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Performance of Hollow Circular Columns in comparison with Solid Circular Columns in High Rise Buildings subjected to Wind Excitations

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Abstract: The number of buildings greater than 10 storeys has shown a phenomenal development in the recent times. According to the IS 875 (Part 3):2015, any building occurring at 10m height above the ground level, wind speed should be considered in its building design. Vibrations that are induced in structures due to the wind loads make it very important to consider in its structural design as the structures are more prone to vibrations from the lateral forces, which use longer floor spans, high-strength, lightweight materials and more flexible framing systems. In any framed structure, columns play an integral part. A column can be defined as a vertical member that takes load effectively by compression. Due to wind, earthquake or accidental loads bending moment may occur. In this paper, two types of circular columns have been considered i.e., hollow and solid circular columns. The analysis of G+15 and G+20 storey buildings by incorporating both the types of columns in each analysis has been used for comparative studies. Many experimentation has been carried out on performance of columns subjected to seismic loading, but very little research work has been done for the assessment of columns subjected to wind load. Therefore, this study is conducted in order to determine the performance of both solid and hollow circular columns in high rise buildings subjected to wind loads by using Equivalent Static method for basic wind zone of 33m/sec (Bangalore region) and analyzed using ETABS software.
Keywords: Hollow circular columns, Solid Circular columns, Buildings and Wind load

I. INTRODUCTION

Nowadays in major metropolitan cities, a boom in the increase ofhigh rise building construction has seen significant growth in both commercial and residential sectors. The lateral loads that may act on these structures can be either wind or earthquake loads which might cause damage to the entire building. So, it is the duty of the structural engineer to design a building by considering these lateral forces so that it is adequate during its anticipated life from the viewpoint of both serviceability and structural safety. IS 875 (Part 3):2015 clearly mentions the use of wind loads in any structural design of a building whose height is more than 10m above the ground surface. While considering the action of wind on the design of high rise building with circular columns, question might arise on choosing either between solid circular section or hollow circular section. The wind behavior of hollow circular columns has been controversial due to lack of understanding. Any section which has higher radius of gyration will have higher strength. Hollow circular section has higher radius of gyration when compared to solid circular section, while both having same area of concrete and steel. Therefore, in general hollow circular columns should perform better against the action of wind when compared to solid circular columns. Based on this concept, hollow circular columns have been adopted in the present study which intends on assessing its performance by analysis and design using ETABS software.

Sherin G Ponnachen and Archana Sukumaran et al.,(2017)studied the comparison of the performance of solid and hollow RC members subjected to seismic loads in the RC building and concluded that there is a 27 percent to 37 percent reduction in the maximum drift in the seismic zone 5 and a 21 percent reduction in the maximum seismic zone 3 due to Hollow members in the RC building.

B.Ajitha and M.Naveen Naik et al.,(2016)conducted wind and seismic analysis at different building heights, taking into account zone 2, 3 and 4. The bracing was used to resist earthquakes and wind loads. The paper concluded that the structural performance is analyzed at various building heights, i.e. without bracing, the displacement is reduced by 45 percent if lateral systems are provided.

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Vikrant Trivedi and Sumit Pahwa et al., reviewed the wind analysis of multi-story buildings and concluded that the structural analysis and design were predominate in the recognition of significant intimidation to the integrity and stability of a structure. When designed, multi-story structures are designed to meet basic aspects and serviceability.
Aditya verma and Ravindra Kumar Goliya et al., describe the wind load building response comparison and has considered the wind loading code of four countries, i.e., Japan, India, Hong Kong and New Zealand. The average value of the three codes of base shear (Japan, Hong Kong and New Zealand) is 31746.24, only 4.4 percent lower than the Indian code.

II. OBJECTIVES

A. To study the structural behaviour and strength parameter of defined hollow and solid circular columns subjected to wind excitations.
B. To study the structural behaviour of buildings subjected to wind loads in Bangalore region of Karnataka which has a basic wind speed of 33m/sec at different heights (G+15 &G+20) as specified in IS 875 (Part 3):2015.
C. To minimize the effects of wind on high rise structures.
D. To study the parameters such as storey displacements and storey drifts.
E. To analyze the building subjected to wind excitations using the recent updated version of IS 875 (Part 3):2015.

