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(RESEARCH ARTICLE)

Structural floor shape efficiency of circular and square high rise structure towards lateral loadings

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Abstract

The building shape is one of the most important considerations in the conceptual stage of building design. Since the building shape determines the size and the orientation of the exterior envelope exposed to the outdoor environment, it can affect building performance in many aspects: energy efficiency, cost and aesthetics. The shape and exterior structure of a house play major roles in determining its energy efficiency and the comfort of residents. The shape is comprised of the building's height, width, and depth-also known as the footprint.

The determination of the structural shape of a high-rise building would preferably involve only the selection and arrangement of the major structural element to resist most efficiently the various combinations of gravity and horizontal loading. Based on the above considerations, this study focuses on the responses by analysing the effects of the lateral loads on two 20 storied high rise structures having edge supported floor systems each of which one with square floor shape and another with circular floor and finally, presents a comparative result.

Keywords: Conceptual; Determination; Horizontal; Envelope; Comparative; Structural

1. Introduction

High-rise buildings, which are developed as a response to population growth, rapid urbanization and economic cycles, are indispensable for a metropolitan city development. This statement holds true for today; however, the relationship between cost and benefit is more complex in today's global marketplace. The political ideology of the city plays an important role in the globalization process [1, 2]. The current trend for constructing buildings is to build higher and higher, and developers tend to compete with one another on heights. Tenants also appreciate a landmark address and politicians are conscious of the symbolic role of high-rise buildings. The international and high technology styles have accompanied nearly all new tall buildings and became landmark of our cities [3]. Nonetheless high-rise buildings are more expensive to construct per square meter, they produce less usable space and their operation costs are more expensive than conventional office buildings. The space efficiency, as well as the shape and geometry of the high-rise building need to satisfy the value and cost of the development equation. Space efficiency, which is determined by the size of the floor slab, dimension of the structural elements and rationalized core, goes along with the financial benefit. The building shape is one of the most important considerations in the conceptual stage of building design. Since the building shape determines the size and the orientation of the exterior envelope exposed to the outdoor environment, it can affect building performance in many aspects: energy efficiency, cost and aesthetics. Too often, however, decisions on the building shape are based on aesthetics only, which has the evident disadvantage of limiting the potential of performance improvement. Shape optimization can help overcome this disadvantage by exploring more design alternatives at the conceptual design stage for specific criteria such as environmental and economic performance [4, 5].

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In this research work, to examined all aspects of lateral loads consideration in the investigate of RCC structures. On other hand, examine the impacts of lateral loads on various structural outer shape of high rise building particularly circular and square floor system in terms of auto lateral load to stories, maximum story drift, story shear as well as overturning moment. The main focus to determine the best structural shape between circular and square under same regular loading.

2. Material and methods

The whole study was carried out based on few considerations and specifications which are summarized below.

2.1. Design code

2.1.1. Description

- American Concrete Institute (ACI) Building design code, 2011 [7].
- Bangladesh National Building Code (BNBC), 1993 [6].
- Uniform Building Code (UBC), 1994 [8].

2.2. Loadings

2.2.1. Description

- Floor plus ceiling finish = 30 psf.
- Live load = 40 psf for Residential floors.
- Partition wall=70 psf for Residential floors.
- Earthquake and wind load are considered.

2.3. Building components

2.3.1. Description

- Column type = Tied
- Footing type = Mat foundation.
- Thickness of all walls = 5 inch

2.4. Material properties

- Yield strength of reinforcing bars, fy = 60,000 psi.
- Concrete compressive strength, f'c = 4,000 psi.
- Normal density concrete having wc = 150 pcf.
- Unit weight of brick, wb = 120 pcf.

2.5. Load Calculation

2.5.1. Load case according to the BNBC code [6]

- 1.00×DL+1.00LL
- 1.40×DL+1.70×LL
- 1.05×DL+1.275×LL +1.275WLX
- 1.05×DL+1.275×LL +1.275(-WLX)
- 1.05×DL+1.275×LL +1.275WLZ
- 1.05×DL+1.275×LL +1.275(-WLZ)
- 1.05×DL+1.275×LL +1.4025EQX
- 1.05×DL+1.275×LL +1.4025(-EQX)
- 1.05×DL+1.275×LL +1.4025(EQZ)
- 1.05×DL+1.275×LL +1.4025(-EQZ)

