where,

Ia =Moment of inertia = (Ie× ta3)/12

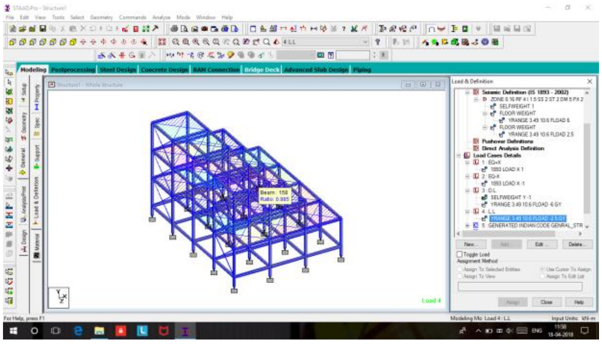
Ie= Length of angle provided

h1=Centerline distance of web

eo= Pitch of the bolt

ta=Thickness of angle

Top and seat angle connection-unsymmetric model:



A] PINNED CONNECTION:-

1] 5th generated load case [1.2 (D.L+L.L.EQ+x)]

2] 6th generated load case [1.2D.L+L.L.EQ+z)]

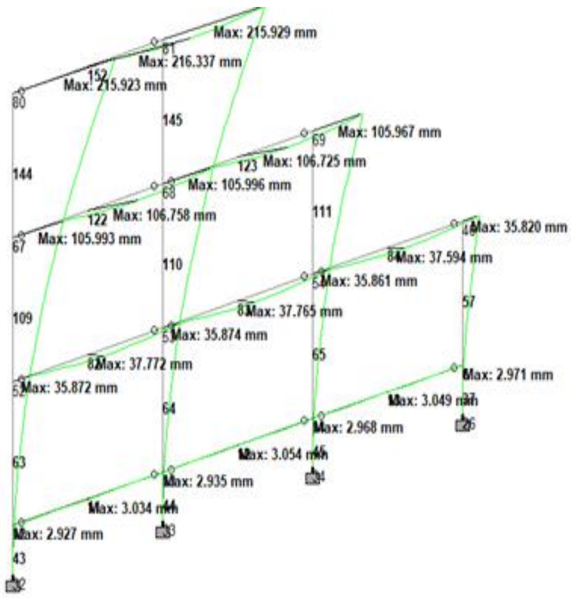


Fig5.4

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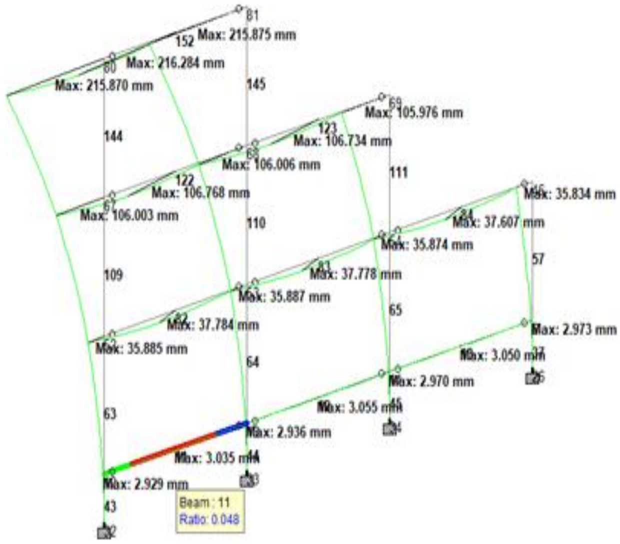


Fig no.6.4

***Table no.9:Top nodes (67&68) of Internal column 109 & External column 110 connected with Beam No:122 for pinned connection:**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
68	1 EQ+X	88.301	0.000	0.000	88.301	0.000	-0.000	-1.203
	2 EQ-X	-88.301	-0.000	-0.000	88.301	-0.000	0.000	1.203
	3 D.L	-0.003	-1.738	0.000	1.738	0.000	0.000	-0.000
	4 L.L	-0.001	-0.690	0.000	0.690	0.000	0.000	-0.000
	5 GENERATE	105.956	-2.913	0.000	105.996	0.000	-0.000	-1.444
	6 GENERATE	-105.966	-2.913	-0.000	106.006	-0.000	0.000	1.444

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
67	1 EQ+X	88.306	-0.000	-0.000	88.306	-0.000	-0.000	-1.191
	2 EQ-X	-88.306	0.000	0.000	88.306	0.000	0.000	1.191
	3 D.L	-0.003	-1.537	0.000	1.537	0.000	0.000	-0.000
	4 L.L	-0.001	-0.605	0.000	0.605	0.000	0.000	-0.000
	5 GENERATE	105.962	-2.570	0.000	105.993	0.000	-0.000	-1.429
	6 GENERATE	-105.972	-2.570	0.000	106.003	0.000	0.000	1.429

