



Assessment of building geometry on wind-induced dynamic behaviour of high-rise buildings in coastal areas

Rahul. S. Patil* and N. K. Patil

Department Of Civil Engineering, Sanjay Ghodawat University, Kolhapur, India.

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Abstract

The growing trend of vertical development in coastal cities has increased the need to understand the behaviour of high-rise buildings subjected to wind loading. The present study focuses on assessing the wind response of a G+30 reinforced concrete building with different plan configurations situated in a coastal environment. Wind loads will be determined using the Gust Factor Method as specified in IS 875 (Part 3), allowing the dynamic effects of wind to be incorporated into the analysis. Four building layouts, namely square, L-shaped, C-shaped, and T-shaped plans, having the same floor area, will be considered for comparison. Structural modelling and analysis will be performed using ETABS software. To examine the influence of vertical irregularity, soft storey provisions will be introduced at the 15th, 20th, and 25th floor levels in each building model. The performance of the structures will be assessed using response parameters such as lateral displacement, storey drift, base shear, and torsional response under wind action. The study aims to examine the combined influence of plan geometry and soft storey irregularity on the dynamic behaviour of tall buildings located in coastal regions.

Keywords: Wind Load Analysis; Gust Factor Method; IS 875 (Part 3); High-Rise Buildings; Coastal Structures

1. Introduction

Rapid urbanization and limited availability of land in coastal cities have led to the construction of increasingly tall and slender buildings. These structures generally possess higher aspect ratios, making them more susceptible to wind-induced forces than conventional low- and mid-rise buildings [7,11]. Coastal environments further intensify this challenge due to the absence of significant terrain obstructions, resulting in higher wind speeds and increased turbulence effects on structures [3,12]. As building height and flexibility increase, the assumptions associated with static wind load analysis become less reliable for predicting actual structural response. Consequently, dynamic wind analysis has become an essential component in the design and assessment of modern high-rise buildings, enabling engineers to accurately evaluate wind-induced vibrations, serviceability requirements, and overall structural safety under varying wind conditions [1,2,4].

Recent developments in climatic conditions have highlighted the need for a more comprehensive assessment of wind effects on tall buildings. Variations in wind patterns, extreme weather events, and changing environmental conditions have increased concerns regarding the adequacy of conventional wind load estimation methods based solely on historical data. Design codes such as IS 875 (Part 3):2015 provide standardized procedures for evaluating wind loads; however, the complex nature of modern wind environments often requires advanced analytical approaches to accurately predict structural response [4,12]. In densely developed coastal urban areas, the close spacing of high-rise buildings can significantly alter local wind flow patterns, resulting in interference effects that modify wind pressures and dynamic responses. These interactions may lead to increased structural vibrations, occupant discomfort, and

* Corresponding author: Rahul. S. Patil

additional demands on façade systems and secondary structural components. Therefore, a detailed investigation of wind-induced behaviour through dynamic analysis has become increasingly important for ensuring the safety, serviceability, and long-term performance of modern tall buildings [3,6,8,10].

Rapid urban growth and limited availability of developable land in urban areas have encouraged the construction of high-rise buildings to meet the increasing demand for residential, commercial, and institutional spaces. Vertical development has emerged as an effective approach for optimizing land use while accommodating population growth and economic expansion. As building height increases, structures become more susceptible to lateral forces, particularly those generated by wind and seismic activities. Among these forces, wind loading is often a governing factor in the design of tall buildings due to its continuous action and significant influence on structural stability, occupant comfort, and serviceability requirements. The impact of wind becomes more pronounced in coastal regions, where higher wind velocities and turbulent flow conditions can induce considerable structural responses, making accurate wind analysis essential for safe and economical design [3,7,11,12].

