DYNAMIC WIND ANALYSIS FOR HIGH RISE BUILDING – TYPICAL OBSERVATIONS

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Abstract
In the high rise building, wind is critical load and needs to be considered for safety and serviceability of structures. There is also need to understand critical effects and assess dynamic behaviour of structures as per the provisions of established standards. The Indian standard IS 875(part 3) is revised in 2015, many modifications are carried out in sections related to dynamic wind effects, very few research papers are available in relevance to these effects. Thus there is great need to understand dynamic wind effects in high rise structures, and prepare database for various sub sections and quantities mentioned in the standard. In this paper, along wind effect on both directions i.e. along shorter as well as longer direction located in category IV having varying base dimensions with same width along shorter direction with varying height of building from 42 to 60 m have been computed as per Indian Standard code IS 875(part 3): 2015 by the Gust Factor Method by developing excel sheets. Base dimension plays critical role, with the increase in dimension in the direction of wind, the response of building reduces.

Key Words: Dynamic wind effects, Along wind,, base dimension, High rise structures.

1. Introduction
One of the principal loads acting on above-ground structures is due to the wind. Accurate determination of design wind loads is important in achieving safety that is consistent with economy of construction. In professional practice throughout the world, design wind loads for a majority of structures are evaluated on the basis of wind load provisions specified in standards and codes. In the present day, advance changes in building construction technique have tended to make tall and more flexible structure for action of wind. So that wind loading are more significant along with other force acting on the structure which considered in design of low as well as flexible structure. We need to analyse the high rise building with considering all parameter of wind which are given by IS 875(Part 3):2015.

Static wind effect primarily causes elastic bending and twisting of structure. For tall, long span and slender structures dynamic analysis of the structure is essential. Wind gusts cause fluctuating forces on the structure which induce large dynamic motions, including oscillations [1]. Several failures of structures have occurred in India due to wind.[2]

Lateral loads due to wind which acting on multi story building can cause shake in the upper stories. This could be effect caused due to wind at upper stories as the wind intensity is increasing with graduating heights [3]. The wind pressures are fluctuating the nature and this is illustrated by the wind spectrum. There is a possibility of the fundamental frequency of the tall building structure machine with the wind frequency[4]. Tall buildings being flexible when subjected to randomly varying wind will experience wind forces which acts in the direction of wind known as along wind component resulting from buffeting effects caused by turbulence [5]. Wind loads and response to wind are important design parameters for many structures including bridges, high rise buildings, tall towers etc.; it is nowadays essential to ensure that such structures can survive the high winds and gusts likely to be encountered[6]. It is necessary for us to study it especially for Tall buildings that are prone to wind-induced oscillations [7]. Different codes have different approach to estimate wind load such as gust factor [8].

In this paper, different base dimensions are considered with varying height of storey. We have to apply static and dynamic wind effect according to their storey height because wind effect can vary with height. We have to find out whether wind effect varies with base dimension of building or not for better performance of building along both dimensions of buildings. We have to also know effect of static force over dynamic effect on the high rise building. Firstly, the effect of static and dynamic force with respect to base dimension and height of building with all considering parameter of wind as per IS 875(Part3): 2015 is investigated.

The paper consists of Relevant Codal Provisions, Basic assumptions made in analysis, Results and discussion and conclusion.
2. **Study of Codal Provisions**

The IS 875 (Part 3): 2015 recommends gust factor method for the calculation of dynamic wind loads depending on the type of building or structure. For that we have to find out aspect ratio i.e. height to minimum lateral dimension. We considered terrain category IV with basic wind speed 44 m/s.

Static force ($F_s$) can be calculated as follows:

$$F_s = C_{f,z} \times P_d \times A_z$$

Where, $A_z$ = surface area of structural element or cladding unit

$C_f,z$ = the drag force coefficient of the buildings corresponding to the area $A_z$

Design wind speed ($V_z$) at any height can be calculated as follows:

$$V_z = V_b \times k_1 \times k_2 \times k_3 \times k_4,$$

Where, $V_z$ = design wind speed at any height $z$ in m/s,

$k_1$ = Probability factor (risk coefficient)

$k_2$ = Terrain Roughness and Height Factor

$k_3$ = Topography Factor

$k_4$ = Importance Factor for Cyclonic Region

Design Wind Pressure - The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$P_z = 0.6 \times V_z^2$$

Where, $P_z$ = design wind pressure in N/m² at height $z$, $V_z$ = design wind velocity in m/s at height $z$ in m/s.

The design wind pressure $P_d$ can be obtained as,

$$P_d = K_d \times K_a \times K_c \times P_z$$

Where, $K_d$ = Wind directionality factor

$K_a$ = Area averaging factor

$K_c$ = Combination factor

ALONG WIND ANALYSIS

Flexible slender structure and structural elements shall be investigated to ascertain the importance of wind induced oscillations or excitations in along wind direction. Dynamic analysis needs to be conducted for wind load computation if the aspect ratio i.e. height to minimum lateral dimension ratio is more than 5 or the natural frequency in the first mode is less than 1.0 Hz. For Calculation of Time Period

1. For moment resisting frames without bracing or shear walls for resisting the lateral loads $T = 0.1 \times n$

Where, $n$ = number of storeys including basement storeys;

2. For all others $T = 0.09 \frac{H}{d}$

Where, $H$ = total height of the main structure of the building in metres,

$d$ = maximum base dimension of building in meters in a direction parallel to the applied wind force.

