EFFICIENT FLOOR SHAPE OF THE HIGH RISE STRUCTURE WITH RESPECT TO THE SEISMIC LOADING: A COMPARATIVE STUDY

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Abstract

One of the most important design criteria for high rise structures is its shape because it provides the outer size, outlook as well as orientation of the building. As the height of the structure increases, the impacts of lateral loading become higher. To resist the lateral loads, we need to bring out alternative procedure which may help us to reduce this effects so that we can build safe and sound tall buildings. The shape of the structure usually comes from its floor orientation and size. Based on this consideration, this study focuses on the responses by analyzing the effects of the lateral loads specially earthquake on two 20 storied high rise structures, one with square floor shape and another with circular floor, having similar floor areas with edge supported floor systems. The study reveals that circular shape is the preferable floor area as it can resist more storey shears and overturning moments compared to square shape though circular shape structure is found less stiff than square shape structure.

Keywords: *Building Shape, Circular Floor System, Earthquake Loading, Square Shape Floor, Tall Buildings*

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1. INTRODUCTION

One of the most important design criteria for high rise structures is its shape because it provides the outer size, outlook as well as orientation of the building. As the height of the structure increases, the impacts of lateral loading become higher. To resist the lateral loads, we need to bring out alternative procedure which may help us to reduce this effects so that we can build safe and sound tall buildings. The shape of the structure usually comes from its floor orientation and size. The shape of a structure is defined as its height, width and depth [5].

2. BACKGROUND OF STUDY

In the recent years, Bangladesh has growing trends towards the construction of multi-storied buildings. Almost of these skyscrapers are being constructed in Dhaka city. For this reason, these types of skyscrapers are being affected by lateral loading. The structural frames of tall buildings must carry vertical gravity loads, but lateral loads are also a major consideration [1], [3]. Lateral loads are always applied horizontally. Wind loads and earthquakes are mainly considered as lateral loads. Earthquake loads are particularly important in the design of large structures, such as tall buildings, that have large open interiors and walls in which large openings may occur. Variation of seismic effects with height must be considered in the design of tall structures [2]. If the EQ effects are not properly considered in the design, then the structure will produce lateral deflection, i.e. sway and the resident of the structure will feel dizziness, headache and other uncomfortable feelings.

3. OBJECTIVES OF THE STUDY

- To observe the effects of earthquake load on different structural outer shape of high rise building especially circular & square floor system in terms of maximum story displacement, maximum story drift, story shear, overturning moment, story stiffness etc. of different building elements.
- To find out the best structural shape with respect to earthquake loading.

4. METHODOLOGY OF THE STUDY

Two 20 storied frame structures having same plinth areas with edge supported floor system had been selected. The both structures have residential floors.

Type-I building- Circular Shape Structure as shown in Fig. 1.
Type-II building-Square Shape Structure as shown in Fig.2.

Square Shape Structure-
Length of building, B = 90 *ft*
Width of building, L = 90 *ft*
Height of building, H = 200 *ft*

Circular Shape Structure-
Diameter or least horizontal dimension of building, D = 51 *ft*
Height of building, H = 200 *ft*

Seismic factor-
Seismic zone Coefficient, Z = 0.150
Special moment resisting frame, *R* = 12
Importance Coefficient for residential building, *I* = 1.0
Soil profile, S = 1.5
Vibration time period, *T*(sec) = 1.07

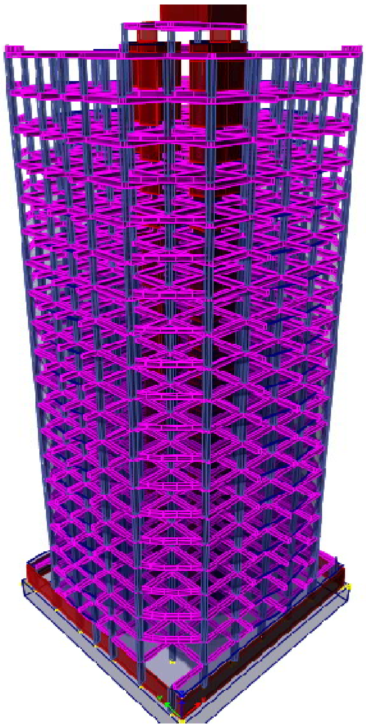


Fig-1: 3-D side view of the Type-I structure (circular shape)

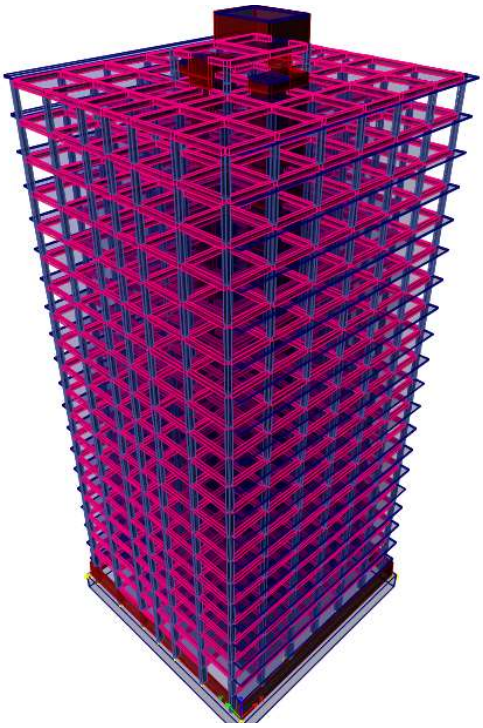


Fig-2: 3-D side view of the Type-II structure (square shape)

4.1 Design data and Specifications Considered in the Study

According to the main objective of this study, the whole comparative study is divided into several sub topics so that a clear picture can be obtained and complete discussions are possible**.**

The whole study was carried out based on few considerations and specifications which are summarized in Table-1.

Table-1: Summary of the design considerations and specification of the study

Items	**Description**
Design code	American Concrete Institute (*ACI*) Building design code, 2011 [6]. BNBC Code [5] Uniform Building Code (UBC), 1994.
Loadings	Floor plus ceiling finish = 30 *psf.* Live load = 40 *psf* Partition wall=70 *psf* Earthquake loads as per UBC 1994.
Building components	Column type = Tied Footing type = Mat foundation. Thickness of all walls = 5 *inch.*
Material properties[1], [4]	Yield strength of reinforcing bars, f_y= 60,000 *psi.* Concrete comp. strength, f'_c = 4,000 *psi.* Normal density concrete, unit wt. w_c = 150 *pcf.* Unit weight of brick, w_b = 120 *pcf.*

5. RESULTS & DISCUSSIONS

This section will present the differences among the responses of Circular and Square Structures towards EQ loading in terms of the following factors:

- Lateral Loads to Stories
- Auto Lateral Loads to Stories
- Maximum Story Displacement
- Maximum Story Drifts
- Story Shears
- Story Overturning Moments

Comparative analysis was done by ETABS 2013. The global X-axis of the model is parallel to the long direction and global Y-axis is parallel to the short direction of the building. The global X-axis and Y-axis of the two models are shown in Fig-3 and Fig.-4 respectively.

