

# Performance of Structures with Floating Columns System Subjected to Lateral Loads

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**ABSTRACT** Increasing population and scarcity of spaces in commercial districts, especially in the city center where crowding and number of cars require more parking spaces, and also the need for large areas un-interrupted by columns within the building, it was essential to find innovative structural design to fulfill these requirements. This was achieved by abandoning the continuity of some columns and replacing them with transfer beams that transfer their loads to the adjacent columns. In this paper the effect of wind loads on a building containing a floating column has been studied using ETABS program, three buildings of different heights were studied (G+5, G+10 and G+15). The wind loads were assumed to be resisted by the rigid frame system for one case of analysis and by the shear walls system at another case and compared models with others without a floating column to determine the percentage difference between them. Also the results were compared with the permissible limits in a number of parameters such as Drift, P-Delta, Soft Story and Torsional Irregularity. A number of results were obtained, the most important are that there are no major differences between (floating column) building and (normal) building, they behave almost the same. The use of the shear walls system reduces the difference in results, especially in the soft story item. Also, the difference between the results of the floating column building and the normal building were found to decrease as the number of stories increased.

**Keywords:** Floating Column, Story Drift, P-Delta, Soft Story, Torsional Irregularity, ETABS.

## 1. INTRODUCTION

In many types of buildings, we need free parking spaces, reception lounges, assembly hall, etc. To meet the architectural requirements, floating column may be used which is defined as a vertical member that rests on a beam but does not transfer its load directly to the foundation. The floating column acts as a concentrated load on a beam and this beam transmits the load to adjacent columns below. The concept of floating columns is demonstrated in Fig. 1.

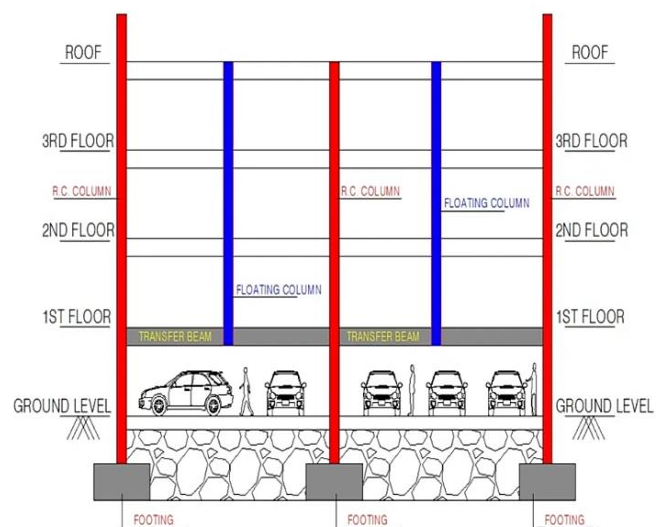


Fig1. Floating columns in a building

A lot of scientific papers in the field of floating columns, one of those papers studied the effect of shear wall within the specific building. Three multi-story building are taken into consideration with eight storey, twelve storey and sixteen storey. All the three instances are taken into consideration having hanging columns furnished with and without shear partition, and moreover analyzed for zone V the usage of software ETABS 2016. They concluded the displacement more in floating column building as compare to building without floating column [1].

Other paper tested the effect of re-locating the positions of the floating columns system. The above mentioned study recorded that there were increase by 56.96 % in the overall displacement when floating columns were used with building composed of Moment resistance frame MRFS. Further on, declared that the fundamental period was increased, and the lateral stiffness decreased while the irregularity effect was independent on the floating columns location [2]. There are studies to reduce displacement in buildings having floating column using bracing in one case and the bracing was omitted on the other case. It was concluded that the system of floated columns when retrofitted by bracing improved and behaved more satisfactory than the one left without bracing. The improvement was interpreted in the reduction of time period and reduction of global displacement [3]. To find out the effect of soil type on buildings having a floating column, a study was conducted Two models of buildings, building without floating column and building with floating column at different floor levels and two different type of soil (medium soil and hard soil). According to results obtained, it was found that building located in medium soil experience 25% larger base shear than building located in hard soil [4]. A residential building with six storey and twelve storey were analyzed with column, Beams & Slabs MRFS. The buildings analyzed & designed with and without edge columns at base story. It calculated quantity of steel and concrete and it concluded (Floating column) building has 40 % more quantity of rebar steel and 42 % more concrete quantity than (Normal) building. So the Floating column

