Comprehensive Study on Sequence of Construction and its Effect on RC Buildings with Floating Column

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Abstract— Structure when modelled for conventional dead load analysis the stiffness of the final structure is considered, which means the entire structure is built in a single stretch. In actual construction practice structure is built in stages. In order to simulate stages of construction sequential construction analysis is performed. Floating column structures are vulnerable to sequence of construction. In this study 3 different floating column structure with 5 Storey variations (G+5, G+10, G+15, G+20 & G+32) is considered. Conventional dead load analysis and sequential construction (with and without time dependent properties) is performed. Parameters are compared.

Key words: Sequence of Construction, Floating Column, Nonlinear Analysis

I. INTRODUCTION

Behavior of structure depends on the sequence of construction. For the structures with irregularity the effect of construction sequence is severe. Modern architecture demands column free space in lower storey of the structure. When floating column is introduced the structure becomes vulnerable to sequence of construction. This is because floating column introduces vertical stiffness irregularity in structure.

Columns are vertical structural elements which start form foundation level, carry load from super structure to foundation and eventually to soil. Floating columns are also vertical structural elements but the difference is that these members do not start from foundation level. Floating column at lower level rests on a horizontal structural member. This horizontal structural member is called as a transfer girder.

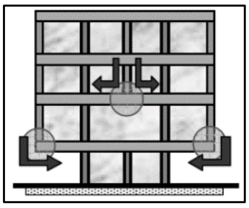


Fig. 1: Hanging or Floating columns

In sequential construction, structure and loads are added in sequence which matches how the structure is constructed.it is a type of nonlinear static analysis.

II. LITERATURE REVIEW

Sukumar behera et.al (May 2012) [1] in his thesis developed FEM codes for multi-storey frame with floating column and without floating column, the response of the structure under various earthquake excitation is studied.

Sreekanth et.al (Sep 2014) [2] performed seismic analysis on G+5 storey building with floating column and without floating column seismic analysis was performed according to Indian code, building was considered to be located in zone Ⅲ, safety and economy of floating column structure was studied.

Hardik and Siddharth shah (Apr 2015) [3] performed investigation to expose the effects of floating column and the effect of soft storey formed by the presence of floating column in various earthquake zones using seismic analysis. Sunil kumar and prof.

Vishwanath B Patil (July 2015) [4] have attempted to study the effect of shear wall on building having floating column, for this study 10 different structural models are considered with different position of shear walls and different shapes of shear walls, the action of infill panels are also considered for analysis and modelled as diagonal struts, Static and dynamic analysis has been performed according to IS 1893.

Mahesha M and K Lakshmi (Aug 2015) [5] performed a comparative study on reinforced concrete frame structure with floating column and without floating columns under seismic excitation.

Sharma R K and Dr. Shelke N L (June 2016) [6] considered storey height as variable for a building with floating column and carried out dynamic analysis

III. AIM OF THE INVESTIGATION

After literature survey on floating column structure. It is observed the sequence of construction was considered during analysis. Whenever floating column is encountered in design practice, transfer girders are designed manually. For this present study effect of sequence of construction in floating column structures is being considered.

IV. DESCRIPTION & METHODOLOGY

A total of 31 models which includes a 2D frame and 3 types of 3D RCC frame models with different location of floating columns, for all these models no of storeys is also taken as a variable and 5 different number of storeys are being considered and for all these models with and without creep case is also being considered in this particular study, all the models are prepared in CSI SAP2000 V19 software package, all the models considered are RCC Frame structures having beams, columns and slabs.

A. *Materials Used*

Grade of concrete considered to be M25 and grade of steel is taken as Fe500 grade, the time dependent properties of concrete is calculated according to ACI209-92 [10]

1) *Concrete Properties*

Sl. No	Property	Value
1	Cement content	320 kg/m^3 (539.378 $lb./yd^3$)
2	Percentage of fine aggregate	37.94%

3	Modulus of elasticity E	25000000 kN/m^2 (25000 N/mm^2)
4	Compressive strength f_{ck}	25000 kN//m^2 (25 N/mm^2)
5	Poisson's ratio u	0.2
6	Humidity	50%
7	Slump	100 mm (0.1m)
8	Air content in percentage	6%
9	Unit weight of concrete	24.9926 kN/m^3