III.METHDOLOGY

In the present study, G+15 and G+20 storey RCC framed structure of plan dimension (36x32)m are used for studying the behaviour of hollow and solid circular columns in high rise buildings subjected to wind excitations. The frame model is structured as three dimensional model and ETABS software is used for analysis. All the geometric and material properties are assigned confirming to IS 456:2000. Dead loads are considered fromIS 875(Part 1)-1987 which includes self-weight of the RCC members, Floor Finishes, wall loads, staircase loads and light machine room load. Imposed loads are taken from IS 875(Part 2)-1987 which includes floor loads, terrace loads, staircase loads and lift machine room loads. Equivalent static wind analysis method has been adopted and the basic wind speed considered in here is 33m/sec. Loads and load combinations are considered from IS 875(Part 3):2015.
In this analysis two different types of columns are considered.

A. Hollow Circular Column
B. Solid Circular Column

The IS 875(Part 3):2015 states the conditions on which a building will be examined for dynamic analysis. They are as follows:
1) The ratio of height to minimum lateral dimension for buildings and closed structures should be more than 5.0.
In our case, for G+15 it is $\frac{47.5}{32} = 1$ and for G+20 it is $\frac{62.5}{32} = 1$
2) Building and structures whose natural frequency in the first mode is less than 1.0 Hz.
In our case, for G+15 it is $T = \frac{0.09x(47.5)}{\sqrt{36}} = 0$, where $T = \frac{0.}{\ }$, d= max. base dimension in meters
but, $f = \frac{1}{T} = \frac{1}{0.71} = 1.4$
For G+20 it is $T = \frac{0.09x(62.5)}{\sqrt{36}} = 0$, but $f = \frac{1}{T} = \frac{1}{0.93} = 1.07$
Therefore, Equivalent static analysis has been carried out in the present paper.

Table 1. Column section data

Building Storey	Column Type	Diameter	Outer Diameter	Inner Diameter
G+15	Hollow circular section	---	1200 mm	740 mm
	Solid circular section	950 mm	---	---
G+20	Hollow circular section	---	1000 mm	600 mm
	Solid circular section	800 mm	---	---

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Table 2. Building data

Type of structure:	Commercial building
Building Plan	36m x 32 m.
Storey Height	3 m each floor.
Height of building	32.5m, 47.5m and 62.5m.
Height of foundation	2.5m
Number of storeys	G+10,G+15and G+20.
Beam size	B 200X750mm
Slab thickness	S 150mm thick
Wall thickness	200mm
Shear wall thickness	200mm
Grade of concrete	M30 - Slabs & Beams M40 - Columns
Grade of steel	Fe500
Unit weight of concrete	25 KN/m^3
Unit weight of light weight blocks	11 KN/m^3

Table 3. Wind loads

Basic Wind Speed	33m/sec (IS 875 Part 3:2015)
Risk Coefficient	1.0(Refer Table 1)
Terrain roughness and height factor	Category 4 (Refer clause 5.3.2.1)
Topography Factor	1.0 (Refer clause 5.3.3)
Importance Factor	1.0 (Refer clause 5.3.4)
Structure Type	RCC Frame Structure

Table 4. Dead Loads

Wall load, 200mm thick (under 750mm beam)	4.95 kN/m
Parapet Wall load, 200mm thick (1m height)	2.2 KN/m
Staircase load (Self weight)	25 kN/m
Staircase load (Floor Finish)	6 KN/m
Floor Finish	1.5 kN/m^2
LMR load (Self weight)	10 KN/m

Table 5. Imposed Loads

Typical Floor load	3 kN/m^2
Roof Live load	1.5 kN/m^2
Above Terrace	0.75 kN/m^2
Staircase load	12 kN/m^2
LMR load	5 kN/m^2

Table 6. Load Combinations as per IS 875 Part 3:2015

1.5 DL + 1.5 LL
1.5 DL + 1.5 WLX
1.5 DL – 1.5 WLX
1.5 DL + 1.5 WLY
1.5 DL – 1.5 WLY
1.2 DL + 1.2 LL + 1.2 WLX
1.2 DL + 1.2 LL - 1.2 WLX
1.2 DL + 1.2 LL + 1.2 WLY
1.2 DL + 1.2 LL – 1.2 WLY

