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The effect of dynamic load on tall building

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ABSTRACT

In this study, the effectiveness of the structure of a tall building (consisting of nineteen floors) was analysed and investigated by the existence or absence of shear walls (SW) to resist loads of wind and earthquake effect. Note that each floor contains four apartments comes under zone 2 Four different styles of shear walls were used in terms of shape and location. The results were analysed and discussed for each case and for each floor, and comparisons were made between those results in terms of (moments, lateral forces, vertical loads, and torsion moments). There are several techniques for solving structural engineering problems, and one of those distinct techniques is the design optimization techniques method. The most complicated high-rise buildings that use design optimization, which includes each of size and topological optimization, are addressed by considering stability, safety, and responsiveness to various sorts of loadings A project includes wall-frame structural optimization. When this wall and core system was subjected to various loadings, it was tested for displacement, internal stresses, and intensities. The SAP2000 Software has made design improvements to the construction of the reinforced concrete plane frame to minimize the costs to beams and columns of the concrete and steel by Using a computer model called an Artificial Neural Network (ANN). The concept method is in accordance with ACI-318-08 Code. To improve the design optimization, many variables have been used depth, width, and the steel reinforcing area Including both (longitudinal and shear reinforcement). It can be concluded that by putting the shear walls nearest the structure geometric center the best performance of seismically loaded structure can be achieved; the maximum displacement, bending moment horizontal forced, and torsional moments were decreased.

Keywords: Tall Building, Consisting of Nineteen Floors, Dynamic Load, Longitudinal and Shear Reinforcement

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1. Introduction

The tall buildings are essential solutions to meet the growing housing needs associated with the development and growth of the community, and the inability of the horizontal buildings style to meet the need for housing. In addition, there are several factors and reasons that have helped to propagate this urban pattern, including geographical nature and social aspect represented by growing population needs and others related to economic aspect, which play the monetary capability an important role. Adopting of this type of construction requires full knowledge of the appropriate structural system, in addition to the type of loads affecting. There is no doubt that high-rise buildings are more affected than others by wind and seismic loads. Columns and walls are the two main forms of vertical load resisting components in tall structures, with the latter functioning as shear walls or as shear wall cores in assemblies. The construction function would naturally provide everything for dividing and enclosing space, and the core for containing and moving services such as elevators. In otherwise unavailable locations, a column will be supplied to transfer gravity loads and horizontal loads in certain types of constructions in otherwise unavailable locations. The (SW) is a structural system consisting of reinforced

(braced) panels (furthermore familiar as shear panel (SP)) to counteract the impacts of the lateral load working on the structure. Loads such as wind and earthquake are considered the most prevalent loads that (SW) are infectious to withstand. Beneath many codes of buildings, every line in outer wall made of (steel or wood) structures ought to be strengthened and steadied. Some internal walls must be strapped according to the size of the structure. It can be considered that the main duty of (SW) for the kind of structure considered here is to increment the rigidity to resist the side or lateral load. The other benefit of employing Shear walls is to withstand loads in a vertical direction, which may not be explicit constantly between both the (SW) and column. The distinctive characteristics are the shear wall's substantially higher moment of inertia than a column, and the shear wall width, certainly, such things cannot be negligible comparing with an adjoining beam span. According to all the specifications of any code of practice to design beams and columns and achieve many agreeable cross-sections, most engineers have hesitation with selecting convenient cross-sections that lead to reduce and minimizing cost with no need for further calculations. In this study, optimization technique is used to solve the structural engineering problems in high-rise structures, both size, stability, safety and response to different loading types are taken in to consideration by using design optimization [2], [3].
Michell [1] could be considered the first to start with an interest in the topic of optimal solutions relevant to structural engineering and then followed suit by Schmidt [4]. It is worth noting that Heyman [5] was the one who identified the minimum absolute weight of the continuous beam (CB). As is well known and clear from the qualitative developments in the field of improving structural engineering designs during the two decades preceding our era, and to reach the optimum design that combines both the effect of gravity and lateral loading, many researchers have employed mathematical techniques as well as advanced research techniques. To optimize the reinforced concrete frames, Krishnamoorthy and Munro [6] technologies based on linear programming techniques (LPT) [7]. At a later stage, both Moharrami and Grierson [8] were able to present an automated computer-based method to arrive at an optimal way to design optimization of RC building frames subject to strength and rigidity restrictions. In contemporary and more modern studies, several researchers such as Lee and Ahn [9], Andres, Panos [10], and others have worked on the optimal design of reinforced concrete (RC) structures. the dispute in behavioral of structural for ten stories that resist the main moment of reinforced concreted frames equipped by two various kinds of (SW) represent the (LLRS),lateral load resisting structural systems has been discussed by S.V. Venkatesh, H. Sharada Bai (2013) [11], as a summary of what has been concluded exterior (SW) can act as substitute to internal SW in modifying construction that suffer from seismic defects, especially when it is difficult and impossible to evacuate the building during a retrofit.
Major aim of this research is to implement structural engineering optimization techniques The structure stability and safety which implies building design is concerned primarily with structural engineering It can so resist all sorts of forces it is exposed to the stiffness of the building is a major resistance to these pressures when the construction is subjected to lateral forces such as earthquake wind etc. Our objective now is to optimize the construction to have sufficient rigidity and strength to hold out forces that could result in structural failure.
Construction components that withstand lateral forces and improve structural rigidity:

- (SW) Shear walls.
- Lift cores

This research investigates the effect of using the single variable optimization technology to improve the G+19 apartment building which accords with mutable the scale of improvement technology globally.