Table 1: Concrete Properties

2) *Rebar Properties*

Sl. No	Property	Value
1	Weight per unit volume	76.97729 kN/m^3
2	Modulus of elasticity E	2x10^8 kN/m^2 (2x10^5 N/mm^2)
3	Shear modulus G	76.92307x10^6 kN/m^2
4	Min Yield stress f_y	500000 kN/m^2 (500 N/mm^2)
5	Min Tensile stress f_u	545000 kN/m^2 (545 N/mm^2)
6	Expected yield stress	550000 kN/m^2 (550 N/mm^2)
7	Expected tensile stress	599500 kN/m^2 (599.5 N/mm^2)

Table 2: Rebar Properties

3) *Time Dependent Properties*

Time dependent properties are generated according to ACI209-92

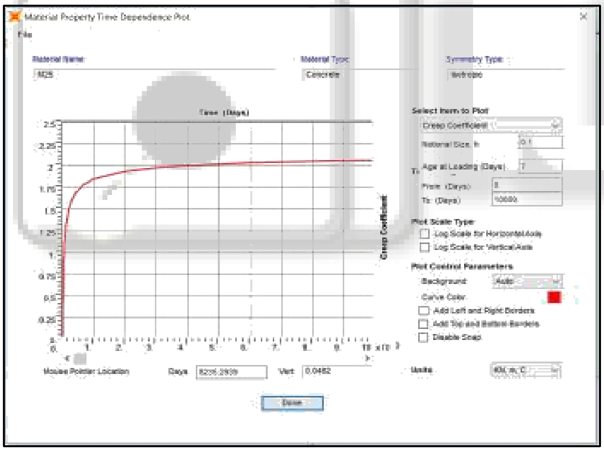


Fig. 2: Time dependent properties

B. *Sections adopted*

No of storey's	Column section (mm)	Beam section	
		Transfer girder(mm)	Other beams(mm)
G+5	450X450	450X600	300X450
G+10	600X600	600X750	300X450
G+15	750X750	750X900	300X450
G+20	900X900	900X1000	300X450
G+32	1500X1500	1500X3500	300X450
Slabs are taken as membrane elements of 150mm thickness			

Table 3: Sections adopted

C. *Structural Models Considered*

The details of the models consider are as follows

- Model 1: 2D Frame element
- Model 2: RC building with floating columns around corners
- Model 3: RC building with floating column at center
- Model 4: RC building with floating column starting

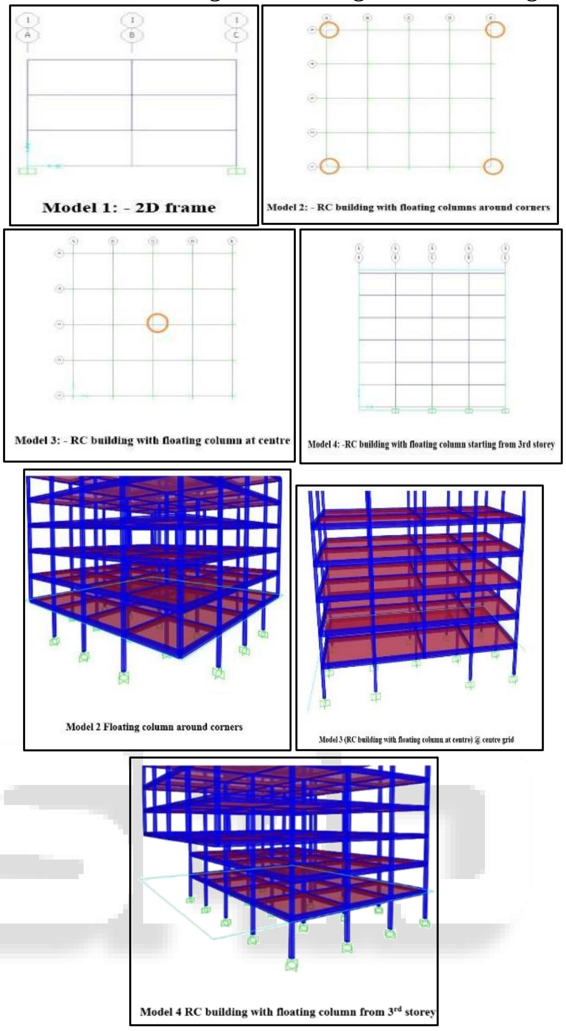


Fig. 3: Structural Models

V. Result and Discussion

A. *Model 1: 2D Frame*

After the analysis of the frame it is noted that for structure which has floating column, sequence of construction affects enormously and hence has to be considered during analysis. It can also be noted that the structures in lower storey's the forces are positively incremented or the forces are increased. Whereas when higher stories are considered the forces keep on decreasing as compared to conventional analysis (i.e. in lower storey the forces are increased in comparison to conventional dead load analysis and in higher storey's the forces are decreased compared to conventional dead load case).

