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SEISMIC RESPONSE OF RC FRAMED MULTI-STOREY BUILDING WITH FLOATING COLUMNS

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ABSTRACT
The present work deals with the study of comparative Seismic Response of RC Framed Multi-storey Buildings with and without Floating Columns in various configurations and with different storey height. To carry out the work two sets of models are taken which differs in storey height of ground floor. Both the sets contain seven models (total fourteen) with different configuration and numbers of floating columns are considered. Various gravity loads are applied and since building is assumed to be located in seismic zone IV, the seismic loads considered accordingly. Models are developed and analysed with the help of STAAD.Pro V8i by performing equivalent static analysis method. Results are obtained and compared in terms of various parameters such as axial force, shear force, moments, node displacements, average storey displacement and storey drift. The study concludes, inter alia, that the diagonal pattern of floating column is preferable as compare to orthogonal pattern and maximum absolute value of the important design parameters appears at ground and first floors.

KEYWORDS: Floating Columns, Equivalent Static Analysis, Base Shear, Node Displacement, Storey Displacement, Storey Drift

INTRODUCTION
Few decades back the populations were not so vast so they used to stay in horizontal system (due to large area available per person), but now a day's people preferring Vertical System (high rise buildings) due to shortage of area. This necessitated an infrastructural boom during last few decades which resulted in construction of many high rise structures in all mega cities. Due to shortage of space, increasing population and also for aesthetic and functional requirements, multi-storey buildings in urban cities are required to have column free space. For this, buildings are provided with ***floating columns*** at one or more storey. The term ***floating column*** is a vertical structural element which (due to architectural design/ site situation) at its lower level (termination level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it. There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. Today many multi-storeyed buildings in India have floating columns as an unavoidable feature. Architects and Structural Designers have provided floating column in many locations in structure.
Most of the time, architect demands for the aesthetic view of the building, in such cases also many of the columns are terminated at certain floors and floating columns are introduced and hence such buildings are planned and constructed with architectural complexities. However, this should not be done at the cost of poor behaviour and earthquake safety of buildings. Architectural features that are detrimental to earthquake response of buildings should be avoided and if not, they must be minimized. When irregular features such as above are included in buildings, a considerably higher level of engineering effort is required in the structural planning & design and yet the building may not be as good as one with simple architectural features. The discontinuity of column at any floor changes the load path and transfers load of the floating column through horizontal beams supporting it. This altered path will cause large vertical earthquake forces due to overturning effect.
Providing floating columns may satisfy some of the functional requirements but structural behaviour changes abruptly. Where provision of floating column is necessary, special care should be given to the transfer girders

and column below the floating column. These beams and column should have sufficient strength to receive the load from floating column and convey it to the lower level.
Since the lateral load resisting system is often integrated with the gravity load resisting system, this can result in serious damage or collapse of the building during seismic attack for presence of floating columns in a building may result in a concentration of forces or deflection or in an undesirable load path in the vertical lateral-force-resisting system. Vertical irregularities typically occur in a storey that is significantly more flexible or weaker than adjacent stories due to many reasons. A structure with floating column can be categorized as vertically irregular as it causes irregular distributions of mass, strength and stiffness along the building height. The building become vulnerable to earthquake hazard due to improper way of flow of seismic force to the ground due to discontinuity in the form of floating column, brought into structure.
Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse by these forces which are initiated in that storey. Lateral forces accumulated in upper floors during the earthquake have to be transmitted by the projected cantilever beams. In case of floating column, shear is stir up to overturning forces to another resting element of the low level. This imposition of overturning forces overpowers the columns of lower level through connecting elements and hence becomes the most critical region of damage. Therefore, the primary concern in load path irregularity is the strength of lower level columns and strength of the connecting beams that support the load of discontinuous frame. Hence, the joint between beam and floating column, the transfer girders and the columns below it are considered as critical since their stability influence the overall stability of building and failure of beam-column joint in concrete moment resisting frame was identified as one of the leading causes of collapse of such structure. So they have to be designed and detailed properly.
Seismic codes are unique to a particular region or country, help to improve the behaviour of structure so that structure may withstand the earthquake effects and without significant loss of life and property. They take into account the local seismology, accepted level of seismic risk, buildings typologies, and materials and methods used in construction. The Bureau of Indian Standards (BIS) published the Seismic Codes such as IS 1893 (PART 1) : 2002, IS 4326 : 1993, IS 13827 : 1993, IS 13828 : 1993 IS 13920 : 1993, and many more.
Software like STAAD Pro, SAP, ETABS, etc. can be used to do the analysis of this type of structure. Moreover software has a greater advantage than the manual technique as it gives more accurate and precise result than the manual technique. So the use of software will make it easy. In this work, facilities of STAAD Pro are utilised. STAAD-PRO along with IS Codes can solve typical problems like Static analysis, Seismic analysis and Natural frequency.

OBJECTIVE
In the present work an attempt is made to study the behaviour of multi-storey buildings with floating columns under earthquake excitations. Number of models of RC Framed structures of G+20 floors each situated in Earthquake Zone IV viz. without floating column (i.e. normal building) and with floating columns in various patterns, above the ground floor are considered to achieve the objectives. The building is modelled and analysed with the help of STAAD Pro V8i software. The seismic performance of building with and without floating columns are presented in terms of various parameters such as maximum bending moment and shear force in Beams, maximum axial force in column, base shear, displacement, storey drift by using software STAAD Pro V8i. Equivalent static analysis is performed on the various buildings and their seismic performance is evaluated.

METHODOLOGY
Method of Analysis
Seismic analysis is a significant tool in earthquake engineering which is used to examine the behaviour of buildings in a simpler manner due to seismic forces. Though the design to counter earthquake effects must consider the dynamic nature of the load, yet for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings and begins with an estimate of peak earthquake load calculated as a function of the parameters given in the code. Equivalent static analysis can, therefore, work well for low- to medium-rise buildings without significant coupled lateral – torsion modes, in which only the first mode in each direction is of significance. Here the analysis of 3D building model is explained using equivalent static analysis method only.

