Journal of Karary University for Engineering and Science (JKUES)

Study Performance of Floating Columns Subjected to Vertical Loads

Abdelrahim Abdalla Bashir*, Kamal M. H. Satti*, Mahgoub Elhaj Mahgoub Kambal*
*College of Engineering, Karary University, Khartoum, Sudan
hemoland@gmail.com

Abstract

In many cases, we need large areas in the building that are free of columns, especially on the lower floors, such as the ground floor and the basement, in order to use them as car parking or otherwise. The load path will change and new terms will appear, including the term ”floating column”, which is the column above the removed column, and the term Transfer beam, is the beam that the floating column is based on it as a concentrated load and then transfers the loads to the adjacent columns. In this paper, the effect of vertical load on a concrete building containing a floating column has been studied and compared to another one without a floating column. Also, the results of the Transfer beam were compared in a number of parameters such as moment, shear force, and deflection. A building consisting of G+4 was studied and analyzed using ETABS, SAFE, and Midas programs, A number of results were reached, the most important is the concept of load path redistribution, also this paper concluded that in normal buildings case all beams have an approximately equal result of bending, shear, and deflection but in floating column building the beams above the Transfer beam have different values which decrease when going upward.

Key words-*Floating Column; Transfer Beam; Construction Sequence; ETABS; Midas*

I. INTRODUCTION

In many cases, the architect requests large areas without any columns, and in order for the structural engineer to meet these wide areas, he must cancel the columns and replace them with Transfer beams that transport the loads safely, So that it resists moments, shear and deflection. Fig.1 illustrates the concept of floating columns [1], [2]. when analyzing the floating column building must be analyzed as a (Sequential analysis) not as (Lumped Analysis), see Fig. 2. The sequential construction analysis or incremental construction, or sectional construction. is the analysis of the building as in the construction stages. It begins with the analysis of the ground floor completely with consideration of the behavior of time-dependent materials such as aging, creep, and contraction then moves to the floor above it and so on [3]. A lumped analysis without consideration of the construction sequence and time-dependent deformations of concrete usually does give not the actual behavior of the structure [4]. There are high differences between the results in many models of building with and without the Sequential analysis. It can be stated that the analysis without Sequential analysis cannot give reliable solutions [5], [6]. The floating column makes a high concentrated load value which leads to a high value of shear force on the Transfer beam. bent up bars (cranked bars) can help the stirrups to resist shear force, but Shear resistance by bent up bars shall not be more than fifty percent of the total shear. The balance shear must be resisted by the stirrups. The degree of angle of the bending bar is usually taken between 45 degrees and 30 degrees and the last value is usually used in shallow beams where effective depth is less than 1.5 times its breadth. Fig. 3 illustrates bent up bars [7], [8].

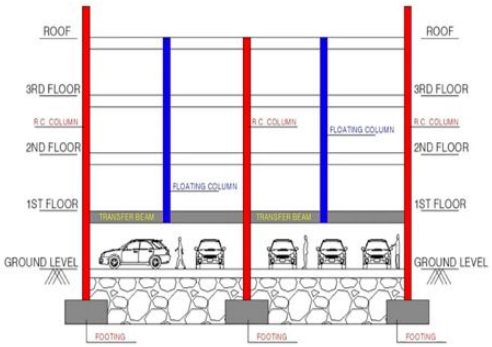


Fig. 1. Floating Columns in a Building

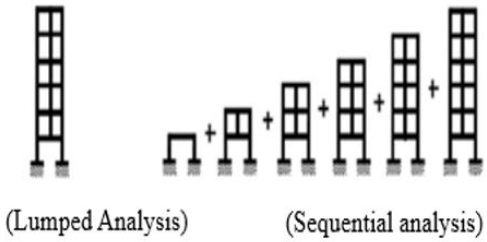


Fig. 2. Example of lumped model and sequential model

II. METHODOLOGY

A. Architectural System

Storey height =3m.
Number of Storey G+4
Number of bays along X-Direction =4
Number of bays along Y-Direction =4
Bay width along X-Direction =5m