1.1. Wind Effects on High-Rise Buildings

Wind interaction with tall buildings is a complex phenomenon involving both static and dynamic components. The total wind load consists of [4,10]:

- Mean wind component
- Fluctuating (gust) component
- Dynamic effects become significant in tall and slender structures where wind-induced vibrations can lead to [1,2,3]:
 - Excessive lateral displacement
 - Increased storey drift
 - Human discomfort due to acceleration
 - Structural fatigue

In coastal regions, wind speeds are generally higher, and terrain conditions lead to increased turbulence intensity, making dynamic analysis essential for accurate assessment of structural behaviour and serviceability performance [3,6,12]

1.2. Wind Analysis

Dynamic wind analysis is necessary to capture the realistic behaviour of tall buildings under fluctuating wind loads. It provides a better understanding of how the structure responds over time, considering factors such as building height, natural frequency, damping, and wind turbulence [1,2,3]. In Indian practice, the Gust Factor Method given in IS 875 (Part 3) is widely used to calculate dynamic wind loads for tall buildings. This method considers the amplification of wind forces caused by gustiness and structural flexibility, making it suitable for evaluating wind effects on high-rise structures [4,10].

The gust factor is used in wind load calculation to account for the dynamic nature of wind, since wind does not act as a constant force but varies continuously due to gusts and turbulence. In high-rise buildings, these fluctuations can generate additional vibrations and increase the lateral response, which may not be adequately represented by static wind analysis. Therefore, the Gust Factor Method is adopted to estimate peak wind effects more accurately, ensuring safer design against wind-induced displacement, storey drift, and torsional response, particularly in coastal regions where wind intensity and turbulence levels are comparatively higher [3,10,12].

2. State Of Development

It highlights the importance of considering gust effects, wind-induced vibrations, and serviceability criteria such as lateral displacement, storey drift, and occupant comfort in the design of tall buildings [1,2,10]. The review also focuses on the influence of building geometry, aspect ratio, and plan irregularity on wind response, including torsional behaviour and overall structural performance [3,7,8,11]. In addition, it discusses the application of analytical tools such as ETABS, Computational Fluid Dynamics (CFD), and code-based approaches including the Gust Factor Method for evaluating wind effects on high-rise structures [4,6]. This chapter assists in identifying the significant findings reported in previous studies and helps establish the research gap addressed in the present investigation [1,3,4].

Qinhua Wang et. al. [1] (2021) developed an innovative passive vibration control device known as the Tuned Liquid Column Damper-Inerter (TLCDI) to reduce wind-induced responses in adjacent high-rise buildings. The proposed

system combines the energy dissipation capability of a Tuned Liquid Column Damper (TLCD) with the mass amplification effect of an inerter, thereby improving vibration control efficiency. A mathematical model of two connected tall buildings subjected to wind loading was formulated, and an equivalent linearization approach was adopted to evaluate the dynamic response. The analytical results were further validated through numerical simulations. The performance of the optimized TLCDI system was compared with that of conventional TLCD arrangements installed in benchmark structures. The study demonstrated that the TLCDI achieved superior vibration mitigation despite having a significantly lower mass. At an across-wind direction of 90° , the device reduced acceleration responses by 37.7% in Building-1 and 42.0% in Building-2. The findings confirmed that TLCDI is an effective and lightweight solution for controlling wind-induced vibrations in high-rise buildings [1].

Nahmat Khodaie et. al. [2] (2023) carried out a parametric investigation to evaluate the effectiveness of Tuned Mass Dampers (TMD) and Tuned Liquid Column Dampers (TLCD) in controlling along-wind and across-wind vibrations of tall buildings. The building was modeled as a multi-degree-of-freedom cantilever system with lumped masses at nodal locations, and its dynamic response was determined using frequency-domain analysis and random vibration theory. The study examined the influence of several parameters, including basic wind speed, damper mass ratio, and the geometric configuration of the TLCD system. The results showed that both TMD and TLCD devices significantly reduced wind-induced structural responses, particularly acceleration. It was observed that the efficiency of the TLCD system was strongly influenced by the ratio of horizontal length to the total liquid column length. As the horizontal length increased, the vibration control performance of the TLCD approached that of the TMD. Although the TMD provided slightly better vibration reduction, the TLCD was found to be more advantageous for practical implementation due to its enhanced safety, lower installation and maintenance costs, and potential for multiple functional uses within buildings [2].