This is because when we consider conventional analysis the entire model is considered to act as a single entity which is constructed at a time, in our case it considers the transfer girder to be supported by the structure above by truss action. But in actual construction transfer girder not only has to support the floating column it also has to support its own span, when sequential construction analysis is adopted this criterion is satisfied hence most realistic results are obtained.

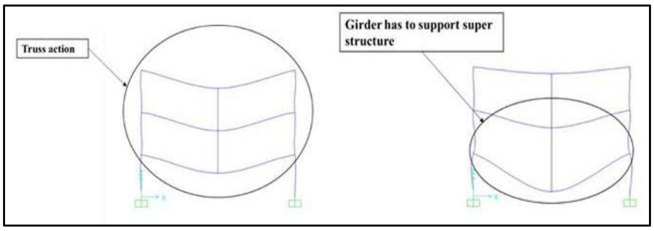


Fig. 4: Results

B. Model 2: RC Building with floating column around corners

In this model transfer girder, floating column, columns supporting transfer girder are considered for discussion.

Element type	Element number
Floating column	C26
Column supporting transfer girder	C2

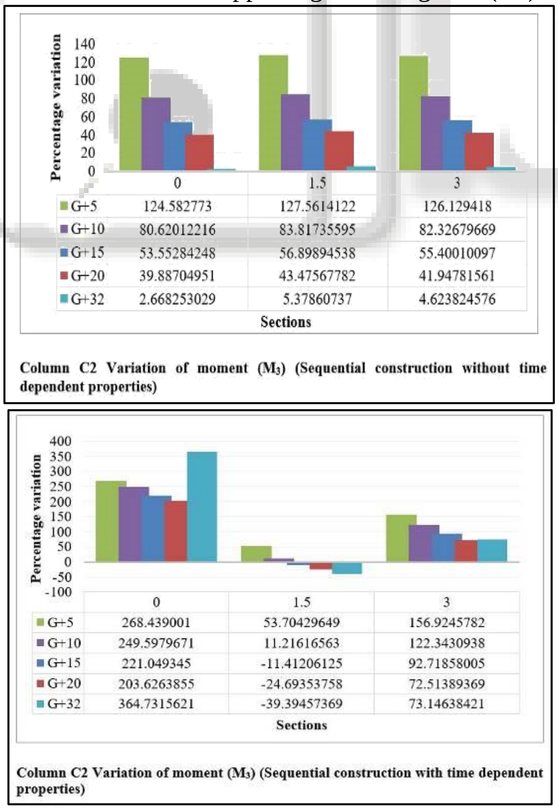
Table 4: RC Building with floating column around corners

C. Consider column supporting transfer girder (C2)

Column C2 Moment (M_3) (kN-m)

Analysis type	Section	G+5	G+10	G+15	G+20	G+32
Conventional analysis	0	31.2	87.2	195.2	360.4	753.4
	1.5	-16.9	-50.0	-120.3	-243.1	-976.0
	3	-65.0	-187.2	-435.8	-846.5	-2705.5
Sequential construction	0	70.1	157.6	299.8	504.2	773.5
	1.5	-38.4	-91.8	-188.7	-348.7	-1028.5
	3	-146.9	-341.2	-677.2	-1201.6	-2830.6
Sequential construction with creep and shrinkage	0	115.1	305.0	626.7	1094.3	3501.4
	1.5	-25.9	-55.6	-106.6	-183.0	-591.5
	3	-166.9	-416.1	-839.8	-1460.4	-4684.4

Table 5: Column supporting transfer girder (C2)



Column C2 Variation of moment (M_3) (Sequential construction without time dependent properties)

Column C2 Variation of moment (M_3) (Sequential construction with time dependent properties)

