

Research Article

Influence of Plan Geometry on the Seismic Response of Reinforced Concrete Buildings

Shahzad Ali ^{1*} , Fahad Shahid Khawaja ², Muhammad Saad Duraiz ¹, Ali Sadeghpour ¹ ¹ Department of Civil Engineering, Engineering Faculty, European University of Lefke, Lefke, Northern Cyprus, TR-10 Mersin, Türkiye² Department of Civil Engineering, University of Engineering and Technology, Taxila, Pakistan

Keywords

Story displacement,
Seismic analysis,
Structural Configuration,
Seismic Performance.

Abstract

To assure seismic safety of strengthened concrete structures, it is necessary to know the effect of building structure on dynamic response. This paper is a detailed assessment of the four building shapes of G + 9 buildings, namely, H shaped, Box shaped, Round, and Hollow, at seismic. ETABS was analyzed in terms of structural models and designs based on ACI 318 and ASCE 7-16 requirements. The complete comparative analysis was done to examine story displacement, story torsion, story bending moments, story axial force, modal properties, mass participation, and ratio of inter-story drifts during seismic loadings. The H-shaped layout and Hollow one had always portrayed better seismic performance by incorporating less lateral movement, less torsion, less bending moments and less axial loads in all storeys. The modal analysis also showed that H-shaped set up has the lowest natural periods and the highest mode frequencies which imply that it is stiffer and capable of enduring earthquakes better. Modal inter-story drift ratios were also within ASCE, and the lowest inter- Story drifts were on the H and Hollow layouts. In general, both the dynamic and the static analysis are involved in the course of the study. The results prove that structural symmetry and distributed stiffness contribute significantly to seismic resilience, and H-shaped configuration has been proved to be the most resistant and efficient in granting the stability of multi-story buildings in the areas with seismic activities.

1. Introduction

Stability and durability of the building are in this modern structural engineering in most areas where earthquakes are the norm [1-2]. Engineers use modeling and analysis tools based on computers to design structures that can meet the forces. The use of ETABS is a comprehensive software type of tool that eases the structure analysis of a complicated building design. ETABS has been demonstrated to predict with great accuracy story displacement [6], bending moments, and base reactions, all of which are critical parameters in designing seismic resistant structures [7] by replicating actual loading conditions [3-5]. The seismic performance of buildings of four structural shapes, i.e., H, Box, Round [8], and Hollow shapes are discussed in this

work. The configurations are all modeled at three, six and nine storeys [9] and the impact of height and geometry on seismic performance assessed. The current study will use the American standards (ASCE 7 [10] and ACI 318) of seismic loading and concrete design, respectively, unlike the prior studies that utilized Indian standards to make the study conform to the international building codes. The investigation area will be examining and comparing seismic performance of various structural forms during earthquake loading. Through observation of the important parameters of response, namely story displacement, peak bending moment and base reaction, this study will determine the structure that provides stability and less seismic vulnerability. The findings of this paper are also meant to assist structural designers and engineers to make informed decisions with

* Corresponding Author: Shahzad Ali

E-mail address: engr.shahzad.ali.awan@gmail.com, ORCID: <https://orcid.org/0009-0002-1887-7399>

Received: 27 October 2025; Revised: 26 December 2025; Accepted: 05 February 2026

<https://doi.org/10.82042/jba.3.2276>

Academic Editor: **Bahar Sultan Qurraie**

Please cite this article as: S. Ali, F. Shahid Khawaja, M. Duraiz, A. Sadeghpour, Influence of Plan Geometry on the Seismic Response of Reinforced Concrete Buildings, Journal of Buildings and Architecture 3 (2026) 1–9, Article ID: 2276.

reference to the most appropriate building forms in areas that experience earthquakes [11-14].

2. Loading Consideration

In structural seismic analysis, the real modeling of applied loads is required to facilitate dependable modeling and analysis in terms of performance. The loading conditions that have been taken into consideration in this work are dictated by the standard practices and the American standards, specifically, ASCE 7-16, according to which the seismic design provisions of the building in the United States are regulated. 2.1. Assumed Loads On the building models, it was exposed to both vertical and lateral loads that were common in office building [15-18]. The assumptions on loads applied were as follows:

- Dead Load (DL): The self-weight of structural components was automatically computed by ETABS based on material properties and cross-sectional dimensions.
- Super Dead Load (SDL): An additional static load of 1.5 kN/m² was assigned to represent non-structural elements such as floor finishes and partitions.
- Live Load (LL): A live load of 2.5 kN/m² was applied to all floor levels to account for variable occupancy and usage, in accordance with standard office loading criteria.
- Wall Cladding Load (DL - Walls): An external wall load of 0.785 kN/m² was applied to simulate the weight of facade materials and cladding elements. These loads collectively represent the real-world conditions expected during both static and dynamic performance evaluations of the buildings.

2.1. Assumptions and Design Parameters

Construction: The construction of the buildings is all reinforced concrete G+9.

Column Design: Strength 28MPa of concrete used in different sizes of columns of 450 mm x 450 mm.

Beam Design: Concrete strength of 28MPa and 300 mm x 450 mm.

Slab Design: Strength 21MPa of concrete and 160 mm of thickness.

Grid Layout: Use of 3 × 3 grid with a 7 m space between grids.

Story Height: The average story precipitate is 3.2 m.

Structural Codes: All models will be designed as per ACI 318 and analyzed as per seismic provisions of ASCE 7-16.

Material Assumptions Concrete and steel are the assumed material where it is assumed to be homogeneous and isotropic; damping is assumed as per code.

