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# Analytical Evaluation of Wind-Induced Response of Victory Valley Tower–C Using the Davenport Gust Factor Method

**Rambabu Sah**
M. Tech. in Structural Engineering, Department of Civil Engineering, CBS Group of Institutions, Jhajjar, Haryana.

**Jaswant Singh**
Structural Engineering, Department of Civil Engineering, CBS Group of Institutions – HR, Jhajjar, Haryana.

## ABSTRACT

This study analytically evaluates wind-induced loading and dynamic response of Victory Valley Tower–C, a 147-metre high-rise building in Gurugram, Haryana. The Davenport Gust Factor Method and IS 875 (Part 3): 1987 were applied to estimate height-wise wind velocity, pressure, and lateral forces. The assessment incorporated terrain characteristics, structural frequency, damping, atmospheric turbulence, resonance, and gust effects. Results showed that wind pressure and lateral force increased progressively with elevation. At 147 m, maximum pressure reached 1608.70 N/m², while lateral force reached 3806.82 kN. The study demonstrates the importance of dynamic wind analysis for safe, stable, serviceable, and economical high-rise structural design.

## I. Introduction

Wind load is a major design consideration for high-rise structures because increasing building height and slenderness make them more sensitive to wind-induced vibration, pressure, suction, and lateral movement. Rapid urbanization and high land costs have encouraged the construction of taller buildings, particularly in densely populated cities. Such structures may experience along-wind and across-wind responses generated by drag, lift, turbulence, vortex shedding, and fluctuating aerodynamic forces. Buildings having a height-to-width ratio greater than five or a fundamental natural frequency below 1.0 Hz require special assessment for dynamic wind effects. The Davenport Gust Factor Method, in accordance with IS 875: Part 3–1987, provides an analytical approach for estimating wind loads on regular high-rise structures. The present study focuses on Victory Valley Tower–C and evaluates its theoretical wind response and storey-wise lateral forces. The study aims to improve understanding of wind-induced structural behaviour and support safe, serviceable, and efficient high-rise building design.

## II. Reviews

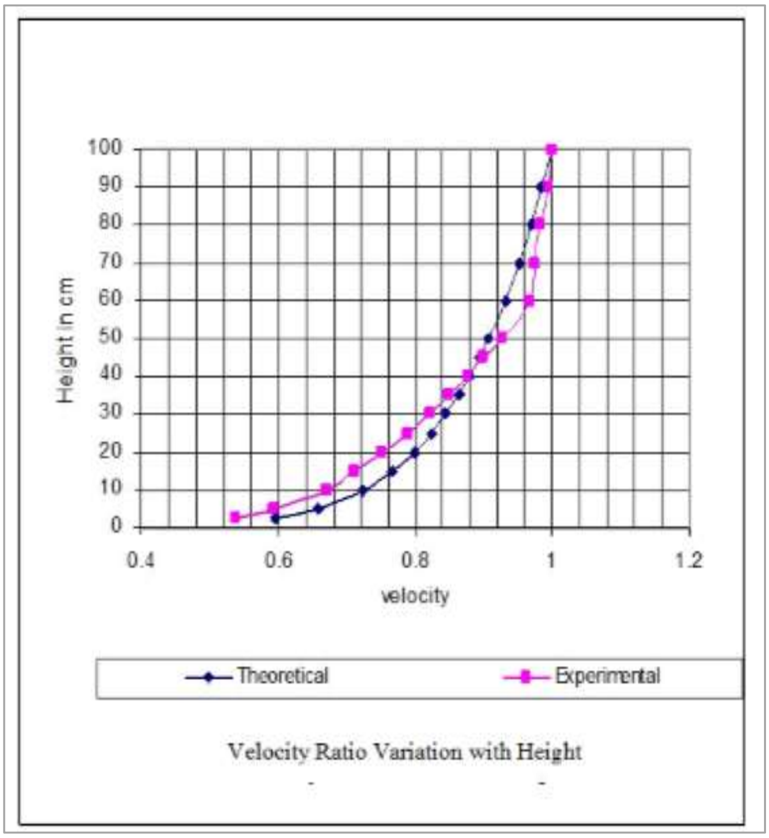
**Lee and Ng (1988)** compared estimated dynamic along-wind responses of tall structures using different analytical procedures. Their findings indicated that variations in modelling assumptions, turbulence characteristics, aerodynamic parameters, and structural properties could influence predicted responses. The study contributed to improving understanding of along-wind behavior and evaluating the reliability of available wind-response estimation techniques.

**Laomarsino (1998)** developed prediction models for estimating structural damping and vibration periods of buildings. The study emphasized that these dynamic properties strongly influence the wind-induced behavior of high-rise structures. Improved forecasting of damping and natural periods was shown to be valuable for estimating accelerations, displacements, resonant responses, and overall structural serviceability.

