DYNAMIC WIND ANALYSIS OF RC BUNDLED TUBE IN TUBE STRUCTURE USING ETABS

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Abstract - *The goal of all super-tall projects is not simply to be the world's highest building; it's to embody the world's highest aspirations. As with all super-tall projects, difficult structural engineering problems are needed to be addressed and resolved. Advancing technology promotes to build in different way. Bundled tube structural system is one of the most efficient structural systems against heavy lateral loads. As tall structures are wind sensitive with increase in height, the same shall be designed for dynamic wind loads. This research presents vulnerability assessment study of tube in tube structures against heavy wind loads using dynamic wind analysis, when it is assembled as bundled tube structures. For the calculation of wind load and response the Gust factor method is used. The modeling and analysis are done using ETABS.*

Key Words: *Tall buildings, Bundled tube structure, Tube in Tube structure, Dynamic Wind analysis, ETABS*

1. INTRODUCTION

Due to influx of heavy population the towns and cities are growing very rapidly. This phenomenon can be seen all over the world. The paucity of available land for construction particularly in major cities all over is a common problem resulting in development of buildings more in vertical direction than in horizontal direction. Nowadays high-rise commercial buildings are icons of the modern society. These symbolize the power of commerce in the present world system. These also add a 3^{rd}dimension to the city. In addition, at the micro level, having a commercial space at an attractive high-rise building gives additional advantage to the business in terms of better customer confidence and corporate identity. High-rise buildings having very large number of stories are being constructed in urban towns and cities all over the world and India is also not exception phenomenon. Tall buildings consisting of multi-storied framework are flexible in nature and they are susceptible to action of wind forces.

1.1 Tubular Structure

The framed tube is one of the most significant modern developments in high-rise structural form. The tube frames consist of closely spaced columns distanced at 2-4 m between centres joined by deep girders. It acts like a hollow cylinder, cantilevered perpendicular to sky propped from the ground. The tube system can be constructed using concrete, steel or a composite of both. The idea is to create a tube that will act like a continuous perforated chimney or stack. The lateral resistance of framed tube structures is provided by very stiff moment resisting frames that form a tube around the perimeter of the building. This structural form offers an efficient, easily constructed structure appropriate for buildings having 40 to100 storeys.

1.2 Bundled Tube Structures

The bundled tube system involves, instead of one tube, several individual tubes interconnected to form a multi-cell tube. Together they work to resist the lateral loads and overturning moments. The increase in stiffness of the structure is apparent. The system allows for the greatest height and the most floor area. Not only is this system economically efficient but it also allows for more versatile building designs, adopting interesting shapes and bundled in dynamic groupings rather than being simply box-like towers.

1.3 Tube In Tube Structures

This is a type of framed tube consisting of an outer-framed tube together with an internal elevator and service core. The inner tube may consist of braced frames. The outer and inner tubes act jointly in resisting both gravity and lateral loading in steel-framed buildings. However, the outer tube usually plays a dominant role because of its much greater structural depth. This type of structures is also called as Hull (Outer tube) and Core (Inner tube) structures

1.4 Dynamic Wind Effect

The difference between the structural design as a result of wind of a typical high-rise building can be explained using the wind spectrum and natural frequencies, since the wind fluctuates with the time. According to winds speeds, wind pressure and the resulting structural response are generally treated as stationary random processes in which the time averaged or mean component is separated from the fluctuating component.

Tall buildings are bluff bodies and when the wind blows against the building vortices are created which result in an alternating force perpendicular to the wind direction. When the vortex shedding phenomenon takes place along a large part of the height of the building it can result in large forces

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and amplitudes. Wind load associated with gustiness or turbulence creating much greater building responses than if the same loads were applied gradually. Therefore wind loads need to be studied as if they were in dynamic in nature. The intensity of wind load depends on how fast it varies and also on the structure.

According to IS 875 part III, Dynamic effects of wind loading is described as flexible slender structures and structural elements shall be investigated to ascertain the wind induced oscillations or excitations along and across the direction of wind.

2. OBJECTIVES

1. To explore the innovative construction method bundled tube-in-tube structure
2. To analyze the effect of wind loading in bundled tube structures.
3. To compare the performance of building when the structure is developed under bundled tube in tube condition.
4. To study the efficiency of tall tubular concrete structures with respect the base shear, storey displacement and storey drift found out for all the models.