Predominant Foundation Assumption: It is assumed that buildings are constructed on rigid foundations; there is no interaction of soil and structure. It involves the site has Type D (stiff) soil and this means that no soil enhancement or deep foundation is needed.

Grid Layout: Use of 3 × 3 grid with a 7 m space between grids.

Story Height: The average story precipitate is 3.2 m.

Structural Codes: All models will be designed as per ACI 318 and analyzed as per seismic provisions of ASCE 7-16.

Material Assumptions Concrete and steel are the assumed material where it is assumed to be homogeneous and isotropic; damping is assumed as per code.

Predominant Foundation Assumption: It is assumed that buildings are constructed on rigid foundations; there is no interaction of soil and structure. It involves the site has Type D (stiff) soil and this means that no soil enhancement or deep foundation is needed.

2.2. Earthquake Risk Conditions

The seismic loading and design conditions were defined based on a moderate seismic risk environment, with specific parameters reflecting local geological and structural safety requirements:

Seismic Zone: The examination had been carried out based on Zoning 2, which is a moderate seismic hazard as stipulated by ASCE 7-16.

Fault Condition: This was a strike-slip type of fault; the most common source of horizontal ground motion which was presumed to model realistic events of seismic motion.

Construction Use: The building is categorized as an office building, which presupposes the moderate significance and frequent use.

Earthquake Equilibrium Code: ASCE 7-16 was used as the design and determining standard of the earthquake loads.

Soil Classification: The soil Type D (stiff soil) was used, which was in line with the usual urban layout and its effect on site-specific seismic response [19-20].

Factor of Response Modification F(R): R 5 was taken into account to indicate the ductility and the shielding power of the structural system and the design seismic force decreases.

These considerations make sure both the simulated loading conditions are realistic and meet the code-compliant criteria and seismic performance can be usefully evaluated with different structural configurations [21-22].

3. Structural Configurations Considered in the Study

The systematic steps of modeling the structure were carried out in order to help in achieving accuracy and reliability. The first stage was to develop the grid system and find story levels to outline the structural framework. The properties of material were then introduced, with cross sectional dimensions of all structural elements being detailed. The members were placed as per the layout that was provided. Regularity and mixes of loads were utilized such as dead loads in the beams and slabs. The support conditions were simulated in order to mimic real-world boundary constraints. Lastly, the model was then vindicated and consistency tests were then done before engaging in the structural analysis in order to determine the integrity and adequacy of the results [20-26].

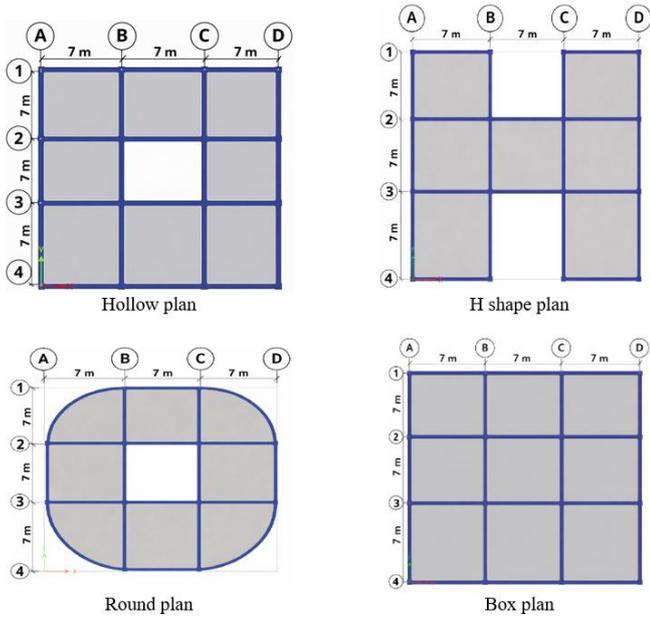


Figure 1. Plans of Hollow, H, Round and Box

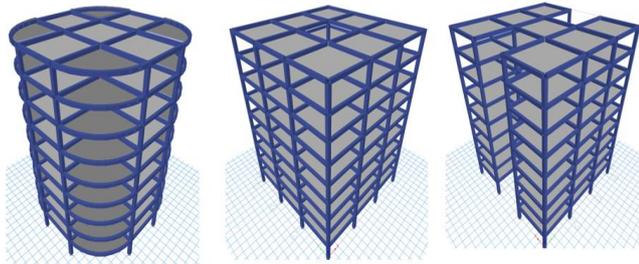


Figure 2. Altitude of Buildings

4. Performance Assessment of Structural Shapes Under Lateral Loads

It was noted that structures of a round form had the largest values of displacement and 82.80 mm in 9-story setup. The next type was box-shaped buildings and the maximum displacement became 75.33 mm. By comparison, the H shaped structures and hollow-shaped structures performed better with maximum displacements of 73.79 mm and 72.48 mm respectively at nine storeys. Displacement values increased with the increase in storeys with all structural forms. This growth was however more regulated in H-shaped and hollow-shaped structures. The round shape registered the highest displacement of 32.54 mm at the level of three stories and the lowest displacement rate of 28.42 mm at the H-shape. The increased displacement at the round forms is due to the lower rigidity and increased tendency to be moved laterally which contributes to about 26% of the total displacement on the X-direction. Conversely, the structures of both shapes, H-shaped and hollow-shaped gave an improved displacement control. The H shape is used on a wide area site as it is stable and the hollow shape supports good lateral performance to the round or box shaped as a compromise where there are a tight design and much better performance on the lateral performance.