2. Computer Modelling

To measure the buildings' reaction (response a building computer model has been developed by (SAP 2000 V. 19.0) program [12]. It is considered one of the Structural Analysis Program depend on Finite Element Method solver for calculating the building's response. To knowing and realizing the extent to which the building response degree is affected by the effect of the shear wall, four different models have been prepared in this research. As shown in Figure 1 (a,b,c, and d), a 3-D building model created by a computer program carrying shear walls for four cases, and each case differs from the other in terms of the location of the shear wall. The four cases can be illustrated as follows: -

Case No. 1: In this case, the influence of the shear wall's presence was ignored, and the building's response was observed as a result, as shown in Figure (1-a).
Case No. 2: In this case, the effect of shear walls (SW) on the building's response was considered, as (2- SW) were located near the geometric center point of the structure, which has low eccentricities between the mass center and stiffness center of the structure. As can be seen in Fig (1-b).

Case No. 3: A new method was used to determine the effect of two shear walls on the building reaction in this case. As indicated in Figure, the total stiffness of the two walls was taken and evenly transferred to the four faces of the building (1-c).

Case No.4: Unlike the previous situations, where the effect of two shear walls was obtained by placing them in two locations at the two opposing corners of the buildings, as illustrated in Figure, this case is different (1-d).

Every condition (case) of the building was subject to consistent standards except for the earthquake zone. According to the seismic zones in UBC-97 [13], each of the four cases was subjected to different seismic forces. It is worth noting that these seismic zones vary in intensity from mild (zone 1) to severe (zone 4). Table 1 provides the zones of earthquakes and their factors that were adopted in this study. As it is clear in Table 1 that the forces in zone (1) are extremely small and almost without significant effect, which led to the adoption of the values of the existing forces from the zone (1 to 4).