building is uneconomical to that of a Normal building [5]. Other paper studied the behavior of multi storey building with and without floating column under different earthquake excitation and it studied analysis of a G+4, G+9, G+14 story normal building and a G+4, G+9, G+14 story floating column building for external lateral forces. It concluded the axial forces are increasing in the columns other than floating columns due to transfer of loads of the floating columns to the conventional columns. It observed that bending moment in columns are greater in the top stories and lesser in the bottom stories. Bending moment varies in each model for every corner column, internal column and peripheral column [6].

The main objective of this paper is to investigate the behavior of floating columns subjected to lateral loads, in below are the specific objective of the study:

- To establish that the stability of the building will be intact when it deemed to use floating columns technique.
- To study the effect of increasing number of story.
- To study and compare the behavior of buildings with shear wall system or rigid frame system.
- To prove that buildings with floating columns are structurally safe so that engineers in Sudan can use them in order to solve space problems.

## 2-METHODOLOGY

The first model in this paper was G + 5, increased progressively by floor, hence a G+10 and G+15 was investigated. Two systems were used to resist wind loads; namely, the rigid frame system (R.F) and, shear walls (S.W) system. A column in the basement was removed from edge for all cases, as in Fig. 2, and Fig. 3 respectfully. Comparison of results between two main building: 1) Building that does not contain a floating column (normal building). 2) Building has contain a floating column, so the results in this research from twelve models were analyzed using ETABS program, see Table I.

TABLE I: ALL CASES OF MODELS IN THIS PAPER

N.O	Models		
1	G+5	Rigid frame	Normal building
2	G+5	Rigid frame	Floating
3	G+5	Shear wall	Normal building
4	G+5	Shear wall	Floating
5	G+10	Rigid frame	Normal building
6	G+10	Rigid frame	Floating
7	G+10	Shear wall	Normal building
8	G+10	Shear wall	Floating
9	G+15	Rigid frame	Normal building
10	G+15	Rigid frame	Floating
11	G+15	Shear wall	Normal building
12	G+15	Shear wall	Floating

A. Architectural data

Story height =3m

Number of bays along X-Direction =4

Number of bays along Y-Direction =4

Bay width along X-Direction =5m

Bay width along Y-Direction=5m

Elevator (shear wall) =1.8x1.7m

Elevator Door 2x0.8m

See Fig. (2&3)