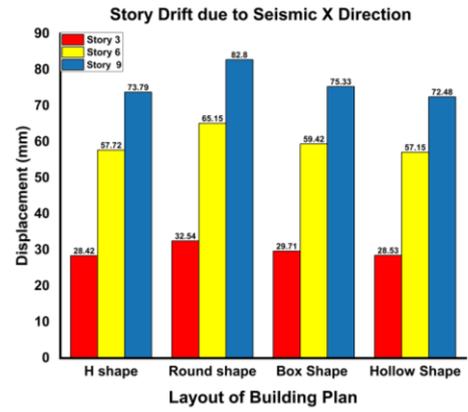


Figure 3. Graph of story Displacement in different shapes and storeys

Each structural shape and number of floors will have story displacement values in X and Y direction (Fig. 3 and Fig. 4). The most displacement was observed in the round-shaped structure to be 82.79 mm in the 9-story set-up. The next was box shaped model, which registered a displacement of 75.33 mm lower values were registered in the case of H-shape and hollow shaped buildings. On the round shape, the difference in displacement was 32.53 mm because it was on the 3-story elevation and on H-shaped, it was lowest at 27.17 mm. With the increase in storeys, post displacement values increased with the form of all structures. Nevertheless, the H-shaped model had a more moderate rate of increment which means that there was better regulation of the lateral movement. It can be expected that the larger displacement of round structures is due to their geometry of curvature, which offers less of the stiffness to lateral loading. Contrastingly, the H-shaped and hollow-shaped designs were more resistant to lateral forces, which resulted in low displacement values, especially in taller designs. The H-shape is regarded as the most appropriate one where the space is available in the location because it is highly resistant to the lateral forces, as well as, it is structurally stable. The hollow shape is also useful as an alternative in scenarios where space is limited, the footprint is small, and it provides a better means of displacement control as compared to round or box-like designs.

5. Structural Response Analysis: Torsion, Bending, and Axial Forces

The torsional effects were observed to be the greatest concerning the round structures especially in the three story and nine-story models. The maximum torsional contribution was realized in the round structure and it was 28 percent in three story model and it reduced to 26 percent in nine storey structure (Table 1). Box, H-shaped and hollow structures, on the contrary, reported lower and improved consistent torsion percentages and were between 23 and 25 percent at all the heights.

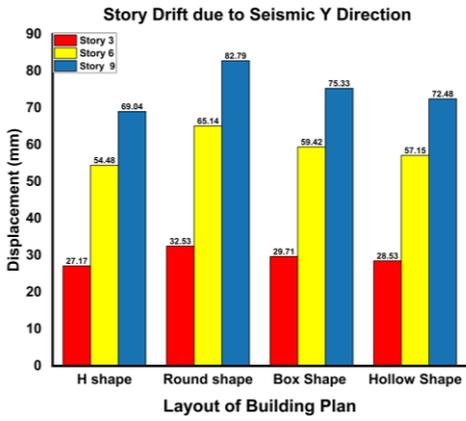


Figure 4. Graph of story Displacement in Y-direction of different shapes and storeys

Table 1. Structural Response Analysis for Torsion

No of Storeys	3- Story	6- Story	9- Story
H shape	0.58	7.42	14.71
Round shape	1.56	6.52	14.73
Box Shape	0.52	8.28	15.18
Hollow Shape	0.67	7.73	14.31

Table 2. Structural Response Analysis for Bending Moments

No of Storeys	3- Story	6- Story	9- Story
H shape	58.22	46.39	27.29
Round shape	74.3	65.38	59.65
Box Shape	71.23	63.35	60.24
Hollow Shape	56.91	45.65	29.97

Table 3. Structural Response Analysis for Axial Forces

No of Storeys	3- Story	6- Story	9- Story
H shape	2363.57	1329.14	330.61
Round shape	2858.66	1615.73	411.9
Box Shape	2903.66	1644.43	419.84
Hollow Shape	2380.2	1342.97	338.75

Round-shaped buildings had the largest torsional values in absolute terms with the torsion of three-story building being at 1.56 kNm and nine-story building being at 14.73 kNm. The box shape recorded a top torsional value of 8.28 kNm at six storey level however recorded a more uniform distribution as one goes through various levels. The hollow and H-shaped designs gave lowest torsion (Fig. 5) at the high rise; the hollow structure had a torsion of 14.31 kN·m and the H-shape yielding the lowest torsion of 0.58 kN·m in three storeys of the models. These results are caused by the geometrical nature of every shape. Round shaped buildings, which are not cornered and are continuously curved, are more likely to focus torsional stresses as the height of the building increases. H shaped and hollow shapes, on the other hand, provide a stronger disturbance towards torsional flow as well as an equal distribution of lateral forces and, as a result, a consistently lower torsion value particularly in mid- to high-rise designs. The structures which showed the largest values of bending moment were round-shaped as demonstrated in Fig. 6 especially in the 3rd and 6th storeys.

The round design was found to contribute 29 and 30 percent to the overall bending moment of the three-story and six-story buildings, respectively, which is significantly greater than the hollow (22, 21) and H-designs (22, 21) (Table 2). Bending moments in the round and box shape also exhibited 34 percent bending in nine-story buildings due to the high seismic scope at higher levels. Conversely, hollow and H-shaped structures were much lower with 15% and 17% respectively implying a 17 to 19 percent decrease on round and box shapes. This implies that hollow shapes and H are the most advantageous in reducing the bending moments due to lateral loads as can be observed in tall buildings.

Analysis of axial forces (Fig. 7) indicated that columns fitted in box-type layout experienced the largest axial loading of 28% then closely round-shaped structures of 27% (Table 3). Compared to it, columns of H-shaped and hollow-shaped forms had their axial forces being 5 to 6 percent lower at all the stories (3, 6 and 9). Although each material and cross sectional had identical properties, the H-shape structure had better performance at under service loads, that is, a 6-percentage decrease in axial loads when compared with box and round structures.