2.6. Dead loads

- Self-weight of edge slab for residential floor = psf
- Floor finish = 30 psf
- 5″ Partition wall Load for residential floor = 70 psf
- Total dead load of 5″ slab thickness for residential floor = slab thickness load + Floor finish load + partition wall load = $(\frac{5}{12} \times 150)$+ 30 + 70 = 62.5 +30 +70 = 162.5 psf

2.7. Seismic load calculation [6-8]

- Height of building = 200 ft = 60.97m
- Seismic zone Coefficient (Dhaka zone) = 0.150
- Special moment resisting frame, R= 12
- Importance Coefficient for residential building, I = 1.0
- Vibration time period, T= 1.07 second
- Soil profile, S = 1.5

2.8. Wind load calculation [6-8]

- Square Shape Structure-
- Length of building, B = 90 ft
- Width of building, L = 90 ft
- Height of building, H = 200 ft
- Wind pressure in Dhaka city, Vb = 210 Km/h
- Importance coefficient, I = 1.0

2.9. Square Shape Structure

- Length of building, B = 90 *ft*
- Width of building, L = 90 *ft*
- Height of building, H = 200 *ft*
- Wind pressure in Dhaka city, V_b = 210 *Km/h*
- Importance coefficient, *I* = 1.0

2.10. Circular Shape Structure

- Diameter or least horizontal dimension of building, D = 51 ft =15.5m
- Height of building, H = 200 ft
- Wind pressure in Dhaka city, Vb = 210 Km/h
- Importance coefficient, I = 1.0

3. Results and discussion

3.1. Comparison based on Different Influencing Factors

Comparative analysis was done by ETABS. 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 Figure 1. To illustrate the different phase of response curves due to lateral loadings in both X & Y direction, and to set comparison these responses, the whole discussion is going to focus on the effects of wind and earthquake separately.

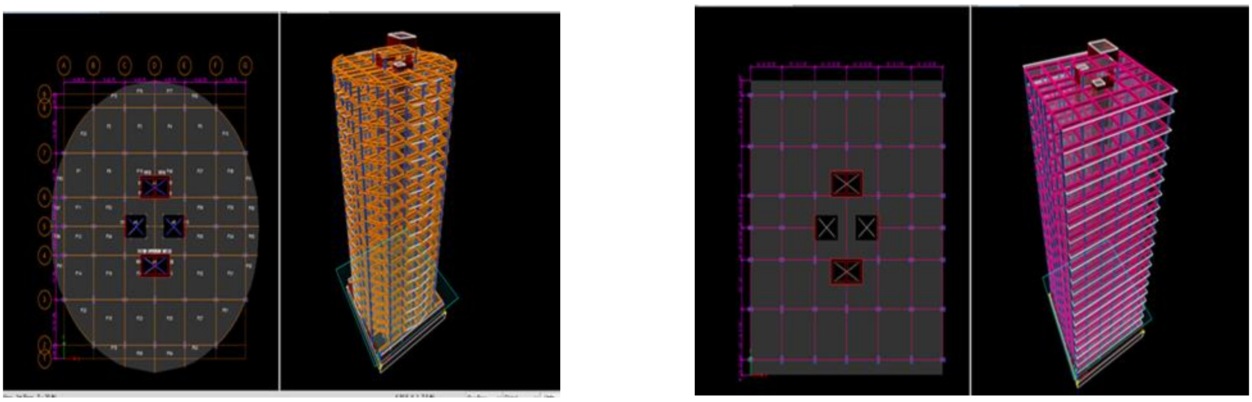

Figure 1 Global X & Y Direction of ETABS Model (Circular + square)

3.2. Response due to Wind Loads

3.2.1. Lateral loads due to WIND resisted by the Stories

Here the horizontal axis represents lateral loads 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. Also comparisons between lateral loads resisting capacities of Square and Circular shape in X and Y direction are clearly figure 2. From figure it is clearly seen that, response curves are near about symmetric in both Square Shape Structure and Circular Shape Structure while the value changes gradually in each story. It shows that the value of lateral load due to both WX and WY increases gradually from Ground Floor to 18th floor.

