

The Effect of Walls on RC High-Rise Buildings

Thanh Quang Khai Lam^{1, a *}

1Faculty of Civil Engineering, Mien Tay Construction University, Vinh Long, Vietnam

Abstract: High-rise buildings are highly sensitive to horizontal loads. Therefore, any changes made to the arrangement, size, or shape of the walls will have significant effects on the strength and performance of the building. The number of walls in each direction is determined based on the load-bearing capacity of that particular direction. The horizontal loads are transferred to the load-bearing walls through floor slabs, which are assumed to be completely rigid within their plane. Hence, the rigid walls function as cantilever beams that have large cross-sectional heights. In this article, the author conducted an investigation on four specific cases: walls located at the corner of the building in the X direction, walls located at the corner of the building in the Y direction, walls present in both directions, and reinforced concrete frames. The analysis results suggest that changing the placement of rigid walls located at the four corners of the structure will significantly influence the bending moment, shear force, and axial force observed at the base of the structure's columns. Simultaneously, it also affects the top displacement based on the main bearing direction of the structure.

Keywords: building; horizontal load; walls; floor slabs; structure; displacement.

Introduction

The analysis of wind factors is essential when designing high-rise buildings. Researchers have conducted studies on the resistance of structures to wind and earthquakes by examining the effects of different wall arrangements. These arrangements include structures without rigid walls, structures with rigid walls placed in the center, and structures with rigid walls positioned at the corners. Research has demonstrated that symmetrical constructions with rigid walls positioned in the center show superior response when compared to constructions without rigid walls or with rigid walls placed at the corners. Contrary to expectations, when it comes to asymmetrical rigid walls in construction, placing rigid walls at the corners results in the most favorable response. This is in contrast to conditions where no rigid walls are present or when rigid walls are positioned in the center [1]. It is essential to conduct a thorough assessment of the seismic response of the structure due to the significant impact that the characteristics of these shear walls have on the overall response of the building's structural system. According to the study, it has been determined that the reconfiguration of shear walls has a notable influence on both the storey shear capacity and the top displacement of the building [2].

Horizontal loads are of significant importance in the structural design of high-rise structures. Rigid walls are a type of vertical component commonly employed in building structures to fulfill the necessary horizontal stiffness requirements. The objective of the research [3] was to investigate the behavior of high-rise buildings with load-bearing rigid walls in terms of their location and arrangement for effective resistance against lateral loads. Specifically, the study focused on understanding the response of these buildings to horizontal weight. The results of the research show that centrally located shear walls in the form of cores demonstrated superior performance in resisting lateral loads. The displacement at the top of a building is approximately 2.5 times less than the displacement at the top floor of a building lacking rigid walls. The effectiveness of shear walls is minimized when they are positioned at corners. Based on the result of research [4], it has been shown that the use of shear walls in a symmetrical way and along shorter spans within the chosen structural option results in reduced displacement and horizontal behavior, in comparison to structures employing shear walls in different directions.

The workings of a high-rise building structure can be compared to a console that has an appropriate slimmness ratio. However, the structure of a bending member is different from a typical column structure. The bending of the building is not limited to just a bending shape, but can also involve a shear form or a combination of bending and shear. In addition, it is worth noting that these shapes can occur not only due to horizontal bending, but also

as a result of torsion or flexion-torsion [5]. When subjected to a horizontal load, the structure makes horizontal displacement. There will be different displacements on each cross section of the building at different points. The analytical results of B.B. Khansi have demonstrated that torsion has a significant influence on horizontal displacement [6]. The torsional component of wind load is mentioned in both Japanese and American wind load calculation standards [7-8]. In Vietnam, earthquake-resistant reinforced concrete frame structures are commonly designed with low to medium elasticity levels. There is a significant difference in the calculation process between earthquake-resistant reinforced concrete frames with low elasticity levels and those with medium elasticity levels. Reinforced concrete frames with low elasticity are analyzed using elastic diagrams, while frames with medium elasticity are analyzed using plastic joint diagrams. In the latter case, plastic joints are formed at the ends of beams and column bases [9].

The impact of horizontal loads has a significant effect on multi-storey buildings. As the height of a building increases, the impact of horizontal loads becomes greater, resulting in a more significant displacement of the structure. Designers are always faced with the challenge of increasing horizontal stiffness and reducing displacement. The structural system is continuously evolving to address this issue. In modern times, the use of a combined frame-wall system has proven to be an effective structural solution to improve the horizontal stiffness of a building [10]. In Vietnam, there are guidelines available for calculating the structures of high-rise buildings [11-12]. Additionally, there are design standards that are used in the calculation of high-rise buildings, such as [13-16].

The research conducted by the authors mentioned above has significantly contributed to the development of suitable conditions for calculating and designing high-rise building structures. However, previous studies have not specifically investigated the relationship between bending moment, shear force, axial force at the base of the column, and displacement at the top of the structural system in relation to the arrangement of rigid walls during impact and the use of load. The author of this article investigates into the issue at combination, providing a detailed examination of the conditions necessary for effectively calculating, designing, and arranging rigid walls.

Research Significance

Research has been conducted to investigate the impact of reinforced concrete walls on the structural integrity of high-rise buildings, as well as the optimal arrangement of these walls. Conducting an investigation into the effects is essential, including both scientific and practical aspects..