Fig. 5: Column supporting transfer girder

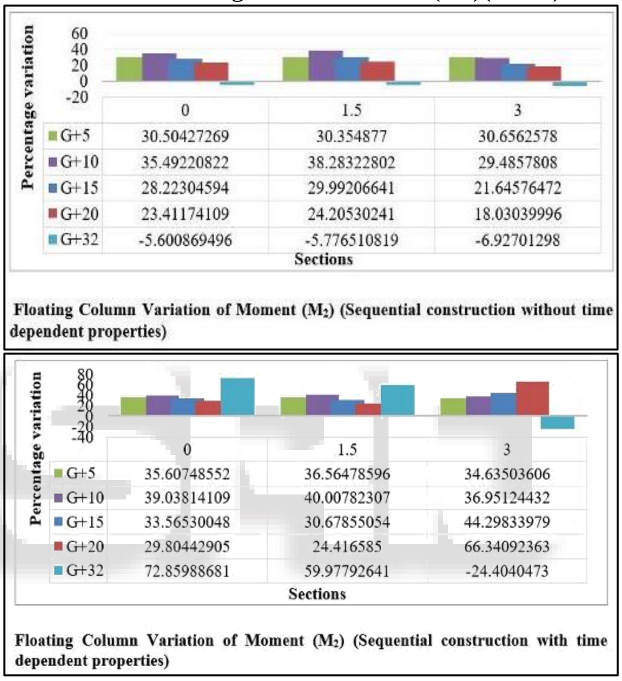
In column adjacent to floating column moment M_3 is the predominant moment in this structure. When sequential construction analysis was performed variation of 2-130% was observed when compared to conventional analysis. Since the value of moment M_3 in conventional analysis case was not that low the percentage variation is not as high. Variation of 10-270% can be observed when time dependent properties are considered in sequential construction analysis and is higher than sequential construction analysis (without considering time dependent properties) by 50%.

In case of axial load 0.5-3% positive variation is seen when sequential construction is considered. When creep and shrinkage is considered the variation is negative.

Consider floating column

Analysis type	Section	G+5	G+10	G+15	G+20	G+32
Conventional analysis	0	135.7	358.0	788.9	1458.4	3261.2
	1.5	34.2	122.2	310.8	635.5	1879.5
	3	-67.3	-113.6	-167.2	-187.4	497.9
Sequential construction	0	177.1	485.0	1011.5	1799.9	3078.5
	1.5	44.6	169.0	404.1	789.3	1771.0
	3	-88.0	-147.1	-203.4	-221.2	463.4
Sequential construction with creep and shrinkage	0	184.1	497.7	1053.6	1893.1	5637.3
	1.5	46.7	171.1	406.2	790.7	3006.8
	3	-90.6	-155.5	-241.3	-311.8	376.4

Table 6: Floating column moment (M_2)(kN-m)



Floating Column Variation of Moment (M_2) (Sequential construction without time dependent properties)

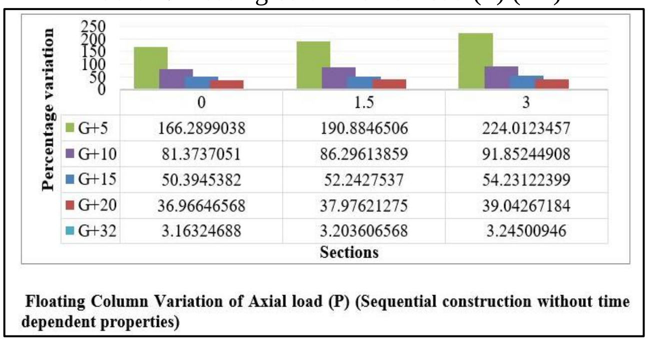
Floating Column Variation of Moment (M_2) (Sequential construction with time dependent properties)

Fig. 6: Floating Column

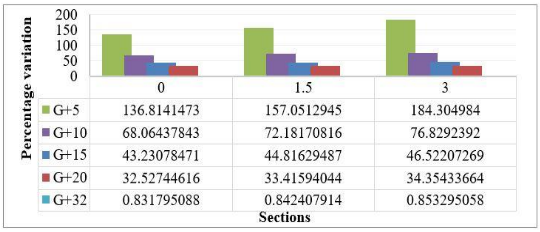
Variation of 5-35% was observed in sequential construction case and 25-75% sequential construction with creep and shrinkage case.