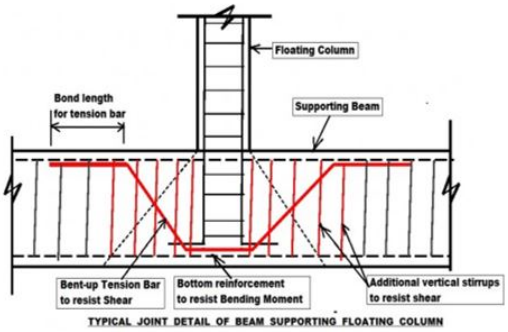


Fig. 3. Bent up bar in a Transfer beam

Bay width along Y-Direction=5m
Removed one edge column from the basement floor. See Fig. (4&5).

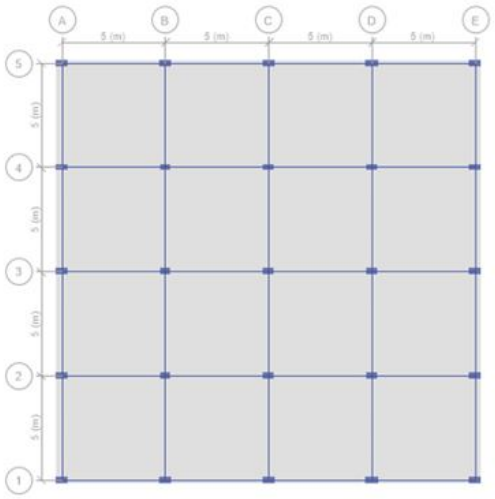


Fig. 4. Typical floor without removed column

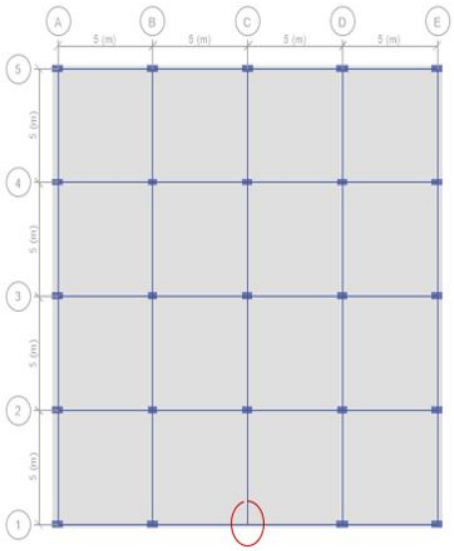


Fig. 5. Basement floor has removed column

TABLE I
DEFINITION OF SECTIONS

Column (mm)	EX	500X300
	INT	600X300
Beam (mm)	Transfer	850x300
	Normal	500x300
Slap (mm)		200
Concrete Grade (MPa)		25
Steel Grade (MPa)		460

B. Structural System

The minimum thickness of the Transfer beam was selected to be economical, and the long-term deflection was not to exceed the maximum permissible deflection [9]. All columns reinforcement are not exceeding the maximum reinforcement ratio (6%). All columns and beams sections selected were determined according to the worst loads combination in Section D and are reported in Table I.

C. Codes Used in Analysis and Design

- ACI 318-14 Building Code Requirements for Structural Concrete.
- ASCE 7-16 Minimum Design Loads for Buildings and other Structures

D. Loads Combinations

- 1.2 Dead Load+1.6 Live Load.
- 1 Dead Load+1 Live Load.
- δ sustained (immediate) = δ DL(immediate) +β
- δ LL(immediate).
- δ sustained (long term) = $\Delta\lambda$ sustained(immediate).
- δ sustained (long term) + $(1-\beta)\delta$ LL(immediate) $<$ L/240.