**Liang et al. (2002)** developed a mathematical model for evaluating across-wind dynamic loads acting on rectangular high-rise structures. The study examined aerodynamic excitation associated with vortex shedding and fluctuating pressure. Their model provided an effective analytical framework for predicting across-wind responses and highlighted the importance of crosswind effects in tall-building design.

## III. Methodology

The methodology of the present study focuses on the determination of wind loads acting on buildings and structural components in accordance with IS 875 (Part 3): 1987. Wind-resistant design is essential to ensure safety against shear, sliding, overturning, uplift, and excessive structural movement. Two principal methods are considered for calculating wind forces. Method 1, known as the simplified procedure, is generally applicable to regular low-rise buildings subjected to specified limitations. This method involves determining the basic wind speed, importance factor ($K_1$), terrain and height factor ($K_2$), and topography factor ($K_3$). These parameters are used to obtain the design wind pressure and simplified wind load acting on horizontal and vertical building surfaces.




**Velocity Ratio Variations with Height**

### 3.1 Method – 2 Analytical Procedures

The steps of analytical procedure, described in IS: 875 (PART 3) – 1987

1. Determine the basic wind speed, V, and wind directionality factor, $K_D$ in accordance with IS: 875 (PART 3) – 1987 section 5.1, 5.2, 5.3 with figure – 1.
2. Determine the importance factor, $K_1$, in accordance with IS: 875 (PART 3) – 1987 section 5.3.1 and table – 1.
3. Determine the exposure category coefficient $K_2$ and velocity pressure coefficients section 5.3.2 and table – 2 and section 5.5.
4. Determine the topographic factor, $K_3$, according to IS: 875 (PART 3) – 1987 section 5.3.3 and clause 5.3.3.1 appendix – c.
5. Determine the gust factor G in accordance with IS: 875 (PART 3) – 1987 section 8.
6. Determine the internal pressure coefficient $GC_{PI}$ in accordance with IS: 875 (PART 3) – 1987 section 6.2.3.
7. Determine the external pressure coefficients $C_P$, or $GC_{PE}$, or force coefficients in accordance with IS: 875 (PART 3) – 1987 section 6.2.2 and table – 4 and section 6.3 with table 23.
8. Determine the velocity pressure, $Q_Z$ in accordance with IS: 875 (PART 3) – 1987 The velocity pressure , $Q_Z$ at a height Z is calculated by the following equations

$Q_Z = 0.00256 * K_1 * K_2 * K_3 * V^2$ (LB/FT$^2$)

$Q_Z = 0.613 * K_1 * K_2 * K_3 * V^2$ (N/M$^2$)

1. Determine the design wind pressure, P or the design wind load. F, in accordance with IS: 875 (PART 3) – 1987 section 5.4.

The design wind pressure is given by this equation

$P = Q * G * C_P - Q_I * (G * C_{PI})$ (N/M$^2$)

The design wind load, F on a building is deliberate by the following equation,

$F = Q_Z * G * C_F * A_F$ (N)

## 4. Analytical Analysis of Wind Load On a High-Rise Structure

This chapter presents the analytical investigation of wind loading and dynamic response of Victory Valley Tower–C, Sector 67, Gurugram, Haryana, using the Davenport Gust Factor Approach in accordance with IS 875 (Part 3): 1987. High-rise structures are generally more sensitive to wind-induced effects because increasing height and structural slenderness lead to greater lateral forces, displacements, and dynamic oscillations. Consequently, the estimation of wind pressure and storey-wise lateral forces becomes an essential part of structural design. The analytical approach adopted in this study considers mean wind effects together with turbulence, resonance, terrain roughness, structural frequency, damping, and gust characteristics. The Davenport method is particularly useful for determining the dynamic response of tall structures subjected to fluctuating atmospheric wind. The present analysis was performed for a building having an overall height of 147 m. Wind velocity, wind pressure, and lateral forces were calculated at different elevations from the ground level to the top of the building at approximately 10 m intervals. The calculations provide a theoretical representation of the variation of wind action along the height of the structure.

## 4.1 Theoretical Background

### 4.1.1 Analytical Estimation of Dynamic Wind Response

The Davenport Gust Factor Approach was developed to represent the effect of atmospheric turbulence on structural response. The method combines the mean wind response with the fluctuating response produced by background turbulence and resonant excitation. The gust factor is defined as the ratio of the maximum structural response to the corresponding mean response. It therefore accounts for amplification in structural response due to wind gusts.

For a tall structure subjected to mean wind velocity at its upper level, the mean wind pressure is determined from air density, wind velocity, and aerodynamic drag characteristics. Wind speed increases with elevation and is influenced by terrain characteristics and surface roughness. The fluctuating wind response contains both background and resonant components. Background excitation represents the slowly varying turbulence acting on the entire structure, while resonant excitation occurs when the frequency components of wind approach the natural frequency of the building.

The gust factor can generally be expressed as:

$$G = 1 + g_f r\sqrt{B + R}$$

where is the gust factor; is the peak factor; is the roughness factor; denotes background turbulence excitation; and denotes resonant response excitation. The overall wind-induced structural response is evaluated by considering structural damping, natural frequency, reduced frequency, gust-energy characteristics, and size-reduction effects.