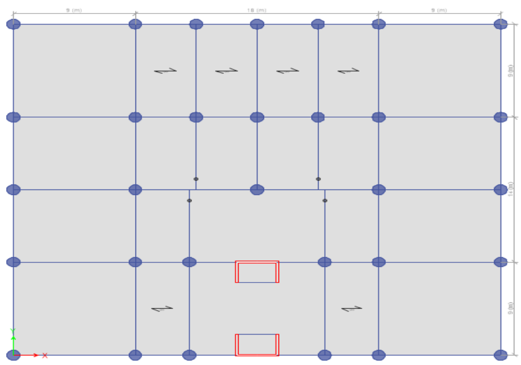


Figure 1. GA at typical floor level with solid columns

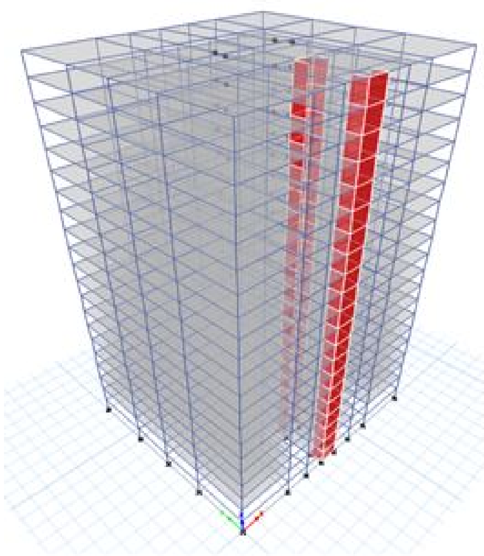
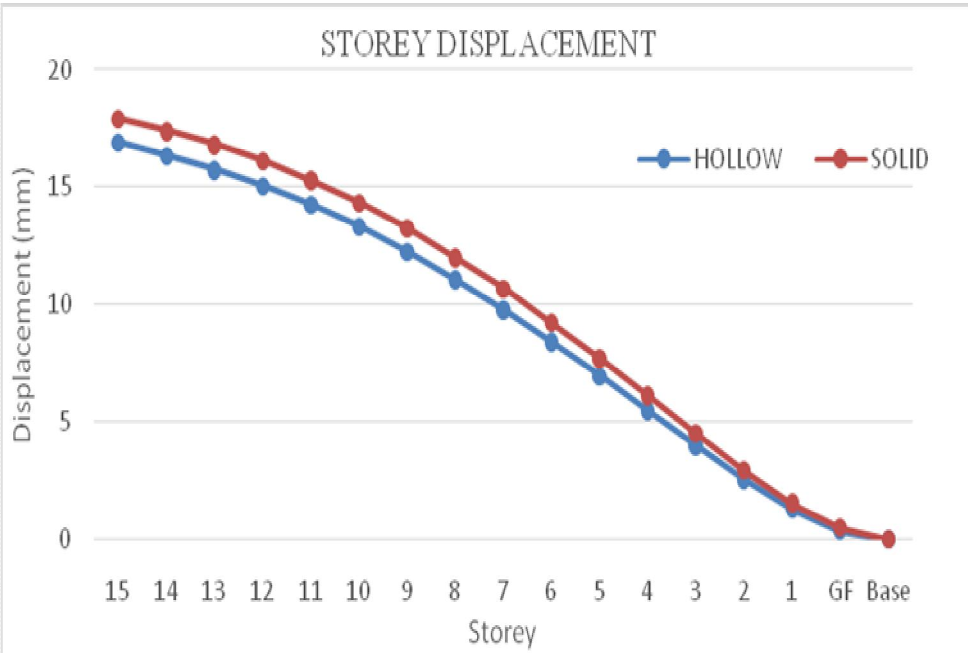


Figure 2 3D view of G+20 Storey Building

IV. RESULTS AND DISCUSSIONS

The following results have been procured from the analysis of G+15 storey building with solid and hollow circular columns subjected to wind loads for a basic wind speed of 33m/sec.

A. Storey Displacement



Graph 1. Storey displacement of hollow and solid circular columns in G+15 storey building

The above graph represents a maximum storey displacement of 17.895 mm for solid circular column, whereas a maximum storey displacement of 16.899 mm has been recorded for hollow circular columns in G+15 storeyed building which was subjected to wind loads for basic wind speed 33 m/sec. The graph clearly shows that the storey displacement varies linearly with the height of the building reaching to a maximum value at the top storey. Also the storey displacement for each storey is slightly higher for solid circular column when compared with hollow circular column.