- Hollow Shape: Exhibited 5%–6% lower axial forces than box and round shapes across all story levels.
- Hollow Shape: Exhibited 5%–6% lower axial forces than box and round shapes across all story levels.
- H Shape: Showed a consistent 6% reduction in axial force at all heights.

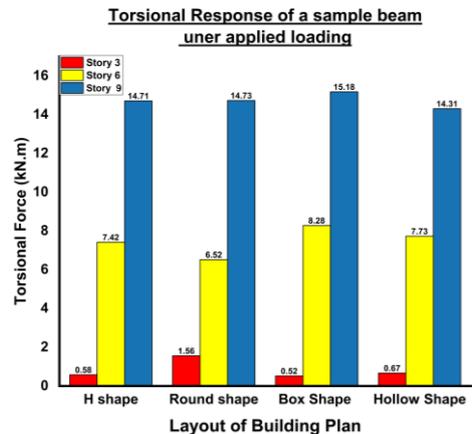


Figure 5. Graph of Torsion in different shapes and storeys

These findings reinforce the structural efficiency of H and hollow shapes, both of which offer improved performance in controlling torsion, bending moments, and axial forces—making them ideal for mid- to high-rise construction under seismic and service load conditions.

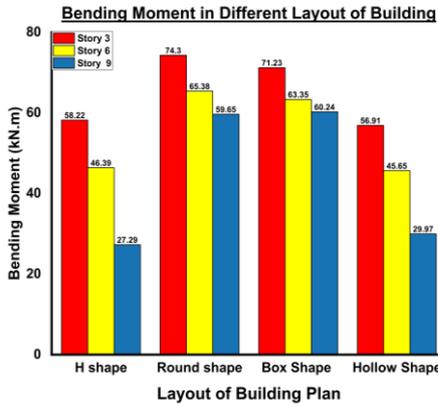


Figure 6. Bending Moment in different shapes and storeys

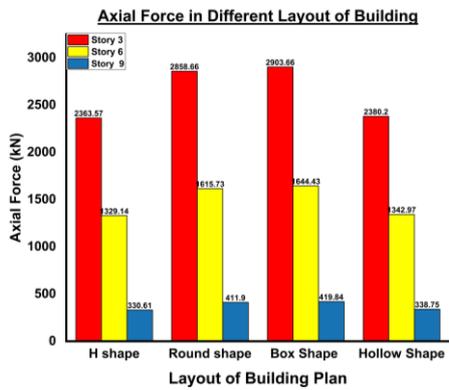


Figure 7. Graph of Axial Force in different shapes and storeys

6. Dynamic Seismic Analysis Results and Discussion

6.1. Modal period and Modal Frequency

The natural modal time period and modal frequency are critical parameters in dynamic analysis as it reflects the flexibility and stiffness of a structure. The time period of the mode or modal time period (Fig. 8) is the time in which a structure attains one cycle of natural vibration. It is measured in seconds (s). The number of vibrations cycles that the structure makes within 1s is the modal frequency (Fig. 9), which is measured in Hertz (Hz). The longer period means that the building is more flexible, and it has slower reaction to seismic excitation, which is likely to produce greater displacements. The smaller the time period, the stiffer the structure and it will withstand deformation better during an earthquake.

In the event of an earthquake, the H-shaped building is actually safer to use in such locales where there is a high seismic activity since the building is more stiff making it resist swaying thus giving more stability and hence protecting the House and the occupants themselves. Under the first vibration mode, the H-shaped building takes 1.616 seconds to complete one cycle but the round building requires 1.790 seconds to complete a cycle because it is more flexible than the H-shaped building. The peak modal frequency of H shape is 6 Hz, and the frequency of round shape is 5.144 Hz- H-shape is more resistance to impact of earthquakes in different mode. Despite the fact that certain flexibility assists in being able to absorb the seismic energy,

there exists a possibility of large displacing the displacing and the inter-story drift due to the over flexibility and this increases the chances that the damage will occur. The H-shaped building has the lowest records and highest frequencies hence it is the most stable and reliable structure in seismic safety.

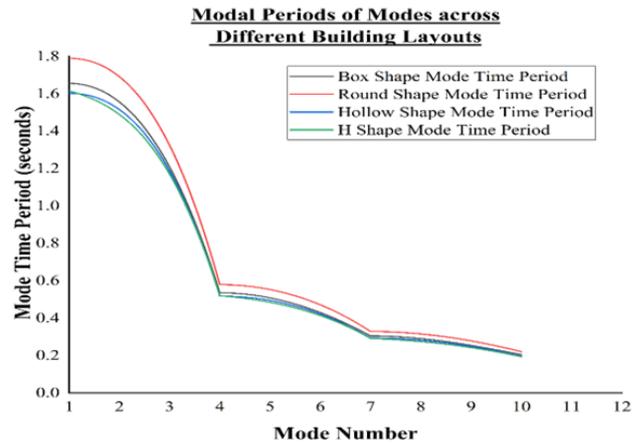


Figure 8. Modal Periods of modes across different building layouts

6.2. Comparative Model analysis of building layouts under seismic loadings under UX and UY directions

The H-shaped arrangement of buildings is quite effective earthquake-resistant because it provides a great deal of strength in security aspect both side-sided (UX) and front-back (UY) methods. The H-shape in its main vibrations utilizes a substantial share of its mass, which is much more effective than the Box shape and almost equals the Round and Hollow layouts. It is important because such a balance of power implies that the H-shape will be able to withstand the earthquake forces in a balanced manner and significantly decrease the possibility of dangerous twisting, or torsional burst that is of great concern during unpredictable seismic processes that result into disastrous impacts. It is stable but flexible in nature to support materials and therefore it is suitable. Unsurprisingly, most architects and engineers are giving preference to the H-shape in these areas.