***Table no.10: Bottom nodes (52&53) of Internal column 109 & External column 110 connected with Beam No: 82 for pinned connection:**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
53	1 EQ+X	29.864	0.000	0.000	29.864	0.000	-0.000	-0.630
	2 EQ-X	-29.864	-0.000	-0.000	29.864	-0.000	0.000	0.630
	3 D.L	-0.004	-1.053	0.000	1.053	0.000	0.000	0.000
	4 L.L	-0.002	-0.417	0.000	0.417	0.000	0.000	0.000
	5 GENERATE	35.830	-1.764	0.000	35.874	0.000	-0.000	-0.756
	6 GENERATE	-35.844	-1.764	-0.000	35.887	-0.000	0.000	0.756

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
52	1 EQ+X	29.872	-0.000	-0.000	29.872	0.000	-0.000	-0.672
	2 EQ-X	-29.872	0.000	0.000	29.872	-0.000	0.000	0.672
	3 D.L	-0.004	-0.905	0.000	0.905	0.000	0.000	0.000
	4 L.L	-0.002	-0.355	0.000	0.355	0.000	0.000	0.000
	5 GENERATE	35.840	-1.513	0.000	35.872	0.000	-0.000	-0.806
	6 GENERATE	-35.854	-1.513	0.000	35.885	0.000	0.000	0.806

Displacement in Rigid connection:

5th generated load case [1.2 (D.L+L.L.EQ+x)]

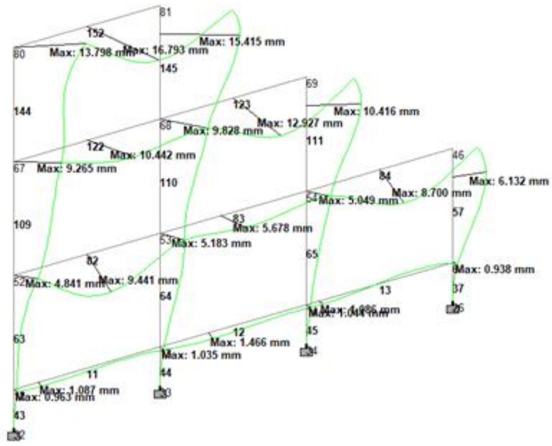


Fig no:5.5

6th generated load case [1.2 (D.L+L.L.EQ+z)

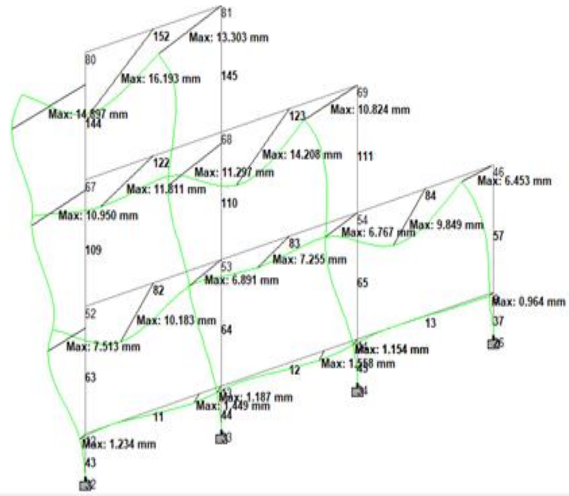


Fig no: 6.5

***Table no. 11: Top nodes (67&68) of Internal column 109 &External column 110 connected with Beam No.122 for rigid connection:**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
67	1 EQ+X	8.058	0.080	-0.000	8.058	0.000	-0.000	-0.022
	2 EQ-X	-8.058	-0.080	0.000	8.058	-0.000	0.000	0.022
	3 D.L	-0.499	-1.731	0.000	1.801	-0.000	0.000	-0.041
	4 L.L	-0.199	-0.680	0.000	0.709	-0.000	0.000	-0.017
	5 GENERATE	8.832	-2.797	0.000	9.265	-0.000	-0.000	-0.097
	6 GENERATE	-10.506	-2.989	0.000	10.923	-0.000	0.000	-0.043