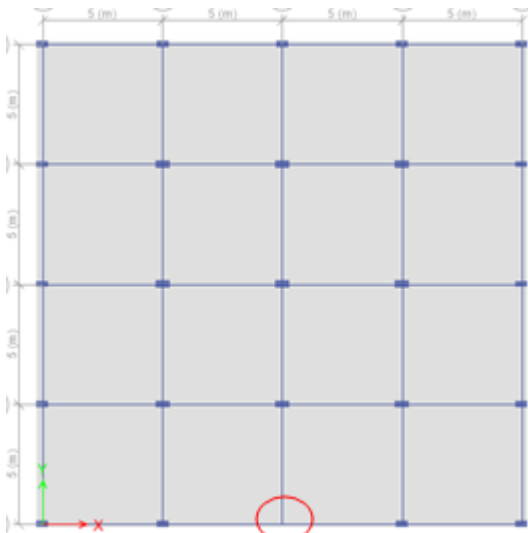


Fig. 2. Rigid frame system

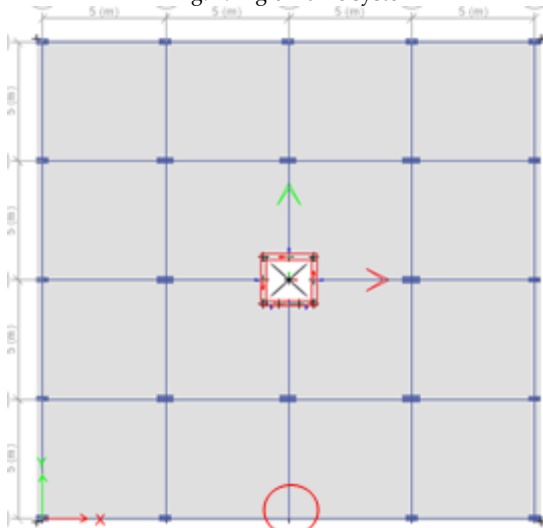


Fig. 3. Shear wall system

B. Structural data

All columns reinforcement dose not exceeding the maximum reinforcement ratio (6%) [7]. and all columns section were selected in Table II according to worst loads combination in Section 4-2-1.

At each story has different values of (Lateral Deflection, Drift, P-Delta ( $\Theta$ ), Soft Story and Torsional Irregularity).In final results were shown just the maximum values from three models (G+5, G+10 and G+15) to compare it with allowable limits in Table III accordance to ASCE.

TABLE II: SECTIONS DEFINITION

Story System	G+5		G+10		G+15		
	R.F	S.W	R.F	S.W	R.F	S.W	
Column (mm)	EX	500X250	500X250	600X300	600X300	650X350	650X350
	INT	600X300	600X300	850X350	1000X300	1200X350	1000X350
Beam (mm)	500x250		600x300		600x300		
Slab (mm)	150		150		150		
Concrete Grade (MPa)	25		25		25		
Steel Grade (MPa)	460		460		460		

C. Loads combination accordance to (ASCE 7-10)

- 1.4Dead Load
- 1.2Dead Load+1.6Live Load
- 1.2Dead Load+1Live Load +1Wind load
- 0.9Dead+1Wind

TABLE III. LIMITS OF DIFFERENT PARAMETERS ACCORDANCE TO ASCE

Parameters	Limits
Lateral Deflection	No Guidance
Drift	0.015
P-Delta ( $\Theta$ )	0.1
Soft Story	0.7
Torsional Irregularity	1.2

D. Types of loads

The loads acting on a structure that require consideration in design are:

- Dead load

-Self Weight= calculated automatically by ETABS

-Partition load = 13.5KN/m on beams

-Finishing Load 2.7KN/m<sup>2</sup>

• Live load

Residential building =1.92 KN/m<sup>2</sup>

• Wind load

- Wind speed in Sudan- Khartoum = 112 mph [9]
- Exposure Type B
- Wind Direction =X-Direction

3- RESULTS AND DISCUSSIONS

A. Displacement

In building that contain floating column the maximum displacement occurs at top of building, see Fig.4. The variation between maximum displacement in floating and normal building shown in Fig.5.

The differences between the results of the floating column building and the normal building are very close and the largest difference did not exceed 8% and shown in the displacement values.