Equivalent static method
Equivalent Static Analysis approach defines a sequence of lateral forces acting on a building to represent the forces generated due to earthquake ground motion, typically defined by a seismic design response spectrum. The

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basic assumption is that the building responds in its fundamental mode. Given the natural frequency of the building, the response is examined from a design response spectrum. The lateral equivalent forces are calculated and then distributed along the height of the building using empirical equations as given in the code. The various parameters considered to calculate the lateral loads are Response reduction factor (R), Zone factor (Z), Importance factor (I), Horizontal acceleration coefficient (A_h), Structural response factor (S_a/g) and Total Seismic Weight of building (W) as per the clause 6.4 and 7.5 of IS Code 1893 (Part 1): 2002.

FORMULATION OF THE PROBLEM

This Section aims toward the problem statement and various data input for modelling, analysis and identifying the parameters to be compared.

Problem Statement

Various models are to be prepared and to be analysed with the help of software STAAD.Pro V8i using equivalent static analysis to achieve the objective.

Load Combinations

Various loads and load combinations in accordance with IS Codes 875 (Part I):1987, 875 (Part II): 1987, IS 456: 2000 and IS 1893 (Part 1): 2002 taken into consideration acting on the building models are as follows:
Dead Load (DL):- Dead Load is defined as the load on a structure due to its own weight (self-weight). They are given in IS Code 875 (Part I):1987.
Live Load (LL):- The load which is moving without acceleration is called Live Load (or Imposed Load). They are given in IS Code 875 (Part II): 1987. In present work live load is taken as 3kN/m^2.
Seismic Load or Earthquake Load (SL):- Seismic Loads are dealt in IS Code IS 1893 (Part 1): 2002. In present work the structure is considered in seismic zone IV and seismic load is considered in the +ve direction of both the orthogonal axes (in plan) as SLX & SLZ
Load Combinations – Load Combination are taken in accordance with clause 6.3.1.2 of IS 1893 (Part-1): 2002. 19 Load combinations are generated through Auto Load Combination utility of STAAD.Pro V8i software.

Data Input

Following are the data assumed/considered/adopted for modelling and analysing the structure:

Table 1: Details of Input Data for Modelling & Analysis

S. No.	Name of Data	Description and Value
A	**Software**	
1	Software used for Modelling & Analysis	**STAAD.Pro V8i**
B	**Model**	
2	Type of Structure	Special RC Moment Resisting Frame (SMRF)
3	Type of Building	Residential
4	Plan Area	18m x 18m
5	Number of Bays	6 of 3m each in both direction
6	Number of stories	21 (G+20)
7	Floor Height	For Set A Models : All Floors 3.0m each For Set B Models : GF 4.0m and 1st to 20th Floor 3.0m each
8	Total Height of Building above Ground Level	For Set A Models : 21 x 3.0m each = 63.0m For Set B Models : (1 x 4.0m) + (20 x 3.0m) = 64.0m
9	Depth of Footings	3.0m below Ground Level
C	**Structural Elements**	
10	Type of Foundation	Fixed
11	Size of column	600mm x 600mm
12	Size of Beam	400mm x 600mm
13	Depth of Slab	125mm
14	Infill wall	100mm thick brick masonry walls at peripheral and central beams along X and Y direction
D	**Material**	

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15	Concrete	M30 Grade, Unit Wt 25kN/m^3
16	Reinforcement Steel	Fe 415
17	Type of Soil	Medium
E	**Seismic Parameters**	
18	Seismic Zone	IV
19	Response Reduction factor	5
20	Importance Factor	1
F	**Loads**	
21	Dead Load	Self Weight : Beams & Columns (25kN/m^3) Floor Weight : Slab (3.125kN/m^2) Member Load : UDL of Infill walls (6.0kN/m)
22	Live load	3.0kN/m^2
23	Seismic Load	In +X and +Z Directions (Calculated by STAAD.Pro V8i)

Points of Comparison

Analysis results are compared on following parameters

1. Maximum Axial Force in Column
2. Maximum Shear Force in Column
3. Maximum Bending Moment in Column
4. Maximum Shear Force in Beams
5. Maximum Bending Moment in Beams
6. Seismic Base Shear
7. Node Displacement
8. Storey Displacement
9. Storey Drift

MODELLING

In the present work, the study is carried out on various models of RC framed G+20 residential building symmetric in plan, with and without floating columns. The loading pattern, plan dimensions and height of each storey is kept same for all the models except the height of ground storey and number of columns at that storey. Other prevalent data is tabulated in Table 1. The building is modelled using the software STAAD.Pro V8i. Only those components that influence the mass, strength, stiffness and deformability of structure, are considered for the analytical modelling of the building and non-structural elements that do not significantly influence the building behaviour are not modelled. The building structural system includes beam, column, slab, wall and foundation. Beams and columns are modelled as two nodded beams. Floor load (Dead load & Live load) is considered for slab and the wall load is uniformly distributed over the peripheral and central beams. Fixed support Foundations are considered over medium soil.

The models prepared in this work can be categorised mainly in two sets viz. Set A and Set B. Set A consist of models with storey height of 3m for all the floors whereas Set B includes the models of same configuration as Set A with ground floor height of 4m and rest of the floors of storey height 3m. Both the sets consist of 7 models each which include one basic model i.e. without floating column and 6 models with different location/pattern of floating columns. All the models (2 x 7) have same plan dimension as 18m x 18m, 6 bays of size 3m each in both directions with varying numbers of floating columns.

EQUIVALENT STATIC ANALYSIS

The IS Code 1893 (Part 1):2002 recommends two methods for seismic analysis viz. Seismic coefficient method popularly known as Equivalent Static method, and Dynamic method. In the present work former method is adopted. The seismic analyses of the structures are carried out by assuming that the lateral forces are equivalent to the actual loads.

In this method, initially the design base shear or lateral forces are computed for the structure as a whole. Then this design lateral force is distributed to the various floor levels along the height of structure based on simple formulae with regular distribution stiffness and mass. Therefore the overall design lateral or seismic forces are obtained at each floor level and then distributed to the individual lateral load resisting elements.

Major steps for determining the lateral forces by equivalent static analysis as per the code IS1893:2002 are as follows:

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(i) Design lateral force or seismic base shear:

The total design seismic base shear (V_B) shall be determined along any principal direction by the following expression:

$$V_B = A_h W$$

Where,

A_h = Design horizontal seismic coefficient by using fundamental natural period (T_a)

= $\frac{ZIS_a}{2Rg}$

W = Seismic weight of the whole building as per clause 7.4.2

Z = Zone factor.

I = Importance factor

R = Response reduction factor

S_a /g = Average response acceleration coefficient for rock and soil sites.