E. Types of Loads

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

- Dead load
  - Partition load = 13.5KN/m on beams.
  - Finishing Load 2.7KN/m2.
- Live load: Residential building =1.92 KN/m2 [10].

III. RESULTS AND DISCUSSION

A. Load path redistribution

When removing any column, the load path will shift far away from the removed column and the load will go to adjacent columns. It was called it in this paper (load path redistribution), to prove this theory, it was analyzed the building manually and using ETABS program in addition to Midas program.

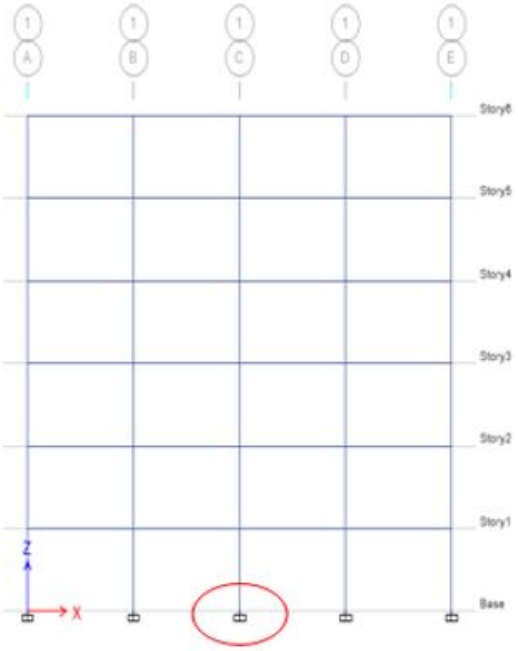


Fig. 6. Elevation of building

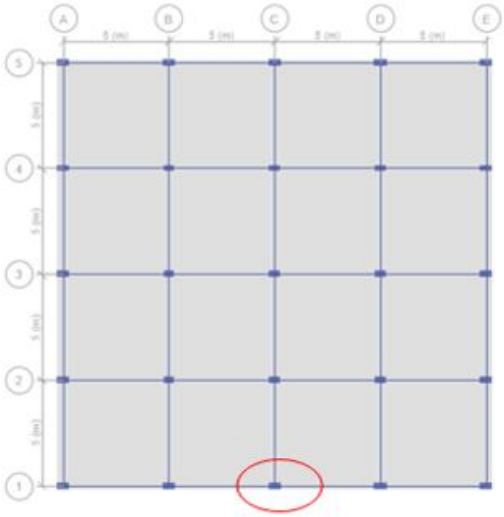


Fig. 7. Plan of building.

B. First model: Normal building (without removing any column)

Calculating the axial load in the base at the intersection of Grid 1 with Grid C (See Fig .6 and Fig .7)

Storey height =3m.
Number of Storey $G+4$
Cross section of Beam and column 500x300
Slab thickness 200mm
Partition load = $13.5KN/m$ on beams
Finishing Load $2.7KN/m2$
Live load 1.92 $KN/m2$

Manual solution:
Live load 5*2.5*1.92*6=144KN

Dead load
Partition $13.5*5*6+13.5*2.5*6=607.5$KN
Finishing $5*2.5*2.7*6=202.5$ KN
Self-weight
Slab $5*2.5*0.2*6*23.6=354$ KN
Beam $5*0.3*0.5*6*23.6=106.2$ KN
Column $3*0.3*0.5*6*23.6=63.72$ KN
Total Dead load = 1333.9 KN (See Fig. 10)
Ultimate load = $1.2D.L+1.6L.L=1.2*1333.9+1.6*144=1831$ KN