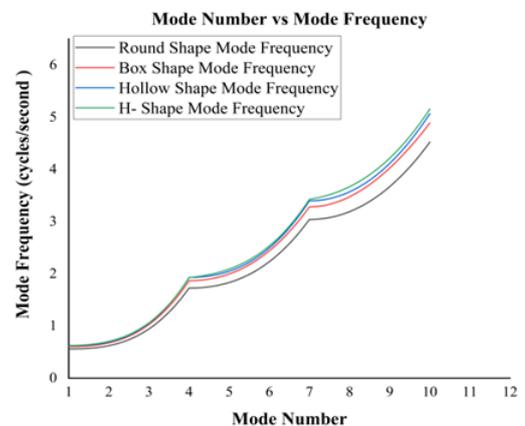


Figure 9. Mode Numbers vs Mode Frequency

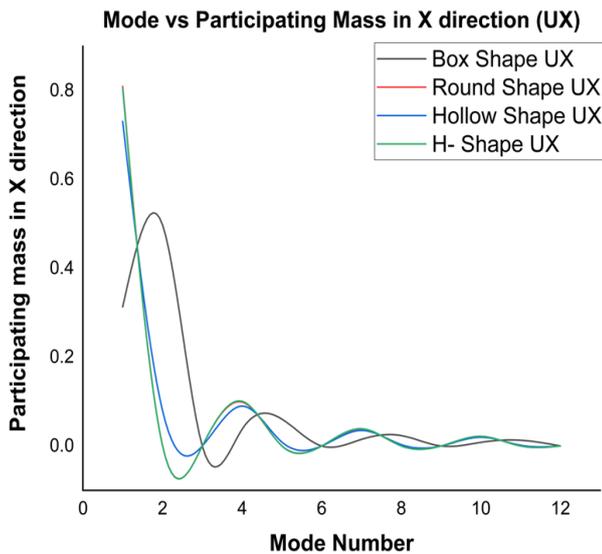


Figure 10. Mode vs Participating Mass in X direction

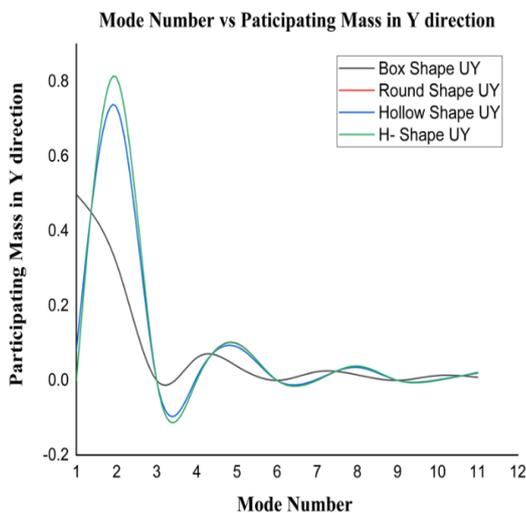


Figure 11. Mode vs Participating Mass in Y direction

In addition to high primary performance, the H-shape is intelligent, in that it redistributes seismic energy between higher vibration modes (such as 4, 5, 7 and 10) which fundamentally represents a natural damping system, and ensures that the structure does not experience high levels of stress. In UX Mode 2 and UY Mode 1, i.e., where the participation is low at 0.0795, whereas Box shape, which has much related difficulty at 0.498, demonstrates its relative lack of stability. This is due to the fact that the H-shaped building is advisable in earthquake prone locations since the building provides swift and measured reaction to the seismic forces. The H-shape is effective in the main directions of its movement, such as side-to-side (UX Mode 1) and front-to back (UY Mode 2) movements, with the necessary participation ratio of 0.731. This greatly compares to the Box-shaped building that has ratio of participation of 0.3132. Although there are other more shapes where the numbers on the key movements are slightly higher, the H-shape does not

invest all its strength in one of the areas, thus avoids being overly stressed. More importantly in higher levels of vibrating modes, such as UX Mode 2 or UY Mode 1; the H-shape participation (0.0795) is significantly lower than the Box shape (0.498) which means that it will be much more stable and will reduce unwanted vibrating motion (Fig. 10 and Fig. 11). H-shape has a uniform performance as compared to the uneven performance of the Round and Hollow layouts. It is a very good alternative to earthquake-resisting structures as it can effectively disperse seismic energy and react similarly in all directions retaliating torsional load and offering buoyancy to the structure.

6.3. Cumulative mass participation across modes in X and Y direction

A building does not act like a solid and inflexible object when an earthquake strikes. Rather, various sections will move in a different manner upon the passage of seismic waves across the structure. These are modes of movement which are known as vibration modes and each of them impacts a different part of the building mass. The cumulative mass is a measure of the proportion of the structure that was actually involved in the processes. The given measurement tells the ratio of the overall mass of the building, which shakes in a large number of modes, and it is an essential measure of the overall dynamic performance of the structure. Looking at each of the modes separately, we can sum up the mass actively vibrating with the shaking. This is an indication of the extent to which the building is realistically impacted in terms of all the modes combined. It gives us the proportion of the mass of the building (in what way) in each of those vibration modes when the ground shakes. This is one of the measures that make the engineers aware of what portions of the structure are dynamically active or in other words how much of the building is moving when the seismic energy is passing through it.