Figure 1. Case 1, without shear wall

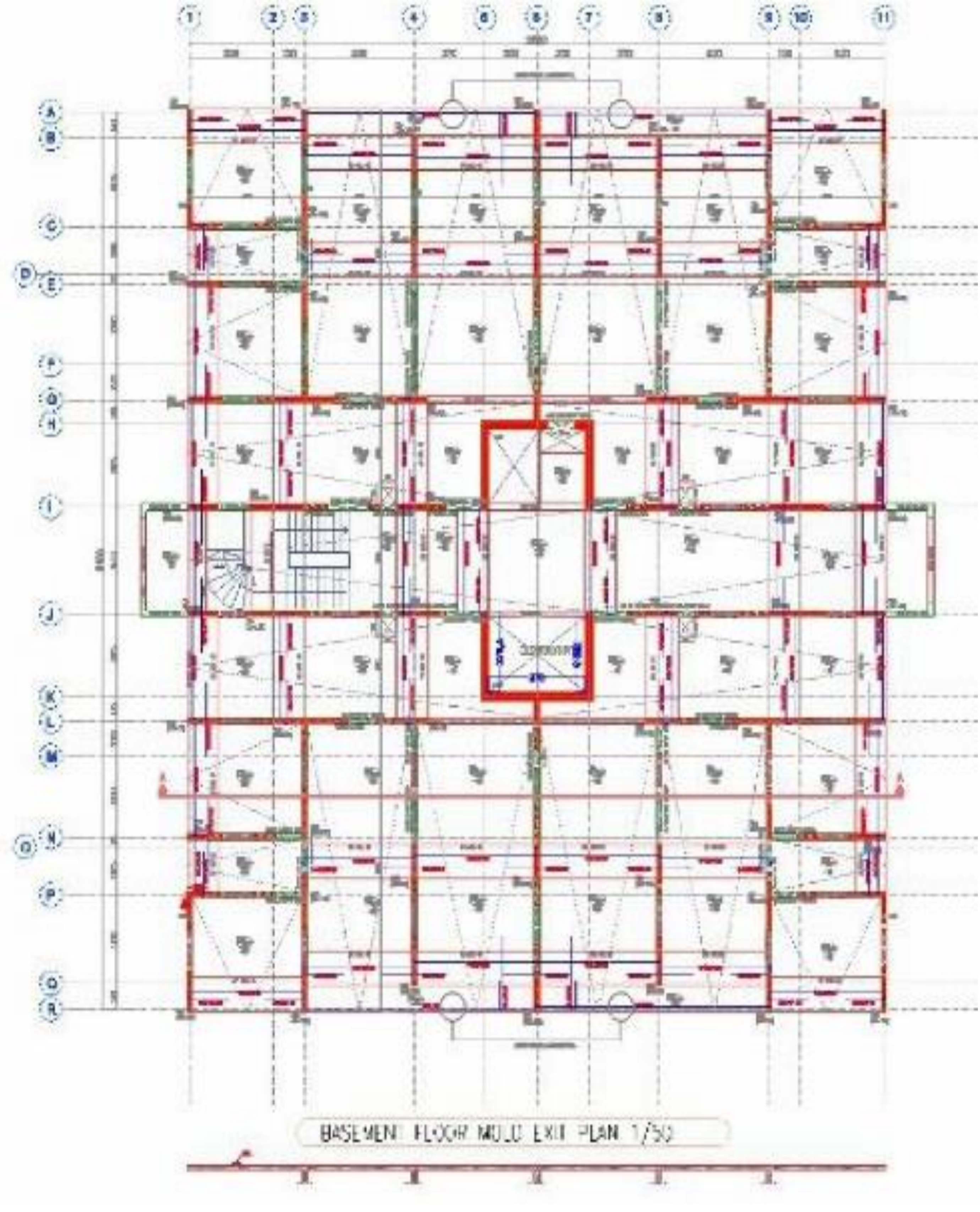


Figure (1-b). Case -2, (SW) located near geometric center

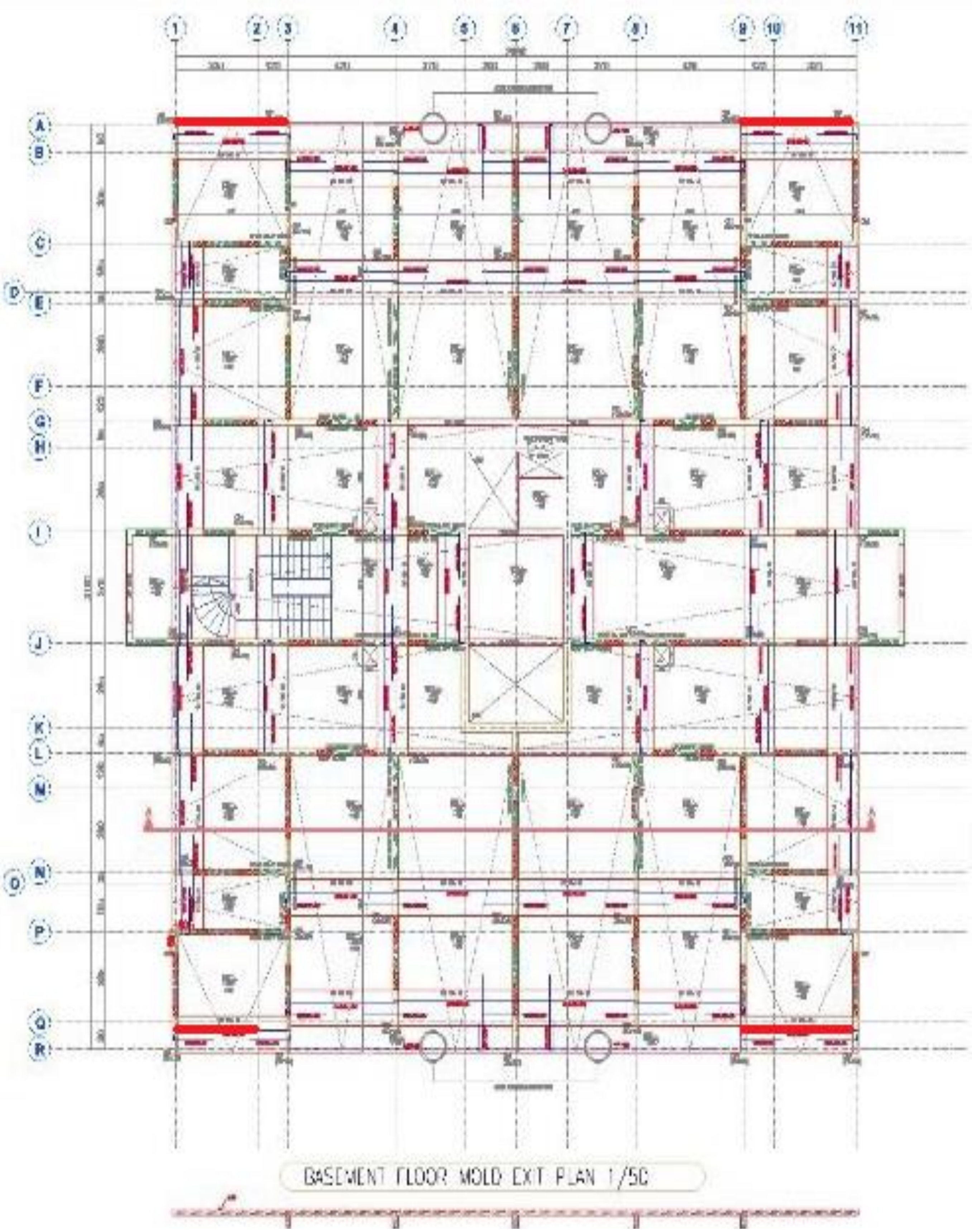


Figure (1-c). Case -3, (SW) regularly redistributed to the four faces of the building