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
68	1 EQ+X	8.056	-0.031	0.000	8.056	0.000	-0.000	-0.015
	2 EQ-X	-8.056	0.031	-0.000	8.056	-0.000	0.000	0.015
	3 D.L	-0.483	-2.515	0.000	2.561	-0.000	0.000	-0.029
	4 L.L	-0.192	-1.003	0.000	1.022	-0.000	0.000	-0.012
	5 GENERATE	8.857	-4.260	0.000	9.828	-0.000	-0.000	-0.067
	6 GENERATE	-10.478	-4.185	0.000	11.283	-0.000	0.000	-0.032

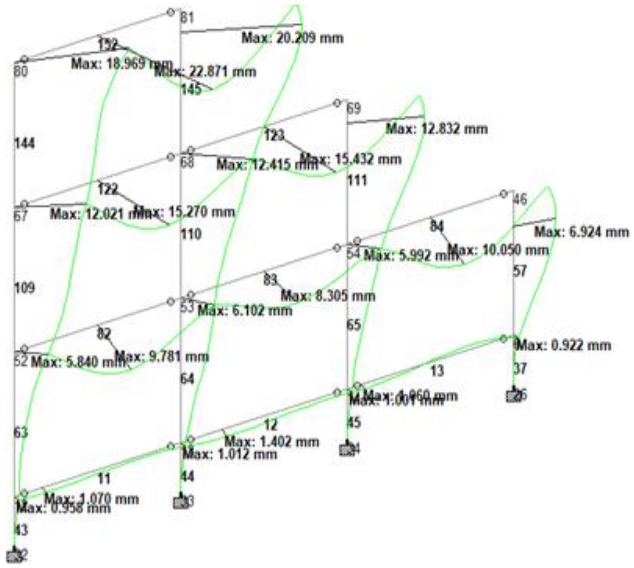
***Table no.12: Bottom nodes (52&53) of internal column 109 & External column 110 connected with Beam No.82 for rigid connection:**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
52	1 EQ+X	4.540	0.056	-0.000	4.540	0.000	-0.000	-0.024
	2 EQ-X	-4.540	-0.056	0.000	4.540	-0.000	0.000	0.024
	3 D.L	-0.574	-1.136	0.000	1.273	-0.000	0.000	-0.068
	4 L.L	-0.232	-0.446	0.000	0.502	-0.000	0.000	-0.028
	5 GENERATE	4.481	-1.832	0.000	4.841	-0.000	-0.000	-0.145
	6 GENERATE	-6.414	-1.966	0.000	6.709	-0.000	0.000	-0.086

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
53	1 EQ+X	4.537	-0.017	0.000	4.537	0.000	-0.000	-0.014
	2 EQ-X	-4.537	0.017	-0.000	4.537	-0.000	0.000	0.014
	3 D.L	-0.568	-1.534	0.000	1.635	-0.000	0.000	0.018
	4 L.L	-0.229	-0.611	0.000	0.653	-0.000	0.000	0.007
	5 GENERATE	4.487	-2.594	0.000	5.183	-0.000	-0.000	0.013
	6 GENERATE	-6.401	-2.553	-0.000	6.891	-0.000	0.000	0.047

C] SEMI-RIGID CONNECTION

1) 5th generated load case [1.2 (D.L+L.L.EQ+x)



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2} 6th generated load case [1.2D.L+L.L.EQ+z)

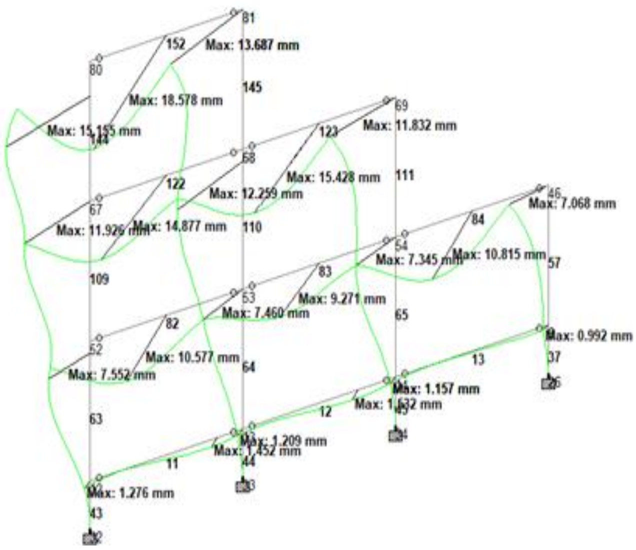

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***Table no.13: Top nodes (67&68) of Internal column 109 & External column 110 connected with Beam No.122 for Semi-rigid connection:**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
68	1 EQ+X	9.665	-0.028	0.000	9.665	0.000	-0.000	-0.023
	2 EQ-X	-9.665	0.028	-0.000	9.665	-0.000	0.000	0.023
	3 D.L	0.045	-2.483	0.000	2.484	-0.000	0.000	-0.036
	4 L.L	0.025	-0.993	0.000	0.993	-0.000	0.000	-0.015
	5 GENERATE	11.681	-4.206	0.000	12.415	-0.000	-0.000	-0.088
	6 GENERATE	-11.514	-4.138	0.000	12.235	-0.000	0.000	-0.034