Upon closer examination of the way this works out in the Y-direction, the pattern of response becomes quite different of that observed in the X-direction. Among the four structural forms that this paper gives consideration to, that is, Box, H, Hollow and Round, the Box is the one that displayed the most initial activity. It becomes active close to 50 percent of its total mass with the first mode implying that it is most sensitive to the movement in the side-to-side direction of the building. The H-shaped arrangement might not result in a spike in the response in both directions, but the advantage of the shape is that it accumulates the participation of modal mass gradually. The H-shape is more responsive on both axes as opposed to shapes, which react sharply in a single direction. It has geometry that promotes the homogenization of stiffness and energy that minimize localized degradation and is likely to prolong the life of the building. This not only makes it sound structurally but also a strategically wise choice as far as safety and efficiency are concerned.

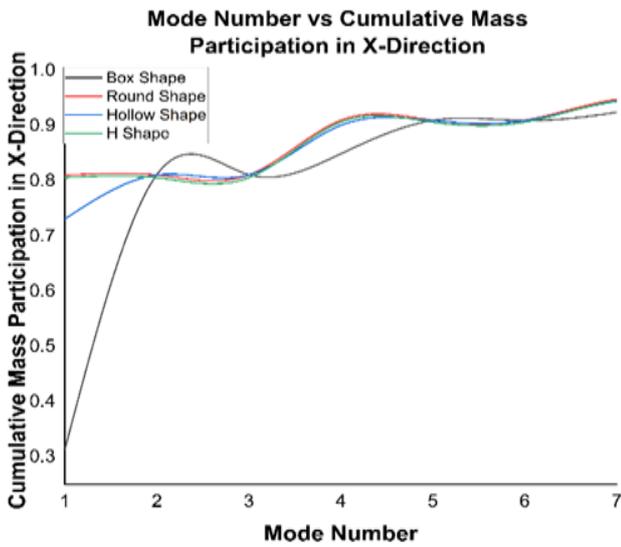


Figure 12. Mode vs Cumulative Mass Participation in X-Direction

Due to such responsiveness, it may be possible to optimize reinforcement, ending up with them in the lateral frames rather than overdesigning the whole building. This does not only save on material, but also creates a matter of improved design efficiency without interfering with the level of safety. Conversely, Box-shaped type is slower to react on the X-direction yet it is very effective when the shaking is along the side (Fig. 12). Its more Y-directional action is what makes it a rather intelligent option in the tightly-layered urban environment, where the buildings are closely located and reducing the lateral sway is a must. It has a natural resistance to transverse forces due to its shape and may minimize the risk of pounding between the building and the other buildings around it. It could be explained by rather compact and symmetrical shape which provides increased resistance to movement at the transverse direction.

On the contrary, the H-shaped and Round structures are not very responsive to the first Y-mode. They are of very low cumulative participation (Fig. 13), nearly negligible. The Hollow shape is a little better, with the bottom rating of about 7.95, although it is still lower than Box layout. And with this said, this difference does not last very long. Once in the fifth layout of vibration, all the four layouts have already caught up. Both of them both rises above 90% cumulative participation in the Y-direction and indicate that higher modes start to dynamically bear the load. Whereas certain structural layouts take time to vibrate within the first few vibration modes, it picks up gradually as the frequency is increased. This steady rise in It is proven by the participation that the designs with a low initial response can play an important role when more vibration modes are activated.

Through this strategy, engineers are able to do away with such unnecessary complexities in their structures as well as concentrating on key issues in the seismic performance of a structure. In the seismic design ASCE 7-16 recommends that lower modes should bring into consideration at least 90% of the entire mass; the graphs indicate that the mass is concentrated in the first seven modes. By paying attention to these crucial modes, engineers can design and attain structural safety.

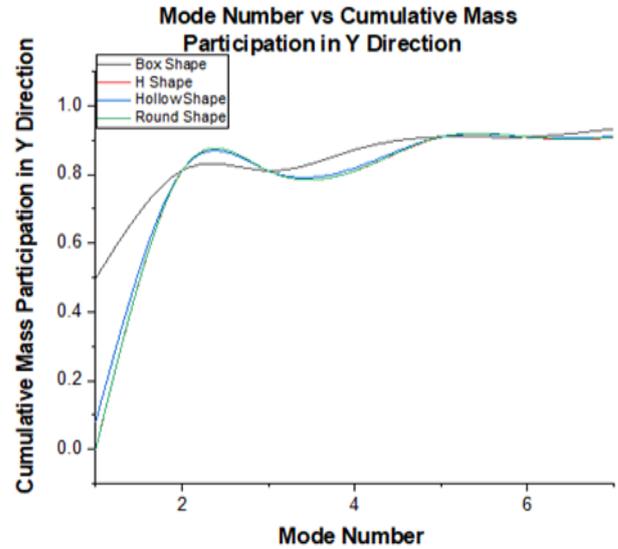


Figure 13. Mode Number vs Cumulative Mass participation in Y direction

6.4. Comparison of Inter-Story Drift Ratios and Story Drifts Across Structural Layouts

One of the important elements that consider how good a building can be in resisting lateral forces is referred to as inter-story drift, which implies the movement between two consecutive floors as a result of an earthquake. ASCE 7-16 establishes a maximum limit of the drift ratio at 2 percent in relation to the office buildings that belong to the risk category II. In this work, the majority of the buildings, either H, Box, Hollow or Round shaped, with 3,6 or 9 storeys- were under this final range of acceptable, even below 0.1% which represented low chances of non- structural damages and high strength against seismic effects.