3. SOFTWARE USED

Modeling and analysis were done using ETABS (Extended 3D (Three-Dimensional) Analysis of Building Systems) 2016. ETABS is a structural analysis and design software. It can be used for linear, non-linear, static and dynamic analysis and for the design and detailing of any type of building and its components.

4. MODELLING OF BUILDING

A bundled tubular building with regular plan of area 2916sq.m at base and a height of 365.5 m above the ground level is modelled for the study. At the base of the building 9 modules form a square, of 18×18m, grouped as a closed square and arrive intact through the first 60 floors, finishing at different heights and creating a form with multiple levels. Such as diminishing of two tubes at 80th and 100th floor height levels respectively. From this level the number of modules / tubes is decreasing until it became only two reinforced concrete tubes from the 100th floor to the top. The building is supposed to be used for both commercial and residential purposes (mixed use type). Centre to centre distance between outer columns is 3m and that of inner columns is 6m. Belt beam is provided at every 20th floor height at the middle outer columns. Thus every 20th floor is considered as mechanical floors for the super elevators provided in the building. Refer to table 1 and Figure 1 & 2 (a, b, c, d & e) which show parameters of building design and plan of different storey level respectively.

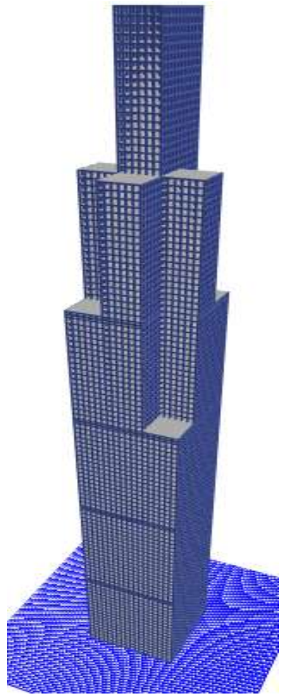
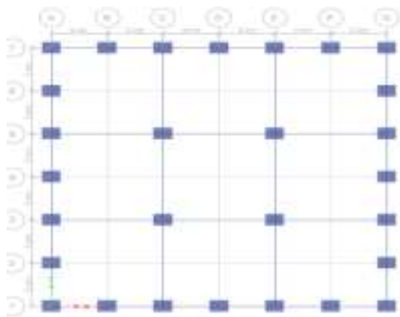
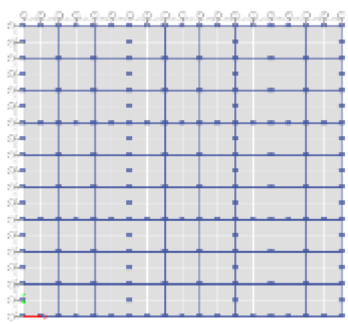


Figure 1

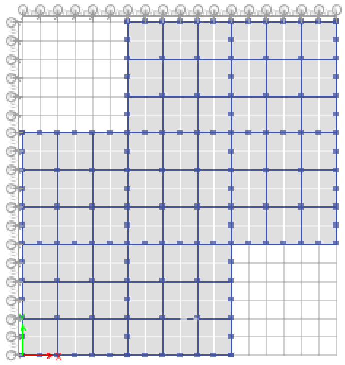
Rendered view of bundled tubular structure



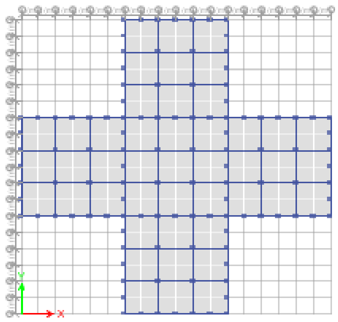
a) Plan of single tube



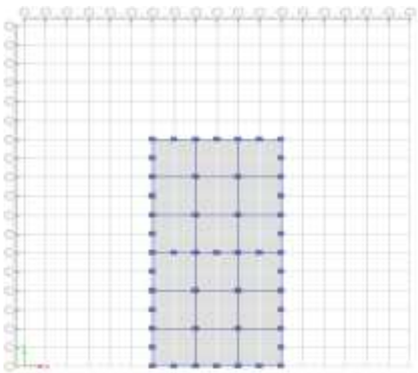
b) Plan of 1st -60th floor



c) Plan of 61-80th floor



d) Plan of 81- 100th floor



e) Plan of 101 -120th floor

Figure 2 Plan of bundled tube structure

Figure 3 Rendered view of tube in tube bundled tube structure

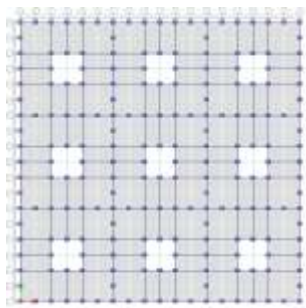


Figure 4 Base level plan of bundled tube in tube structure

4.1 Assumptions

Several important modeling and analysis approaches used for the parametric study are summarized as follows