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
67	1 EQ+X	9.668	0.076	-0.000	9.668	0.000	-0.000	-0.037
	2 EQ-X	-9.668	-0.076	0.000	9.668	-0.000	0.000	0.037
	3 D.L	0.038	-1.769	0.000	1.770	-0.000	-0.000	-0.046
	4 L.L	0.022	-0.699	0.000	0.699	-0.000	-0.000	-0.019
	5 GENERATE	11.673	-2.870	0.000	12.021	-0.000	-0.000	-0.122
	6 GENERATE	-11.529	-3.053	0.000	11.926	-0.000	0.000	-0.034

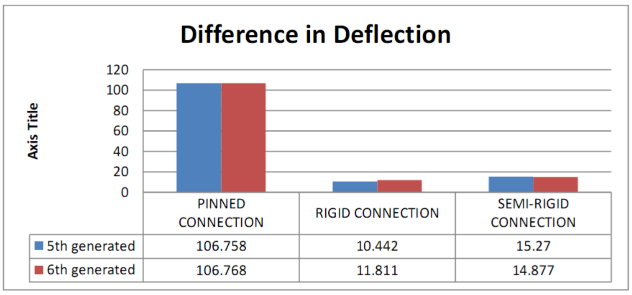
***Table no.14: Bottom nodes (52&53) of Internal column 109 & External column 110 connected with Beam No:82 for semi-rigid connection**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
53	1 EQ+X	5.231	-0.016	0.000	5.231	0.000	-0.000	-0.036
	2 EQ-X	-5.231	0.016	-0.000	5.231	-0.000	0.000	0.036
	3 D.L	-0.441	-1.517	0.000	1.580	-0.000	0.000	0.013
	4 L.L	-0.177	-0.606	0.000	0.632	-0.000	-0.000	0.005
	5 GENERATE	5.535	-2.567	0.000	6.102	-0.000	-0.000	-0.022
	6 GENERATE	-7.018	-2.529	0.000	7.460	-0.000	0.000	0.065

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
52	1 EQ+X	5.234	0.053	-0.000	5.234	0.000	-0.000	-0.046
	2 EQ-X	-5.234	-0.053	0.000	5.234	-0.000	0.000	0.046
	3 D.L	-0.447	-1.163	0.000	1.246	-0.000	0.000	-0.083
	4 L.L	-0.180	-0.458	0.000	0.492	-0.000	0.000	-0.034
	5 GENERATE	5.528	-1.882	0.000	5.839	-0.000	-0.000	-0.196
	6 GENERATE	-7.034	-2.009	0.000	7.315	-0.000	0.000	-0.085

Table15: Values of Maximum Deflection for Different Load Cases:

Connection Type	Load case detail	Beam number	Max Deflection in beam in mm
PINNED CONNECTION	5TH GENERATED	122	106.758
	6TH GENERATED	122	106.768
RIGID CONNECTION	5TH GENERATED	122	10.442
	6TH GENERATED	122	11.811
SEMI-RIGID CONNECTION	5TH GENERATED	122	15.270
	6TH GENERATED	122	14.877



Behavior detail after observing above result :

Load case 5*{1.2(D.L+L.L+EQ+x)}:*

- Deflection in semi-rigid reduces by[(106.758-15.270)/106.758*100] 85.7% as per table 15when compared with pinned connection results as shown in fig 5.4 for pinned connection & fig 5.6 for semi-rigid connection.

- Deflection in Rigid connection reduces by[(106.758-10.442)/106.758*100]90.21% as per table 15when compared with pinned connection results as shown in fig 5.4 for pinned connection & fig 5.5 for rigid connection.

- Deflection in semi-rigid connection increases by [(15.270-10.442)/15.270*100]31.61% as per table 15when compared with rigid connection as shown in fig 5.5 for rigid connection & fig 5.6 for semi-rigid connection.

Load case 6 *{1.2(D.L+L.L+EQ+z)}:*

- Deflection in semi-rigid reduces by[(106.768-14.877)/106.768*100] 86.06% as per table 15when compared with pinned connection results as shown in fig 6.4 for pinned connection & fig 6.6 for semi-rigid connection.