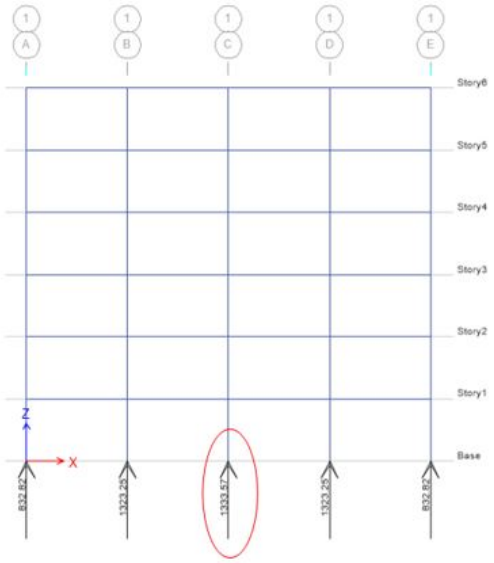


Fig. 8. Axial dead load from ETABS.

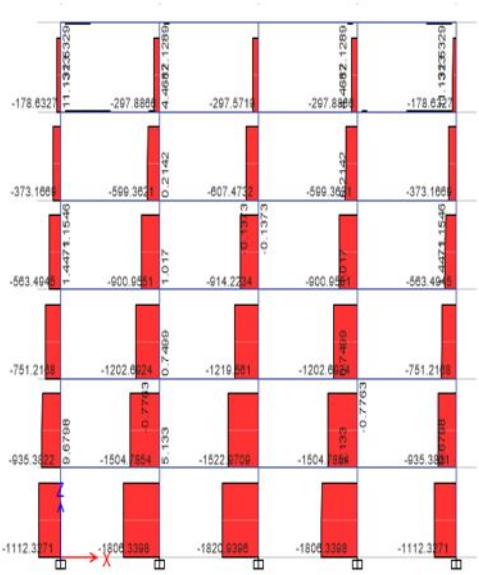


Fig. 9. Ultimate Axial load from ETABS.

C. Second model: Floating column building:

- Removed one column from basement floor at intersection of Grid 1 with Grid C. (See Fig .11 and Fig .12).

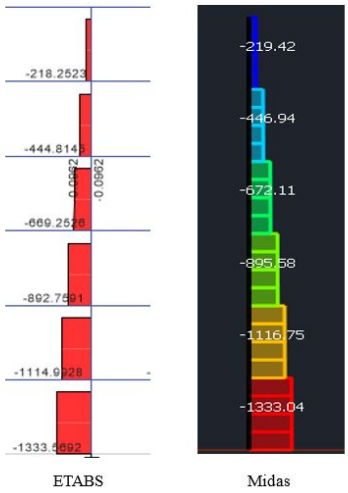


Fig. 10. Comparative result of axial dead load between Etabs and Midas.

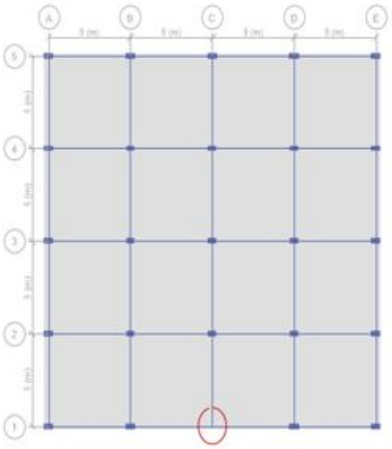


Fig. 11. Plan of building .

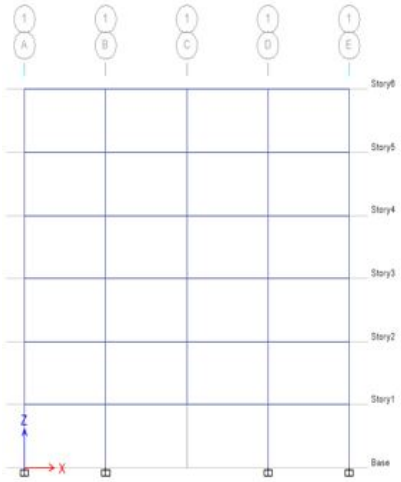


Fig. 12. Elevation of building.