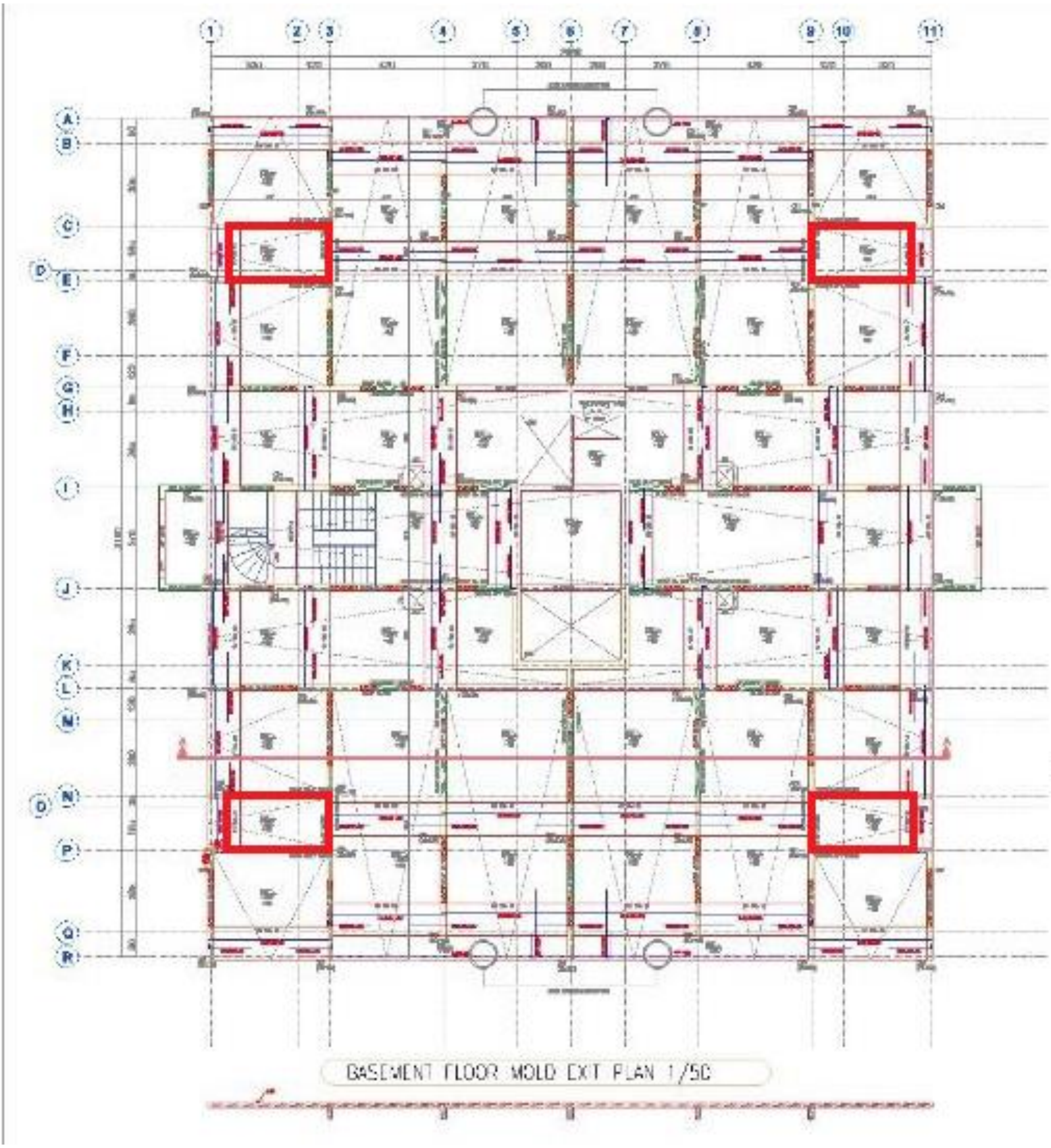


Figure (1-d). Case -4, (SW) placing at the two adverse corners of the building

Figure 1. The modeled RC building with different layouts (cases) of shear wall locations.

Table 1. Adopted earthquakes zones and their factors

Case	Zone	Peak ground acceleration based on UBC-97
----	Zone 1	0.075
One	Zone 2A	0.15
Two	Zone 2B	0.20
Three	Zone 3	0.3
Four	Zone 4	0.4

3. Dynamic analysis of building using techniques of response spectrum

In this manuscript for the building G + 19, the dynamic analysis is performed utilizing the reaction spectrum methodologies, for the evaluation of seismic behavior under earthquake conditions. Steady state response of several oscillators of variable natural frequency such as (displacement, speed or acceleration) pushed to motion by the basic vibration or shock selfsame. In view of its natural frequency of oscillation the resulting plot can therefore be used for the reactions of any linear system. As an example, one such utilize is to evaluate structures' peak response to the earthquake.

Wind loading as per IS 875: Part 3 [14]

Exposure Parameters

Basic Wind Speed (Vb) = 44 m/sec

Height of Building above G.L = 60.96 m

Width of Building = 23.343 m

Length of Building = 30.537 m

Top Story = Story19

Bottom Story = Base

Exposure From = Diaphragms

Class of structure = Class B

Category of land = Category 2

Cp, wind =0.8	Trend of the wind= 0;90 degrees Coefficient of Windward.
Cp, lee = 0.5	Leeward Coefficient

3.1 Laterally load

Wind velocity design according to [IS 5.3]Vz = Vb x K1 x K2 x K3

Vz = 49.06 m/sec

Design Wind Pressure, [IS 5.4] Pz = 06. Vz2

Pz = 1444.13 N/m2

= 1.5 kN/m2

3.2 Calculation of horizontal seismic coefficient in x direction

Base dimension in X- direction (D) = 23.343 m

Height of Building (H) = 60.96 m

Ta= 0.09 H√D(Sa/g) =1.13556

(Sa/g) = 2.5

Ah = Horizontal Seismic Co-eff =ZI (Sa/g)/2R. where:

Z = Zone Factor = 0.1

I = Importance Factor = 1

R = Response Reduction Factor = 3

Ah = 0.1 *1 * 3/2.5 *2 = 0.04167

3.3 Calculation of horizontal seismic coefficient in y direction

Base dimension in Y- direction (D) = 30.537 m

Height of Building (H) = 60.96 m

Ta= 0.09 H√D(Sa/g) =1.13556

(Sa/g) = 2.5

Ah = Horizontal Seismic Co-eff =ZI (Sa/g)/2R. where:

Z = Zone Factor = 0.1

I = Importance Factor = 1

R = Response Reduction Factor = 3

Ah = 0.1 *1 * 3/2.5 *2 = 0.04167

Table 2 shows the initial design loads of this study

Table 2. Initial Design Loads

S.no	Name	Type	Self Weight Multiplier
1	DL	Dead	7
2	LL	Live	3
3	LL for stairs	Live	3
4	Walls	Live	8
5	Wind, dead, & seismic =		0

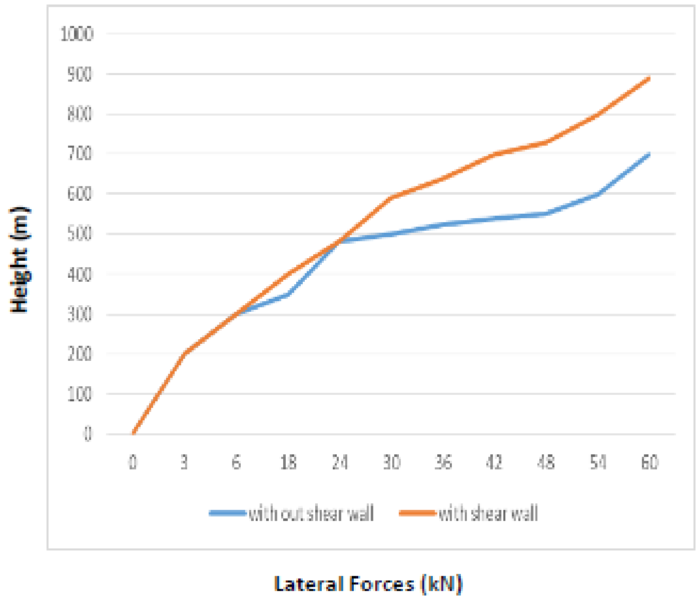


Figure 2. Comparison of Lateral Forces of a Building with and without Shear Walls in X Direction