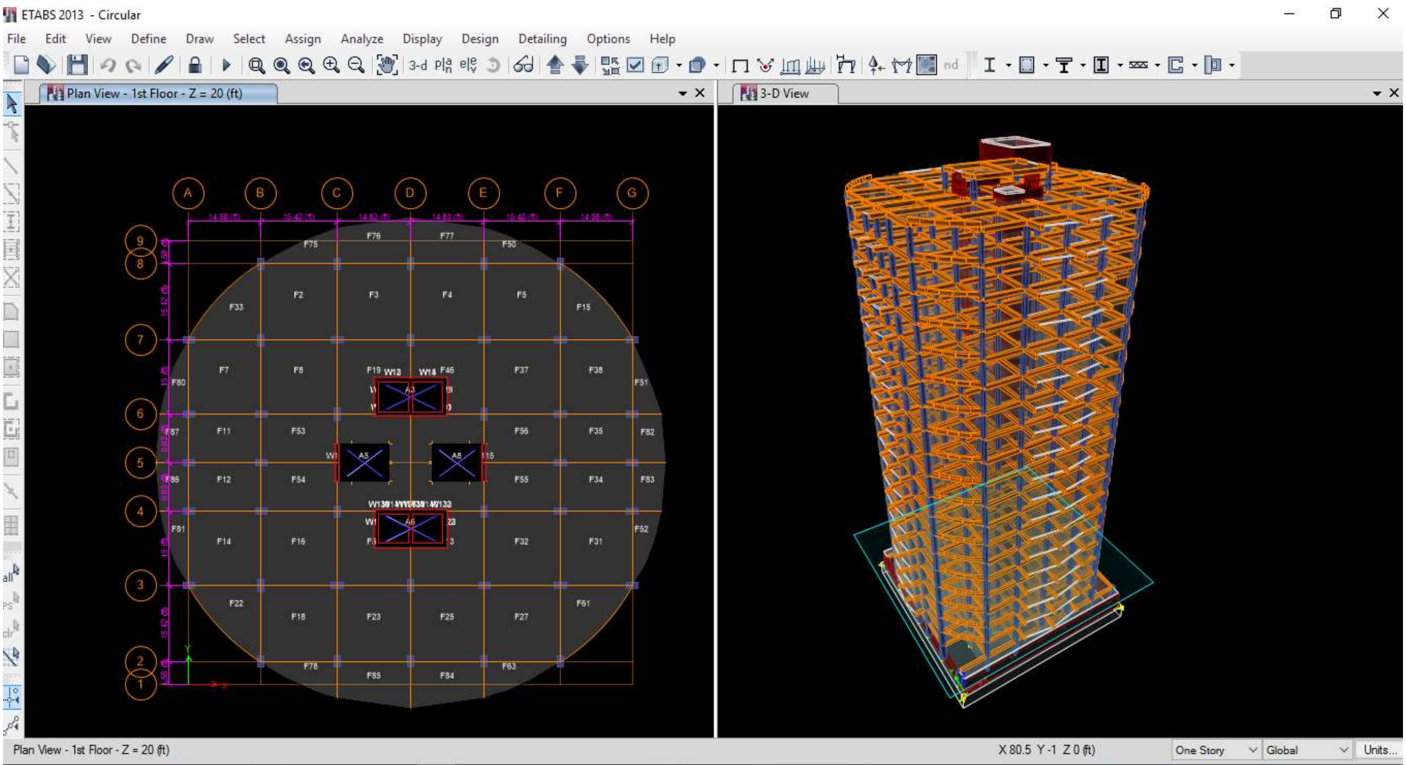


Fig-3: Global X & Y Direction of ETABS Model (Circular)

