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Behavior of Semi-Rigid Steel Connection for G+3 Symmetrical Structures under Consideration of Seismic Forces Civil Engineering Department

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Abstract – As the Pinned & Rigid connections does not provide true behavior of the structure so the connection called Semi-rigid connection are introduced in the structure by mean of joint spring stiffnessto 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.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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1. 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.

2. LITERATURE STUDY:

[2.1] Praveen Biradar, Dr. M.M. Awati(1)

In this paper joint stiffness is calculated and applied on the steel structure by means of software called STAAD-Pro & beam-column behavior is observed.

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

Top & seat angle bolted connection is design by considering the seismic factors on structure and practical models are checked for full and partial strength and the models are analyzed and validated in ABAQUS. Models are checked mechanically.

[2.3] A. Pirmoz, F.Danesh(3)

In this research finite element models are prepared using non-linear FEM and experimental testing are carried out to check the role of seat angle. Study carried out by considering the parameter as length of beam.

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

In this research connection moment rotation response is studied under combined axial tension and monotonic moment using non-linear FEM analysis. Experimental models are tested mechanically.

3. LOADS 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[5] =Rki={3*Ia*h1^2/e0(e0^2+.78*ta^2)}

=544.1718464

Where,

Ia =Moment of inertia = (Ie× ta3)/12

Ie= Length of angle provided

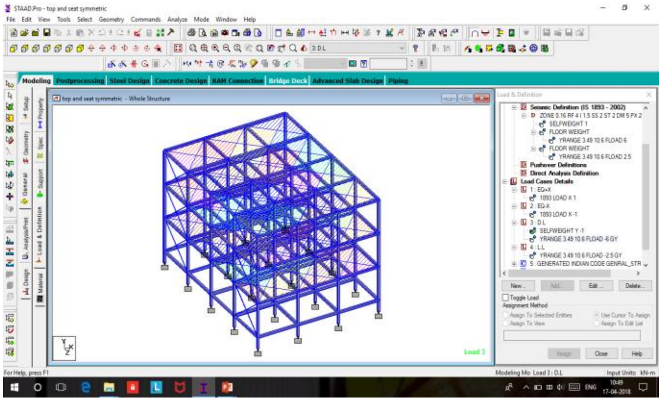
h1=Centerline distance of web

eo= Pitch of the bolt

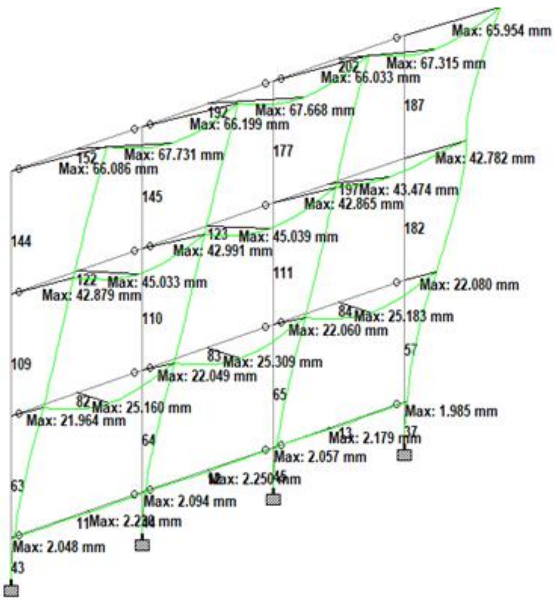
ta=Thickness of angle

Assumed load cases:-

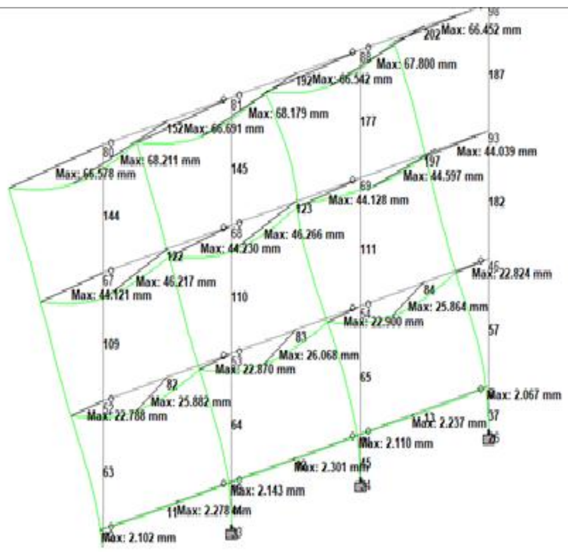
A] 1.2[D.L+L.L+EQ+x] B]1.2[D.L+L.L+EQ+z] **Top and seat angle connection-symmetric model:**