Qinhua Wang et. al. [3] (2023) investigated the wind-induced behaviour of a super high-rise building having different cross-sectional configurations and a high aspect ratio. Due to increasing urban density and site constraints in metropolitan areas, such slender buildings are becoming more common and are highly susceptible to wind effects. To evaluate their performance, atmospheric boundary layer wind tunnel tests were conducted on a practical building model along with its surrounding structures. The study focused on determining equivalent static wind loads (ESWLs), wind-induced responses, and the distribution of wind pressures over the building surfaces. Special attention was given to the base overturning moment about the axis having lower lateral stiffness, which is critical for structural design. The results revealed that the maximum wind-induced base overturning moments and acceleration responses occurred at wind directions of 60° and 330° , rather than at the conventional orthogonal directions. It was also observed that surrounding buildings significantly influenced the wind pressure distribution due to aerodynamic interference effects. The study concluded that building geometry, aspect ratio, and neighboring structures play an important role in determining wind response, and these factors should be carefully considered in the wind-resistant design of super high-rise buildings [3].

Shirlin Charles et. al. [4] (2018) conducted a comparative study to evaluate wind loads on tall buildings using Computational Fluid Dynamics (CFD) and the provisions of IS 875 (Part 3). The authors highlighted that the code-based approach has certain limitations, as pressure coefficient (C_p) values are primarily available for standard building shapes and for wind incidence angles of only 0° and 90° . To overcome these limitations, a numerical investigation was carried out using ANSYS Fluent 15.0 to simulate wind flow around different building configurations specified in IS 875 (Part 3). The wind loads obtained from CFD analysis were compared with those calculated using code provisions. The results showed good agreement between the two approaches, demonstrating the reliability of CFD as an alternative tool for wind load assessment. In addition, mean area-weighted pressure coefficients were determined for various wind incidence angles, providing a more comprehensive understanding of wind pressure distribution on building surfaces. The study concluded that CFD can effectively supplement conventional code-based methods for accurate prediction of wind-induced effects on tall buildings [4].

Ahmet Durap et. al. [5] (2025) investigated the application of interpretable machine learning techniques for improving coastal wind prediction and risk assessment. The study demonstrated the effectiveness of the Random Forest Regression (RFR) model in predicting wind behaviour under complex coastal meteorological conditions and showed its superiority over conventional prediction approaches. To enhance model transparency and interpretability, SHAP (Shapley Additive Explanations) analysis was employed to identify the most influential parameters affecting wind prediction. The results indicated that wind direction and atmospheric pressure were the dominant predictors of extreme wind events, with southeast and south-southwest wind directions (100° – 200°) having a significant impact on coastal hazards. The developed model achieved approximately 84% accuracy in forecasting wind conditions up to six hours in advance. Furthermore, the study highlighted the usefulness of integrating machine learning models with seasonal and temporal meteorological analyses to identify high-risk periods and support decision-making for coastal

protection measures, storm surge prediction, and early warning systems. The findings confirmed that interpretable machine learning approaches can significantly enhance coastal risk management and contribute to the development of resilient and sustainable coastal infrastructure systems [5].

Chengdong Feng et. al. [6] (2021) investigated the influence of wind veering on the wind-induced behaviour of square-section super high-rise buildings using Computational Fluid Dynamics (CFD). The study highlighted that most previous research primarily considered the variation of wind speed with height, while the effects of wind veering caused by the Ekman layer were often neglected. After validating the numerical simulation methodology, Large Eddy Simulations (LES) were performed on a three-dimensional square-section building model with an aspect ratio of approximately 9:1 under various wind directions ranging from 0° to 75°. The wind loads obtained from cases with and without wind veering were compared, and the associated flow mechanisms were examined in detail. The results showed that the inclusion of wind veering significantly altered the wind pressure distribution and loading patterns. In particular, wind loads corresponding to wind directions between 60° and 75° were found to be greater than those produced under a conventional 0° wind direction without veering effects. The study also emphasized that, in cities where prevailing winds occur at non-zero directions, the resulting wind loads may become the governing design loads. The authors concluded that wind veering should be carefully considered in the wind-resistant design of super high-rise buildings to ensure accurate assessment of structural response and safety [6].