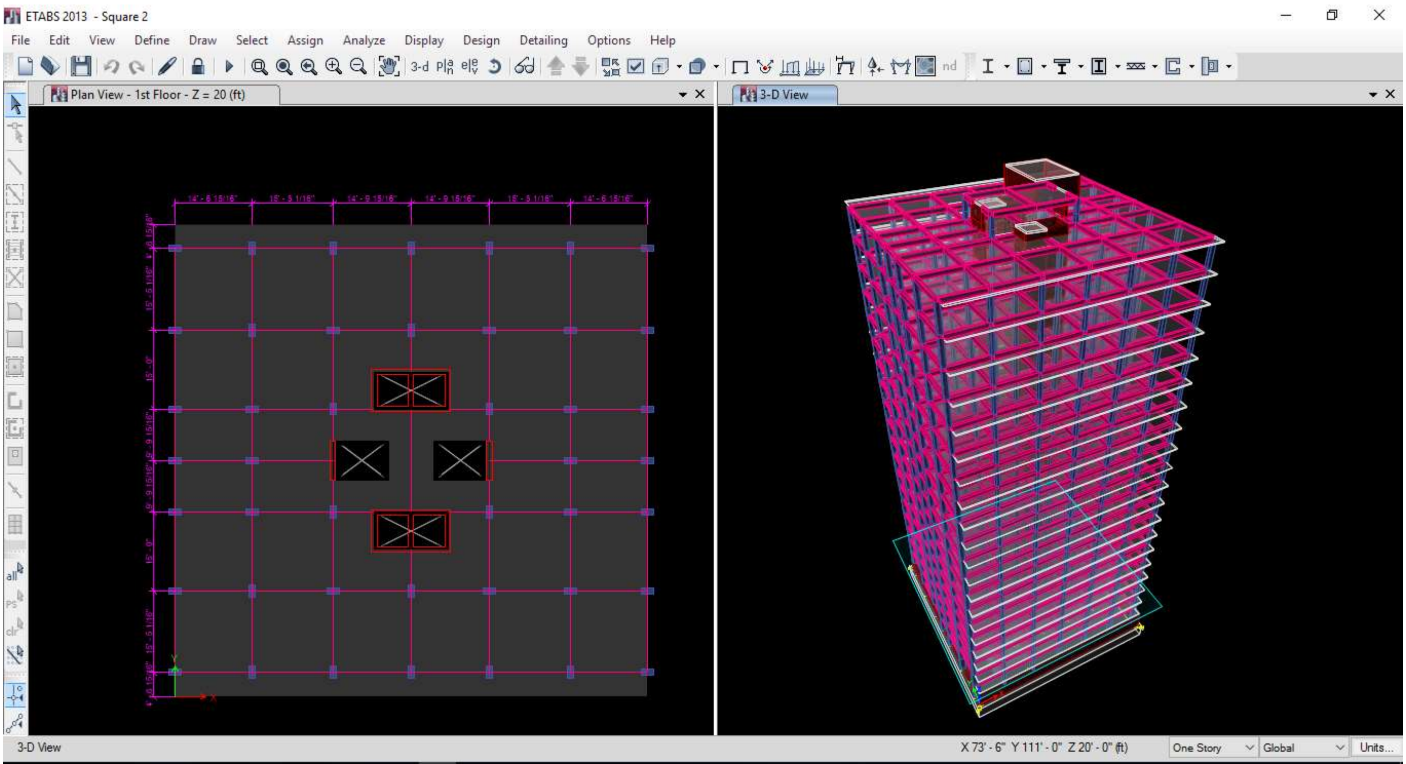


Fig-4: Global X & Y Direction of ETABS Model (Square)

5.1 Maximum Story Displacement Resisted at each Storey

Fig.5(a~b) provide information about the response for maximum story displacement. Here the horizontal axis represents displacement in inch and the vertical axis represents the stories of the building. Blue curves state the response due to lateral loads implying in X direction of the model and red curves in Y direction. From figures, it is clearly seen that maximum displacement at roof top is 4.04 and 4.43 inch for square shape and circular shape structure in X-direction respectively. Similarly, respective displacements are 4.48 and 5.02 inch in Y-direction.

5.2 Maximum Story Drifts

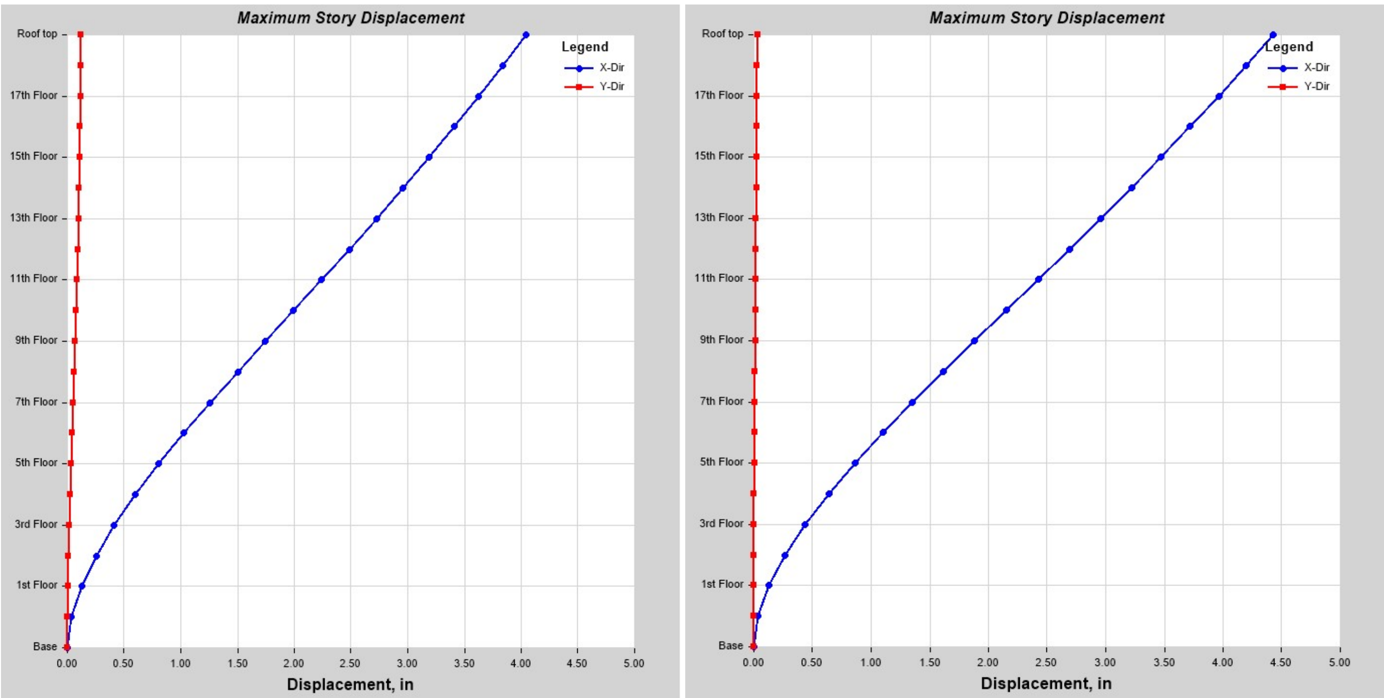
Fig 6(a~b) give story drifts. Here the horizontal axis represents drifts and the vertical axis represents the number of the stories of the building. Blue curves state the response due to lateral loads implying in X direction of the model and red curves in Y direction. From figure it is clearly seen that, the storey drift form a parabolic shape with zero drift at bottom, increases toward mid and finally decreases again at top. From figures, it is clearly seen that maximum drift at 10^{th} floor level is 0.002057 and 0.002257 for square shape and circular shape structure in X-direction respectively. Similarly, respective drifts are 0.002433 and 0.002725 at 8^{th} floor level in Y-direction.

5.3 Story Shears

Fig 7(a~b) provide information about the response for story shears. Here the horizontal axis represents story shear in kips and the vertical axis represents the stories of the building. Blue curves state the response due to lateral loads implying in X direction of the model and red curves in Y direction. From figures, it is clearly seen that maximum shear at ground floor level is 849.58 kip and 919.41 kip for square shape and circular shape structure in both directions respectively.