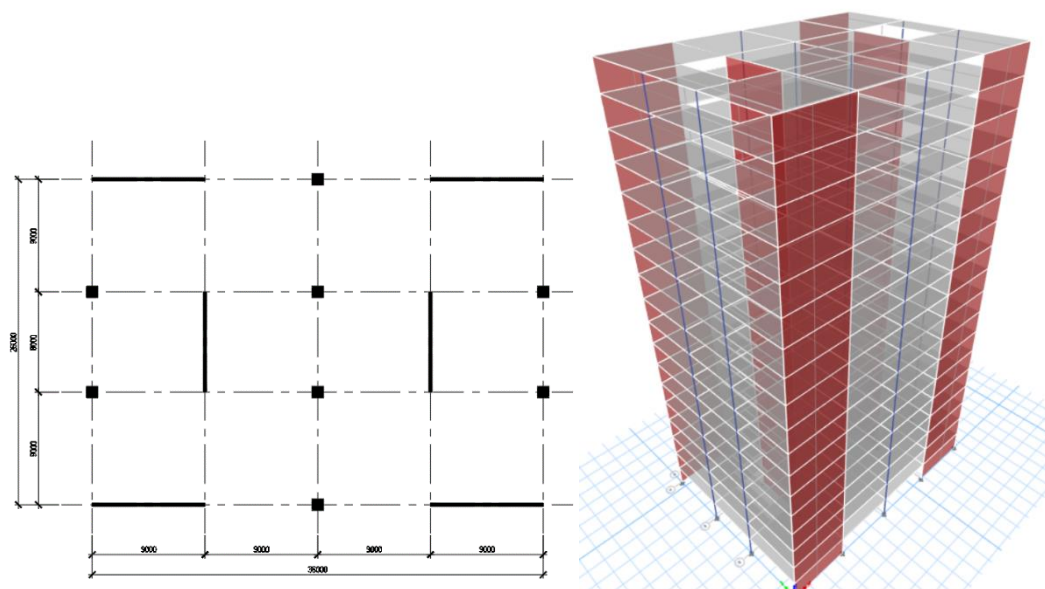
Objective of the current study

Conduct a survey to analyze the bending moment, shear force, and axial force at the base of the column, as well as the horizontal displacement at the top of the building, all on the same plane. Guarantee that the applied load remains constant throughout the survey. Based on the results, provide comments and assessments regarding the impact of changing the position of the walls.

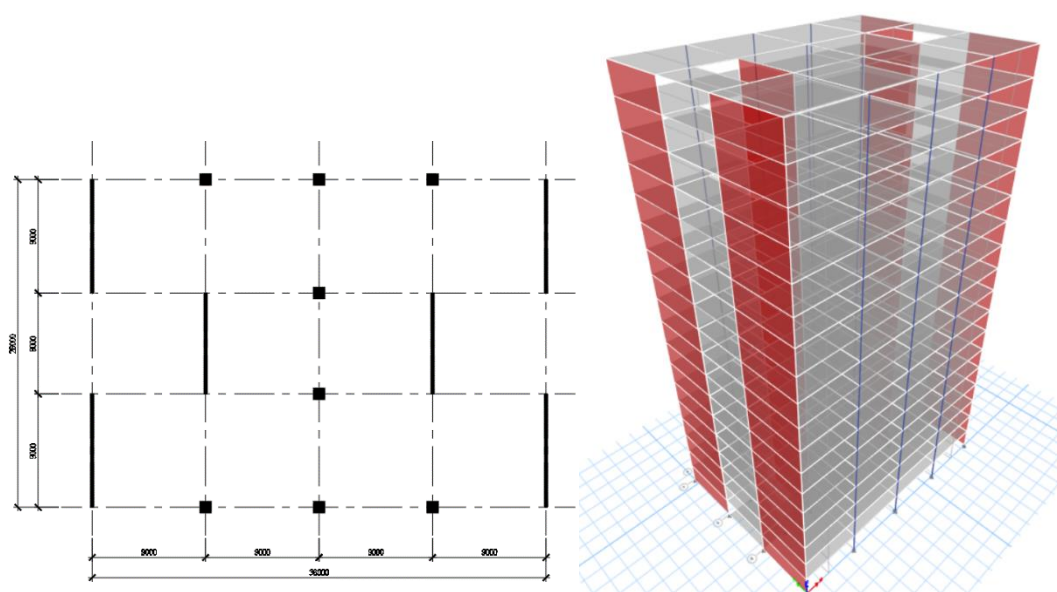
2. Materials

The building has been surveyed based on the following cases:

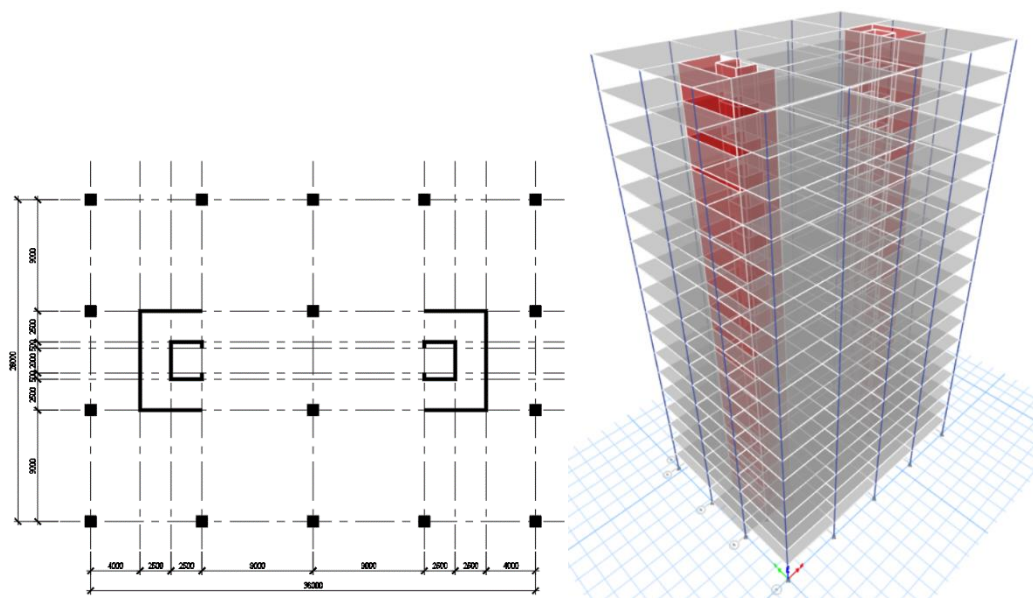
- Case 1: Symmetrical arrangement, walls at the corners of the building in the X direction, shown in Fig. 1a
- Case 2: Symmetrical arrangement, walls at the corners of the building in the Y direction, shown in Fig. 1b
- Case 3: Arrange walls symmetrically in both directions at core, shown in Fig. 1c
- Case 4: Reinforced concrete frame model is symmetrical in both directions, shown in Fig. 1d