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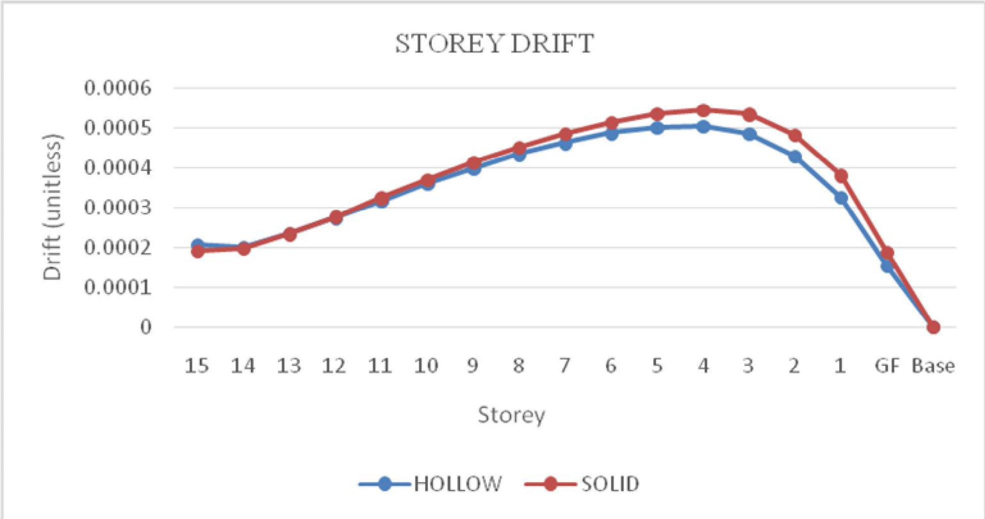
B. Storey Drift



Graph 2. Storey drift of hollow and solid circular columns in G+15 storey building

The above graph represents a maximum storey drift of 0.000543 at storey 5 for solid circular column, whereas a maximum storey drift of 0.000502 at storey 5 has been recorded for hollow circular columns in G+15 storeyed building which was subjected to wind loads for basic wind speed 33 m/sec. The graph clearly shows that the storey drift increases from storey 1 reaching to a maximum at storey 5 and then decreases above storey 5 until the top storey.

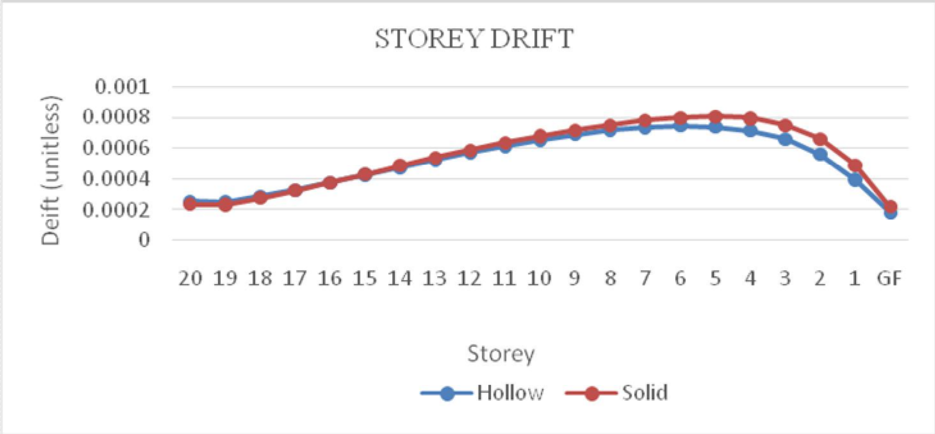
The following results have been procured from the analysis of G+20 storey building with solid and hollow circular columns subjected to wind loads for a basic wind speed of 33m/sec.

C. Storey Displacement

Graph 3. Storey displacement of hollow and solid circular columns in G+20 storey building

The above graph represents a maximum storey displacement of 34.159 mm for solid circular column, whereas a maximum storey displacement of 32.273 mm has been recorded for hollow circular columns in G+20 storeyed building which was subjected to wind loads for basic wind speed 33 m/sec. The graph clearly shows that the storey displacement varies linearly with the height of the building reaching to a maximum value at the top storey. Also the storey displacement for each storey is slightly higher for solid circular column when compared with hollow circular column.

D. Storey Drift



Graph 4. Storey drift of hollow and solid circular columns in G+20 storey building

The above graph represents a maximum storey drift of 0.000803 at storey 6 for solid circular column, whereas a maximum storey drift of 0.000738 at storey 6 has been recorded for hollow circular columns in G+20 storeyed building which was subjected to wind loads for basic wind speed 33 m/sec. The graph clearly shows that the storey drift increases from storey 1 reaching to a maximum at storey 6 and then decreases above storey 6 until the top storey.