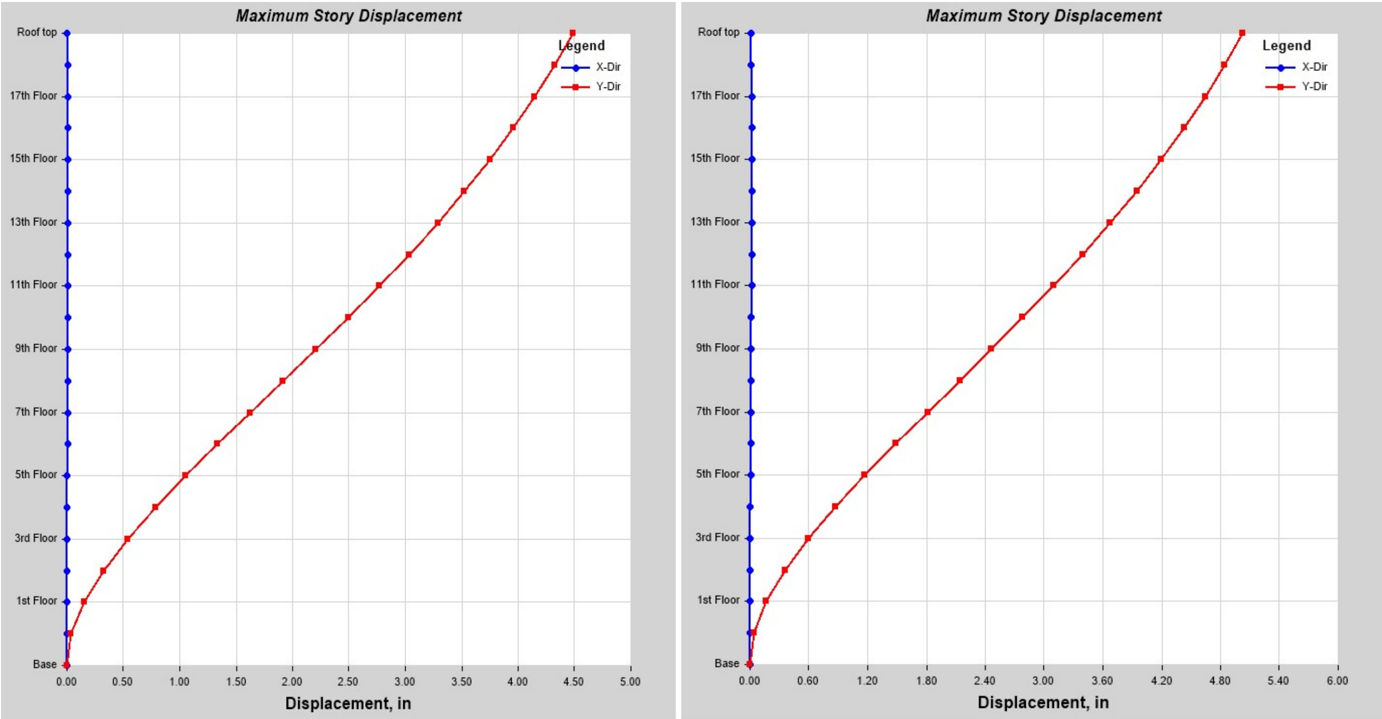
5.4 Resisting Story Overturning Moments [MR]

Fig 8(a~b) show the response for story overturning moments. Here the horizontal axis represents overturning moments in kip-inch and the vertical axis represents the stories of the building. Blue curves state the response due to lateral loads implying in X direction of the model and red curves in Y direction. From figures, it is clearly seen that, curve starts from base with its peak value and sharply goes down to18^{th} story in both WX and WY. It is noted here that due to lateral loads in X-direction, the whole structure will resist its overturn with respect to Y-axis and creates a resisting overturning moment with respect to Y-axis. Similar case can be explained for loads in Y-direction. However, it is shown that circular shape structure can withstand greater storey overturning moment (127593& 124573.8 k-ft) compared to square shape structure (118255 &115574.21 k-ft) in X and Y directions respectively.



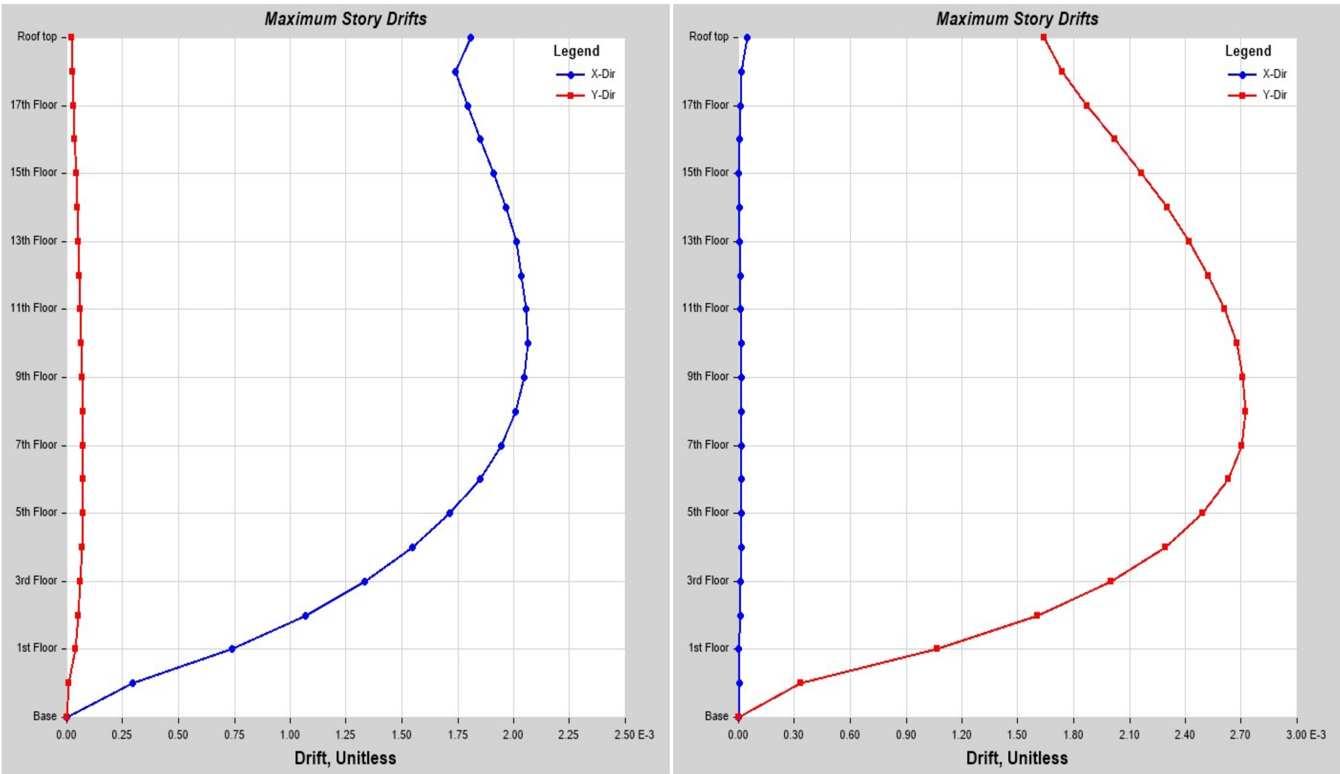
Square Shape Structure   Circular Shape Structure