Number of Storey $G+4$
Cross section of Beam and column $500x300$
Slab thickness 200mm
Partition load = $13.5KN/m$ on beams
Finishing Load $2.7KN/m2$
Live load 1.92 $KN/m2$
Manual solution:
Live load $5*2.5*1.92*5=120$ KN
Dead load
Partition $13.5*5*5+13.5*2.5*5=506$ KN
Finishing $5*2.5*2.7*5=168.8$ KN
Self-weight
Slab $5*2.5*0.2*5*23.6=295$ KN
Beam $5*0.3*0.5*5*23.6=88.5$ KN
Column $3*0.3*0.5*5*23.6=53.1$ KN
Total Dead load = 1111.4 KN
Ultimate load = $1.2D.L+1.6L.L=1.2*1111.4+1.6*120=$ 1525.7KN (it is consider as a concentrated load on Transfer beam) [11]. See Fig. 13.

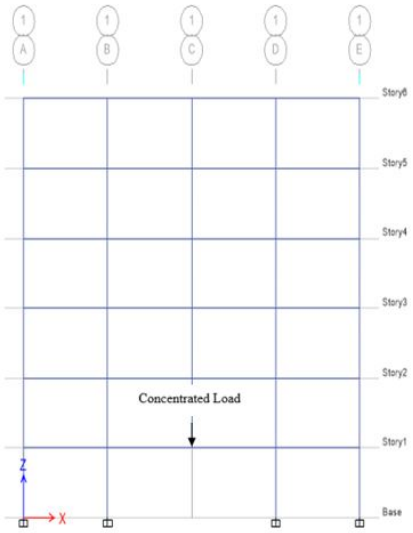


Fig. 13. Elevation of building .

D. Solution using finite element programs

When it was analyzed a floating column building in a finite element program and compared the concentrated load that reached on Transfer beam manually it was found a large different value of axil load because in a finite element program in the case of floating column building the load path depend on rigidity (EI) of Transfer beam, for example in this case when increasing the thickness of Transfer beam the concentrated load will increase. See Table II.

In Fig. (14 & 15) the axial load before removing the column was (1522KN) and after removing the column, it became a concentrated load on Transfer beam (770KN), which means (752KN) from axial loads were redistributed to other columns, this is a concept of (load path redistribution), and it will only occur when removing a column.

E. Redistribution beams

In floating column building usually need to Transfer beam which effects on all structure results this effect is called

TABLE II
RELATIONSHIP BETWEEN THE THICKNESS OF TRANSFER BEAM AND CONCENTRATED LOAD

Thickness of Transfer beam(mm)	Concentrated load(KN)
500	440
600	550
700	648
850	770

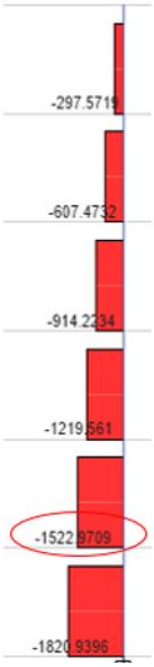


Fig. 14. Normal building .

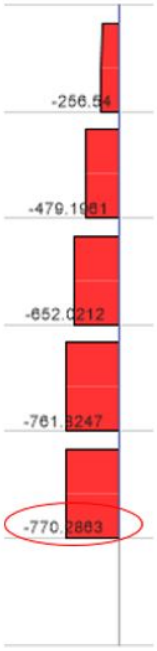


Fig. 15. Floating column building .

(redistribution of beams), which means the effect of (Transfer beam) on the (Upper Beams) see Fig. 16 these effects include:

- Negative moment of (upper beams) changed to a positive moment when it was compared between (floating column building) and (normal building).
- The moment, shear, and deflection of (upper beams) decrease when going upward. See Fig. (17 to 22).