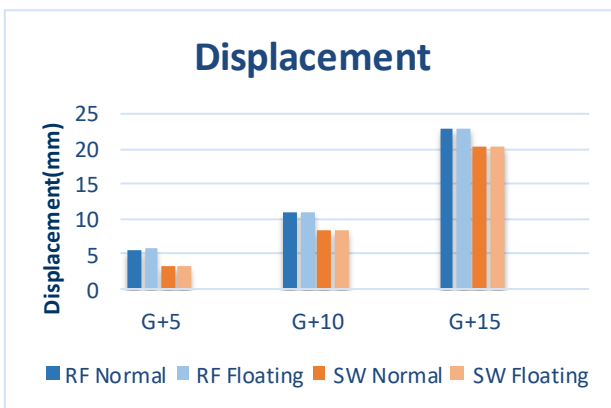


Fig. 4. Maximum displacement

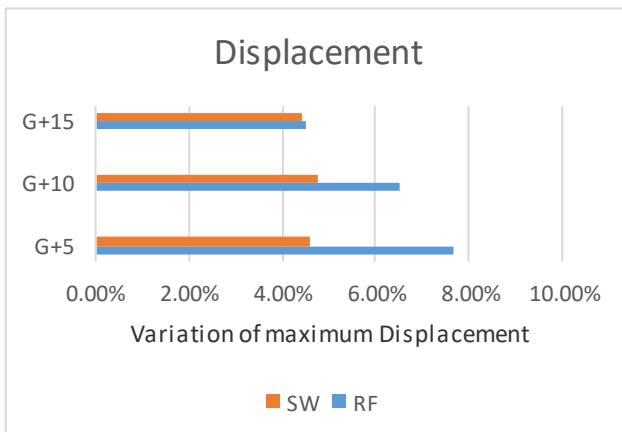


Fig. 5. Differences of maximum displacement

B. Drift

Story Drift is the lateral displacement of one level relative to the level below and story drift ratio is the story drift divided by the story height .In Fig. 6 showed all values in all cases have not exceed the allowable story drift ratio 0.015 (From Table 12-12-1 in ASCE7-10[8]) .In Fig.7 Showed the differences between floating and normal building in Maximum Drift Ratio.

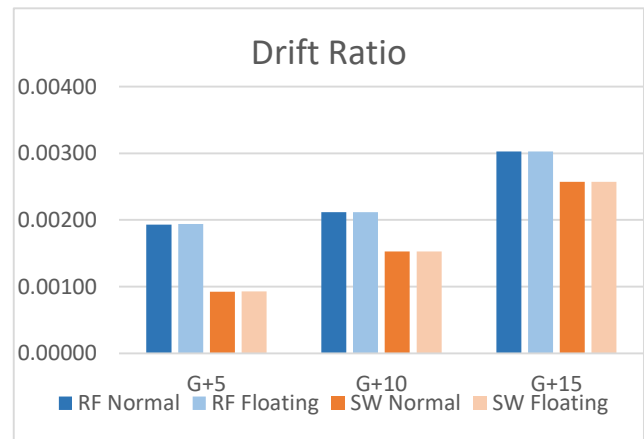


Fig.6. Maximum drift ratio

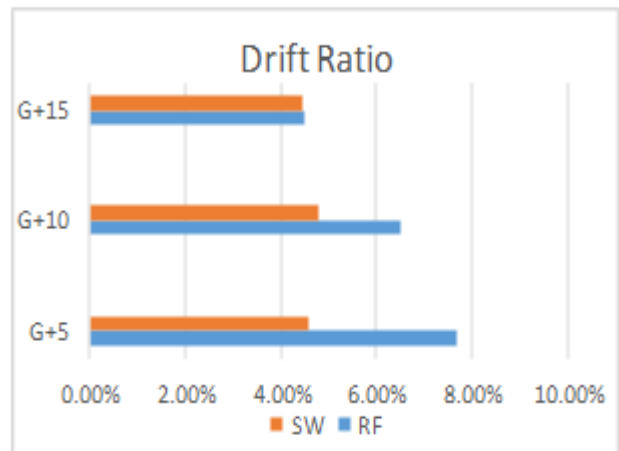


Fig. 7. Differences of maximum drift ratio

C. P-delta effects

P-delta effects on story shears and moments, the resulting member forces and moments, and the story drifts induced by these effects are not required to be considered where the stability coefficient ( $\Theta$ ) is equal to or less than 0.10.[8]

In Fig.8 showed the maximum values of ( $\Theta$ ) from G+5,G+10 and G+15 , it found the P-Delta effects are not required to be considered because all stability coefficients ( $\Theta$ )were not exceed 0.1. In Fig. 9 showed differences of stability coefficient ( $\Theta$ ) for all cases.

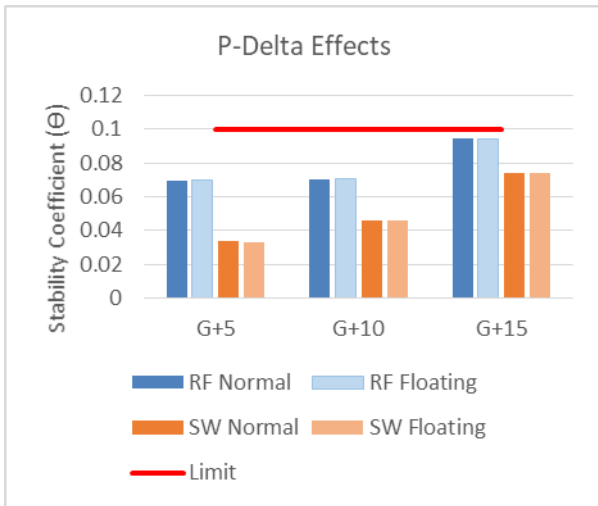


Fig. 8. Stability coefficient (Θ)