Fig-5a: Maximum Story Displacement in global X direction



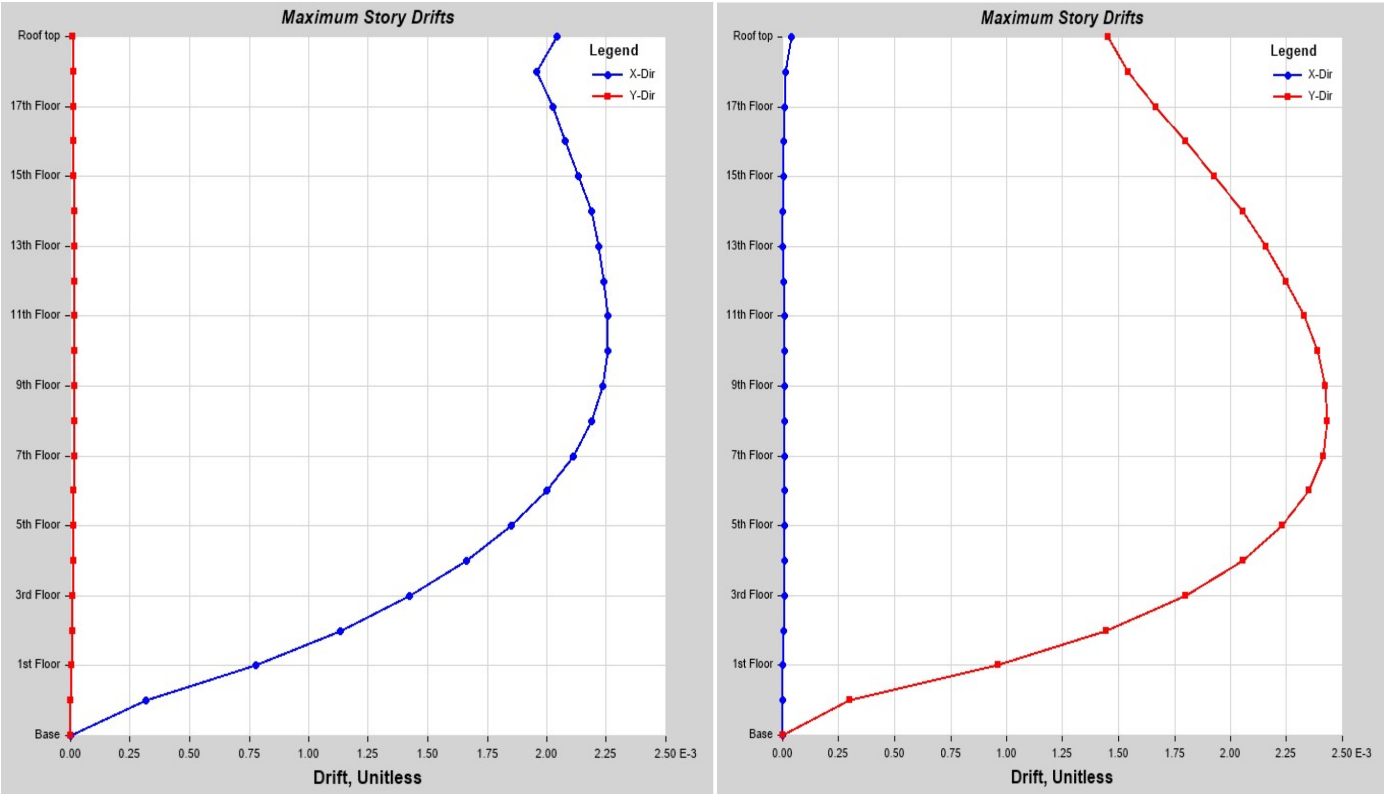
Square Shape Structure Circular Shape Structure

Fig-5b: Maximum Story Displacement in global Y direction.



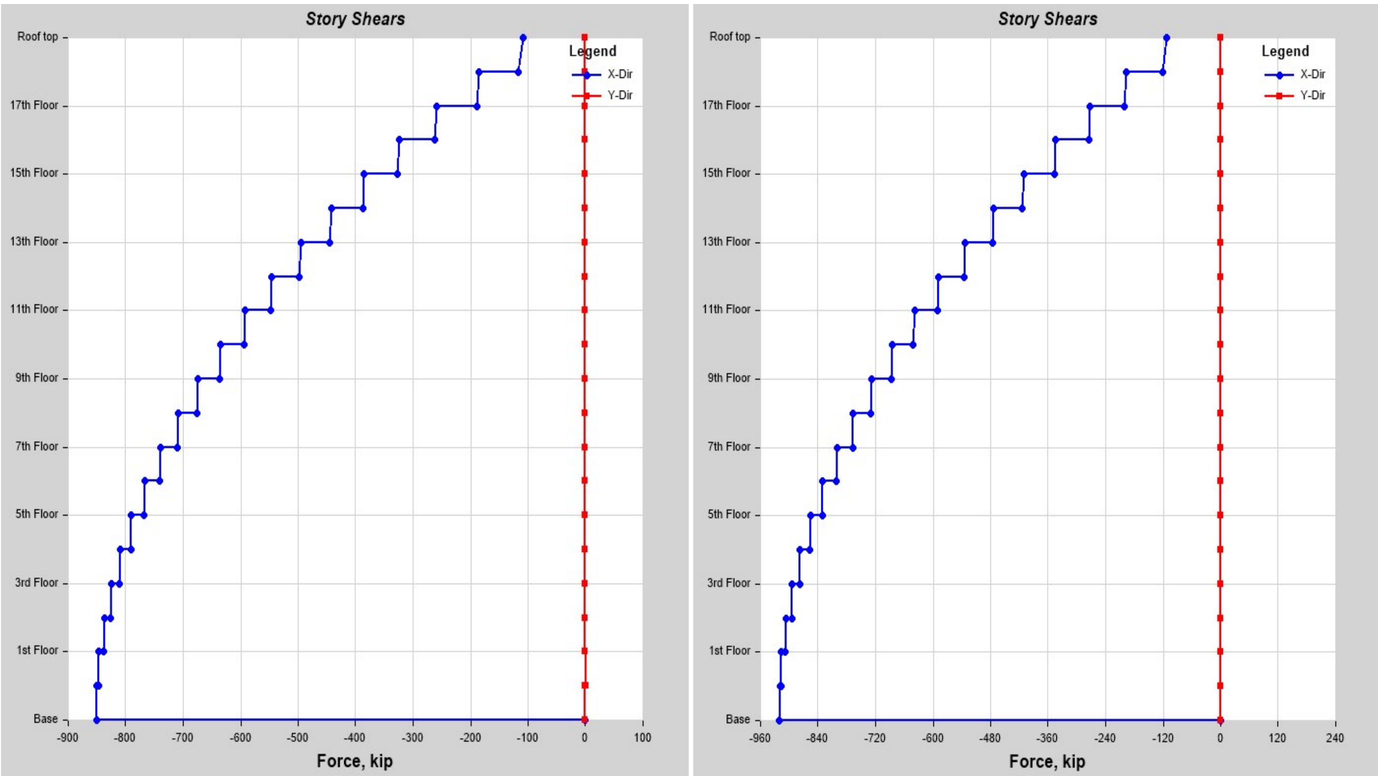
Square Shape Structure Circular Shape Structure