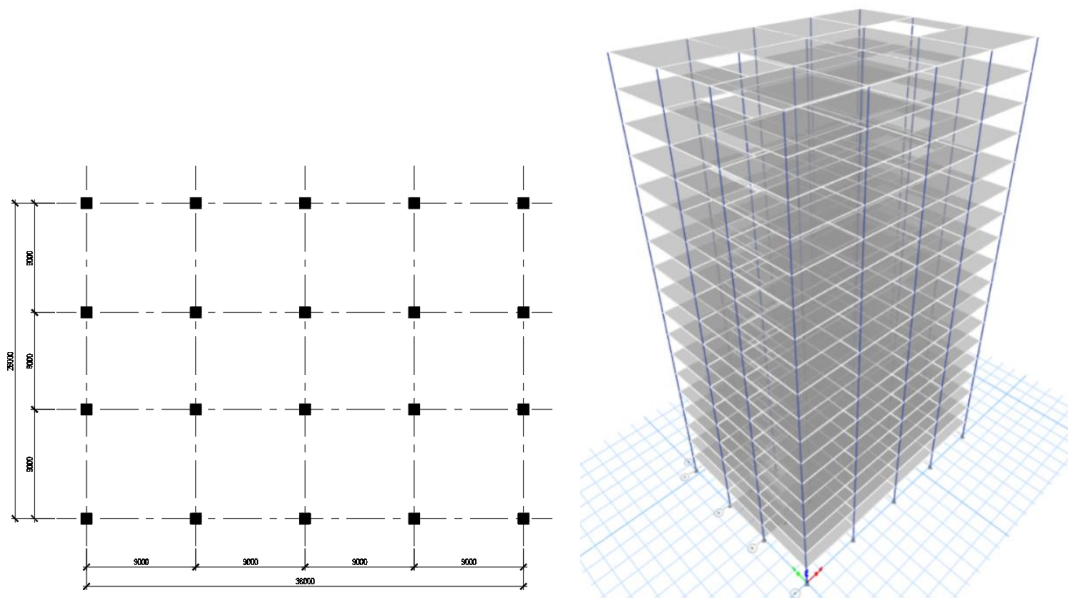
a) Case 1



b) Case 2



c) Case 3



d) Case 4

Fig. 1. Plan and 3D model of surveyed cases

The building has a total of 17 floors and 1 basement. It is constructed with a reinforced concrete wall frame structure, designed to withstand earthquake loads. The design includes consideration for the following parameters:

- The building's floor plan is 26m×36m, 62.8m high.
- The height of each floor is 3.5m, the basement is 3.3m high.
- Assume a brick wall with a thickness of 200mm is built on all beams (the roof floor does not have brick walls).
- The dead load of the layers on the floor is 2 kN/m²
- The live load acting on the floor is 2.5 kN/m²

- The live load acting on the roof floor is 1 kN/m^2
- The dead load applied by the brick wall on the beam is 1.5 kN/m^2
- Select the sizes: floor that is 0.15 m thick, beams that are $0.3 \times 0.6 \text{ m}$, and walls that are 0.25 m thick and made of reinforced concrete.
- Concrete with Grade B25 and AII steel group are the materials that are needed.

3.Methodology

Table 1 displays the sizes of the columns.

Table 1. Sizes of the columns

Base ÷ Story 3	Story 4 ÷ Story 7	Story 8 ÷ Story 11	Story 12 ÷ Story 15	Story 16÷Story 18
$0.9 \times 0.9 \text{ m}$	$0.8 \times 0.8 \text{ m}$	$0.7 \times 0.7 \text{ m}$	$0.6 \times 0.6 \text{ m}$	$0.5 \times 0.5 \text{ m}$

Wind loads that are both static and dynamic on the building, shown in Table 2 and The wind load is assigned to the geometric center of the structure, as shown in Fig.2.

Table 2. Wind loads

Story	Staticload of win (kN)		Dynamic load of win (kN)	
	Xdirection	Ydirection	Xdirection	Ydirection
Story 18	192.2	316.2	84.2	136.1
Story 17	190.2	312.8	84.2	128.7
Story 16	188	309.3	73.9	103.9
Story 15	185.7	305.6	63.6	107.5
Story 14	183.4	301.6	63.6	109.7
Story 13	180.8	297.5	53	95.5
Story 12	178.1	293	53	105.3
Story 11	175.2	288.2	42.6	98.2
Story 10	172	282.9	32.2	98.8
Story 9	168.5	277.3	32.2	86.4
Story 8	164.7	271	21.4	86.4
Story 7	160.4	264	21.4	76.3
Story 6	155.6	256	10.7	66.8
Story 5	149.9	246.6	10.8	48.5
Story 4	143.1	235.4	10.8	38.3
Story 3	134.3	220.9	3.4	13.5
Story 2	121.6	200.1	1.2	5.8
Story 1	35.4	58.2	0	0

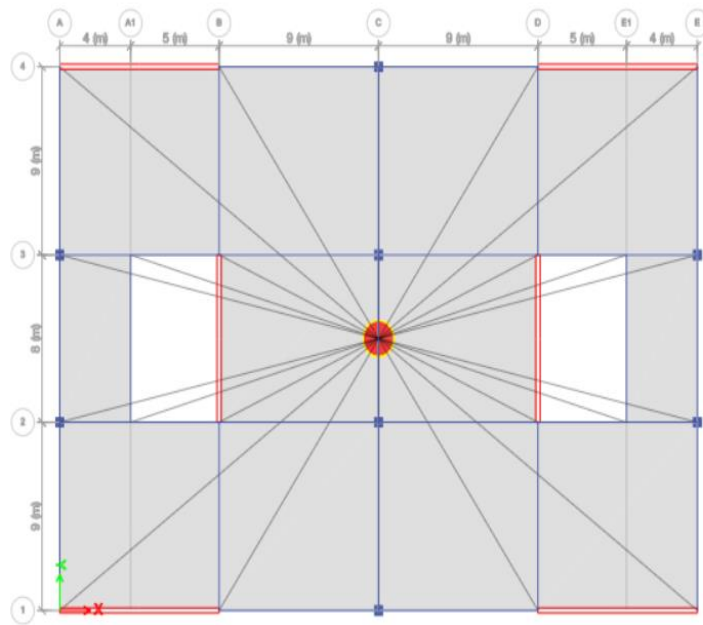


Fig. 2. Wind load is assigned to the geometric center of the structure

Load combination:

COMB 1: 1 DEAD + 1 LIVE

COMB 2: 1 DEAD + 1 WINX

COMB 3: 1 DEAD + 1 WINXX

COMB 4: 1 DEAD + 1 WINY

COMB 5: 1 DEAD + 1 WINYY

COMB 6: 1 DEAD + 0.9 LIVE + 0.9 WINX

COMB 7: 1 DEAD + 0.9 LIVE + 0.9 WINXX

COMB 8: 1 DEAD + 0.9 LIVE + 0.9 WINY

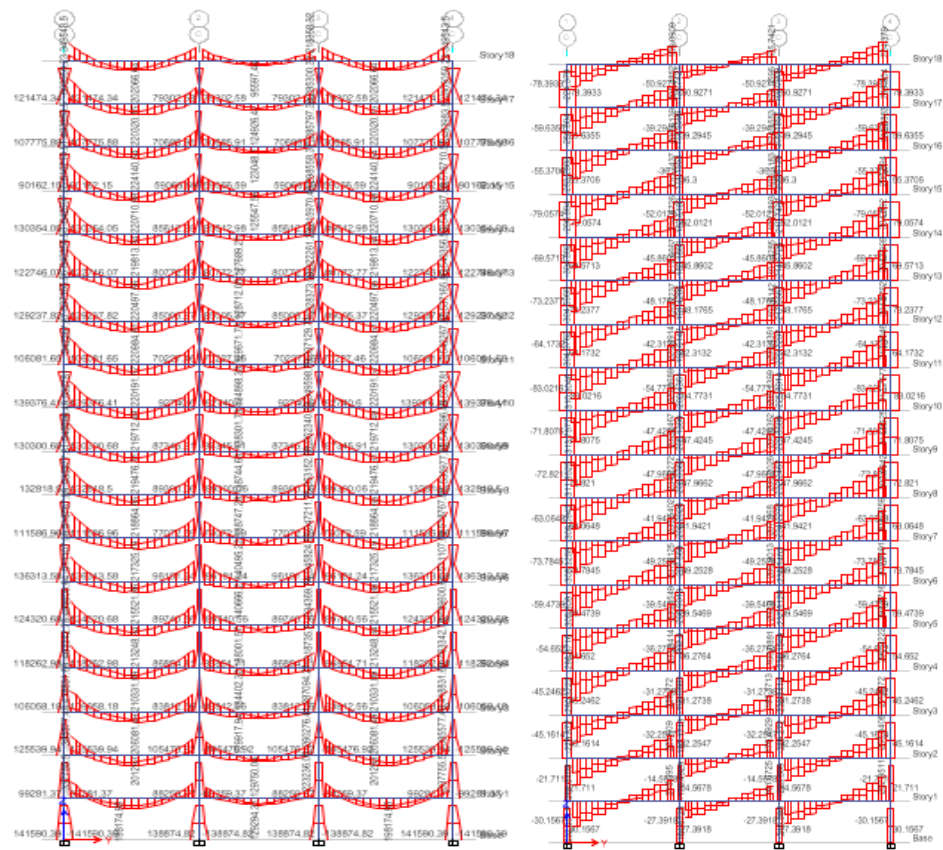
COMB 9: 1 DEAD + 0.9 LIVE + 0.9 WINYY

ENV: COMB1+COMB2+...+COMB9

4. Results and Discussions

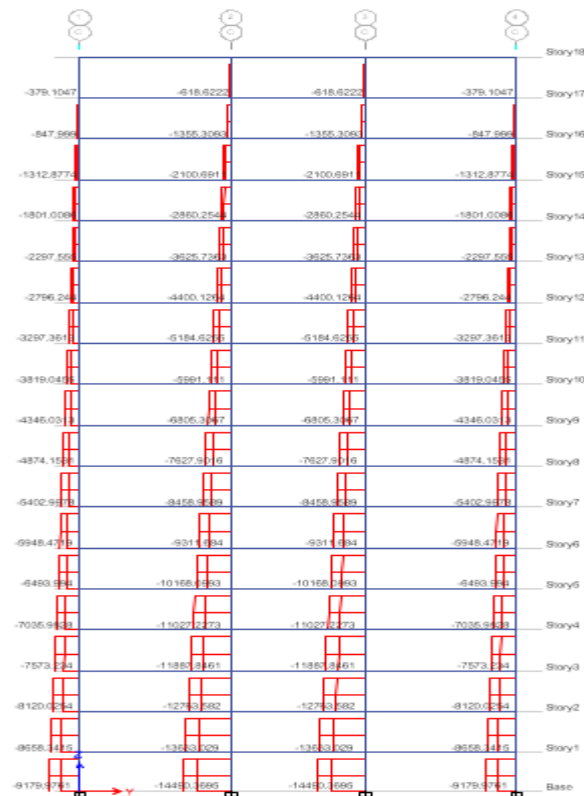
The Envelopediagram of bending moment, shear force and axial force of C-axis frame, case 1, shown in Fig. 3

Case 1:



a) diagram of bending moment (kNm)

b) diagram of shear force (kN)



c) diagram of axial force (kN)

Fig. 3. The Envelope diagram of bending moment, shear force and axial force of C-axis frame, Case 1

The Envelopediagram of bending moment, shear force and axial force of C-axis frame, case 2, shown in Fig. 4 Case 2:

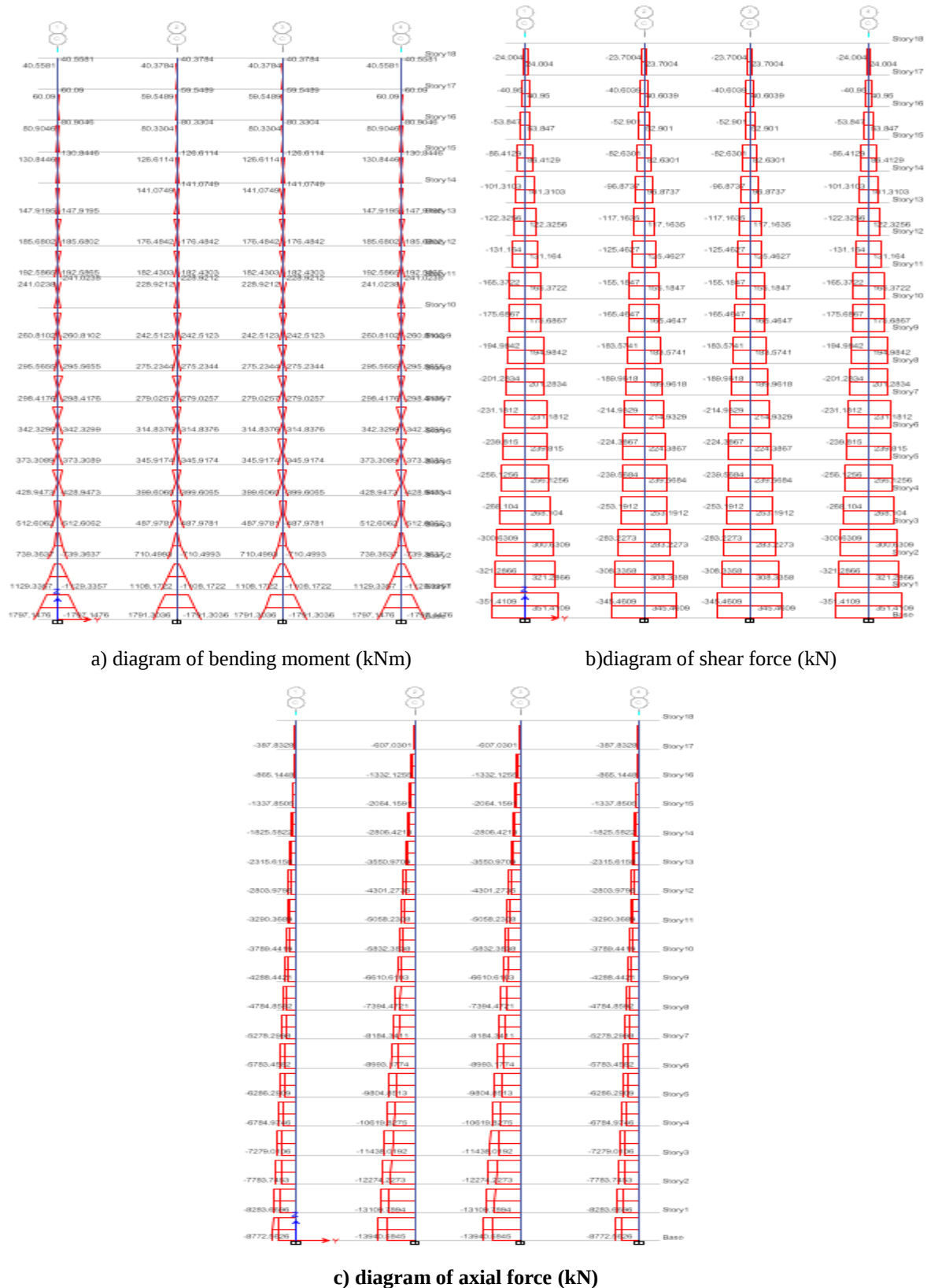


Fig. 4.The Envelopediagram of bending moment, shear force and axial force of C-axis frame, Case 2

The Envelopediagram of bending moment, shear force and axial force of C-axis frame, case 3, shown in Fig. 5 Case 3:

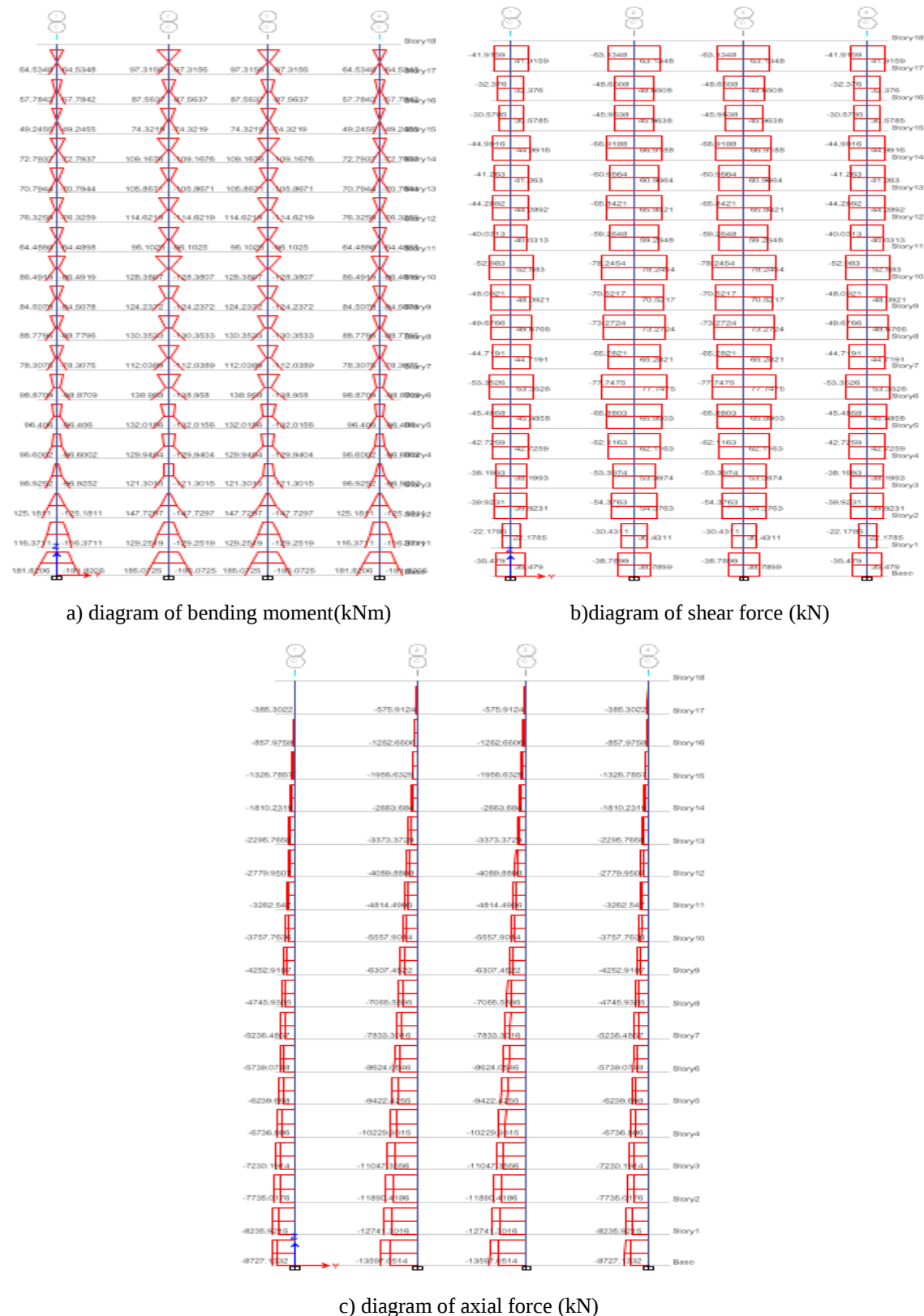
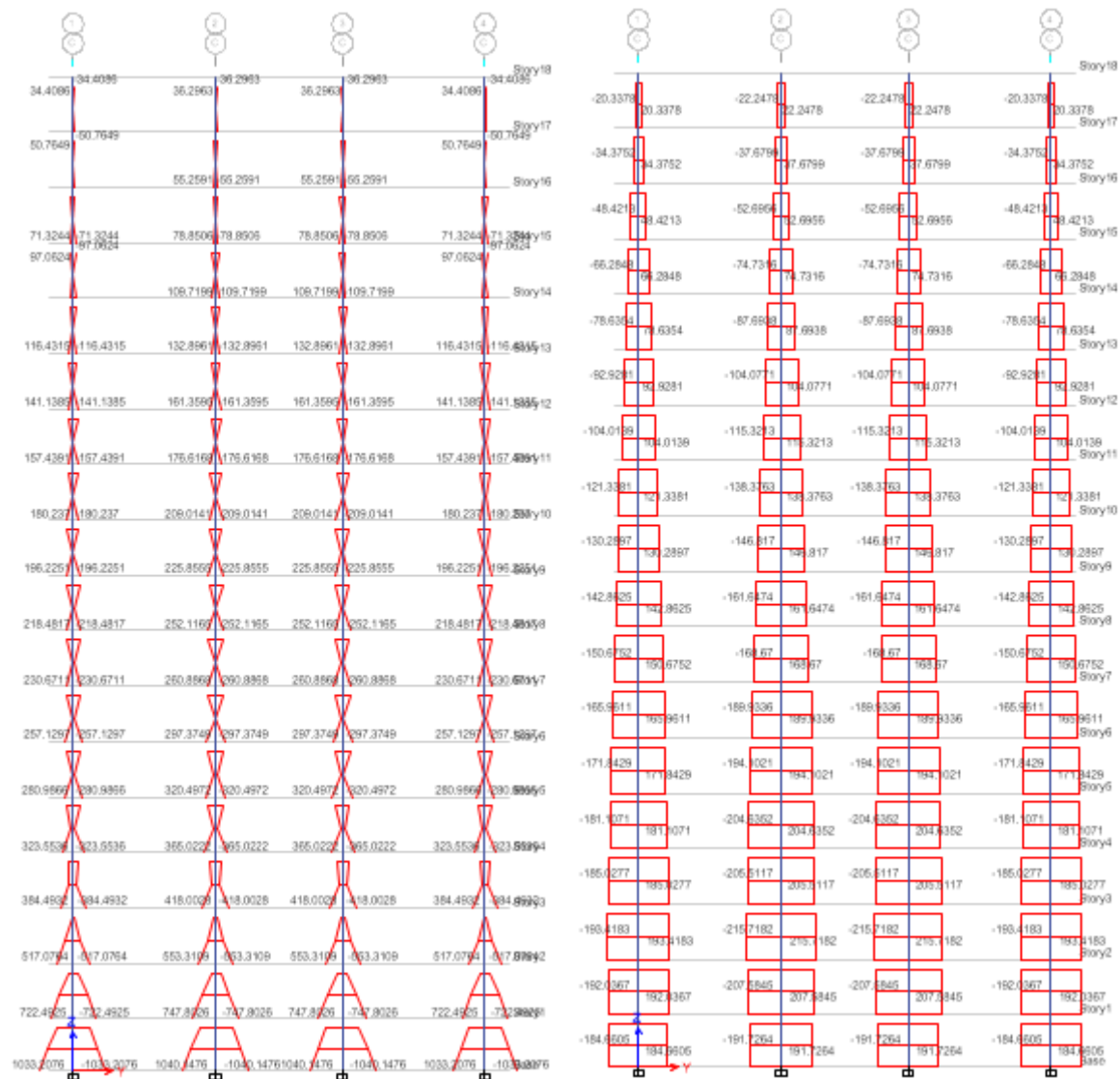