V. CONCLUSIONS

The present study indicated the feasibility of using hollow circular concrete columns instead of solid circular concrete columns in high rise building construction. The following conclusions can be drawn out:

A. The results showed that the storey displacement was higher in solid circular column when compared to hollow circular columns in both (G+15) and (G+20) storey building for basic wind speed of 33 m/sec, thus proving that hollow circular columns are better in withstanding the wind load in high rise buildings.

B. A reduction in storey drift was noted in case of hollow circular columns when compared with solid circular columns in both (G+15) and (G+20) storey building for basic wind speed of 33 m/sec.

C. Ultimately, it was seen that the hollow circular columns performed better against the lateral wind loads when compare to the solid circular sections for a basic wind speed of 33m/sec.

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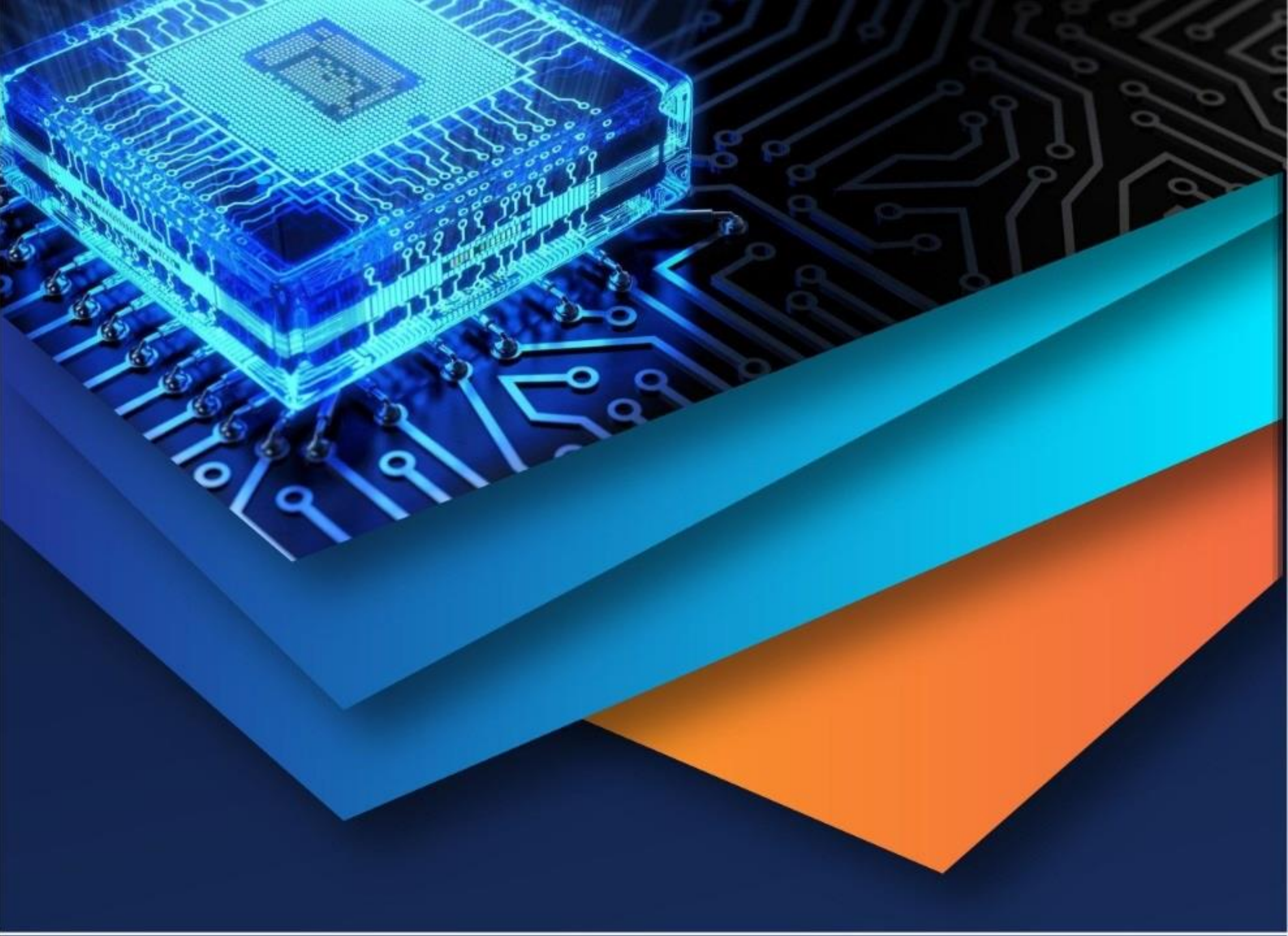

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