The design peak along wind base bending MOMENT, $(M_a)$ shall be obtained by summing the moments resulting from design peak along wind loads acting at different heights $z$, along the height of the building/structure and can be obtained from,

$$M_a = \sum F_z \times Z$$

Where,

$C_{f,z}$ = the drag force coefficient of the building/structure corresponding to the area $A_z$

$A_z$ = the effective frontal area of the building/structure at any height $z$ in m²

$V_{zd}$ = design hourly mean wind speed at height $z$, in m/s

$P_z = 0.6 \times V_z^2$

$P_d$ = design hourly mean wind pressure

$F_z = \text{design peak along wind load on the building/structure at any height } z$

Gust factor $(G)$ is given by:

$$G = 1 + r \sqrt{\left( g_v^2 \times B_s (1 + g) \right) + \left( \frac{H_s \times g_R^2 \times S \times E}{\beta} \right)}$$

Where,

$r$ = roughness factor which is twice the longitudinal turbulence intensity $(lh) = 2l_h$

$g_v$ = peak factor for upwind velocity fluctuation

$B_s$ = background factor indicating the measure of slowly varying component of fluctuating wind load caused by lower frequency wind speed variations.
Where, bsh = avg breadth of the building/structure between h and h

\[
L_n = \text{measure of effective turbulence length scale at } \text{ht} h, \text{ in m} = 85(h/10)^{0.25} \text{ for terrain category 1 to 3} = 70(h/10)^{0.25} \text{ for terrain category 4}
\]

\( \Phi \) = factor to account for the second order turbulence intensity

\[
\Phi = \frac{g_\nu^L h_i \sqrt{B_s}}{2}
\]

Hs = ht factor for resonance response

\[
H_s = 1 + \left(\frac{\varepsilon}{h}\right)^2
\]

S = Size reduction factor

\[
S = \frac{1}{\left[1 + \frac{3.5 f_a h}{V_{h.d}}\right] \left[1 + \frac{4 f_a b_{0h}}{V_{h.d}}\right]}
\]

Where,

b0h = av breadth of the building/structure bet 0 and h=20

E = spectrum of turbulence in the approaching wind stream

\[
E = \frac{\pi N}{(1 + 70.8 N^2)^{3/2}}
\]

N = effective reduced frequency

\[
N = \frac{f_a L_h}{V_{h.d}}
\]

Where,

f_a = first mode natural frequency of the building/structure in along wind direction in Hz

Vhd = design hourly mean wind speed at ht h in m/s

\( \beta \) = damping coeff of building/structure

gR = peak factor for resonant response

\[
gR = \sqrt{2 \ln(3600 f_a)}
\]

2. Basic Assumption Made in Analysis

High rise building of different base dimension of varying aspect ratio and height of buildings were analysed for along wind load calculation on the both direction of buildings. RC frame high rise structural parameters are listed in following tables. The wind loads were estimated considering the effect on both base direction of building. first one is the along shorter wind load calculation is assumed to act parallel to the shorter dimension and other one is along longer wind load calculation is assumed to act parallel to longer dimension.

A. Wind Analysis Data.

| Sr. No. | Parameters          | Details                  |
|---------|---------------------|--------------------------|
| 1       | Base dimension      | 20x20, 20x40, 20x60      |
| 2       | Height of Building  | 42m, 51m, 60m            |
| 3       | Terrain category    | IV                       |
| 4       | Basic wind speed    | 44m/s                    |
| 5       | Each storey height  | 3m                       |
| 6       | Grid size           | 5m                       |

3. Results and Discussions

The along wind loads acting on all the buildings considered are computed as per IS 875 (Part 3): 2015. The variation of the natural frequency with respect to aspect ratio of the buildings is shown in Fig.1 It was observed that the natural frequency decreased with increase in the building aspect ratio.

The variation of the drag force coefficient with respective height of structural building. It was observed that the drag force coefficient increases with increase in the height of structural building as shown in Fig 2.
Turbulence intensity, which is totally based on different terrain categories of structure varies with height of structure. As per IS 875 (Part 3): 2015 equations for different category are as follows:

| Terrain category | Equation                                      |
|------------------|-----------------------------------------------|
| 1                | $I_{w1} = 0.3507 - 0.05351 \log_{10} \frac{z}{z_{0.1}}$ |
| 2                | $I_{w2} = I_{w1} + \frac{1}{7}(I_{w4} - I_{w1})$   |
| 3                | $I_{w3} = I_{w1} + \frac{3}{7}(I_{w4} - I_{w1})$   |
| 4                | $I_{w4} = 0.466 - 0.135 \log_{10} \frac{z}{z_{0.4}}$ |

Alternative equations are developed for the turbulence intensity, figure 3 gives details of these equations. It was observed that there is almost negligible percentage error as comparing actual equation of turbulence intensity given by IS 875(Part 3): 2015 with interpreted graphical equation. In this equation, we have to give value of height of structure and we get turbulence intensity for that height as shown in Fig 3.

The wind load induced along shorter as well as longer direction obtained dynamic forces for all the buildings. It was observed that there is slightly increasing effect of base dimension on dynamic wind analysis when wind flow considered along shorter direction as shown in figure 4 & 5. These observation shows that dynamic effect is completely depend on increasing floor height of buildings. If we consider variation based on base dimension of building, it was observed that base dimension is more important for considering wind dynamic effect.

4. Conclusions

The following conclusions can be drawn.

1. Along wind induced response of high rise building is increasing with increasing aspect ratio i.e. h/b ratio due to this also drag force coefficient (Cf.z) increases with height of height of building structure.
2. From the observation of turbulence intensity for different terrain category, alternative equations developed gives turbulence intensity directly for various heights of structure.
3. Wind dynamic varies with increasing height of building structure, but it slightly varies with base dimensions also.
4. Wind dynamic effect is more along shorter dimension i.e. when we consider same width for all buildings than along longer direction where width is different for all building. Hence shorter dimension gives maximum along wind induced response as compared to longer direction.
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