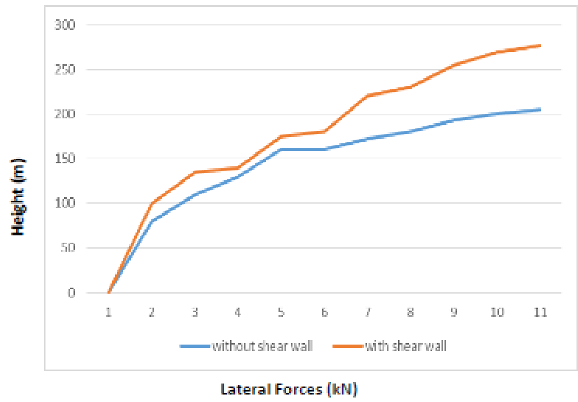


Figure 3. Comparison of Lateral Forces of a Building with and without Shear Walls in Y Direction

Figure 4. Comparison of Drifts of Building with and Without Shear Walls in X Direction

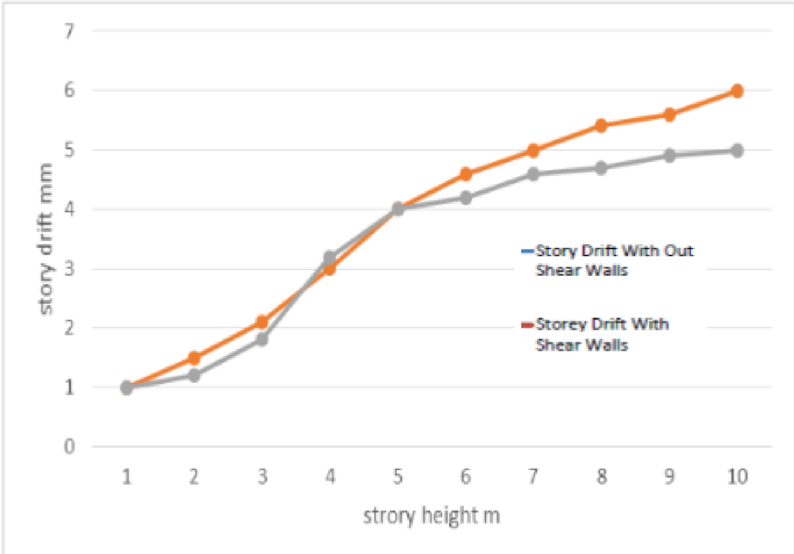


Figure 5. Comparison of Drifts of Building with and Without Shear Walls in Y Direction

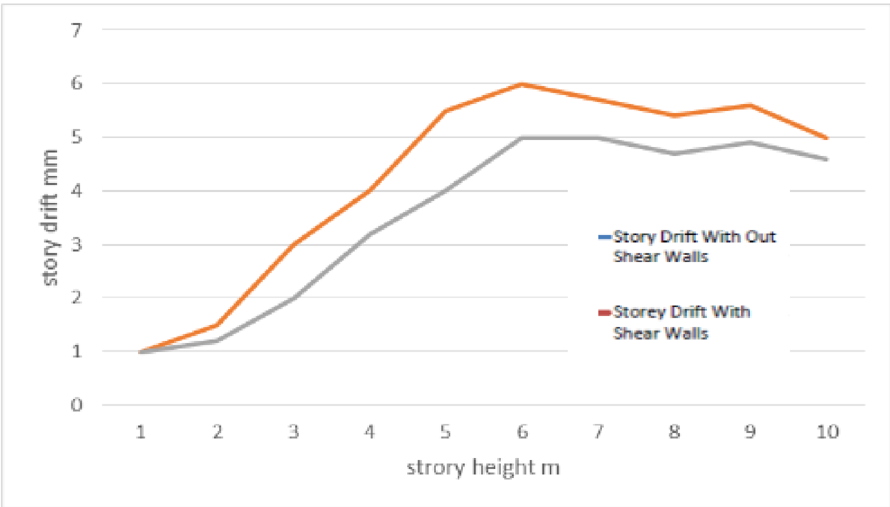


Figure 6. Comparison of Drifts of Building with and Without Shear Walls in Z Direction

4. Applying optimization method for g+ 19 residential structures

At 1st run, across the building height, the thickness of the (SW) remains steady and columns depicted as line elements are constantly size. Based on the limited condition of failure and serviceability the limitations for design factors are set. (SW) are designed to optimize mainly the elements of both (D L & L L) around all the cores of elevator and corners of the building. Thickness limits for the wall are as follows:

Minimum thickness = 150 mm

Maximum thickness = 210 mm

In view of these four shear walls of varying thicknesses are considered and after running various iterations best optimized wall had been selected in various positions depending on all factors.

1. Shear wall – SW-150 (150 mm thick)
2. Shear wall – SW- 175 (175 mm thick)
3. Shear wall – SW-203 (203 mm thick)
4. Shear wall – SW-250 (250 mm thick)

5. Results

It should be noted that in the case of earthquake loads in EQX-direction, the show results are in the shape of floor height versus displacement curves. Also, it should be noted that the corner of the building under point A considered as a displacement reference point. The results of the analysis confirm that the structure remains stable when applying the permissible limits that are explained in the building codes mentioned above. In Figure (3-a to 3-d), depicts the highest value of the displacement goes through by each case with respect to the story height. The building displacement profile at diverse seismic earthquake zone when (SW) were unsupplied can be shown in Figure (3-a).