Analysis type	Section	G+5	G+10	G+15	G+20	G+32
Conventional analysis	0	-58.9	-236.6	-596.1	-1142.1	-6695.4
	1.5	-51.3	-223.1	-575.1	-1111.7	-6611.0
	3	-43.7	-209.6	-554.0	-1081.3	-6526.7
Sequential construction	0	-156.9	-429.1	-896.6	-1564.2	-6907.2
	1.5	-149.3	-415.6	-875.5	-1533.9	-6822.8
	3	-141.7	-402.1	-854.4	-1503.5	-6738.5
Sequential construction with creep and shrinkage	0	-139.5	-397.6	-853.9	-1513.5	-6751.1
	1.5	-131.9	-384.1	-832.8	-1483.2	-6666.7
	3	-124.4	-370.7	-811.7	-1452.8	-6582.4

Table 7: Floating column axial load (P) (kN)



Floating Column Variation of Axial load (P) (Sequential construction without time dependent properties)



Floating Column Variation of Axial load (P) (Sequential construction with time dependent properties)

Fig. 7: Floating column

Axial load (P) increased due to sequential construction analysis and a variation of 3-225% was seen in case of sequential construction. When creep and shrinkage was considered variation of 0.8-185% was observed.

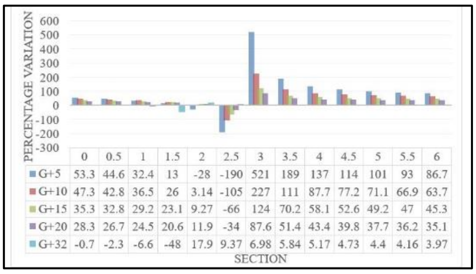
Moment M_3 variation is similar to variation of M_2 in this floating column.

D. Consider transfer girder

1) Transfer girder Bending moment (M_3) (kN-m)

Analysis type	Section	G+5	G+10	G+15	G+20	G+32
Conventional analysis	0	157.2443	415.4435	918.3543	1687.13	5602.111
	0.5	133.2351	346.4524	758.7755	1390.37	3903.424
	1	107.5389	274.6496	594.9793	1087.986	2171.935
	1.5	80.1556	200.0351	426.9655	779.9795	407.6433
	2	51.0854	122.6089	254.7343	466.3492	-1389.45
	2.5	20.3281	42.3711	78.2855	147.0957	-3219.35
	3	-12.1161	-40.6784	-102.381	-177.781	-5082.05
	3.5	-46.2474	-126.54	-287.265	-508.282	-6977.55
	4	-82.0657	-215.213	-476.366	-844.405	-8905.86
	4.5	-119.571	-306.697	-669.685	-1186.15	-10867
	5	-158.763	-400.993	-867.221	-1533.52	-12860.9
	5.5	-199.642	-498.101	-1068.97	-1886.52	-14887.6
	6	-242.209	-598.021	-1274.95	-2245.13	-16947.1
Sequential construction	0	241.1293	611.8199	1242.38	2164.592	5565.152
	0.5	192.6243	494.6961	1007.695	1762.287	3813.518
	1	142.4324	374.7607	768.7935	1354.359	2029.081
	1.5	90.5534	252.0136	525.6742	940.8081	211.8408
	2	36.9875	126.4549	278.3373	521.6335	-1638.2
	2.5	-18.2655	-1.9155	26.783	96.8356	-3521.05
	3	-75.2054	-133.098	-228.989	-333.586	-5436.7
	3.5	-133.832	-267.091	-488.978	-769.63	-7385.15
	4	-194.146	-403.897	-753.185	-1211.3	-9366.4
	4.5	-256.147	-543.514	-1021.61	-1658.59	-11380.5
	5	-319.835	-685.943	-1294.25	-2111.5	-13427.3
	5.5	-385.21	-831.183	-1571.11	-2570.04	-15507
	6	-452.272	-979.235	-1852.19	-3034.2	-17619.4
Sequential construction with creep and shrinkage	0	241.6946	614.9493	1269.054	2231.892	7785.739
	0.5	197.5316	505.698	1045.046	1842.262	6073.13
	1	151.6816	393.635	816.821	1447.008	4327.718
	1.5	104.1446	278.7603	584.3782	1046.131	2549.503
	2	54.9205	161.0739	347.7178	639.6308	738.4851
	2.5	4.0095	40.5758	106.84	227.5071	-1105.34
	3	-48.5885	-82.7339	-138.255	-190.24	-2981.96
	3.5	-102.874	-208.855	-387.568	-613.61	-4891.38
	4	-158.846	-337.788	-641.099	-1042.6	-6833.61
	4.5	-216.505	-469.533	-898.847	-1477.22	-8808.65
	5	-275.851	-604.089	-1160.81	-1917.46	-10816.5
	5.5	-336.884	-741.457	-1426.99	-2363.33	-12857.1
	6	-399.604	-881.637	-1697.4	-2814.81	-14930.6