Nevertheless, the high drift in the round shape can be associated to its circular shape, with no sharp corners and prone to less torsional rigidity. Angular shapes such as the H and hollow forms on the other hand are stiffer by nature and more advantageous in withstanding side-to-side movements. This can be explained as previous analysis outcomes had already indicated that the round structure had more torsional effects and bending moments. This round design was free across all levels, especially those below but the H and hollow configurations were always used with lower drift values as one went up.

Having considered real displacements in millimeters, the round-shaped building again gave the highest values. In the ninth story, its launching was approximately 6.5 mm which was far much higher than those in the rest of the configurations. These findings verify that the round form permits higher lateral sway when an earthquake occurs as opposed to the H and hollow forms which limit it to a lesser extent.

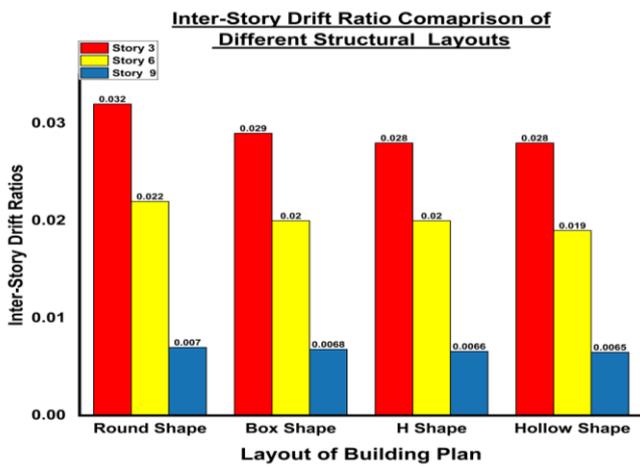


Figure 14. Graph of Inter story drift ratio

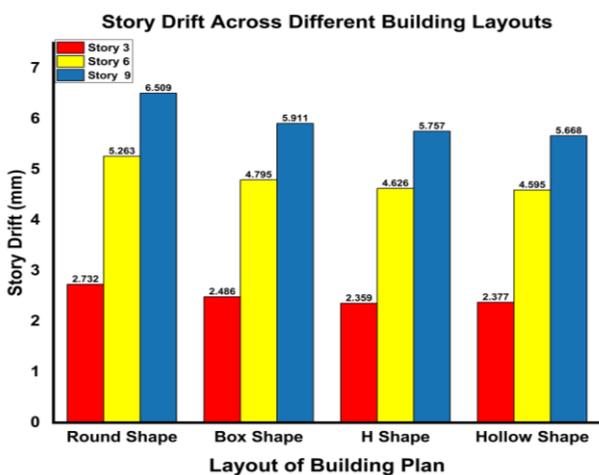


Figure 15. Graph of story drift ratio

As the linear models do not account for the energy absorption or deformation in the materials, the results can overestimate the geometrical movement in the structure particularly the round shape which is irregular. Besides that, ASCE 7-16 proposes nonlinear analysis in irregularly shaped structures. The building can be said to be safe generally but some specific design enhancements in future could be done to minimize the drift should there be a need. The lateral resistance of the building may be augmented which may include diagonal bracing or slightly broadening the columns on the 3rd floor or lead Rubber Bearings (LRB). These modifications could be done without making significant alterations to the architectural disposition of the building. More complex tools of analysis like the pushover or time-history simulation tool should be utilized in future research since it may be necessary to determine whether the localized exceedance of drift warrants design modifications. Nonlinear methods that enable engineers to observe the reaction of a structure as the material commences to break enable a far more realistic view of the behavior of a structure in the real occurrences of an earthquake. Round buildings are aesthetically pleasing but with the flexibility of design, they tend to move on a lateral angle especially on low rise. The article notes that architectural designs may increase the level of safety against earthquakes with the help of strong and

geometrically balanced shapes such as h and hollow ones without undermining the purpose of the architecture.

7. Conclusion

Symmetry-free structures tend to be more susceptible and not resistant to earthquakes. We have talked about symmetrical layouts in this research and in the end, we were able to locate an earthquake efficient layout. In conclusion of the analysis made we come to the following conclusion:

- One of the causes of seismic failure is torsional irregularity. The torsional value of round shape buildings has been had to be greater due to their continuous geometry in comparison to the H-shape layout due to low torsional value. Also, the H-shape better distributes forces of seismic nature that ultimately reduces the forces of twisting or torsion and enhances seismic stability.
- The structure exhibiting less bending moment, and axial force is thought of as more efficient structure, which will be able to withstand the seismic loads. The H-shape has minuscule bending moments and forces of axial compared to other layouts. The H-shape design had reduced bending and axial stress.
- Building height also showed drift where H-shaped and hollow buildings showed the lowest values in both horizontal and vertical directions, which means more security of occupants and adherence to the code.
- Harder structures possess bigger frequency and short period. The H-shaped buildings react fast to earthquake and are very rigid. The H-shape layout also showed peak modal frequencies which showed that those structures were more rigid and tolerant to earthquakes than the round, flexible buildings.
- In earthquakes, box-shaped edifices are quickly adopted with energy on the initial few vibration modes and therefore presents a lot of pressure to certain locations of the building and can easily cause a failure. In comparison, the modal distribution of energy in H-shaped buildings is much more even, and therefore, change the forces concentration on the weaker part is minimal, and the structural efficiency of H-shaped can also mean that the energy of this type of building is largely limited and predictable modal range, and thus their manageability is increased.
- Round shape and Box shape experience excessive sideways movement and are liable to damages; H-shaped and hollow layouts cause very low displacements to the floors. These shape reduce lateral drift and offer safeguard to the structural and non-structural systems and thus the seismic environment causes resilience hence safeguarding not only the primary frame but the other parts of the building. That is why they are safer and more resilient against earthquake areas.