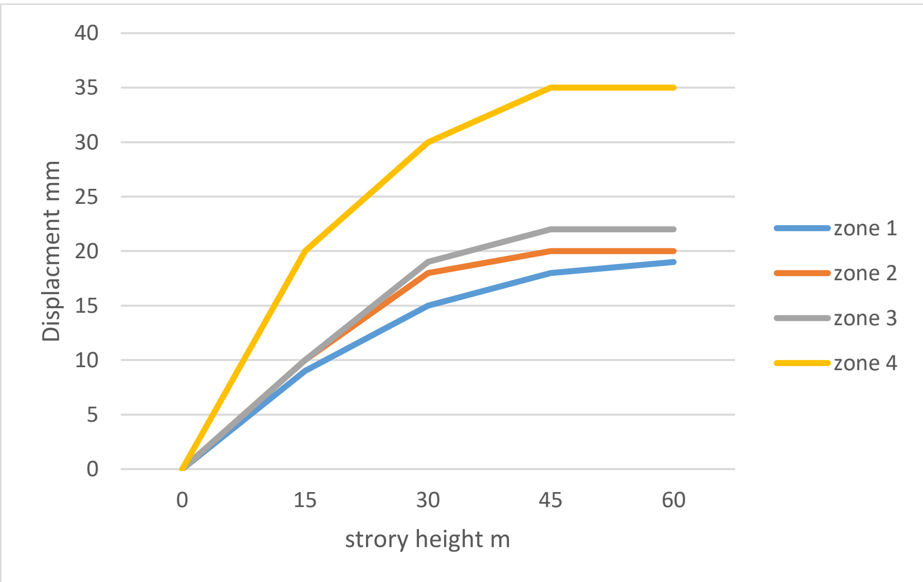
It is worthy that there is a similarity between building response and SDOF (System One Degree of Freedom). Also, in relation to the building displacements, no significant change of displacement seen when the loads applied respectively for the Zones 2A, 2B and 3.

The building displacement has been increased significantly at zone number (4) and this increase in displacements can be attributed to the structure nonlinearity behavior. It was noted that the values of the recorded displacements of the building for zones 2A, 2B, and 3 are similar up to a height of 6 m. When the building reached a height of 21 meters from the ground level, the following values were recorded: (23.9, 39.5, 34.7 and 71.9) mm as highest value of displacement respectively for zones 2A, 2B, 3 and 4. At every story level, the building displacement profile can be shown in Figure (3-b), as for (case two) when two of (SW) were placed near the gravity center point of the building that has minimal eccentricities amongst both of (mass and stiffness) center of the building. Furthermore, providing shear walls as mentioned in (case -2) and shown in Figure (1-b) led to a significant reduction in displacements of story at every floor level.

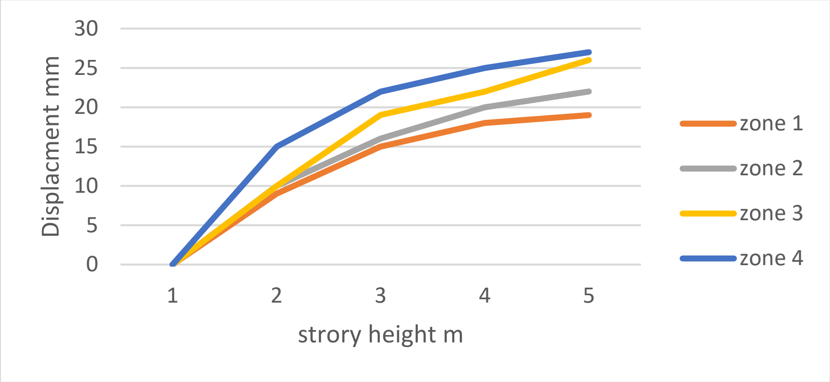
The highest displacement by about (6.8, 14.9, 24.4, and 29.5) mm has been registered respectively for zones 2A, 2B, 3 and 4.

The displacement value decreased by about four to six times, depending on the earthquake zone, in case of providing the building with shear walls. It indicates that a large part of the lateral strength comes from the shear walls. Figure (3-b) shows that the increased displacement for this case-2 was likewise shown to be related to the increase of zonal forces proportionally. Moreover, Figure (3- c) illustrate the profile of displacement when the two shear walls was taken and regularly redistributed to the four faces of structure as mentioned in (case -3). Note that, highest displacement amount by about (19, 20.6, 29.7 and 56.4) mm has been registered respectively for zones 2A, 2B, 3 and 4.

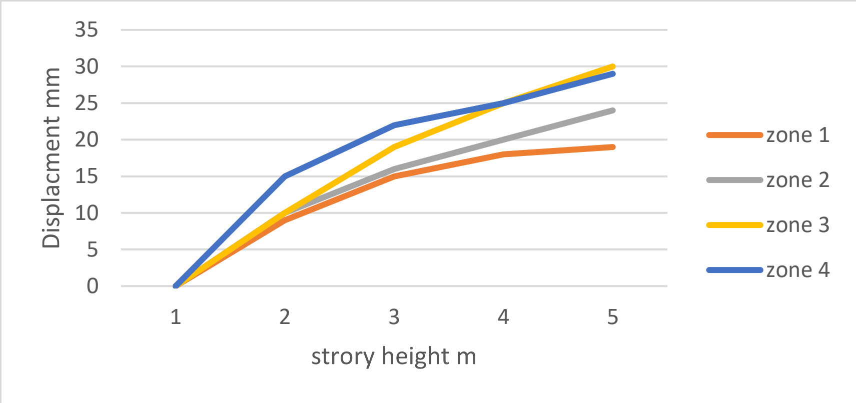
It is worth noting that the displacement values at this stage (case-3) compared to the first and second cases, it was found that the displacement values are less than what is found in the first case, but therewith higher than amounts of displacement in the second case (case-2). As an example, 24.4 mm recorded as the topmost displacement in zone 4 for (case- 2), which is less than the displacement in (case -3) by half. The response of building structure was SDOF just similar to (case-1) and (case-2). By noticing Figure (3-c), it was found there is no considerable increase in displacements paired with increasing in forces starting from the zone 2A to zone 2B