Fig-6a: Maximum Story Drifts in global X direction.



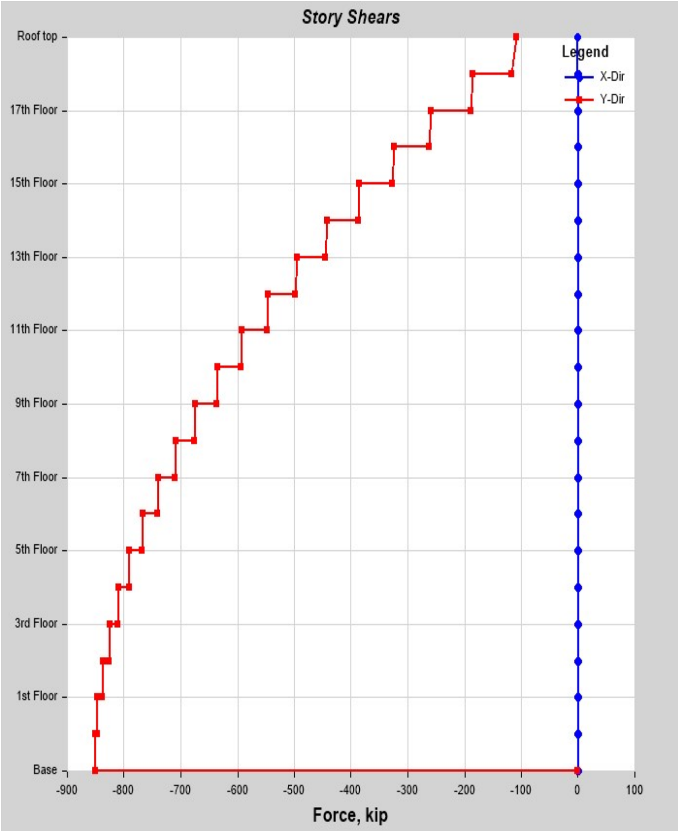
Square Shape Structure Circular Shape Structure

Fig-6b: Maximum Story Drifts in global Y direction.

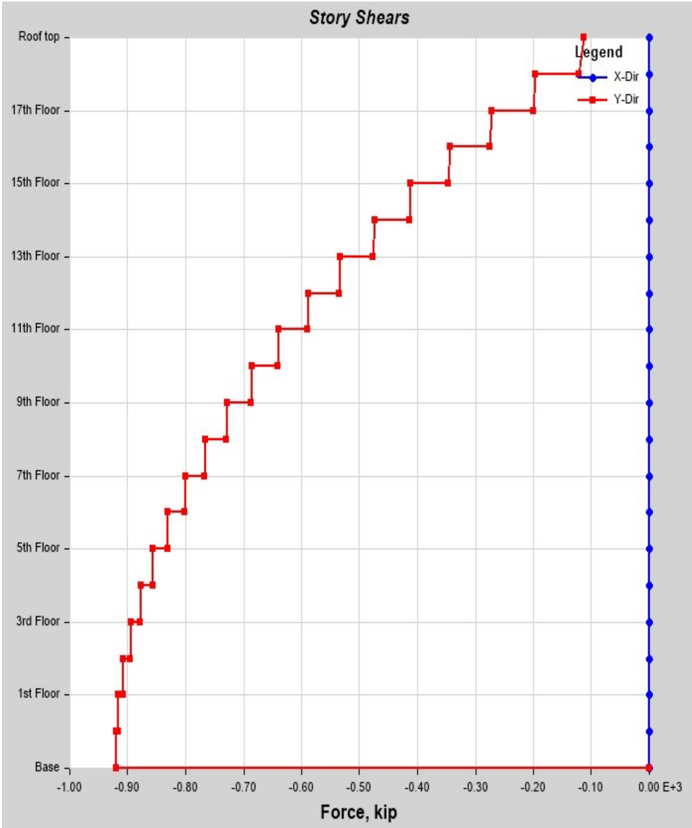


Square Shape Structure Circular Shape Structure

Fig-7a: Story Shears in global X direction.