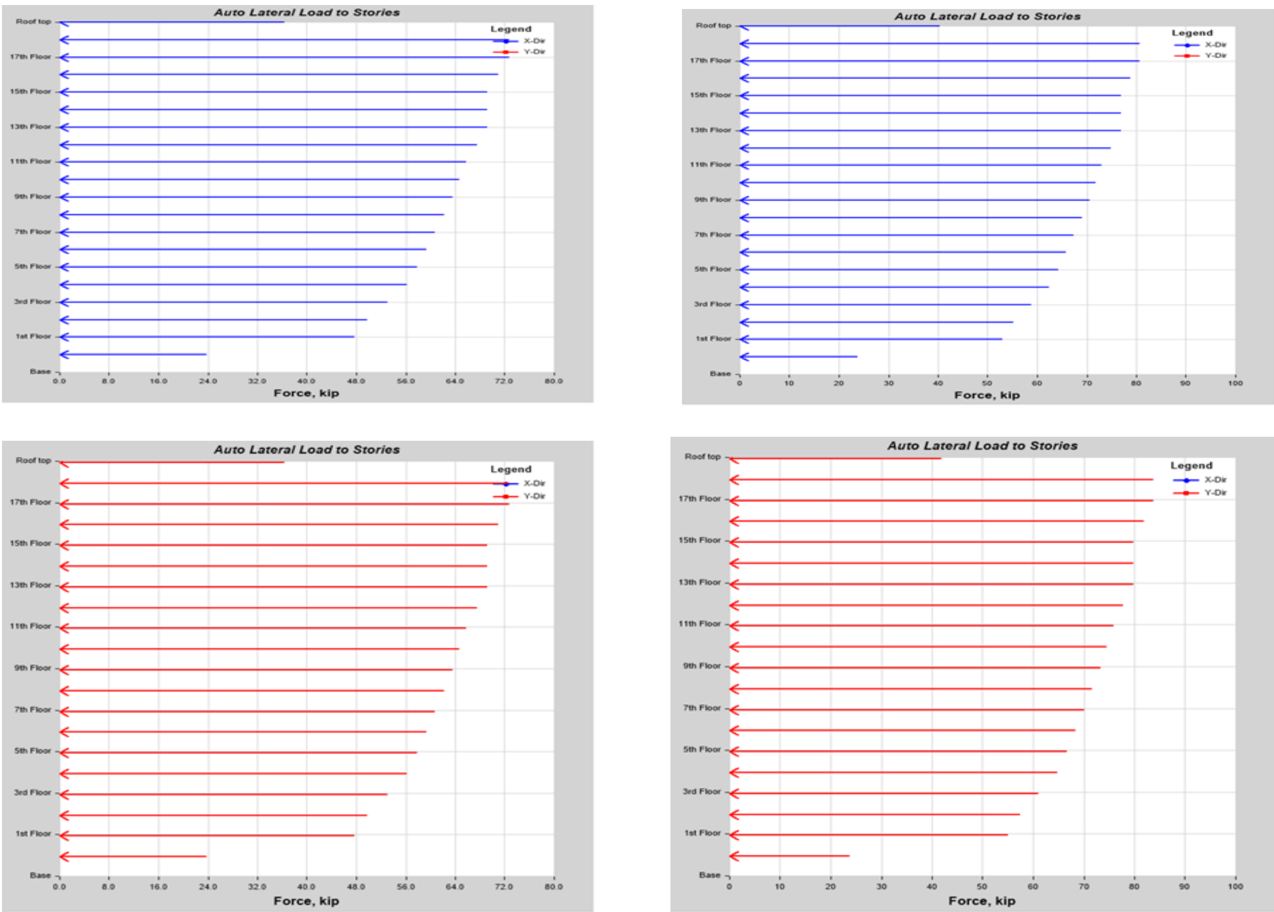

Figure 2 Resisting Wind loads at storeys in global X direction and Y direction

3.2.2. Maximum Story Displacement due to WIND resisted at each storey

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. Also comparisons between displacements of Square and Circular shape in X and Y direction are clearly shown in figure.