T_a = Approximate fundamental natural period of vibration for moment resisting frame building in seconds.

= $\frac{0.09h}{\sqrt{d}}$

h = Height of the building, in m.

d = Base dimension of the building, in m, along the considered principal direction of the lateral force.

(ii) Distribution of Base Shear and Design Force:

The computed design base shear (V_B) shall be distributed along the building height by following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

Where,

Q_i = Design lateral force at floor i.

W_i = Seismic weight of floor i.

h_i = Height of floor i measured from base.

n = Number of storey in the building (number of levels at which the masses are located)

STAAD.Pro V8i software calculates and applies the static seismic forces to analyse the structure in accordance with the procedures as recommended by the relevant IS Codes.

CLASSIFICATION AND NOMENCLATURE OF MODELS

On the basis of number and location of floating columns in different pattern and ground floor height, 14 different models are developed. Models so developed can broadly be classified in two category viz. Set A and Set B. The models under Set A are with the ground floor height as 3m whereas models under Set B have ground floor height of 4m. Both the sets have 7 types of models as shown in following table:

Table 2 – Nomenclature and description of Models

Models Developed & Analysed (Total 14)	
Set A - With GF Height = 3m (Total height 63m)	**Set B - With GF Height = 4m (Total height 64m)**
1. **Model 0A** - Basic Model without FC	1. **Model 0B** - Basic Model without FC
2. **Model 1A** – Model with 12 FC (in Diagonal)	2. **Model 1B** – Model with 12 FC (in Diagonal)
3. **Model 2A** – Model with 12 FC (in Diagonal) + 1 (at Centre)	3. **Model 2B** – Model with 12 FC (in Diagonal) + 1 (at Centre)
4. **Model 3A** – Model with 12 FC (in Orthogonal)	4. **Model 3B** – Model with 12 FC (in Orthogonal)
5. **Model 4A** - Model with 12 FC (in Orthogonal) + 1 (at Centre)	5. **Model 4B** - Model with 12 FC (in Orthogonal) + 1 (at Centre)
6. **Model 5A** - Model with 24 FC in Alternate	6. **Model 5B** - Model with 24 FC in Alternate
7. **Model 6A** - Model with 25 FC in Alternate including Corner and centre columns	7. **Model 6B** - Model with 25 FC in Alternate including Corner and centre columns

A 3D Rendered views and Plans at ground floor of all the models showing positions of Floating Columns are shown below:

Figure 1:

Figure 2:

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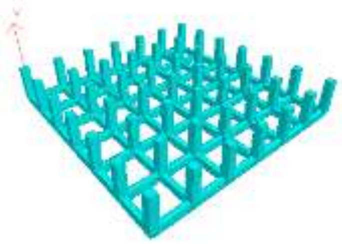
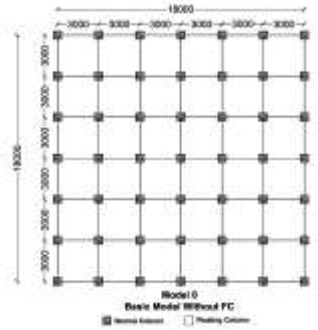
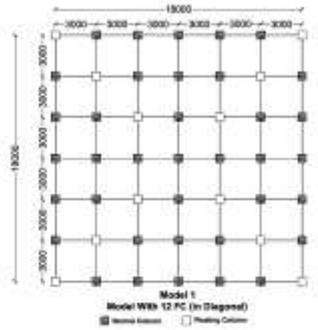


3D Rendered View of the Model 0



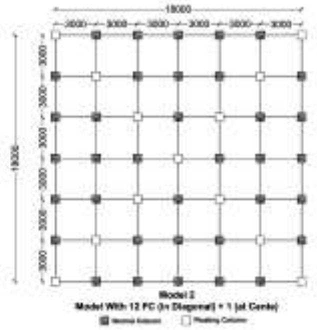
Plan of Model 0

Figure 3:



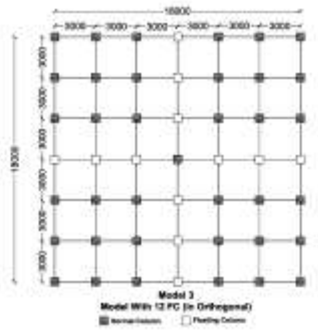
Plan of Model 1

Figure 4:



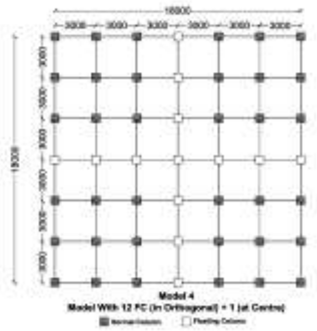
Plan of Model 2

Figure 5:



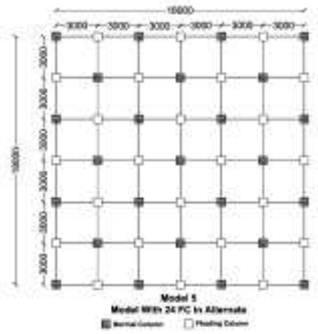
Plan of Model 3

Figure 6:



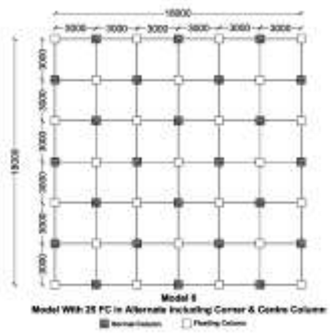
Plan of Model 4

Figure 7:



Plan of Model 5

Figure 8:



Plan of Model 6

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RESULTS AND DISCUSSION

Results for all models of both the Sets are obtained, summarised by taking maximum absolute values of each parameter and compared. The variations in parameters are compared among the Models of Set A which are affected due to varying the location and pattern of floating columns in plan. Further, same sets of results are also used to compare the above said parameters between Models of Set A and corresponding Models Set B for change in height of a storey.