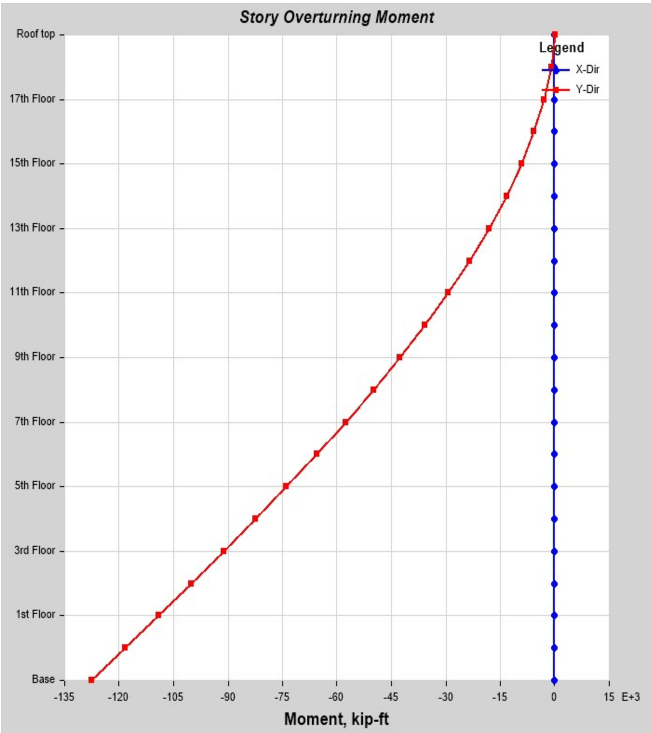


Square Shape Structure

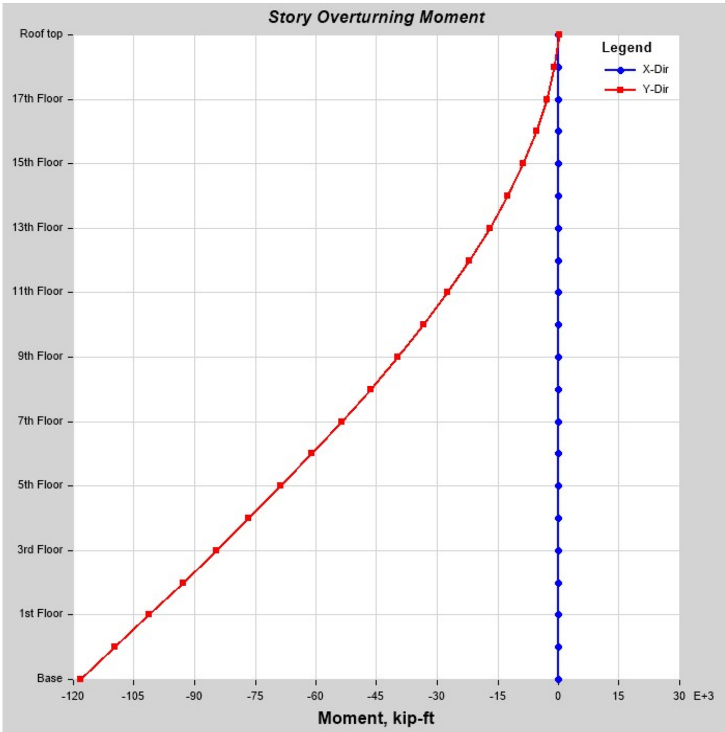


Circular Shape Structure

Fig-7b: Story Shears in global Y direction

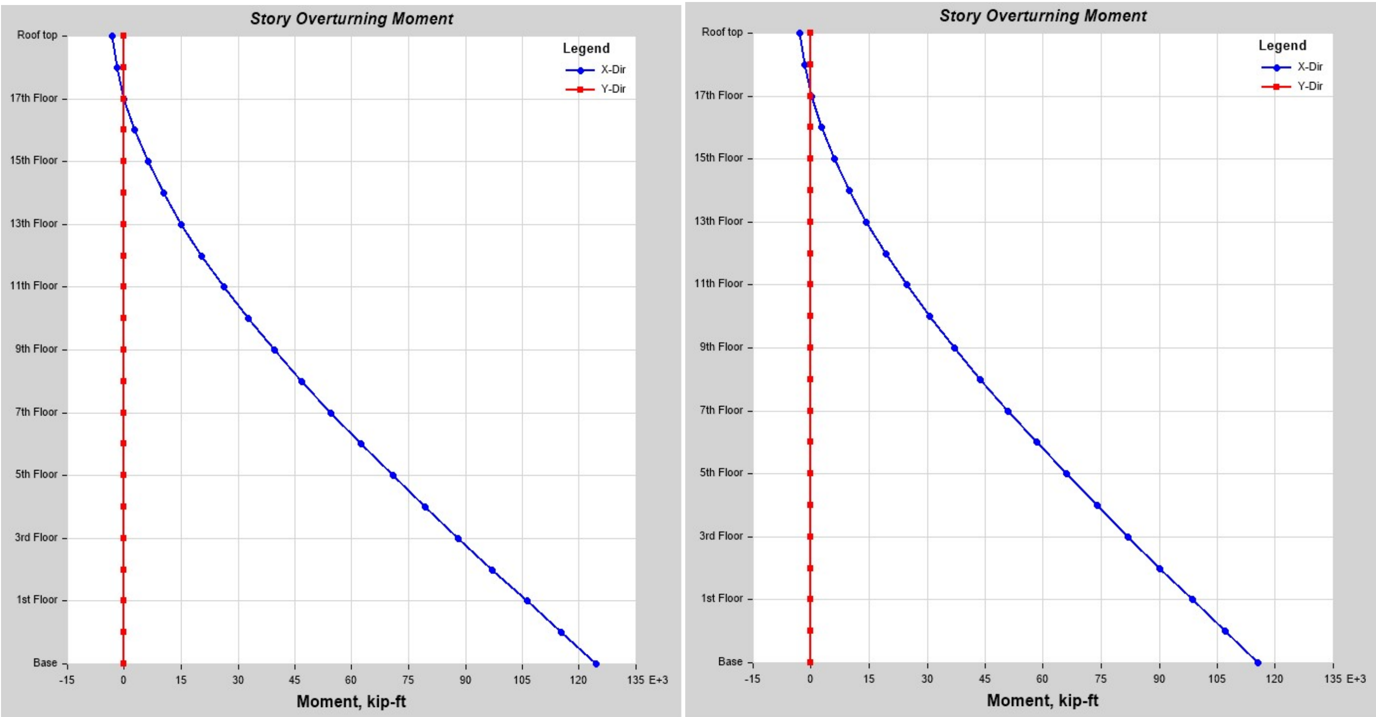


Square Shape Structure



Circular Shape Structure

Fig-8a: Story Overturning Moments in global X direction

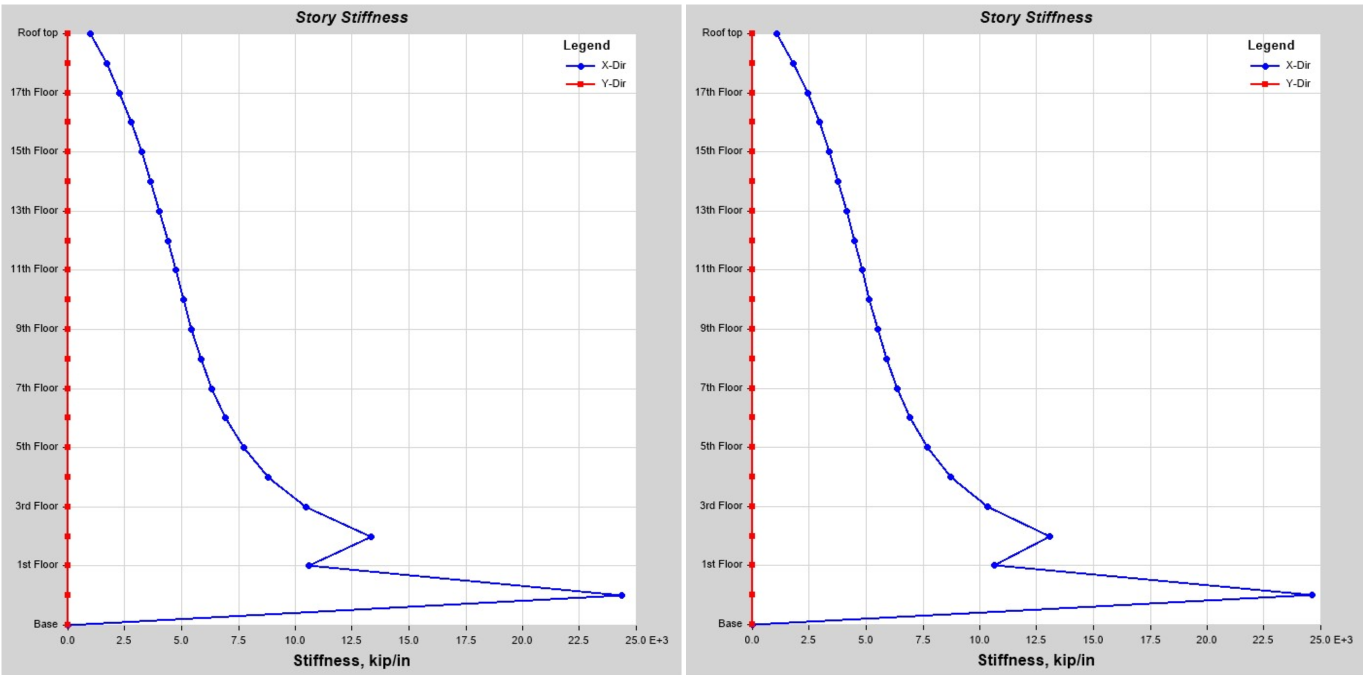


Square Shape Structure Circular Shape Structure

Fig-8b: Story Overturning Moments in global Y direction

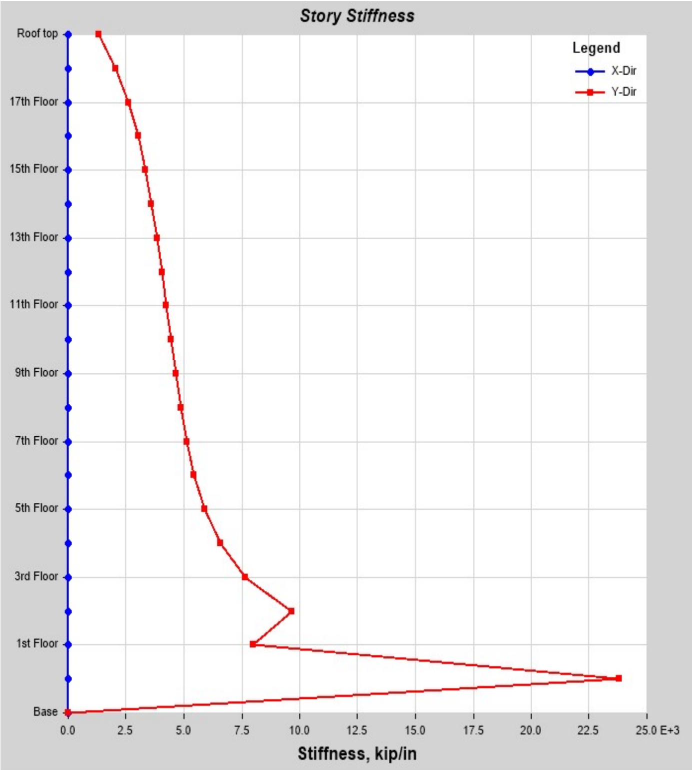
5.5 Story Stiffness

Fig 9 (a~b) illustrated below provide information about the response for story stiffness. Here the horizontal axis represents story stiffness in kip-inch and the vertical axis represents the stories of the building. Blue curves state the response due to lateral loads implying in X direction of the model and red curves in Y direction. From figures, it is clearly seen that, circular shape structure has lower stiffness compared to square shape structure.