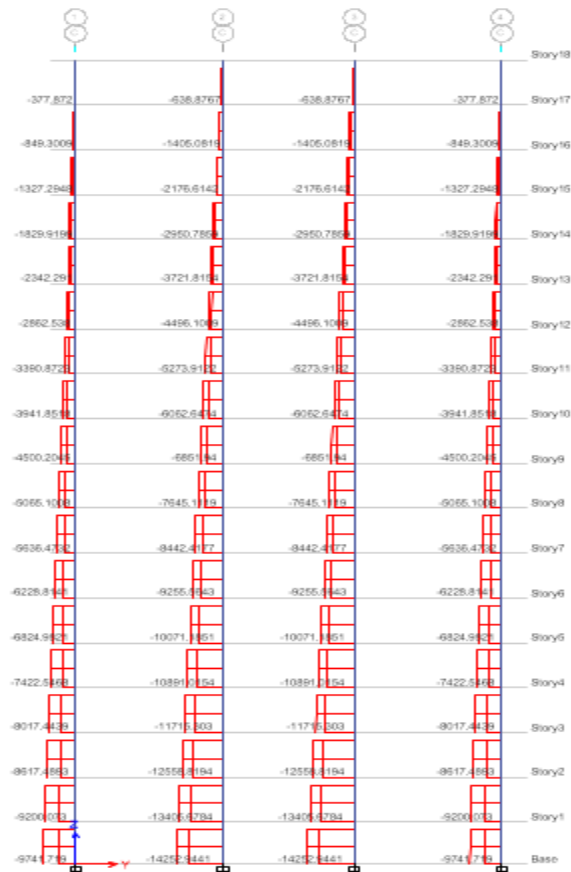
Fig. 5.The Envelopediagram of bending moment, shear force and axial force of C-axis frame, Case 3

The Envelopediagram of bending moment, shear force and axial force of C-axis frame, case 4, shown in Fig. 6
Case 4:



a) diagram of bending moment(kNm)

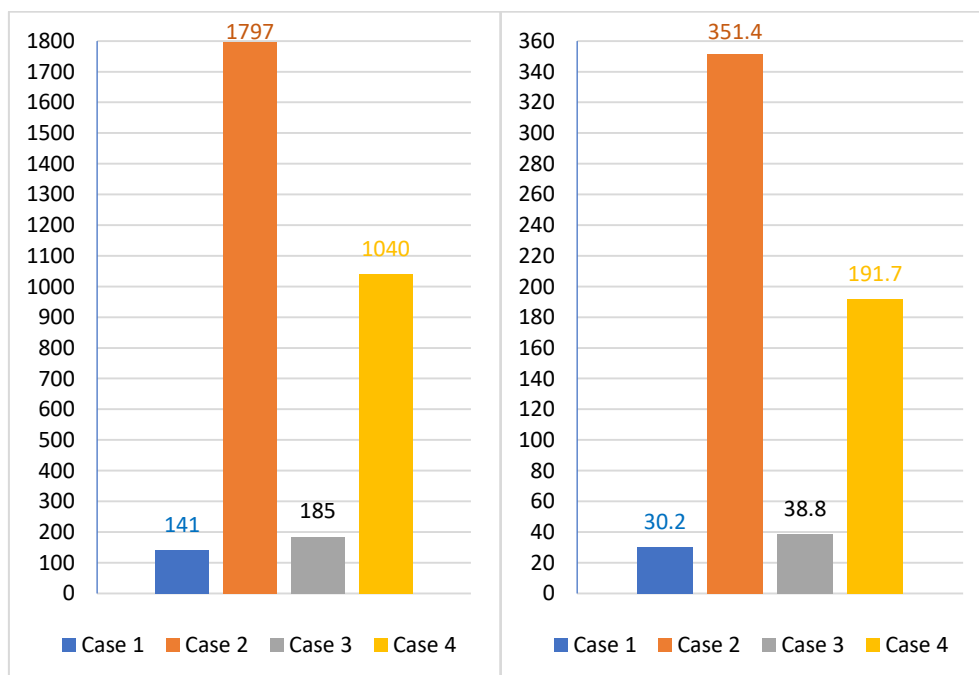
b) diagram of shear force (kN)



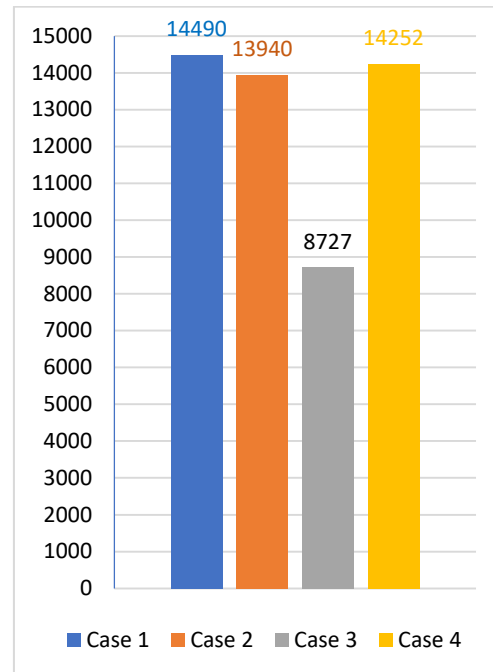
c) diagram of axial force (kN)

Fig. 6. The Envelopediagram of bending moment, shear force and axial force of C-axis frame, Case 4

In this analysis, we will compare the values of bending moment, shear force, and axial force at the base of the column in four different cases of the C-axis frame, shown in Fig. 7



a) bending moment(kNm)b) shear force (kN)