Displacement in 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)]

Fig no:5.1Fig no:6.1

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***Table 1: For Top nodes (69 & 93) of internal column 111 & external column 182 Connected with Beam No. 197 for pinned connection:**

Modeling | Postprocessing | Steel Design | Concrete Design | RAM Connection | Bridge Deck | Advance

All | Summary

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
69	1 EQ+X	36.135	0.115	0.000	36.135	0.000	-0.000	-0.136
	2 EQ-X	-36.135	-0.115	-0.000	36.135	-0.000	0.000	0.136
	3 D.L	-0.368	-2.037	0.000	2.070	0.000	0.000	-0.070
	4 L.L	-0.151	-0.809	0.000	0.823	0.000	0.000	-0.028
	5 GENERATE	42.739	-3.277	0.000	42.864	0.000	-0.000	-0.282
	6 GENERATE	-43.985	-3.552	-0.000	44.128	-0.000	0.000	0.046

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
93	1 EQ+X	36.124	-0.148	0.000	36.125	0.000	-0.000	-0.117
	2 EQ-X	-36.124	0.148	-0.000	36.125	-0.000	0.000	0.117
	3 D.L	-0.377	-1.371	0.000	1.422	0.000	0.000	0.086
	4 L.L	-0.155	-0.536	0.000	0.558	0.000	0.000	0.035
	5 GENERATE	42.710	-2.465	0.000	42.781	0.000	-0.000	0.005
	6 GENERATE	-43.989	-2.111	-0.000	44.039	-0.000	0.000	0.285

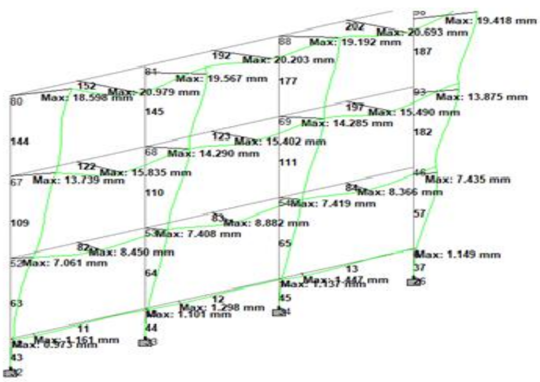
***Table 2: For Bottom nodes (54 & 46) of internal column 111 & External column 182 connected with Beam No. 84 for pinned connection:**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
54	1 EQ+X	18.636	0.066	0.000	18.636	0.000	-0.000	-0.350
	2 EQ-X	-18.636	-0.066	-0.000	18.636	-0.000	0.000	0.350
	3 D.L	-0.245	-1.363	0.000	1.385	0.000	0.000	0.021
	4 L.L	-0.100	-0.541	0.000	0.550	0.000	0.000	0.009
	5 GENERATE	21.949	-2.205	0.000	22.059	0.000	-0.000	-0.383
	6 GENERATE	-22.778	-2.363	-0.000	22.900	-0.000	0.000	0.456

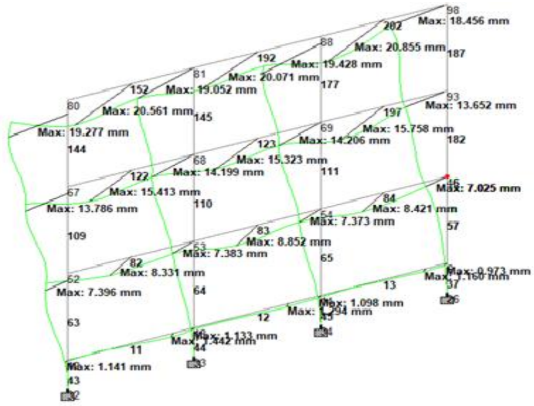
All | Summary

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
46	1 EQ+X	18.658	-0.095	0.000	18.658	0.000	-0.000	-0.360
	2 EQ-X	-18.658	0.095	-0.000	18.658	-0.000	0.000	0.360
	3 D.L	-0.226	-1.001	0.000	1.026	0.000	0.000	-0.025
	4 L.L	-0.092	-0.390	0.000	0.401	0.000	0.000	-0.010
	5 GENERATE	22.008	-1.783	0.000	22.080	0.000	-0.000	-0.474
	6 GENERATE	-22.771	-1.555	-0.000	22.824	-0.000	0.000	0.389