Table 8: Transfer girder Bending moment (M_3) (kN-m)



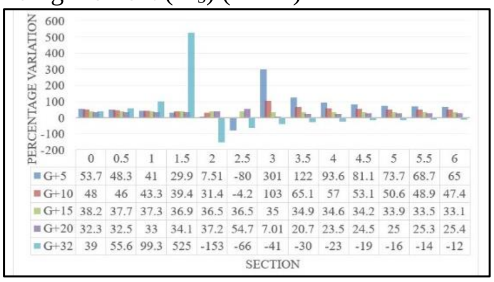


Fig. 8: Transfer girder variation of bending moment (M3) (Sequential construction with time dependent properties)

Peak variation was seen between sections 2.5 and 3 this is because the point of contra flexure shifts during sequential construction analysis. Max variation was seen for G+5 storey structure. When creep and shrinkage is considered the variation is non uniform and negative moment in the beam reduced.

E. Joint Displacement

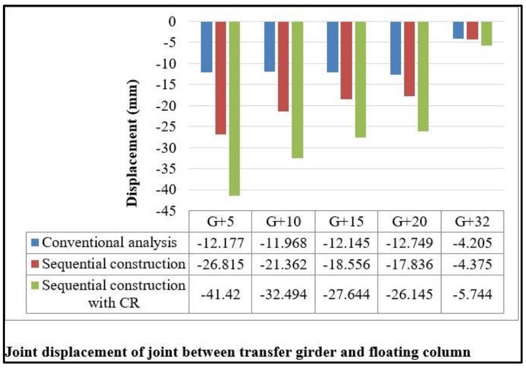


Fig. 9: Joint displacement

When sequential construction analysis is carried out joint displace increased. Max variation is G+5 storey building. When creep and shrinkage was considered deflection increased.

F. Model 3 & Model 4

Similar to model 2, models 3 and 4 were analyzed in sequence of construction analysis with and without time dependent properties. An interior column was also considered in order to understand the effect of presence of floating column. Based on the results conclusions are drawn.

VI. CONCLUSIONS

Based on analytical results following conclusions can be drawn

1) Behavior of structure is unique when sequence of construction is considered.
2) In case of column supporting transfer girder
   – In model 2&3 there is positive increment in moments and the variation reduced as higher number of storey's are considered. Model 4 the variation is not uniform.
   – When creep and shrinkage is taken into consideration, in model 2 there is positive increment in moments and variation reduced when number of storey's considered became higher. In model 3 there is decrement in moments and variation increases as number of storey's considered increases. In model 4 when creep and shrinkage are considered the moment variation is non uniform.
   – There is increment in axial load in all the three models and variation decreases when number of storey considered increases. When creep and shrinkage is taken into consideration axial load decreases and variation increases when the number of storey's considered increases.
3) In case of column adjacent to floating column at top storey
   – In models 2&3 there is negative variation in moments and variation increases when the number of storey's considered increases. In model 4 the variation is negative but the variation deceases as the number of storey considered increases.
   – When creep and shrinkage is also taken into consideration the variation is negative and as the number of storey's considered increases variation also increases.
   – Axial load for both with and without creep and shrinkage cases the variation is negative and as the number of storey's considered increases the variation decreases.
4) In case of floating column
   – Variation of moments cannot be generalized, the axial load in the column increases and as the number of storey's considered increases the variation decreases.
5) In transfer girder bending moment, shear force and torsional moment increase when sequence of construction is considered. As the number of storey's considered increases the variation decreases.
6) In column resting on floating column in top storey the forces are decreased and as the number of storey's considered increases variation also increases.
7) Displacement in critical joints are also increased and as the number of storey's considered increases, displacement decreases.
8) Finally, it can be concluded that in the bottom part of critical elements there is positive increment and variation decreases when the number of storey's of structure is more. In top portion negative increment is observed as the number of storey's considered increases the variation also increases.

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