M. R. Wakchaure et. al. [7] (2015) conducted an analytical study to evaluate the influence of building shape on the wind response of high-rise structures. The authors observed that modern tall buildings are becoming increasingly sensitive to wind effects due to their slenderness, flexibility, reduced weight, and complex geometrical configurations. Various building plan shapes were considered and analyzed under wind loading conditions calculated in accordance with IS 875 (Part 3):1987, both with and without the application of the Gust Factor Method. The structural models were developed and analyzed using ETABS 13.1.1 software to assess important response parameters such as storey displacement, storey drift, and storey shear. A comparative evaluation was carried out to determine the effect of building geometry on wind-induced structural behaviour and overall performance. The study concluded that building shape has a significant influence on wind response and structural efficiency, and therefore should be carefully considered during the design stage of high-rise buildings to achieve improved wind-resistant performance [7].

Liu, Y.; Kopp, Gregory [8] (2022) conducted a wind tunnel investigation to study the influence of plan dimensions on gust wind loads acting on high-rise buildings. Scale-model pressure measurements were performed on rectangular-plan buildings with plan ratios varying from 0.11 to 9. The study evaluated mean, fluctuating, and peak wall pressure coefficients along with area-averaged pressure distributions. Furthermore, the experimental results were compared with the provisions specified in ASCE 7-16 for the Main Wind Force-Resisting System (MWFRS). The findings indicated that plan ratio significantly affects pressure coefficients on leeward and side walls, particularly for plan ratios less than 4. The maximum mean base shear coefficient was observed at a plan ratio of approximately 0.67, while lower or higher plan ratios resulted in reduced values. Comparisons with ASCE 7-16 showed that the code generally underestimated both mean and peak wind load coefficients, mainly due to differences in leeward wall pressure coefficients and the gust effect factor. Experimental measurements suggested that the gust effect factor for rigid buildings is closer to 1.0 for plan ratios ranging between 0.67 and 2, whereas ASCE 7-16 recommends a value of 0.85. The study concluded that building plan ratio plays a crucial role in determining wind loads and should be carefully considered in the wind-resistant design of high-rise structures [8].

Sumit Pahwa et. al. [9] (2017) investigated the behaviour of a 30-storey reinforced concrete building under different soil conditions, considering the presence and absence of shear walls. The study emphasized the importance of shear walls as an effective lateral load-resisting system capable of improving structural stability against wind and earthquake forces. Recognizing that buildings are often designed assuming fixed-base conditions on hard, medium, or soft soils, the authors highlighted the significance of soil-structure interaction (SSI) in accurately assessing structural performance during seismic events. The research focused on understanding the transfer of seismic energy from the supporting soil to the building and evaluating its effect on overall structural response. A symmetrical high-rise building located in Seismic Zone V was modeled and analyzed using STAAD.Pro software under varying soil conditions. Comparative analyses were performed for buildings with and without shear walls. The results demonstrated that soil characteristics significantly influence the seismic response of high-rise structures and that the inclusion of shear walls considerably enhances lateral stiffness and overall structural performance. The study concluded that both soil conditions and lateral load-resisting systems must be carefully considered in the design of earthquake-resistant tall buildings [9].

Jin Wang et. al. [10] (2021) examined the aerodynamic characteristics associated with gust effect factors acting on the windward walls of rigid buildings. The study utilized experimental data obtained from 58 rectangular-plan building models to investigate the statistical properties of windward wall pressures, including skewness, kurtosis, peak factors,

wind spectra characteristics, and aerodynamic admittance functions. The results indicated that these pressure characteristics are strongly influenced by the aspect ratio (H/B), defined as the ratio of building height to breadth. It was observed that area-averaged windward wall pressures tend to follow a Gaussian distribution when the aspect ratio exceeds 6. The study also found that the measured aerodynamic admittance function agreed well with Vickery's theoretical model when referenced to mid-height velocity spectra. Furthermore, pressure fluctuations on low-rise buildings ($H/B < 1$) were significantly affected by horseshoe vortices, whereas high-rise buildings experienced additional influences from vortex shedding near side-wall edges. A comparison with ASCE 7–16 provisions revealed that the adopted gust effect factor model provides accurate predictions for rigid high-rise buildings but is less reliable for low-rise structures due to the complex aerodynamic effects generated by horseshoe vortices. The study highlighted the importance of considering building aspect ratio and aerodynamic behaviour for accurate estimation of gust-induced wind loads [10].