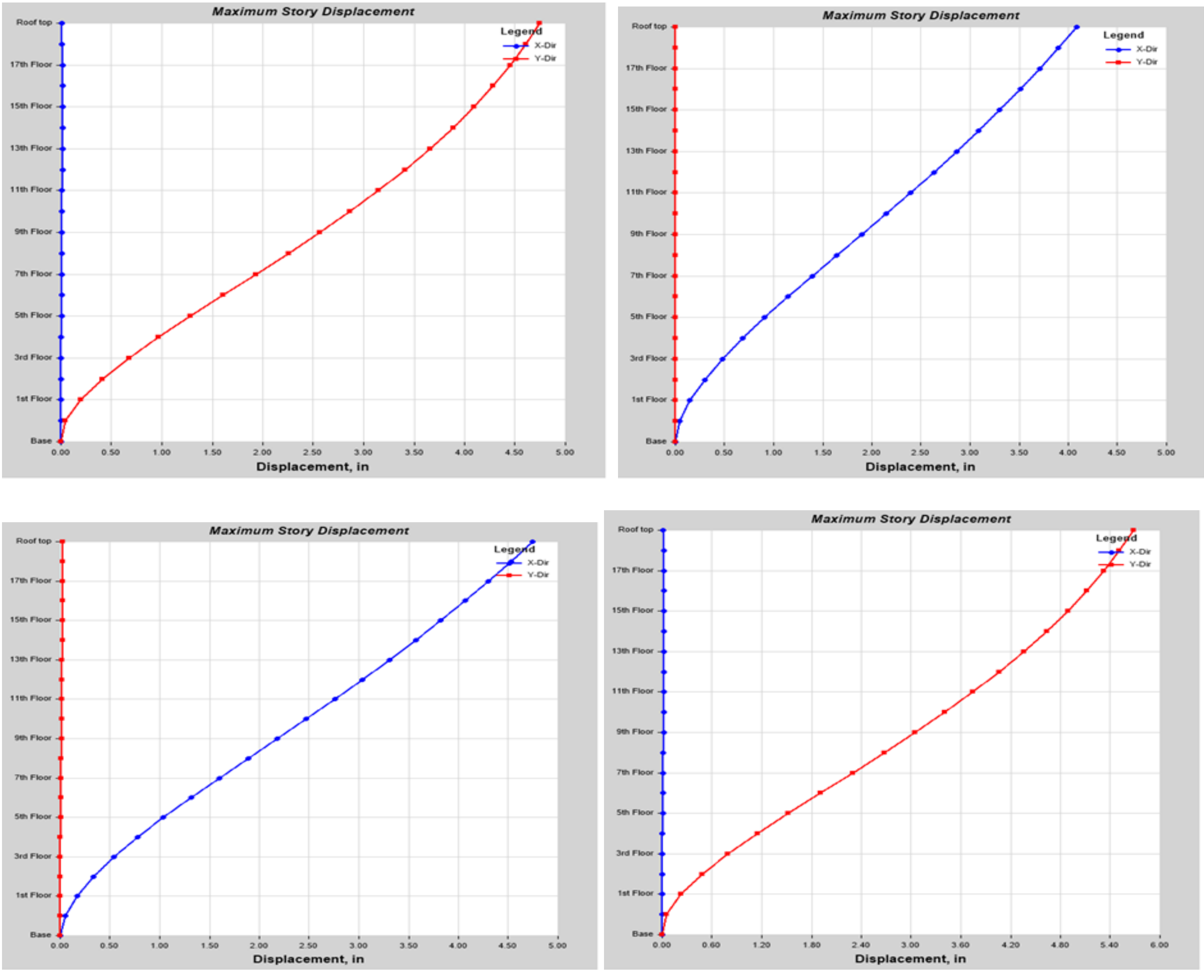

Figure 3 Maximum Story Displacement due to Wind loads in global Y and X direction

From figure it is clearly seen that curve starts from base and sharply goes on Roof Top in both WX and WY. The displacement curve of Square Shape Structure fluctuates slightly from the displacement curve of Circular Shape Structure in WX. Fluctuation occurs similarly in WY.

3.2.3. Maximum 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.

3.2.4. Resisting Story Overturning Moments [MR]

Curve starts from base with its peak value and sharply goes down to18th 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 MR with respect to Y-axis as shown in figure below. Similar case can be explained for loads in Y-direction. However, it is shown that circular shape structure can withstand greater storey overturning compared to square shape structure. 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.

Table 1 Story Overturning Moments due to Earthquake loads in global X direction.