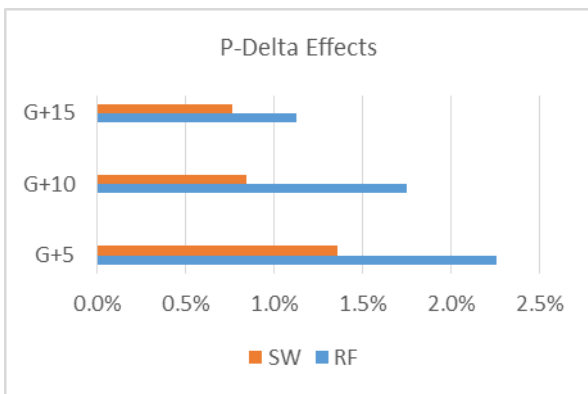


Fig. 9. Differences of maximum stability coefficient (Θ)

D. Soft story

According to (ASCE 7-10 - Table 12.3-2), the Stiffness-Soft Story Irregularity is defined to exist where there is a story in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above [8].

In Fig. 10 all cases (G+5,G+10 and G+15) the worst story was at the middle of height and all values in Fig. 10 was more than 70% ,that mean no soft story in all cases. In Fig. 11 showed maximum variation for all cases.

The shear wall system reduces the differences between floating column building and normal building, the best reduction in soft story item.

The worst story of all cases (G + 5, G + 10 and G + 15) in the soft story check was in the middle of the building height. Therefore, we recommend that be

careful when making a floating column on a floor in the middle of the building height.

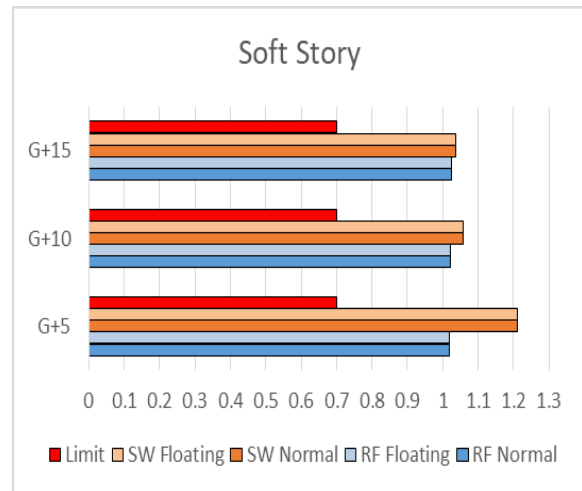


Fig. 10. Maximum soft story

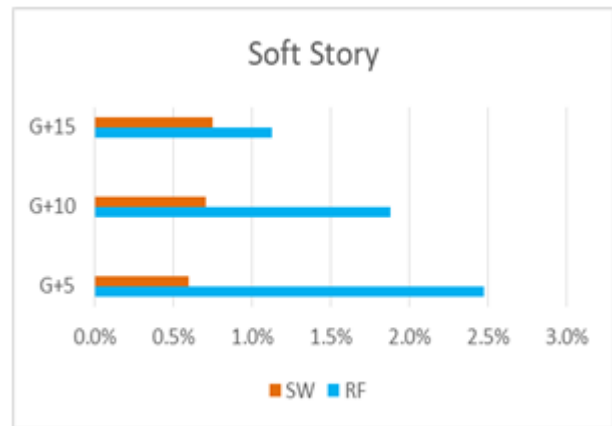


Fig. 11. Differences of maximum soft story

E. Torsional irregularity

In Fig. 12 illustrated the limitation of torsional irregularity when the ratio between maximum displacements to average displacement equal or exceed 1.2 (According to ASCE 7-10 - Table 12.3-1[8]). In our case, the plan appears regular in Fig.2, but in Fig. 3 although the elevator (shear wall) in the center of the plan, there was a small irregularity in normal model (without floating column) due to the hole for the elevator door, but within the limits of torsion irregularity. All cases in Fig. 13 did not exceed 1.2, and it was observed that the G + 5 model approached the limit of 1.2 more than G + 10 and G + 15. In Fig. 14, it showed the greater difference in the results of torsional irregularity between the floating model and normal model of different heights.