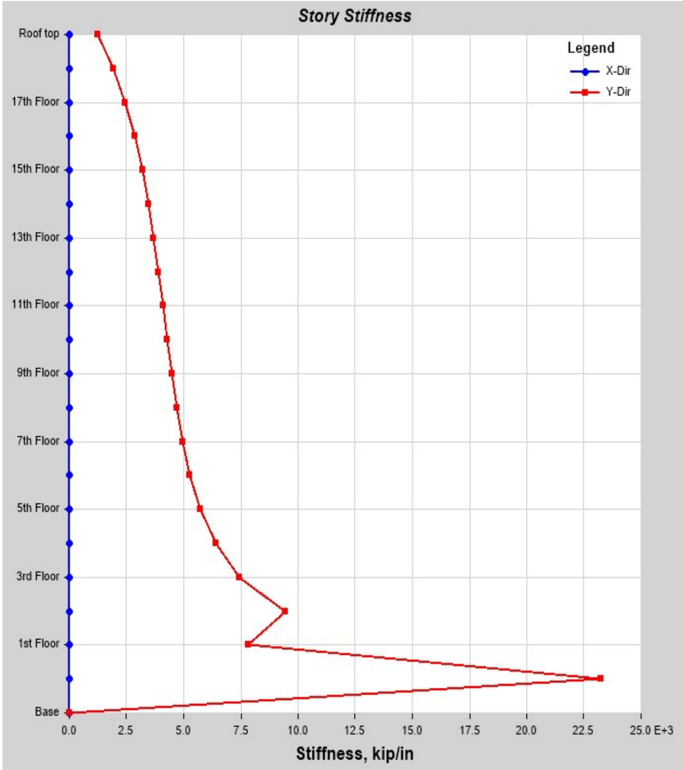


Square Shape Structure Circular Shape Structure

Fig-9a: Story Stiffness in global X direction



Square Shape Structure



Circular Shape Structure

Fig-9b: Story Stiffness in global Y direction

6. CONCLUSION

From this analysis & findings, it can be concluded that:

- Circular Shape structure shows greater story displacement at top floor compared to Square Shape structure.
- Circular Shape structure can resist higher story overturning moment at base compared to Square Shape structure.
- Circular Shape structure can resist higher story shear at base compared to Square Shape structure.
- Square Shape structure is stiffer than Circular Shape structure.
- Circular Shape structures have higher story drift compared to Square Shape structure.
- Overall, it can be justified that Circular shape structure is the best one against lateral loadings with compared to Square shape structure.

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