Table 3: Comparison of Column Forces, Beam Forces and Base Shear among Models of Set A

Models	COLUMN FORCES			BEAM FORCES		Base Shear
	Axial Force (Fx) kN	**Shear Force (Fy & Fz) kN**	**Moment-Y (My & Mz) kNm**	**Shear Force (Fy) kN**	**Moment (Mz) kNm**	
Model 0A	**3968.662**	**94.632**	**148.516**	**137.250**	**169.749**	**2328.67**
Model 1A	**5513.972**	**191.384**	**352.768**	**324.661**	**486.494**	**2321.21**
	39%	***102%***	***138%***	***137%***	***187%***	***-0.32%***
Model 2A	**5810.331**	**192.417**	**354.695**	**331.915**	**489.054**	**2320.59**
	46%	***103%***	***139%***	***142%***	***188%***	***-0.35%***
Model 3A	**6932.262**	**216.722**	**338.651**	**405.406**	**582.088**	**2321.21**
	75%	***129%***	***128%***	***195%***	***243%***	***-0.32%***
Model 4A	**6468.981**	**230.126**	**358.065**	**458.926**	**662.688**	**2320.59**
	63%	***143%***	***141%***	***234%***	***290%***	***-0.35%***
Model 5A	**7409.526**	**160.836**	**302.672**	**431.372**	**628.938**	**2313.75**
	87%	***70%***	***104%***	***214%***	***271%***	***-0.64%***
Model 6A	**7387.042**	**226.369**	**420.957**	**454.861**	**684.786**	**2313.13**
	86%	***139%***	***183%***	***231%***	***303%***	***-0.67%***

Table 4: Comparison of Node Displacement, Storey Displacement and Storey Drift among Models of Set A

Models	Node Displacement			Avg. Disp. of Top Storey (mm)	Storey Drift (mm)	
	X- & Z- Translation mm	**Y- Translation mm**	**Absolute mm**		**At GF**	**At 8th Flr.**
Model 0A	**53.130**	**-16.940**	**55.414**	**35.329**	**1.487**	**1.908**
Model 1A	**58.814**	**-18.940**	**61.513**	**39.159**	**1.868**	**2.079**
	11%	***12%***	***11%***	***11%***	***26%***	***9%***
Model 2A	**58.865**	**-19.405**	**61.589**	**39.188**	**1.900**	**2.079**
	11%	***15%***	***11%***	***11%***	***28%***	***9%***
Model 3A	**55.924**	**-20.184**	**58.847**	**37.157**	**1.936**	**1.976**
	5%	***19%***	***6%***	***5%***	***30%***	***4%***
Model 4A	**56.123**	**-21.292**	**59.135**	**37.279**	**2.074**	**1.975**
	6%	***26%***	***7%***	***6%***	***39%***	***4%***
Model 5A	**62.292**	**-21.955**	**65.746**	**41.429**	**2.540**	**2.158**
	17%	***30%***	***19%***	***17%***	***71%***	***13%***
Model 6A	**65.761**	**-22.218**	**69.245**	**43.771**	**2.638**	**2.270**
	24%	***31%***	***25%***	***24%***	***77%***	***19%***

Table 5: Comparison of Column Forces, Beam Forces and Base Shear between Models of Set A & Set B

Models	COLUMN FORCES			BEAM FORCES		Base Shear
	Axial Force (Fx) kN	**Shear Force (Fy & Fz) kN**	**Moment-Y (My & Mz) kNm**	**Shear Force (Fy) kN**	**Moment (Mz) kNm**	

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Model 0A	3968.662	94.632	148.516	137.250	169.749	2328.67
Model 0B	3969.036	95.180	169.441	137.838	170.645	2338.83
0A v/s 0B	**0.01%**	**0.58%**	**14.09%**	**0.43%**	**0.53%**	**0.44%**
Model 1A	5513.972	191.384	352.768	324.661	486.494	2321.21
Model 1B	5507.512	189.356	348.906	321.585	476.902	2328.88
1A v/s 1B	**-0.12%**	**-1.06%**	**-1.09%**	**-0.95%**	**-1.97%**	**0.33%**
Model 2A	5810.331	192.417	354.695	331.915	489.054	2320.59
Model 2B	5772.109	190.472	350.983	337.543	479.636	2328.05
2A v/s 2B	**-0.66%**	**-1.01%**	**-1.05%**	**1.70%**	**-1.93%**	**0.32%**
Model 3A	6932.262	216.722	338.651	405.406	582.088	2321.21
Model 3B	6845.789	222.922	345.334	405.576	577.430	2328.88
3A v/s 3B	**-1.25%**	**2.86%**	**1.97%**	**0.04%**	**-0.80%**	**0.33%**
Model 4A	6468.981	230.126	358.065	458.926	662.688	2320.59
Model 4B	6403.288	234.329	363.800	450.569	653.125	2328.05
4A v/s 4B	**-1.02%**	**1.83%**	**1.60%**	**-1.82%**	**-1.44%**	**0.32%**
Model 5A	7409.526	160.836	302.672	431.372	628.938	2313.75
Model 5B	7394.347	166.938	349.125	435.203	655.274	2318.93
5A v/s 5B	**-0.20%**	**3.79%**	**15.35%**	**0.89%**	**4.19%**	**0.22%**
Model 6A	7387.042	226.369	420.957	454.861	684.786	2313.13
Model 6B	7415.909	226.200	420.537	468.898	714.569	2318.11
6A v/s 6B	**0.39%**	**-0.07%**	**-0.10%**	**3.09%**	**4.35%**	**0.22%**

Table 6: Comparison of Node Displacement, Storey Displacement and Storey Drift between Models of Set A & Set B

Models	Node Displacement			**Avg. Disp. of Top Storey (mm)**	**Storey Drift (mm)**	
	X- & Z- Translation mm	**Y- Translation mm**	**Absolute mm**		**At GF**	**At 8th Flr.**
Model 0A	53.130	-16.940	55.414	35.329	1.487	1.908
Model 0B	55.880	-17.390	58.184	37.163	2.669	1.933
0A v/s 0B	**5.18%**	**2.66%**	**5.00%**	**5.19%**	**79.49%**	**1.31%**
Model 1A	58.814	-18.940	61.513	39.159	1.868	2.079
Model 1B	62.339	-19.538	65.077	41.510	3.380	2.114
1A v/s 1B	**5.99%**	**3.16%**	**5.79%**	**6.00%**	**80.94%**	**1.68%**
Model 2A	58.865	-19.405	61.589	39.188	1.900	2.079
Model 2B	62.441	-20.031	65.204	41.573	3.447	2.113
2A v/s 2B	**6.07%**	**3.23%**	**5.87%**	**6.09%**	**81.42%**	**1.64%**
Model 3A	55.924	-20.184	58.847	37.157	1.936	1.976
Model 3B	59.294	-20.818	62.240	39.403	3.469	2.004
3A v/s 3B	**6.03%**	**3.14%**	**5.77%**	**6.04%**	**79.18%**	**1.42%**
Model 4A	56.123	-21.292	59.135	37.279	2.074	1.975
Model 4B	59.548	-21.945	62.582	39.561	3.646	2.003
4A v/s 4B	**6.10%**	**3.07%**	**5.83%**	**6.12%**	**75.80%**	**1.42%**
Model 5A	62.292	-21.955	65.746	41.429	2.540	2.158
Model 5B	67.084	-22.831	70.577	44.624	4.709	2.202
5A v/s 5B	**7.69%**	**3.99%**	**7.35%**	**7.71%**	**85.39%**	**2.04%**
Model 6A	65.761	-22.218	69.245	43.771	2.638	2.270
Model 6B	70.862	-23.120	74.390	47.172	4.881	2.320
6A v/s 6B	**7.76%**	**4.06%**	**7.43%**	**7.77%**	**85.03%**	**2.20%**