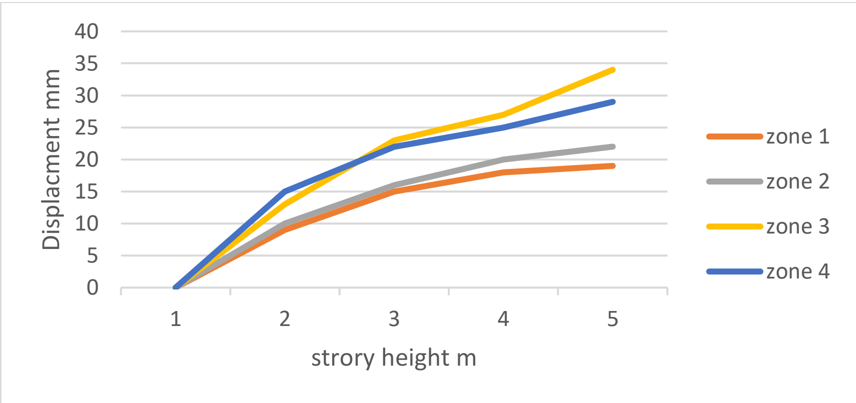
(3-a) case one.



(3-b) case two.



(3-c) case three.



(3-d) case four

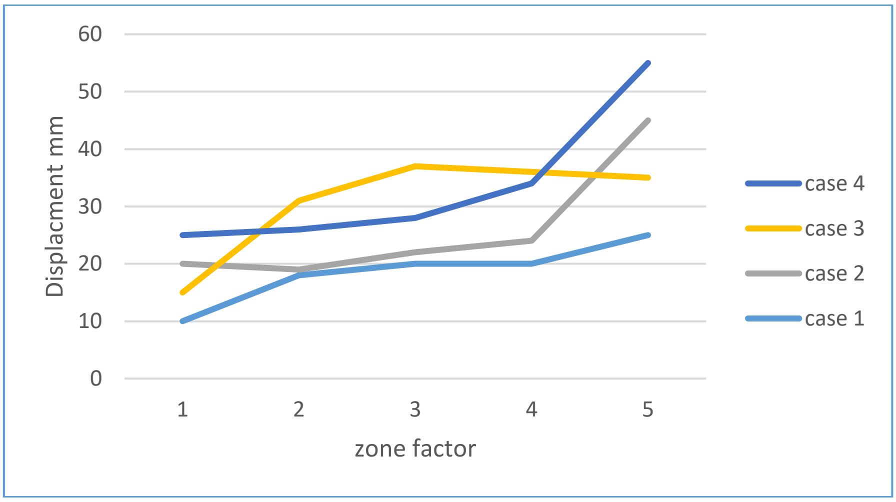
Figure 7. Displacement distributions of diverse structure models under different earthquake zones.

Figure (3- d) illustrate the profile of displacement when the effect of two shear walls was taken by placing them in two places at the two adverse corners of the buildings as clear in Figure (1-d) as mentioned in (case -4). Diverse behavior was seen as the force of zone-3 showed greater displacement than the force of zone -4 till the height of the story was 18.0 m. Furthermore, displacement is proportionate to the forces of the earthquake. In zone 1, 2, 3 and 4 correspondingly, the highest displacement amounts for zones respectively recorded were (14.9, 25.7, 40.3 and 44.8) mm.

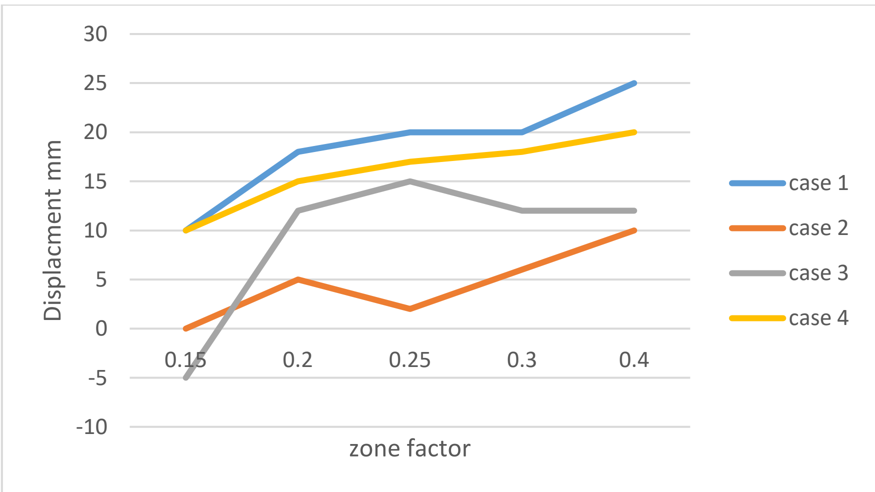
Regarding the difference in displacements, it has also been noted that zone-3 and zone-4 displacements were significantly least than the difference between cases one and two.