- Building is assumed to be doubly symmetric in plan
- Both beams and columns sections are uniform throughout the height of the building
- Joints between slabs and beams are assumed to be rigid
- T-beam action is ignored
- Concrete floors are modeled with rigid diaphragm

- The building is idealized as a prismatic cantilever beam

4.2 Structural parameters

TABLE 1 PARAMETERS OF STRUCTURE

Sl. No	*Particulars*	*Data*
1	Number of storey	G+119
2	Storey height	• 3 m for all storey except ground storey • Ground 3.5m
3	Beam Size • Outer Beams • Inner Beams • Belt beam	800 x 800 mm 250 x 250 mm 800 x 1000 mm
4	Column Size	1000 x 800 mm
5	Slab Thickness	250 mm
6	Grade of Materials and Concrete	• M30 for all beams and slab except belt beam • M40 for all columns and belt beam • Fe415 steel for rebar

TABLE 2. SEISMIC PARAMETERS CONSIDERED

Seismic zone	III
Zone factor	0.16
Soil type	Medium
Importance factor	1.5
Response reduction factor	5

5. LOAD CALCULATION

Static Load

- LIVE LOAD = 4 KN/m^2
- DEAD LOAD

Self-weight of slab = 6 KN/m^2

Floor Finish = 1 KN/m^2

Total load on slab = 7 KN/m^2

5. ANALYSIS

Wind analysis

As per IS 875 part III, tall building/structures are 'wind sensitive' and shall be designed for dynamic wind loads. For calculation of along wind load and response the Gust factor method is used.

Flexible slender structures and structural elements shall be investigated to ascertain wind induced oscillations or excitations along and across the direction of wind. In general following guidelines are used for examining wind induced oscillations,

- Buildings or closed structures with a height to minimum lateral dimension ratio more than 5, and
- Buildings or closed structures whose natural frequency in first mode is less than 1.0 Hz

Along wind load on a structure on a strip area (Ae) at any height(z) is given by,

$F_Z = C_t A_e p_z G$

Where,

F_z = Along wind load on a structure at any height z corresponding to strip area Ae,

C_t = Force coefficient for the building,

A_e= Effective frontal area considered for the structure at height z,

p_z = design pressure at height z due to hourly mean wind obtained as

$0.6\ Vz^2 (N/m^2)$

G= Gust factor, and is given by:

$$= 1+ g_t r \sqrt{[B(1+\phi)^2 + (SE/\beta)]}$$

Where,

g_t = peak factor

r = roughness factor

The value of '$g_t r$' is given in (Figure 8*)

B = background factor, (Fig. 9*)

SE/β = measure of the resonant component of the fluctuating wind load

S = size reduction factor (Figure 10*)

E = Measure of available energy in wind stream (Fig. 11*)

β = Damping co-efficient (from table 34*)

ϕ = $g_t r/4$

* Figures and Tables of IS 875 part III

Dynamic wind analysis is done for both the models. The gust factor is calculated manually and value of gust factor G = 2.8064. The analysis is carried out by the ETABS software. The value of G is multiplied with wind load during analysis procedure.

6. RESULTS AND DISCUSSIONS

From the results obtained on the basis of response spectrum analysis and dynamic wind analysis for each models the results can summarise as follws.

TABLE 5. AVERAGE REDUCTION IN STOREY RESPONSES

Configuration	Storey displacement (%)	Storey Drift (%)	Base shear (%)
Bundled tubular structure	43.69	30.42	21.84
Bundled tube in tube structure	32.25	19.74	20.96

7. CONCLUSION

Bundled tube structural system is one of the most efficient structural systems against heavy lateral load. From the above results it is clear that bundled tube in tube structures response against heavy lateral loads of entire building. From the study it can be concluded that by providing shear core at the central portion of each tubes in bundled tubular structure can improve the efficiency of the structure. Thus it will act like bundled tube in tube structure. The portion of inner tubular core can be used for super elevators or double ducker elevators which is essential for super tall buildings. For super-tall buildings, connecting the inner tube with exterior mega columns opens up the facade system for flexible aesthetic and architectural articulation thereby overcoming a principal drawback of closed-form tubular systems.

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