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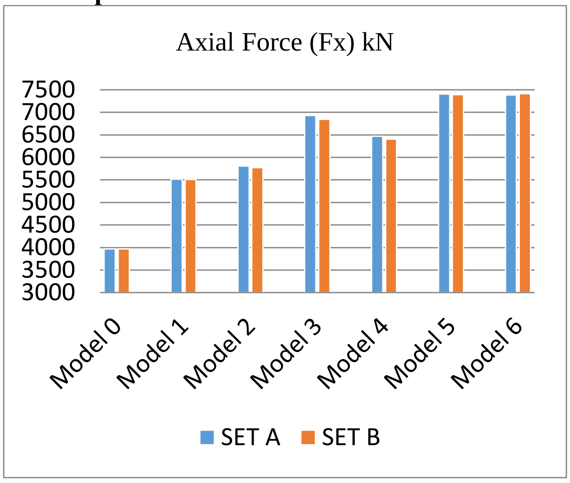
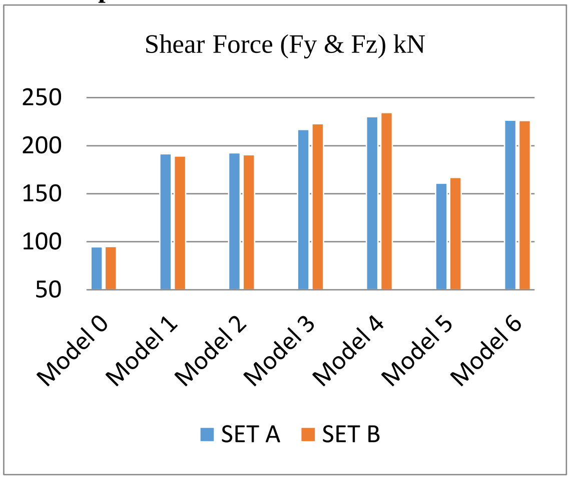
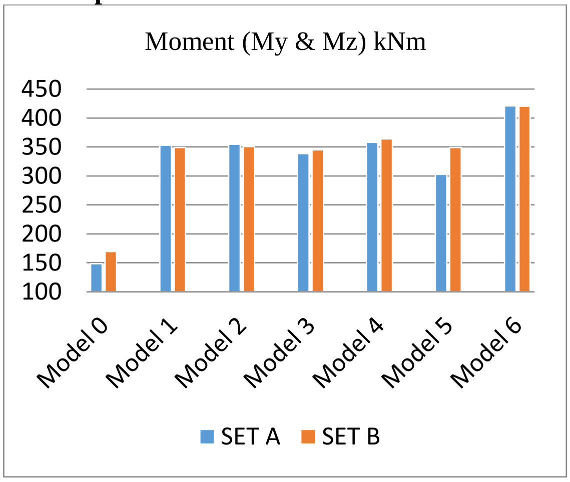
Graph 4.1: Column Axial Force