Results of torsional irregularity are far from the limits as the number of story increases.

Effect of torsional irregularity depend on position of floating column and shear wall so we recommended to select a position of shear wall at suitable place to avoid torsional irregularity.

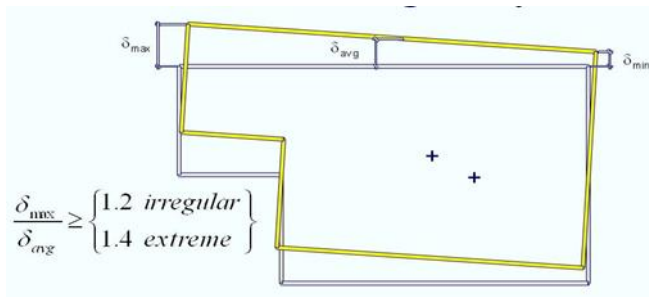


Fig. 12. Illustrated the limitation of torsional irregularity

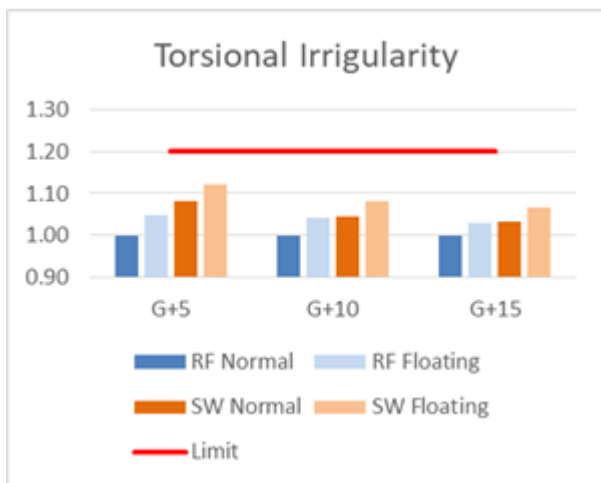


Fig.13. Maximum torsional irregularity

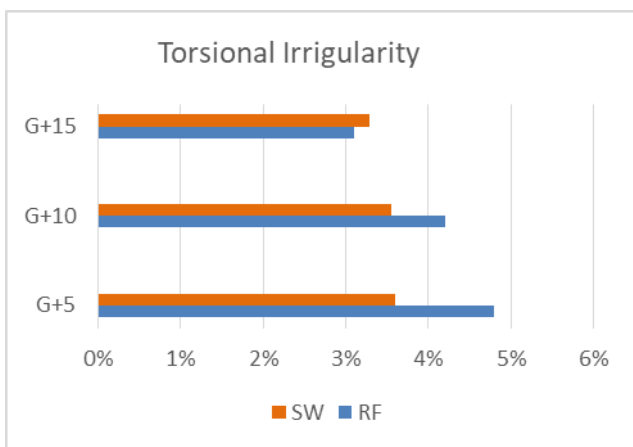


Fig. 14. Differences of torsional irregularity

4-CONCLUSION

1-All variable parameters (Lateral Deflection, Drift, P-Delta (Θ), Soft Story and Torsional

Irregularity) are within the limits of the code, because we have chosen the appropriate cross-sections of the columns. So we recommend choosing the cross-section of the column accordance to the ACI 318-14 code (reinforcement ratios no more than 6%).

2- The deviation of results between building with or without floating column will be lessened when the number of story increased which can be concluded that floating column system is beneficial in high rise building if deemed necessary.

3-There were no significant differences in results between floating column building and normal building when using the shear wall system compared to the rigid frame system which showed a wide difference. Therefore, we recommend to use shear walls when the parameters exceed the limits to reduce additional cost.

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