For every case, the side sway at A corner compared in the two directions (X) and (Y) shown in the relevant Figures (4-a) & (4-b) sequentially. By studying Figures (4-a) and (4-2), it is possible to observe the recorded ultimate displacement for each case under various zones the forces of earthquake operating in the directions of X and Y. The highest values attained at point A are these depicted displacements for the building when it is exposed to earthquake forces in a certain zone factor. It is clearly visible and as in Figure (4-a), for each utilized

zone factors the highest value of displacement was recorded in the first case (case-1). Moreover, for the (case-1) at zone factor 4, the greatest displacement of 71.9 mm was detected. When the (SW) were situated towards the structure gravitational center as in second case. However, the displacement was determined to be the smallest. At zone-4, the greatest displacement of 29.5 mm was discovered once more. However, this number was substantially lower than (case-1) comparable value. Comparing the structural response of (case-3) with cases (1 and 4), the results showed that (case-3) recorded a preferable structural response comparing with both cases 1 and 4 respectively but not as good as second case. 56.4 mm was the utmost displacement of case three was bigger than (case-4) at zone factor 0.4. Just for zones 1 and 4, the displacement response was leading for (case-4) as compared with (case-3). However, in zone3, there was much more displacement than every case. It might be because of torsional forces erupted owing to the eccentricities of stiffness and the building's mass center.
The spectrum response of RC building models subjected to the earthquake forces in Y-direction (EQY) is shown in Figure (4-b). Building models responded in general similarly to that of the EQX. When there are no shear walls, and as mentioned in the first case (case-1), the displacement values are the highest at all, but at the same time, these displacements are higher than their corresponding values in the EQX direction. In the same way as EQX, (case-2) showed the greatest performance between all EQX directions with displacement levels substantially below (case-1).



a



b

Figure 8. RC buildings Spectral displacements under diverse factors of the earthquake zone. (a) EQX response spectral; (b) EQY response spectral.

What can be observed, in the third case, the applied earthquake forces in the Y direction as the displaced values are comparable to (case-1), a substantial improvement in the structural behavior was not seen. As mentioned in (case-4) (where the effect of two shear walls was taken by placing them in two places at the two adverse corners of the buildings) relatively utmost response recorded especially at zones one and four as illustrated in Figure (4-b). The construction shows minimum distortion in X and Y direction in all four options when shear walls are supplied in the center of the structure. The displacement of (case-2) (in the direction Y) was more worthy than (X direction). While Case 3 demonstrated higher displacement, overall stability was enhanced and defection at every corner was uniform (case-1) had pretty excellent outcomes, was an economical choice, and had minimal deflections. The conclusion was that the positioning of shear walls in the center as mentioned in (case-1) is the utmost suited considered as a suitable one in design as it improves immutability at every corner in building and, it functions as a structural backbone.

Bending Moments of columns at ground floor level were high in the case of buildings without shear walls in both directions i.e., in x and y directions in both directions were reduced at each floor level by using shear walls for a building from 0 to 99 percent depending on the floor height and gets reduced from ground floor to 18th floor and then increased for terrace floor i.e. for 19th floor in both directions for buildings without shear walls which are away from s. which are away from shear walls is reduced from 0 to 77.77 percent in the Y – Direction for the case of building with shear walls, from 0 to 90.37 percent in the X – Direction for the case of building with shear walls, and from 0 to 99.01 percent in the Y – Direction for the case of building with shear walls.

When shear walls were applied, natural frequencies were increased from 21.15 percent for the first mode to 79.85 percent for the ninth mode, then decreased to 31.53 percent for the 15th mode. Up to the 15th mode, the corresponding time durations grew and then declined. Lateral forces were increased from 0 to 41% in the direction where shear walls were built and decreased from 18 to 55% in the opposite direction, i.e., the Y direction, which was comparable to the construction without shear walls. In buildings without shear walls, lateral forces were raised from the ground to the sixth storey, then lowered until the thirteenth floor, then increased again until the nineteenth floor in the X direction. In the direction of Y, these pressures were increased from the ground to the fourth floor, then decreased to the eighth story, then increased to the eleventh floor, then lowered to the fifteenth floor, and finally increased to the nineteenth floor.

Shear walls are used in buildings having shear walls. In the X direction, lateral forces were raised from the ground to the 6th floor, then lowered until the 15th floor, then increased again until the 19th floor. These forces were increased in the Y direction from the ground to the 6th floor, then decreased up to the 10th floor, then increased up to the 12th floor, then decreased up to the 15th floor, then increased up to the 19th floor.

The Plot From the ground to the 19th level, drifts were reduced by 0 to 77 percent in the X direction, 0 to 68 percent in the Y direction, and 0 to 75.5 percent in the Z direction. By employing shear walls for the building, maximum torsional moments of each level along the axis of the vertical members were lowered from 0 to 60%. When shear walls are given for the lift cores and corners of the building, internal stresses are decreased from 79.81 MPa to 72.2 MPa, resulting in a reduction of internal stresses from 79.81 MPa to 72.2 MPa. During an earthquake, displacements in the X direction are lowered from 49 mm to 44.74 mm, and displacements in the Y direction are reduced from 276.5 mm to 275.1 mm. Wind load displacements are reduced in the X direction from 19.2 mm to 14.84 mm, and in the Y direction from 315.3 mm to 266.6 mm.

6. Conclusion

The conclusion of this study summarized in points below:

1. Maximum displacement was decreased to minimum when (SW) positioned nearest the building's geometrical center.
2. When shear walls positioned in opposing corners, the maximum displacement was less than that when shear walls located at building edges.
3. It can be concluded that, the best performance of seismically loaded structure can be achieved when located the shear walls close to the structure's geometric core.
4. The bending moments of columns at ground floor were reduced in the case of building with shear walls, the minimum values of bending moments were attained in case of the building with shear walls near geometric center of the building.
5. As the center of the structure's stiffness varies and the eccentricity rises from the mass center, the torsional influence can result and despite the existence of shear walls does not have an impact or even a reverse effect on building performance.
6. Furthermore, the structural response was linear in all situations up to the small ranges of displacement while the structural responses were not linear in the case of larger earthquake forces.
7. The lateral forces at columns ends were reduced in case of constructed the shear walls; it is minimum in case of the shear wall located at the geometric center of the building.
8. The torsional moments were decreased along the axis of vertical members due to using shear walls.

9. In case of wind load, the maximum displacement, bending moment, horizontal forces and torsional moments were reduced due to using shear walls in the structure.
10. Presence of shear walls had a lower influence by Placing it on obverse building corners.
11. In all cases of shear walls positions, as an (SDOF) oscillation mechanism, the building has vibrated.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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