Displacement in Rigid connection:



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



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

***Table 3: For Top nodes (69 & 93) of Internal column 111 & External column 182 connected with beam No. 197 for Rigid connection:**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
69	1 EQ+X	11.256	0.023	0.000	11.256	0.000	-0.000	-0.017
	2 EQ-X	-11.256	-0.023	-0.000	11.256	-0.000	0.000	0.017
	3 D.L	0.029	-2.692	0.000	2.692	-0.000	0.000	-0.002
	4 L.L	0.013	-1.081	0.000	1.081	-0.000	0.000	-0.001
	5 GENERATE	13.558	-4.501	0.000	14.285	-0.000	-0.000	-0.023
	6 GENERATE	-13.456	-4.555	0.000	14.206	-0.000	0.000	0.017

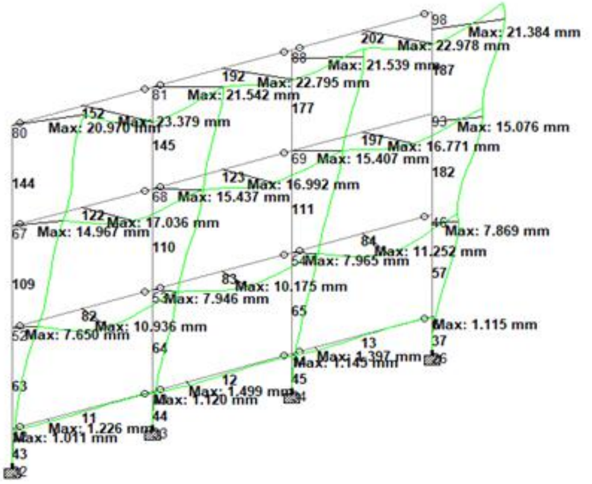
		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
93	1 EQ+X	11.254	-0.072	0.000	11.254	0.000	-0.000	-0.050
	2 EQ-X	-11.254	0.072	-0.000	11.254	-0.000	0.000	0.050
	3 D.L	0.037	-1.482	0.000	1.483	-0.000	0.000	0.066
	4 L.L	0.016	-0.583	0.000	0.583	-0.000	0.000	0.027
	5 GENERATE	13.568	-2.564	0.000	13.808	-0.000	-0.000	0.052
	6 GENERATE	-13.442	-2.391	-0.000	13.653	-0.000	0.000	0.172

***Table 4: For bottom nodes (54 & 46) of internal column 111 & External column 182 connected with beam No. 84 for Rigid connection:**

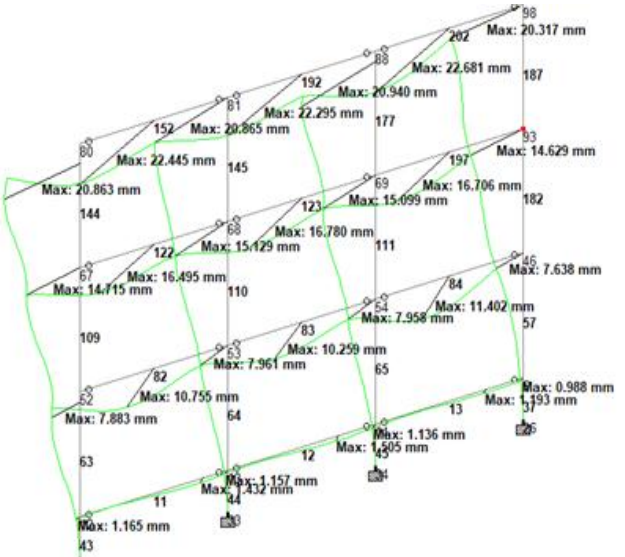
		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
46	1 EQ+X	5.730	-0.055	0.000	5.730	0.000	-0.000	-0.051
	2 EQ-X	-5.730	0.055	-0.000	5.730	-0.000	0.000	0.051
	3 D.L	0.032	-1.045	0.000	1.046	-0.000	0.000	0.084
	4 L.L	0.014	-0.410	0.000	0.410	-0.000	0.000	0.034
	5 GENERATE	6.931	-1.812	0.000	7.164	-0.000	-0.000	0.081
	6 GENERATE	-6.821	-1.681	-0.000	7.026	-0.000	0.000	0.204