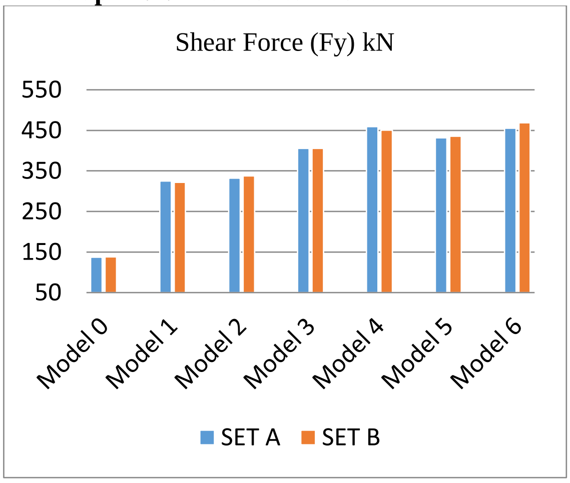
Graph 4.2: Column Shear Force



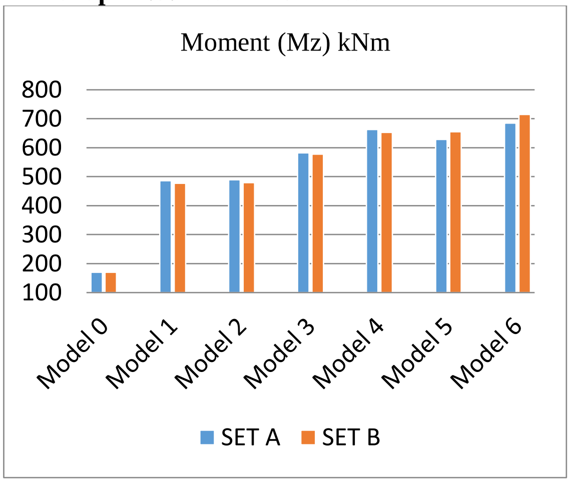
Graph 4.3: Column Moments



Graph 4.4: Beam Shear Force



Graph 4.5: Beam Moments



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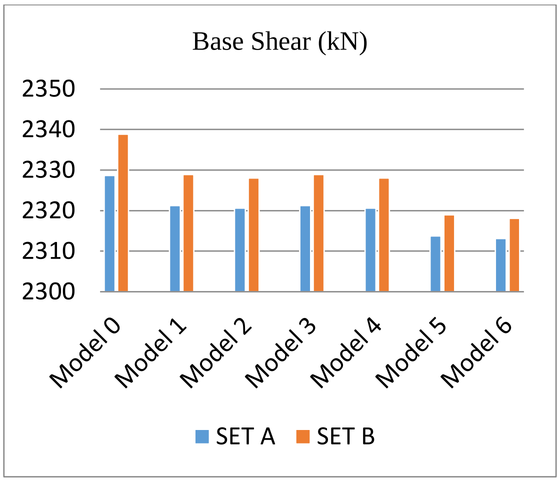
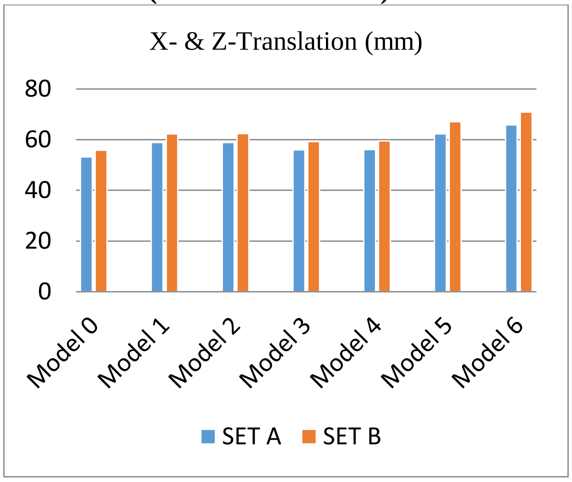
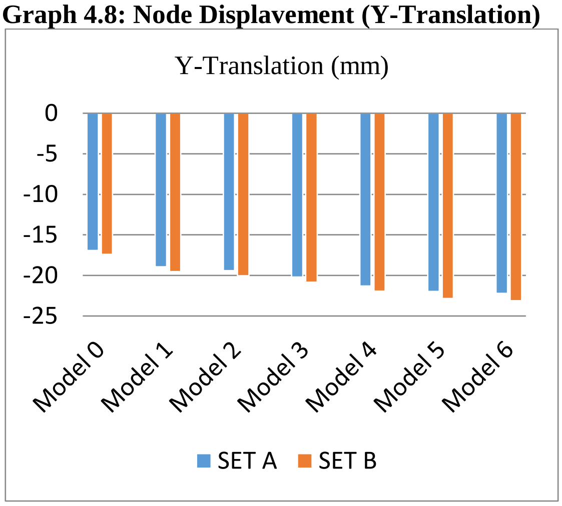
Graph 4.6: Base Shear



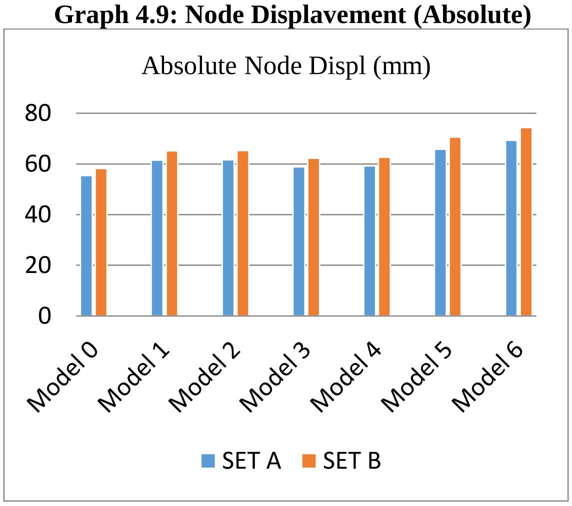
Graph 4.7: Node Displavement (X- & Z-Translation)



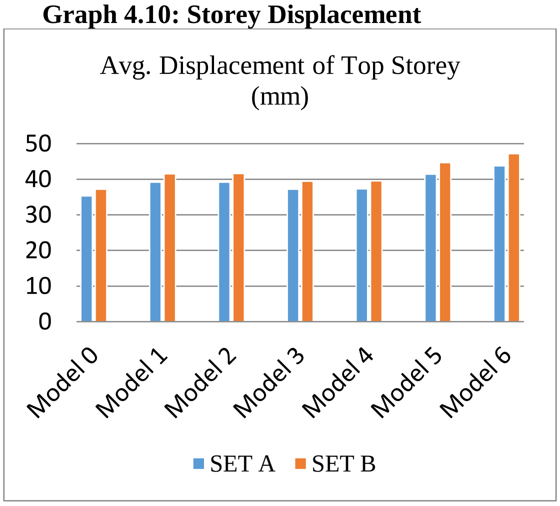
Graph 4.8: Node Displavement (Y-Translation)



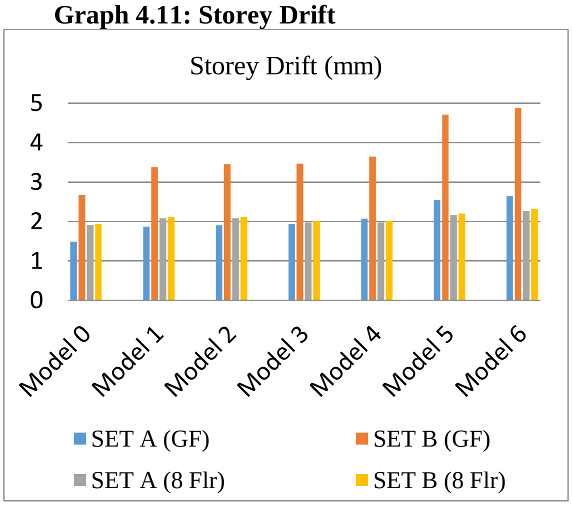
Graph 4.9: Node Displavement (Absolute)