## 4.2 Building and Wind Parameters

The basic wind speed considered for Victory Valley Tower–C was **38 m/s**. The values of the risk coefficient (K_1) and topography factor (K_3) were taken as 1.0. The terrain and height factor (K_2) varied with elevation, increasing from approximately 0.50 at 10 m to 0.84 at 147 m. The reference wind velocity at 10 m was calculated as:

The reference wind velocity was calculated using:

$$V_{\text{ref}} = V_b K_1 K_2 K_3$$

At 10 m height:

$$V_{\text{ref}} = 38 \times 1.0 \times 0.50 \times 1.0 = 19.0\ \text{m/s}$$

At the highest level (147 m):

$$V_{\text{ref}} = 38 \times 1.0 \times 0.84 \times 1.0 = 31.92\ \text{m/s}$$

At the highest level, the corresponding design wind velocity based on the selected factors was calculated using the same relationship. Important dynamic parameters adopted in the analytical study included a structural frequency of 0.196 Hz, damping coefficient of 0.035, natural period of approximately 5.10 seconds, and peak factor of approximately 3.78. The final gust factor used in the storey-wise force calculations was approximately 2.23.

### 4.3 Calculation of Wind Pressure and Wind Force

The design wind pressure at any elevation was evaluated from:

$$P_z = 0.6V_z^2$$

where $P_z$ is the design wind pressure in N/m² and $V_z$ is the design wind velocity at the corresponding height in m/s.

The lateral wind force acting on the structure was then calculated as:

$$F_h = G \times A_e \times C_p \times P_z$$

The analytical calculations showed a progressive increase in wind velocity, pressure, and lateral force with increasing building height. At ground level, the wind force was considered zero. At 10 m, the wind velocity was approximately 19 m/s, producing a wind pressure of 216.60 N/m² and a lateral force of approximately 512.50 kN. At 50 m, the calculated pressure increased to approximately 757.42 N/m², corresponding to a force of 1792.35 kN. At 100 m, the wind pressure reached approximately 1238.33 N/m², while the corresponding lateral force was approximately 2930.38 kN.

**Victory Valley Tower – C, Gurugram (Haryana, India)**

At the uppermost elevation of 147 m, the calculated wind velocity used in the height-wise response reached approximately 51.78 m/s. The resulting wind pressure was approximately 1608.70 N/m², while the maximum storey-level lateral force was approximately 3806.82 kN. The total lateral wind force obtained by summing the forces acting at the various levels was reported as approximately 35,649.20 kN.

### 4.4 Analytical Response of Victory Valley Tower–C

| Height (m) | Wind Pressure (P_z) (N/m²) | Lateral Force (F_z) (kN) |
|---|---|---|
| 10 | 216.60 | 512.50 |
| 30 | 526.76 | 1246.52 |
| 50 | 757.42 | 1792.35 |
| 70 | 945.17 | 2236.50 |
| 90 | 1138.48 | 2694.09 |
| 110 | 1214.50 | 3110.63 |
| 130 | 1466.58 | 3470.50 |
| 147 | 1608.70 | 3806.82 |

The results clearly demonstrate that wind loading becomes progressively more significant toward the upper levels of the building. The increase results from the rise in wind velocity with elevation, which directly increases wind pressure and consequently the lateral force acting on the structure. The upper portion of the tower therefore experiences considerably greater wind-induced demand than the lower levels.

### 4.5 Result and Discussion

The analytical study of Victory Valley Tower–C demonstrates the effectiveness of the Davenport Gust Factor Method for estimating dynamic wind effects on a high-rise structure. The results indicate a continuous increase in wind pressure and lateral force with height. The maximum storey-level force was observed at the top elevation of 147 m, while the cumulative lateral wind force was reported as 35,649.20 kN. The calculated response emphasizes the importance of considering dynamic wind effects in the structural design of tall and slender buildings. Parameters such as building height, terrain condition, natural frequency, damping, turbulence, aerodynamic characteristics, and gust effects significantly influence the overall response. The analytical results obtained in this chapter provide the necessary basis for evaluating the wind-resistant performance of Victory Valley Tower–C and for understanding the distribution of lateral wind forces throughout its height.

## 5. Conclusion

The study concludes that structural height strongly influences wind velocity, pressure, and lateral loading on Victory Valley Tower–C. Application of the Davenport Gust Factor Method effectively represented mean wind response, background turbulence, resonant excitation, damping, and dynamic amplification. Wind pressure increased from 216.60 N/m² at 10 m to 1608.70 N/m² at 147 m, while the corresponding lateral force rose from 512.50 kN to 3806.82 kN. The accumulated lateral wind force was approximately 35,649.20 kN. These findings confirm that dynamic wind assessment is essential for controlling displacement, vibration, stability, serviceability, and occupant comfort in slender high-rise buildings under severe wind conditions.

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