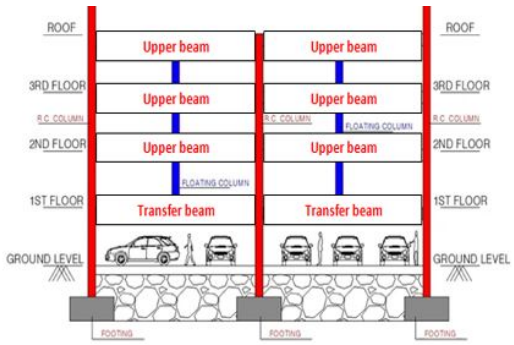


Fig. 16. Position of Transfer beam and upper beams.

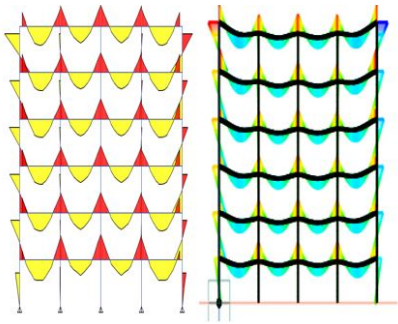


Fig. 17. Moment diagram for Normal building (ETABS-Midas).

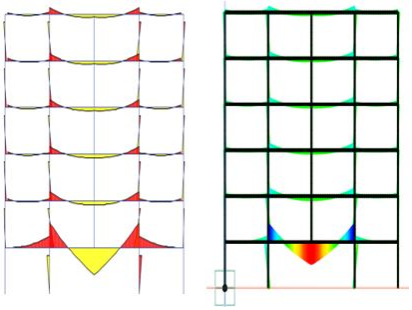


Fig. 18. Moment diagram for floating column building (ETABS-Midas).

F. Construction Sequences

When analyzing a building with a floating column using ETABS the dead load should be inserted as a construction sequence. This means that the Transfer beam initially acts by itself because Transfer beams are sensitive to construction sequence. Without construction sequencing, the dead load is carried by truss action [12], [13]. Fig. (23 & 24) show the

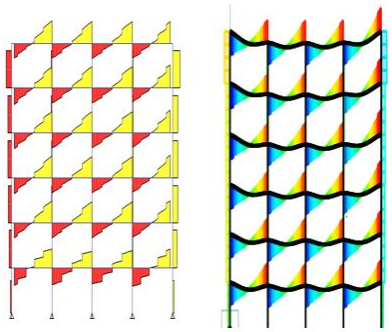


Fig. 19. Shear force diagram for normal building (ETABS-Midas).

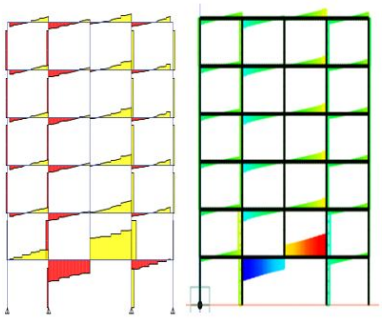


Fig. 20. Shear force diagram for floating column building (ETABS-Midas).

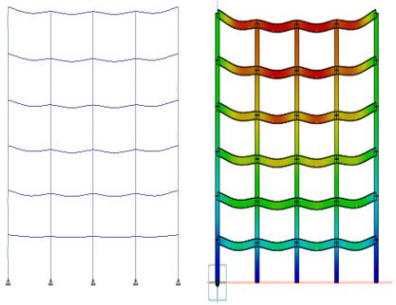


Fig. 21. Deflection shape for normal building (ETABS-Midas)

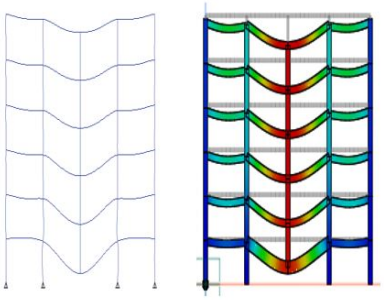


Fig. 22. Deflection shape for floating column building (ETABS-Midas)

values of the moment in Transfer beam due to ultimate load in non-sequential case (912KN.m) and in the construction sequential case the moment on the Transfer beam (1433KN.m) means more than 35 of the moment not taken into consideration in case of design according to result from Non-sequential

TABLE III
COMPARATIVE BETWEEN LUMPED AND SEQUENTIAL ANALYSIS

Content	Lumped analysis	Sequential analysis	Increase in sequential analysis %
Moment KN.m	912	1433	36.4
Shear(KN)	417	577	27.7
Deflection(mm)	12	22	45.5

case.