Graph 4.10: Storey Displacement



Graph 4.11: Storey Drift



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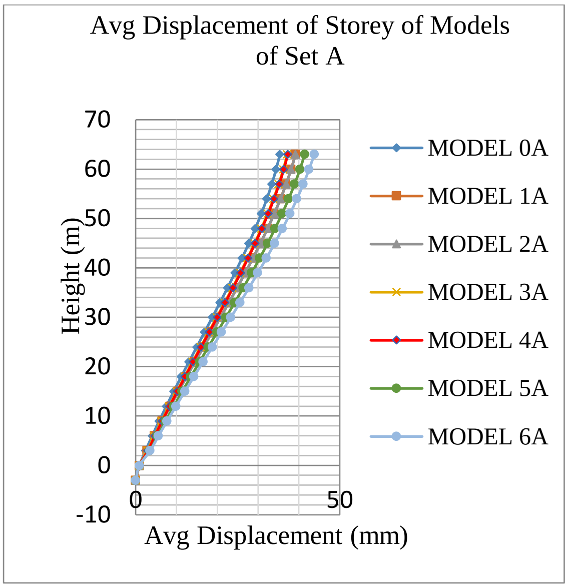
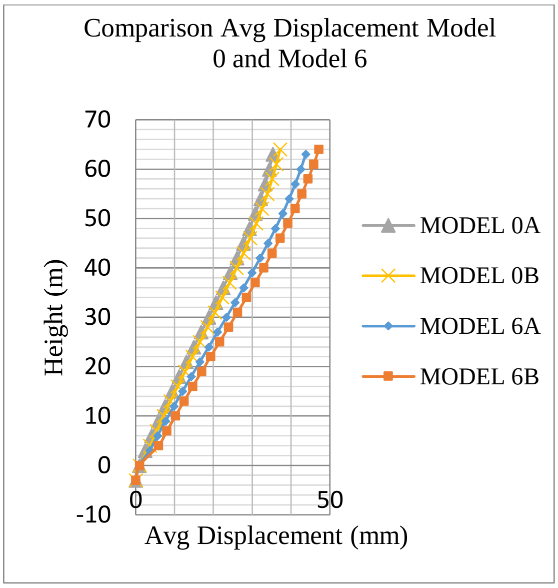
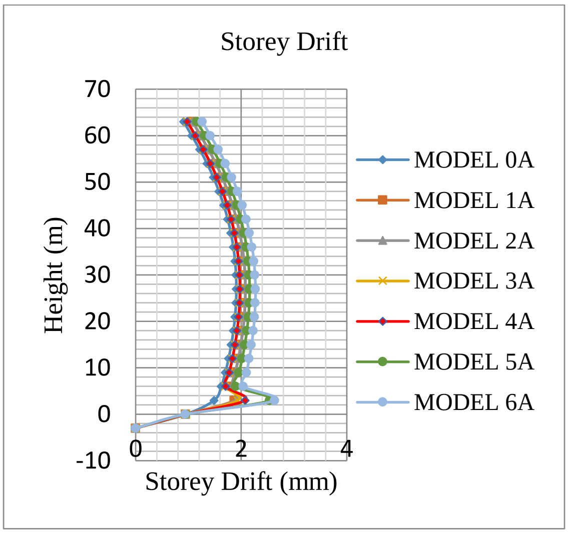
Graph 4.12: Average Displacement



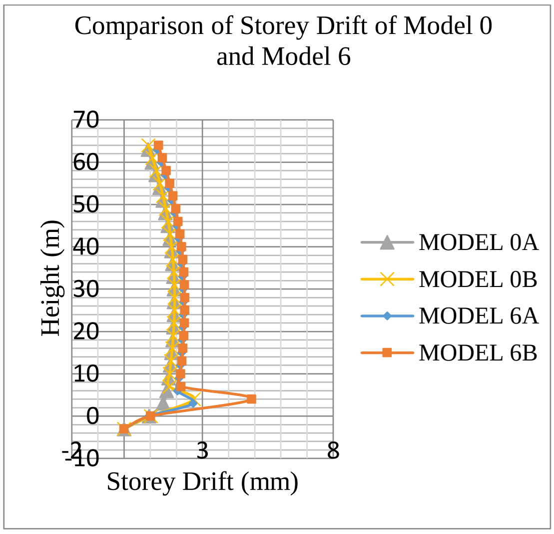
Graph 4.13: Comparison of Avg Displacement of Model 0 and Model 6



Graph 4.14: Storey Drift



Graph 4.15: Comparison of Storey Drift of Model 0 and Model 6 of both Sets



Effect of Floating Columns

Effect of introducing floating columns above Ground Storey level on the response of 3D RC Framed structure as adopted for the present work in view of different parameters, are mentioned below. Here the models of Set A are compared *ab intra*. The models with floating columns, viz. Model 1A to 6A, are compared with basic model i.e. Model 0A. The percentage increase (or decrease) in the magnitude of various parameters are calculated as shown in Table 3 & 4.

A) Forces in Columns

i) Axial Force (F_x) in Columns: Value of maximum axial force increased as the number of floating columns increased and location of its occurrence shifted to the columns at GL from foundation level. But keeping the number of floating columns same the magnitude increases more as pattern changes from diagonal to orthogonal. Contrasting this, the value decreased for Model 4A as the floating columns increased from 12 to 13 and for Model 6A marginal decrease in value as number of floating columns increased from 24 to 25.

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ii) Shear Forces (F_y & F_z) in Y- and Z-direction: Due to symmetry in plan and loading as well, the values of shear forces in both directions are same for all the models. About 25% of the columns in diagonal pattern are floated initially in model 1A and 2A, Shear forces increased by more than double (increased by ~100%) as compared with basic model. The models with orthogonal pattern show the higher values as compare to diagonal pattern, though the numbers of floating columns are same. In both cases shear forces increased further when central column is floated. Shear force in Model 5A (24 FC) is lowest, 1.7 times (70% higher), among models with floating columns exceptionally. Maximum shear force magnitude in Model 6A is almost equal to Model 4A, though it has double numbers of floating columns. For all the models, location of maximum shear force are at I floor which is occurring at sixth floor in Model 0A.

iii) Moments (M_y & M_z) about Y- and Z-directions: Since structure is symmetric in geometry as well as loading, the Moments about both the lateral axes are same. In models 1A to 4A with 12 (or 13) floating columns, moment values increased by about 2.4 times (increased by about 140%) but remains 2 times (104%) when 24 columns floated (Model 5A) and is about 2.8 times (183%) when 25 columns floated, for Model 6A. Location of maximum moment is below GL in Model 0A and for rest of the models it appears in columns at I floor except for Model 5A in which the location is ground floor.