Story	Square	Circular
	Resisting Overturning Moment kip-ft	Resisting Overturning Moment kip-ft
Roof top	150.3171	167.2066
18th Floor	-978.6687	-1002.8975
17th Floor	-2851.53	-2990.4328
16th Floor	-5453.9915	-5733.1131
15th Floor	-8705.4654	-9189.0285
14th Floor	-12567.8211	-13316.2689
13th Floor	-17002.9252	-18072.9237
12th Floor	-21972.6456	-23417.0836
11th Floor	-27441.5982	-29309.1792
10th Floor	-33374.554	-35709.934
9th Floor	-39732.9104	-42577.024
8th Floor	-46478.0661	-49868.1246
7th Floor	-53571.4184	-57540.9111
6th Floor	-60974.3646	-65553.0596
5th Floor	-68648.3021	-73862.2453
4th Floor	-76555.2626	-82426.688
3rd Floor	-84657.1863	-91204.5586
2nd Floor	-92915.2345	-100153
1st Floor	-101291	-109230
GF	-109754	-118394
Base	-118255	-127593

Table 2 All comparison table

Topic	Story Level	Square Shape Structure				Circular Shape Structure			
		EQX	EQY	WX	WY	EQX	EQY	WX	WY
Lateral Loads to Stories (kip)	GF	4.117	4.117	23.752	23.752	3.961	3.961	23.752	23.752
	Top Floor	116.294	116.294	**72.713**	**72.713**	120.574	120.574	**80.693**	**83.802**
Maximum Story Displacement (inch)	GF	0.035426	0.035917	0.044409	0.046742	0.037827	0.04005	0.049727	0.055342
	Top Floor	4.040148	4.483857	**4.086595**	**4.745737**	4.424742	5.023357	**4.747572**	**5.679509**
Maximum Story Drifts	GF	0.000295	0.000299	0.00037	0.00039	0.000315	0.000334	0.000414	0.000461
	Top Floor	0.00181	0.001453	0.001681	0.001256	0.002043	0.001641	0.001972	0.001536
Story Shears (kip)	GF	-849.581	-849.62	-1192.601	-1192.644	-919.412	-919.437	-1320.9	-1370.904
	Top Floor	-108.581	-108.582	-36.357	-36.357	-112.479	-112.479	-40.347	-41.901
Story Overturning Moment (k-in)	Basement	-118255	115574.2095	-133088	130623.4292	-127593	124573.8316	-147665	150347.2893
Story Stiffness (kip/in)	GF	24621.4045	23804.8294	26870.0794	25644.8372	24362.6869	23262.5152	26580.6041	25068.6709
	Top Floor	1073.2005	1335.9351	360.5034	482.3509	984.246	1225.1935	340.9998	454.6619

4. Future suggestions

Based on the intentions, possibilities and limitations of the study (stated in Chapter I), some suggestions can be projected for future studies:

- This study was accompanied based on 15 storied Square Shape floor systems, further examines considering other floor system such as flat slab can be considered to see the modification in moment, shear, axial forces etc. in different building elements and also their cross sectional dimensions as well strengthening necessities.

Sway and deflection control may be measured in investigation.

5. Conclusion

After this research work determined that, Circular Shape structure shows greater story displacement at top floor due to the effects of wind and earthquake compared to the Square Shape structure. As well as Square Shape structure can resist higher story overturning moment at base due to earthquake/winds effects compared to circular shape structure. Also work showed that, square shape structure can resist higher story shear at base and lateral loads at top story due to earthquake/winds effects compared to circular shape structure. And the main findings of this study the circular shape structures have higher story drift compared to square shape structure.

Compliance with ethical standards

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Disclosure of conflict of interest

The author have no conflict of interest.

References

[1] Newman P, A Thornley. Planning World Cities: Globalization and Urban Politics. Palgrave Macmillan. 2011.

[2] Sev A, A Özgen. Space Efficiency In High-Rise Office Buildings. METU Journal of the Faculty of Architecture. 2009; 26(2): 69-89.

[3] Architecture, Banal Nationalism and Re-territorialization, DONALD MCNEILL and MARK TEWDWR-JONES.

[4] Wang W, H Rivard, R Zmeureanu. Floor shape optimization for green building design. Advanced Engineering Informatics. 2006; 20(4): 363-378.

[5] Shape effects on the wind-induced response of high-rise buildings.

[6] Bangladesh National Building Code, 1st Edition, City Art Press, Dhaka, Bangladesh. 1993.

[7] American Concrete Institute Building Design Code, ACI, New York, USA. 2011.

[8] Uniform Building code, Structural Engineering Design Provisions. 1994; 2.