- Deflection in Rigid connection reduces by[(106.768-11.811)/106.768*100] 88.93% as per table 15 when compared with pinned connection results as shown in fig 6.4 for pinned connection & fig 6.5for rigid connection.

- Deflection in semi-rigid connection increases by [(14.877-11.811)/11.811*100] 20.60% as per ta

Conclusion after comparing both load cases for maximum deflection when designed as top and seat angle connection [Unsymmetrical structure]:-

- When deflection is compared in semi-rigid and pinned connection for both load cases, it is observed that decrease in deflection in semi-rigid connection is more in load case 6 as compared to load case 5.

- Increase in deflection of semi-rigid connection is more in load case-5 is more as compared with load case 6.

- As the semi-rigid connection gives realistic behavior of structure and as per above results the semi-rigid connection is acting more ductile in nature compare to rigid connection so that it can be said that due to increase in the deflection in semi-rigid connection the collapse time of flexural member will increase.

- As the collapse time increases in connection it tends to provide more safety against the major lateral loads acting on structures like earthquake, wind forces, etc.

Beam -column joint displacement behavior [unsymmetrical structure]:

Table No. 8: Joint displacement for column:

Sr.no.	Connection	Load case detail	Column	Internal[I]or external[E]	Top node displacement	Bottom node displacement	Top and Bottom node
1.	Pinned connection	5th generated	109	I	105.962	35.840	(67,52)
		6th generated	109	I	105.972	-35.854	(67,52)
		5th generated	110	E	105.956	35.830	(68,53)
		6th generated	110	E	105.966	-35.844	(68,53)
2.	Rigid connection	5th generated	109	I	8.832	4.481	(67,52)
		6th generated	109	I	10.506	-6.414	(67,52)
		5th generated	110	E	8.857	4.487	(68,53)
		6th generated	110	E	10.478	-6.401	(68,53)
3.	Semi-rigid	5th generated	109	I	11.673	5.528	(67,52)
		6th generated	109	I	11.529	-7.034	(67,52)
		5th generated	110	E	11.681	5.535	(68,53)
		6th generate	110	E	11.514	-7.018	(68,53)

Result:

1. For load case 5 (1.2*[DL+LL+EQ+x])

- As the pinned connection will be having free rotation at the joint the joint displacement in both external and internal column is very high as compare to rigid and semi-rigid connection. The difference in joint displacement in internal column (109) & external (110) column are same which about {[105.962-8.832]/105.962*100}=91.66% increase in is pinned connection when compared with the rigid connection.

- The difference in joint displacement in internal column (109) & external (110) column are same which increases joint displacement about {[105.962-11.673]/105.962*100=88.99 % in pinned connection when compared with the semi- rigid connection.

- External (110) and internal (109) column Joint displacement increases by{[11.673-8.832]/11.673*100= 24.33% in semi-rigid connection when compared with rigid connection which provided more flexible connection than rigid connection which tends to provide long time service as well as safety.

2. For load case 6(1.2*[DL+LL+EQ+z])

- As the pinned connection will be having free rotation at the joint the joint displacement in both external and internal column is very high as compare to rigid and semi-rigid connection. The difference in joint displacement in internal column (109) & external (110) column are same which about {[105.972-10.506]/105.972*100}=90.08% increase in is pinned conned when compared with the rigid connection.

- The difference in joint displacement in internal column (109) & external (110) column are same which increases joint displacement about {[105.972-11.529]/105.972*100}=89.12 % in pinned connection when compared with the semi- rigid connection.

- External and internal column Joint displacement increases by {[11.529-10.506]/11.529*100}=8.87 % in semi-rigid connection when compared with rigid connection which provided more flexible connection than rigid connection which tends to provide long time service as well as safety.

Beam-column joint displacement result after comparing both load cases:

- Beam-Column joint displacement is more in load case 6 as compare to load case 5 {[(105.972-105.962)/105.972]*100= 0.009%} which is about 0.009% more in load case 6.

- Beam-Column joint displacement is more in load case 6 as compare to load case 5{[(10.506-8.832)/10.506]*100=15.93%} which is about 15.93% more in load case 6 when compared with load case-5 for internal column & {[(10.478-8.857)/10.478]*100= 15.47%} about 15.47% more in load case 5 when compared with load case 6 for external column when designed as rigid connection.

- Beam-Column joint displacement is more in load case 5 as compare to load case 6 {[(11.673-11.529)/11.673]*100= 1.23%} which is about 1.23 % more in load case 5 when compared with load case-6 for internal column & {[(11.681-11.514)/11.681]*100= 1.42%} about 1.42% more in load case 5 when compared with load case 6 for external column when designed as semi-rigid connection.

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