B) Forces in Beams:

i) Shear Forces (F_y & F_z) in Y- and Z-direction: Shear force in Z-direction (lateral) is much less and can be ignored. Shear force in Y-direction increased to about 2.4 times when one-fourth columns are floated in diagonal pattern (Model 1A & 2A). The Shear Force increased to 3 times when pattern changes to orthogonal with same number of floating columns (Model 3A) and further increased to more than 3.3 when central column also floated. The value remains almost same as orthogonal pattern when 50% columns are floated. The location of occurrence shifted to I floor from 7th floor.

ii) Moments (M_y & M_z) about Y- and Z-directions: Moment about Y-axis (vertical) is very very less (can be seen in the tables) as compared to moment about Z-axis and hence, it is ignored. Moment about Z-axis increased about 3 times when 25% floating columns are present in diagonal pattern but when patter changes to orthogonal moment becomes 3.5 to 4 times i.e. increased by about 250-300%. Same is the situation when floating columns increased to 50% (Model 5A & 6A). Location of occurrence of absolute maximum moment shifted from top floor to 1st/Ground Floor.

C) Base Shear:

Base shear depends upon the Seismic weight of the whole building. When columns are floated without changing the dimensions of other structural members, it obvious that the Seismic weight of the whole building will be reduced, and hence the Base Shear. Results above also confirm the same. As the number of floating columns increased, the magnitude of base shear decreased accordingly, though marginally.

D) Node Displacement:

i) X- and Z-Translation: Since the model is about both the orthogonal axes the values of translations of nodes in X- and Z- Direction are same. Results show that the maximum Translation is at top floor hence only those values are compared. Translation increased by 11% when 25% floating columns are provided in diagonal pattern but increased by only 5-6% when pattern is orthogonal. As the % of floating columns increased to 50%, the value is also increased by 17% (Model5A) and by 24% (Model 6A).

ii) Y-Translation: When number and patter of floating columns changes according to Model 1A to 6A, value of translation also gradually increased by 12% to 31%. Negative value indicates the downward displacement of nodes.

iii) Absolute Translation: Translation increased by 11% when 25% floating columns are provided in diagonal pattern but increased by only 6-7% when pattern is orthogonal. As the % of floating columns increased to 50%, the value is also increased by 19% (Model5A) and by 25% (Model 6A).

E) Average Storey Displacement and Storey Drift:

The maximum value of Average Storey Displacement occurs at top storey only and varies in the same pattern as X- (or Z-) Translation as above. Average Storey Displacement for full height of the building can be observed in Graph 4.12.

Store Drift is compared at two levels viz. at Ground Floor Level and at 8th Floor Level as these levels are found critical and comparable. The value of storey drift at 8th floor is higher than that at ground floor in model without floating columns. These values increased when columns are floated. In Model 1A & 2A, values increased by 26-28% and 9% respectively and in Model 3A, these values increased by 30% & 4%. The value of drift at 8th floor for Models 1A & 2A remains larger than the value at ground floor and for Model 3A value of drift at 8th floor is slightly higher than that at ground floor. But for rest of the models this pattern is reversed i.e. the value of drift at ground floor exceeds the value at 8th floor. In Model4A drift

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increased by 39% at ground floor and by 4% at 8th floor and in Model 5A & 6A it increased by more than 70% at ground floor and 13% & 19% respectively at 8th floor. Notwithstanding this, the values of Storey drift are within safe limit as prescribed by the IS codes. Storey Drift for full height of the building can be observed in Graph 4.14.

Effect of variation in Floor Height

Effect of variation in floor height of Ground Storey can be understood by comparing various parameters (absolute maximum values) of the models of Set B with that of Set A. The percentage increase (or decrease) in the magnitude of various parameters of corresponding Models are calculated and tabulated in Table 5 & 6.

i) Column Forces, Beam Forces, Base Shear: It was observed that there is not much variation in maximum absolute values of these parameters and also the location of occurrence also remains unchanged for maximum parameters, so not discussed here.
ii) Node Displacement, Average Storey Displacement and Storey Drift: The values of Node displacement and Average storey displacement of top floor increased by 5-8% for Set B Models as compared with Set A Models and similarly the value of storey drift at 8th floor is marginally increased in the range of 1.3-2.2%. But a significant variation is observed, increment by 80-85%, in the values of Storey Drift at ground floor where floor height is increased by 1m and also the number of columns was reduced thereat. The variation in Average Storey Displacement and Storey Drift for full height of the building can be seen in Graph No. 4.13 & 4.15 respectively.

CONCLUSION

In the present work a comparative study is carried out on effect of provision of floating columns under seismic conditions assuming zone IV. The study is based on response of an 3D RCC framed G+20 residential building which is reflected through various parameters such as Axial Forces, Shear Forces & Moments in columns & beams, Node Displacement, Storey Displacement and Storey Drift. Floating columns were introduced above ground floor level in different positions and various patterns. The effect of variation in storey height was also studied by varying the storey height of ground floor. All the models of were analysed with the help of STAAD.Pro software and results were compared with the results of models without floating columns. Following conclusions were drawn in light of above comparisons.

Building with uniform storey height

The values of all the parameters increase significantly with increase in number of floating columns except Base Shear, which is getting reduced.

When one-fourth columns are required to be floated, the diagonal pattern is a better option as compared to the orthogonal pattern from design point of view as the increment in governing forces is lesser in diagonal pattern. But from displacement consideration orthogonal pattern proves to be better.

Location of Maximum Absolute Axial force in column shifted from foundation level to GF where lesser number of columns is present whereas Shear Forces and Moment shifted to 1st floor from 6th floor and below ground floor respectively.

Appearance of Maximum absolute of Fy & Mz in beams shifted from 7th floor as in normal building (one-third height) to 1st floor (where floating columns started).

Maximum value of storey drift is observed at 8th floor level in building without floating columns and building with one fourth floating columns whereas when floating columns increased, the maximum value found to be at ground floor.

Building with increased storey height of Ground Floor

The maximum absolute value of parameters related to displacement not much increased (about 5-7%) but the storey drift at ground floor is very much increased (about 80-85%). It can be concluded that the variation in storey height should be avoided and if it is unavoidable, may be controlled by increasing the area of cross-sections of columns thereat.

Variation in the value of various parameters related to forces in columns and beams are very marginal.

FUTURE SCOPE

The present research work is done by analysing the models of G+20 building, symmetrical in plan by equivalent static method using STAAD.Pro V8i and compared on the basis of ten parameters. Research can be further extended by keeping in view the following points:

a) Adopting Dynamic analysis method;
b) Assuming Unsymmetrical building;
c) Analysing taller structure;

d) Using other tools for analysing such as ETABS, SAP, etc.

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