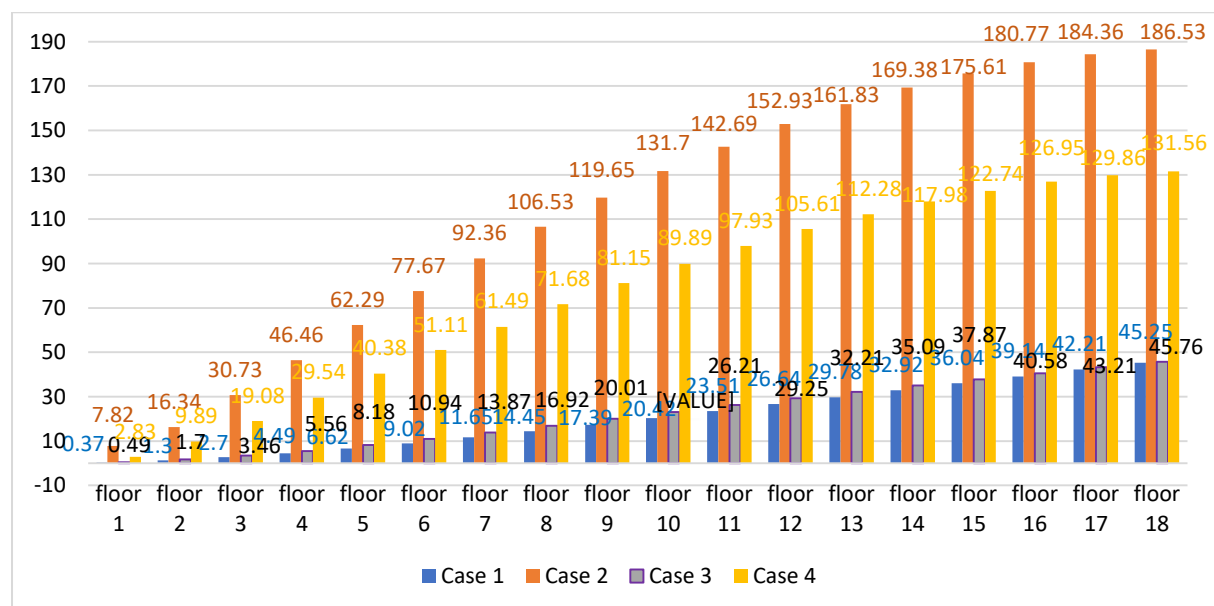


c) axial force (kN)

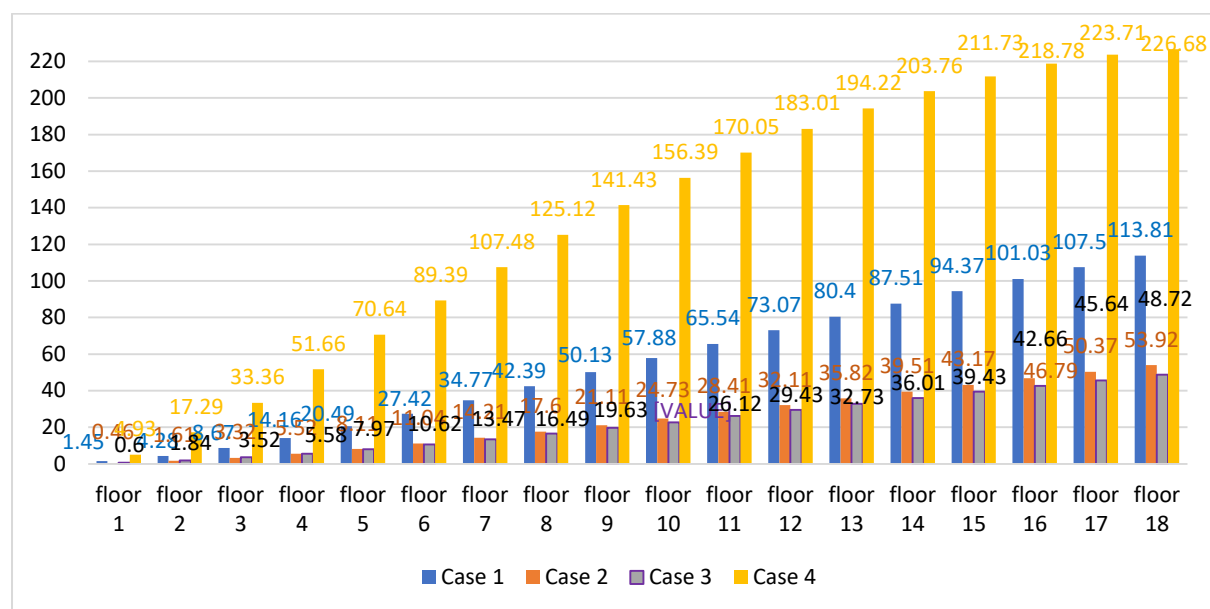
Fig. 7. The four investigated cases at the base of the column

Comment: In Figures 7a and 7b, it is observed that the bending moment and shear force values for Case 1 and Case 3 are 10 times smaller than those for Case 2. Case 2 shows significantly high moment and shear force values. This suggests that Case 1 and Case 3 are the preferred choices for calculating and designing the structure of this high-rise building. In this project, the column is considered the most important structure. Figure 7c shows that Case 3 shows the lowest axial force value. It means that Case 3 is the most optimal choice for purposes of calculation and design. Case 3 in Figure 1c represents a situation where the walls are positioned in close proximity to the geometric center of the building. Furthermore, these solid walls are highly effective in calculating and designing structures with minimal values of bending moment, shear force, and axial force. Additionally, walls are commonly utilized for housing elevators and/or stairs.

Compare the displacement at the building's floors for all of the four cases that were investigated by the C-axis frame, shown in Fig. 8



a) X direction (mm)



a) Y direction (mm)

Fig. 8. Displacement at the building's floors

Comment: In Figures 8a and 8b, it can be observed that Case 3 shows the lowest displacement values at both the floors and the top of the building. This result matches the observations made in Figures 7a, 7b, and 7c. The average horizontal displacement value of Case 3 is five times less than that of the other cases. Case 3 is considered the most optimal and highly recommended in structural design for high-rise buildings. The project's meeting the horizontal displacement limit for multi-storey buildings, as stated in TCVN 5574-2018, has been achieved.

5. Conclusions

Based on the results of the study lead to the following conclusions:

1. Based on the analysis of the 4 cases surveyed, it is evident that Case 3 shows the lowest values for various factors including bending moment, shear force, axial force, and displacement at the top of the structure. Therefore, it is recommended to consider Case 3 in the structural design of multi-storey houses.
2. Based on the analysis results above, it is evident that affecting the position of the hard walls at the four corners of the building will significantly affect the internal force created on the column base of the load-bearing structural system of the building. Simultaneously, it changes the top displacement based on the primary carrying direction of the structure. When the hard walls are connected to form a symmetrical hard core, it improves the stiffness of the structure. This, in turn, leads to a significant reduction in internal forces and top displacement within the structural system.

6. References

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