K. Vishnu Haritha [11] (2013) studied the effect of wind on tall building frames with different aspect ratios. The authors highlighted that wind plays a significant role in the design of tall structures due to its dynamic characteristics. The effect of wind depends on factors such as the location and height of the structure. In this study, the Equivalent Static Method was adopted for the analysis of wind loads on buildings having different aspect ratios. Aspect ratios of 1, 2, and 3 were considered by varying the number of bays. The structural analysis was carried out using STAAD.Pro software to evaluate the behaviour of buildings subjected to wind loading [11].

B. Dean Kumar and B.L.P. Swami [13] (2010) studied the effect of wind loads on tall buildings and high-rise towers in India. The authors pointed out that the increasing construction of tall structures requires careful consideration of wind forces during the design stage, similar to other slender structures such as transmission towers, microwave towers, cooling towers, and multi-storeyed building towers. The study also highlighted that several structural failures in India have been attributed to wind effects. Wind load evaluation was carried out in accordance with the provisions of IS 875 (Part 3). The Gust Effectiveness Factor Method was adopted in the analysis as it provides a more realistic estimation of wind loads acting on flexible and slender structures. Building frames of different heights were analyzed to study their behaviour under wind loading conditions [13].

Mohammed Asim Ahmed, et. al. [12] (2015) studied the effect of wind loads on tall buildings under different terrain categories. The authors explained that wind speed varies depending on the surrounding terrain, with lower wind speeds occurring in rough terrain and higher wind speeds in smooth terrain conditions. In this study, three building models were analyzed using ETABS 2015 software to evaluate storey displacements caused by wind loading. The research examined the variation in deflection with changes in building height and compared the percentage change in deflection of the same building model under different terrain categories. The study provided useful information regarding the influence of terrain conditions on the wind-induced response of tall buildings [12].

K. Rama Raju, et. al [14] (2013) studied the analysis and design of a 40-storey reinforced concrete high-rise building subjected to wind and earthquake loads. The authors emphasized the importance of considering site-specific lateral loads along with gravity loads to accurately evaluate the behaviour of tall buildings. The study noted that the requirement of structural material increases significantly with building height due to the need to resist lateral forces. The design process involved conceptual planning, approximate analysis, preliminary design, and optimization to ensure adequate performance under both vertical and lateral loading conditions. The analysis and design were carried out using the limit state method in accordance with relevant Indian Standard codes. Structural safety was evaluated by checking parameters such as base shear, roof displacement, inter-storey drift, and acceleration against permissible limits specified in design codes and related literature. The study highlighted the importance of satisfying strength, serviceability, and occupant comfort requirements in the design of tall buildings [14].

Mohammed Elwi, et. al. [15] (2018) studied the effect of soil-structure interaction on multi-storey buildings subjected to earthquake loading. The authors highlighted that although structures are supported on soil, the influence of soil-structure interaction is often neglected during structural design. The study emphasized that soil properties significantly affect the propagation of seismic waves and consequently influence the response of the structure during an earthquake. In this research, multi-storey buildings with rigid and flexible foundation systems were analyzed under hard, medium, and soft soil conditions as specified in IS 1893:2002. The analysis was performed using the Response Spectrum Method in SAP2000 software. Parameters such as lateral displacement, storey drift, base shear, axial force, and column moments were evaluated for different building frames. The study provided a comparative assessment of the seismic response of buildings considering various soil conditions and foundation types, highlighting the importance of soil-structure interaction in seismic analysis and design [15].