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
54	1 EQ+X	5.726	0.014	0.000	5.726	0.000	-0.000	-0.030
	2 EQ-X	-5.726	-0.014	-0.000	5.726	-0.000	0.000	0.030
	3 D.L	0.018	-1.627	0.000	1.627	-0.000	0.000	-0.011
	4 L.L	0.008	-0.652	0.000	0.652	-0.000	0.000	-0.004
	5 GENERATE	6.903	-2.718	0.000	7.419	-0.000	-0.000	-0.054
	6 GENERATE	-6.840	-2.751	0.000	7.372	-0.000	0.000	0.018

Displacement in Semi-rigid connection



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



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

***Table 5: For top nodes (69 & 93) of Internal column 111 & External column 182 connected with beam No. 197 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
93	1 EQ+X	12.166	-0.083	0.000	12.166	0.000	-0.000	-0.053
	2 EQ-X	-12.166	0.083	-0.000	12.166	-0.000	0.000	0.053
	3 D.L	0.108	-1.549	0.000	1.553	-0.000	-0.000	0.072
	4 L.L	0.045	-0.612	0.000	0.614	-0.000	-0.000	0.029
	5 GENERATE	14.782	-2.694	0.000	15.026	-0.000	-0.000	0.059
	6 GENERATE	-14.415	-2.494	-0.000	14.629	-0.000	0.000	0.185

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
69	1 EQ+X	12.164	0.030	0.000	12.164	0.000	-0.000	-0.029
	2 EQ-X	-12.164	-0.030	-0.000	12.164	-0.000	0.000	0.029
	3 D.L	0.101	-2.628	0.000	2.630	-0.000	-0.000	-0.016
	4 L.L	0.042	-1.057	0.000	1.058	-0.000	-0.000	-0.006
	5 GENERATE	14.769	-4.387	0.000	15.406	-0.000	-0.000	-0.061
	6 GENERATE	-14.426	-4.458	0.000	15.099	-0.000	0.000	0.007

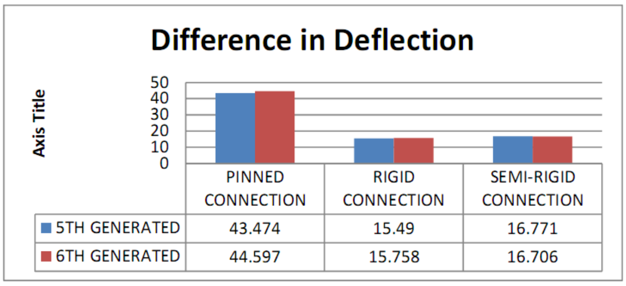
***Table 6: For bottom nodes (54 & 46) of internal column 111 & External column 182 Connectedwith beam No.84 for Semi-rigid connection:**

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
46	1 EQ+X	6.233	-0.060	0.000	6.233	0.000	-0.000	-0.059
	2 EQ-X	-6.233	0.060	-0.000	6.233	-0.000	0.000	0.059
	3 D.L	0.021	-1.068	0.000	1.069	-0.000	0.000	0.078
	4 L.L	0.009	-0.421	0.000	0.421	-0.000	0.000	0.032
	5 GENERATE	7.515	-1.860	0.000	7.742	-0.000	-0.000	0.061
	6 GENERATE	-7.443	-1.715	-0.000	7.638	-0.000	0.000	0.201

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX deg	rY deg	rZ deg
54	1 EQ+X	6.228	0.017	0.000	6.228	0.000	-0.000	-0.046
	2 EQ-X	-6.228	-0.017	-0.000	6.228	-0.000	0.000	0.046
	3 D.L	0.006	-1.631	0.000	1.631	-0.000	0.000	-0.005
	4 L.L	0.003	-0.655	0.000	0.655	-0.000	0.000	-0.002
	5 GENERATE	7.485	-2.723	0.000	7.964	-0.000	-0.000	-0.063
	6 GENERATE	-7.463	-2.763	0.000	7.958	-0.000	0.000	0.047

Table no.7: 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	197	43.474
	6TH GENERATED	197	44.597
RIGID CONNECTION	5TH GENERATED	197	15.490
	6TH GENERATED	197	15.758
SEMI-RIGID CONNECTION	5TH GENERATED	197	16.771
	6TH GENERATED	197	16.706



Behavior detail after observing above

Result :-

Loadcase5*{1.2(DL+LL+EQ+x)}*:

- Deflection in semi-rigid connection reduces by [(43.474-16.771)/43.474*100] 61.42% as per table-7 when compared with pinned connection results as shown in fig no.5.1for pinned connection &fig no.5.3 for semi-rigid connection.
- Deflection in Rigid connection reduces by [(43.474-15.490)/43.474*100] 64.36 % as per table-7 when compared with pinned connection results as shown infig no.5.1for pinned connection &fig.no.5.2 rigid connection.
- Deflection in semi-rigid connection increases by [(16.771-15.490)/16.771*100] 7.64%as per table-7 when compared with rigid connection

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as shown in fig no.5.2for rigid connection &fig no.5.3 semi-rigid connection.