Conflict of Interest Statement

The authors declare no conflict of interest.

References

- [1] S. Javad, A. A. Hamane, Comparative study of seismic analysis of various shapes of buildings by Indian code and American code, *International Research Journal of Engineering and Technology* (2018).
- [2] I. Bedi, G. Sharma, A. Gupta, Comparative study of RCC frame structures using STAAD.Pro, ETABS, and SAP, *International Journal of Advance Research in Science and Engineering* 6(9) (2017).
- [3] M. G. Guler, K. Guler, The effect of story drifts in determining the earthquake performance of high-rise buildings, *Buildings* 14 (2024).
- [4] S. Qurraie, Assessing accessibility and promoting inclusion for people with disabilities in a historical context in Tabriz, *Journal of Buildings and Architecture* 1 (2024) 2005.
- [5] M. N. Haque, M. B. Zisan, M. G. Kibria, A. K. Dey, Influence of planar irregularities on seismic responses of RC buildings, *Asian Journal of Civil Engineering* 22 (2021) 995–1009.
- [6] A. Deshmukh, R. P. An, Structural analysis of buildings using ETABS for different plan configurations, *International Journal of Advance Research and Innovative Ideas in Education (IJARIE)* (2021).
- [7] R. Shukla, P. Saha, Comparative study of a G+10 storied building using ETABS and STAAD, *International Journal of Engineering and Technology* 6 (2017) 108–112.
- [8] ASCE 7-22, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, American Society of Civil Engineers 2022.
- [9] Y. Alashker, S. Nazar, M. Ismaiel, Effects of building configuration on seismic performance of RC buildings by pushover analysis, *Open Journal of Civil Engineering* 5 (2015) 203–213.
- [10] T. Shiga, Torsional vibration of multi-story buildings, *Proceedings of the 3rd World Conference on Earthquake Engineering* (1965) II-569–II-585.
- [11] R. R. Bhandarkar, U. M. Ratanpara, M. Qureshi, Seismic analysis and design of multistory building using ETABS, *IJEDR* 5 (2017).
- [12] H. Hariri Asli, M. Arabani, Analysis of Strain and Failure of Asphalt Pavement, *CRPASE: Transactions of Civil and Environmental Engineering* 8 (2022) 1–11.
- [13] A. Sadeghpour, G. Ozay, Investigating the predictive capabilities of ANN, RSM, and ANFIS in assessing collapse potential of RC structures, *Arabian Journal for Science and Engineering* (2024) 1–22.
- [14] H. Dwela, M. Tuna Kayili, The Determination of the Retrofitting Strategies on Thermal Comfort and Energy Efficiency of Mosques: The Case of Yasamkent Mosque, *CRPASE: Transactions of Civil and Environmental Engineering* 9 (2022) 1–10.
- [15] M. M. M. Ahmed, M. A. B. Abdo, W. A. E. W. Mohamed, Vertical geometric irregularity effect on performance-based seismic design for moderate rise RC moment resisting frame buildings, *Arabian Journal for Science and Engineering* 47 (2022) 12333-12348.
- [16] R. B. Antwi, S. Okai, J. Quaye-Ballard, E. E. Ozguven, Geospatial Analysis of Fuel and Gas Station Distribution: Evaluating the Compliance and Impact of Station Siting on Public Health and Safety in Kumasi, Ghana, *CRPASE: Transactions of Civil and Environmental Engineering* 10 (2024) 1–19.
- [17] A. Furtado, H. Rodrigues, A. Arêde, Effect of the openings on the seismic response of an infilled reinforced concrete structure, *Buildings* 12 (2020).
- [18] M. Naseri, G. R. Shobeyri, A. Rajabi, A. Sadeghpour, Evaluation of groundwater resources potential using AHP and GIS: Garmsar catchment basin, *CRPASE: Transactions of Civil and Environmental Engineering* 7 (2021) 1–8.
- [19] A. Sadeghpour, Comparison of artificial intelligence and soft computing applications in structural engineering, *ENG Transactions* 1(1) (2024) 1–2.
- [20] S. Jourian, A. Sadeghpour, The interplay of order and complexity: A comparative study of modern and postmodern architectural paradigms, *Journal of Buildings and Architecture* 2 (2025) 2952.
- [21] P. N. Pizarro, L. M. Massone, Structural design of reinforced concrete buildings based on deep neural networks, *Engineering structures* 241 (2021) 112377.
- [22] B. Sultan Qurraie, Ö. Özeren, E. B. Özeren, The Impact of 3D Printing on Architectural Student Design Skills, *Journal of Buildings and Architecture* 1 (2024) 1–5.
- [23] A. Sadeghpour, G. Ozay, A multi-algorithm approach for optimizing collapse margin ratio in seismic design of reinforced concrete structures, *Bulletin of Earthquake Engineering* 23 (2025) 4789–4830.
- [24] E. B. Özeren, M. Haji Amiri, S. Z. İpek, The Role of Daylight in Architectural Design: A Review of the 2018 Velux Competition, *Journal of Buildings and Architecture* 1 (2024) 1–9.
- [25] S. Mohammadi, F. Latif Far, The Influence of Sustainability Policy on Procurement Approaches for Sustainable AEC Projects, *Journal of Buildings and Architecture* 2 (2025) 1–6.
- [26] S. Sultan Qurraie, Assessing Accessibility and Promoting Inclusion for People with Disabilities in a Historical Context in Tabriz, *Journal of Buildings and Architecture* 1 (2024) 1–6.