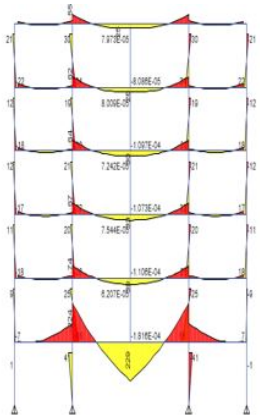


Fig. 23. Lumped Analysis (Non-sequential case)

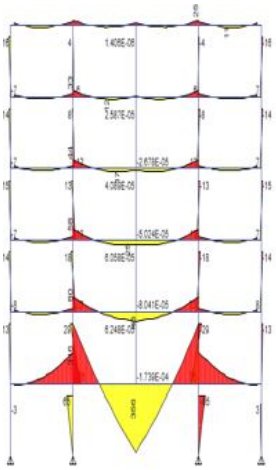


Fig. 24. Sequential analysis (Construction sequential case)

G. Deflection

The deflection is one of the most important parameters in the serviceability limit so it should check the deflection of the Transfer beam and compared with the maximum permissible calculated deflections according to [Table 24.2.2 ACI 318-19] corresponding to immediate deflection because the Transfer beam always is not supporting or attached to nonstructural elements likely to be damage by large deflections [14], [15],

TABLE IV
DEFLECTION FROM ETABS/MIDAS

	Deflection (mm)		Permissible Limit (mm)
	SAFE	Midas	ACI
Transfer beam	22	23.9	27.8

[16], [17]. Span length (L) = 10m Deflection limitation= L/360=10,000/360=27.8mm

IV. CONCLUSIONS

1) There was a large difference in the results between the Sequential analysis (construction sequences case) and Lumped analysis (non-sequential case), so it recommend insertion the dead load as construction sequences because it simulates the actual building.
2) The columns around the removed column and floating column have a large axial load due to the load transport path to it, so it is recommended to increase its cross-section for columns adjacent to the removed column and around the floating column.
3) In normal buildings case all beams have an approximately equal result of bending, shear, and deflection but in a floating column building the beams above the Transfer beam have different values which decrease when going upward, so it is recommended to design each beam separately to be economical.
4) ETABS program give more realistic result than Midas program because it has a feature of construction sequences so it is recommended to use it at any building that has a floating column.

REFERENCES

[1] A. A. BASHIR, "Performance of structures with floating columns system subjected to lateral loads," *FES Journal of Engineering Sciences*, vol. 10, no. 1, pp. 37–41, 2021.

[2] M. E. M. Kambal and Y. Jia, "Theoretical and experimental study on flexural behavior of prestressed steel plate girders," *Journal of constructional steel research*, vol. 142, pp. 5–16, 2018.

[3] R. Pranay, I. Sreevalli, and Er, "Thota. suneel kumar, study and comparison of construction sequence analysis with conventional lumped analysis using etabs, civil engineering systems and sustainable innovations,vol.78,pages 220-228."

[4] H.-G. Kwak and J.-K. Kim, "Time-dependent analysis of rc frame structures considering construction sequences," *Building and Environment*, vol. 41, no. 10, pp. 1423–1434, 2006.

[5] S. Adanur, M. Günaydin, A. C. Altunişik, and B. Sevim, "Construction stage analysis of humber suspension bridge," *Applied Mathematical Modelling*, vol. 36, no. 11, pp. 5492–5505, 2012.