Loadcase6*{1.2(DL+LL+EQ+z)}*:

- Deflection in semi-rigid reduces by [(44.597-16.706)/44.597*100] 62.54% as per table-7 when compared with pinned connection results as shown in fig no.6.1for pinned connection &fig no.6.3 for semi-rigid connection.

- Deflection in Rigid connection reduces by [(44.597-15.758)/44.597*100] 64.66 % as per table-7 when compared with pinned connection results as shown infig no.6.1for pinned connection &fig.no. 6.2 forrigid connection.

- Deflection in semi-rigid connection increases by [(16.706-15.758)/16.706*100] 5.67% when compared with rigid connection as shown in fig no.6.2for rigid connection & fig. no.6.3 for semi-rigid connection.

Conclusion after comparing both load cases for maximum deflection when designed as top and seat angle connection [Symmetrical 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.

Table no.8: Beam-Column Joint Displacement Behavior [Symmetrical Structure]

Sr. No.	Connection	Load case detail	Column	Internal [I] or external [E]	Top node Displacement[mm]	Bottom node displacement [mm]	Top and Bottom node
1.	Pinned connection	5^{th} generated	111	I	42.739	21.949	(69,54)
		6^{th} generated	111	I	43.985	22.778	(69,54)
		5^{th} generated	182	E	42.710	22.008	(93,46)
		6^{th} generated	182	E	43.989	22.771	(93,46)
2.	Rigid connection	5^{th} generated	111	I	13.566	6.903	(69,54)
		6^{th} generated	111	I	13.442	6.840	(69,54)
		5^{th} generated	182	E	13.558	6.931	(93,46)
		6^{th} generated	182	E	13.456	6.821	(93,46)
3.	Semi-rigid	5^{th} generated	111	I	14.782	7.515	(69,54)
		6^{th} generated	111	I	14.415	7.443	(69,54)
		5^{th} generated	182	E	14.769	7.485	(93,46)
		6^{th} generated	182	E	14.426	7.463	(93,46)

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 beam-column joint is very high as compare to rigid and semi-rigid connection. The difference in beam-column joint displacement in internal column (111) & external (182) column are same which about [(42.739-13.566/42.739)*100] 68.25% increase in pinned connection when compared with the rigid connection.

- The difference in joint displacement in internal column (111) & external (182) column are same which is about [(42.739-14.782/42.739)*100] 65.41% increase in pinned connection when compared with the semi- rigid connection.

- External (182) and internal (111) beam-column Joint displacement increases by [(14.782-13.566)/14.782] 8.23% in semi-rigid connection.

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

- 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 (111) & external (182) column are same which about [(43.985-13.442)/43.985*100] 69.44 % increase in pinned connection when compared with the rigid connection.

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- The difference in joint displacement in internal column (111) & external (182) column are same which increases joint displacement about [(43.985-14.415)/43.985*100] 67.22 % in pinned connection when compared with the semi- rigid connection.

- External (182) and internal (111) column Joint displacement increases by [(14.415-13.442)/14.415*100] 6.74 % in semi-rigid connection when compared with rigid connection.

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 {[(43.985-42.739)/43.985]*100= 2.83%} which is about 2.83% more in load case 6 when designed as pinned connection.

- Beam-Column joint displacement is more in load case 5 as compare to load case 6 {[(13.566-13.422)/13.566]*100= 1.06%} which is about 1.06% more in load case 5 when compared with load case-6 for internal column & {[(13.558-13.456)/13.558]*100= 0.75%} about 0.75% 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 {[(14.782-14.415)/14.782]*100= 2.42%} which is about 2.42 % more in load case 5 when compared with load case-6 for internal column & {[(14.769-14.426)/14.769]*100= 2.32%} about 2.32% more in load case 5 when compared with load case 6 for external column when designed as semi-rigid connection.

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