[6] H. Kim and S. Shin, "Column shortening analysis with lumped construction sequences," *Procedia Engineering*, vol. 14, pp. 1791–1798, 2011.

[7] W. Teo and G. Müller, "Shear effectiveness of shallow-angle bent-up bars for reinforced concrete beams," *Proceedings of the Institution of Civil Engineers-Structures and Buildings*, vol. 167, no. 7, pp. 398–413, 2014.

[8] M. Attaelmanan, M. E. M. Kambal, and M. I. Mansour, "A study the effect of using ceramic waste powder as partial replacement for cement on concrete properties," *Journal of Karary University for Engineering and Science*, 2021.

[9] M. Osman, M. Awad, M. E. M. Kambal, and I. Burhaneldain, "A structural behaviour of concrete-filled steel tubular stub columns-comparative study," *Journal of Karary University for Engineering and Science*, 2022.

[10] G. Y. Chock, "Design for tsunami loads and effects in the asce 7-16 standard," *Journal of Structural Engineering*, vol. 142, no. 11, p. 04016093, 2016.

[11] J. Boldt and D. W. BODENSCHATZ, "Managing pipe expansion in shafts," *Stainless Steel*, vol. 1, no. 19,300, pp. 28–55, 2020.

[12] A. Al Mamun and M. Saatcioglu, "Fragility curves for seismic vulnerability assessment of reinforced concrete frame buildings in canada," in *16th World Conference on Earthquake Engineering*, pp. 9–13, 2017.

[13] M. E. M. Kambal, M. Awad, and M. M. Ali, "Nonlinear finite element modelling and parametric study of prestressed steel box girder," *Journal of Karary University for Engineering and Science*, 2021.

[14] A. C. I. A. Committee *et al.*, "Building code requirements for structural concrete aci 318-19 and commentary 318r–19," *American Concrete Institute ACI Committee: Farmington Hills, MI, USA*, 2019.

[15] M. E. M. Kambal and Y. Jia, "Theoretical and experimental study on flexural behavior of prestressed steel plate girders," *Journal of constructional steel research*, vol. 142, pp. 5–16, 2018.

[16] M. E. M. Kambal, M. Awad, and M. M. Ali, "Nonlinear finite element modelling and parametric study of prestressed steel box girder," *Journal of Karary University for Engineering and Science*, 2021.

[17] M. Kambal and Y. Jia, "Analysis of behavior of steel box girders prestressed with external tendons," *The Open Civil Engineering Journal*, vol. 11, no. 1, 2017.



Abdelrahim Bashir is a lecturer in Civil Engineering Department, Faculty of Engineering, International University of Africa, Khartoum, Sudan. He received his B.Sc. from Omdurman Islamic University and M.Sc. degrees in structural engineering from University of Khartoum and his Ph.D. degree in Structural from Karary University



Kamal M. H. Satti is an associate professor in Civil Engineering Department, Faculty of Engineering, International University of Africa, Khartoum, Sudan. He received his B.Sc. from University of Khartoum and his Ph.D. degree from University of Edinburgh, Scotland. He is a Member of The American Society of Civil Engineers, Consultant of Sudan Engineering Council, and he is a Fellow of Sudanese Engineering Society. He was a Technical Advisor with the Joint Engineering Team (JET) which included engineers from Saudi Arabian National Guard (SANG) and US Government, for preparation and construction management of SANG development projects using US Contracts. He was the founder head of the Department of Civil Engineering and Deputy Dean of the College of Engineering at Almoghterbeen University.



Mahgoub Elhaj Mahgoub Kambal is an assistant professor of structural engineering in Civil Engineering Department, Faculty of Engineering, Karary University, Khartoum, Sudan. He received his B.Sc. and M.Sc. degrees in structural engineering from Karary University and his Ph.D. degree in Steel Structural from Northeast Forestry University, Harbin, China. His current research interests include design of concrete, steel and masonry structures, and computer aided analysis and design.