Ketan Bajaj et. al. (2013) investigated the seismic behaviour of buildings under different soil conditions. The study emphasized that structural response during earthquakes varies significantly depending on the characteristics of the supporting soil, such as hard, medium, and soft soil. The authors highlighted that soil properties influence the propagation of seismic waves and affect the interaction between the structure, foundation, and ground. In this research, buildings with different numbers of storeys (G+4, G+5, and G+6) were considered under Seismic Zones III, IV, and V. The analysis was carried out in accordance with the response spectrum provisions of IS 1893:2002 for different soil types. Building models were developed in SAP2000 software using Winkler spring foundations to represent various soil conditions. Parameters such as base shear and lateral displacement were evaluated to study the influence of soil characteristics on seismic response. The study provided useful insights into the role of soil conditions in earthquake-resistant design and geotechnical earthquake engineering applications [16].

Amer Hassan, et. al. [17] (2018) investigated the effect of soil conditions on the seismic response of base-isolated buildings. The study employed nonlinear time history analysis and response spectrum analysis using ETABS 2015 software to evaluate the influence of soil flexibility beneath isolated foundations. Different soil conditions were considered, and parameters such as spectral acceleration, spectral displacement, base shear, storey displacement, storey drift, and storey shear were examined in accordance with Indian seismic design provisions. A parametric study was carried out to assess the performance of buildings equipped with base isolation systems under various soil conditions. The results indicated that base shear increased with increasing soil flexibility and superstructure stiffness. It was also observed that spectral acceleration and spectral displacement were higher for soft soil conditions, demonstrating the significant influence of soil properties on structural response. The study concluded that hard and medium soils are more suitable for base-isolated buildings and provided recommendations to assist designers during the preliminary design stage of isolated and conventional structures [17].

M Roopa, H. G. Naikar, Dr. D. S. Prakash, [18] (2015) studied the influence of Soil Structure Interaction (SSI) on the seismic response of reinforced concrete buildings. The authors explained that SSI is a phenomenon in which the response of soil to earthquake ground motion affects the behaviour of the structure, while the structural response simultaneously influences the surrounding soil mass. The study noted that multi-storey buildings are commonly analyzed by assuming fixed-base conditions using the provisions of IS 1893:2002; however, the actual soil conditions surrounding the foundation also contribute to the seismic response. Unlike conventional SSI studies that consider hard, medium, and soft soils, the present investigation focused specifically on in-situ clayey soil conditions. A G+12 storey reinforced concrete apartment building with a height of 40.15 m and plan dimensions of 28.2 m × 16.1 m, located at Mambakkam in South Chennai, was selected for analysis. ETABS 9.7.4 was used for structural modelling, while SAP2000 Version 17 was employed to perform the soil-structure interaction analysis [18].

Table 1 Literature review

Author	Year	Findings
Sumit Pahwa et al. [9]	2017	Evaluated the seismic behaviour of multi-storey buildings with and without shear walls under hard, medium, and soft soil conditions in Seismic Zone V using STAAD.Pro. The study highlighted the contribution of shear walls in enhancing lateral stiffness and demonstrated the influence of soil conditions on overall structural response.
Jin Wang et al. [10]	2021	Examined gust effect factors on windward walls using experimental investigations. The study reported that wind pressure characteristics are strongly influenced by building aspect ratio and identified limitations in conventional code provisions for certain building configurations.
K. Vishnu Haritha [11]	2013	Investigated the effect of aspect ratio on wind response using the Equivalent Static Method in STAAD.Pro. The research emphasized the significance of building proportions in determining wind-induced structural behaviour.
B. Dean Kumar & B.L.P. Swami [13]	2010	Assessed wind effects on tall structures using the Gust Effectiveness Factor Method. The study highlighted the suitability of this approach for evaluating wind loads on flexible and slender buildings and emphasized the importance of wind-resistant design.
Mohammed Asim Ahmed et al. [12]	2015	Studied the influence of terrain categories on wind-induced displacement in tall buildings through ETABS analysis. The results indicated noticeable variations in structural deflection with changes in terrain characteristics and building height.

K. Rama Raju et al. [14]	2013	Analyzed a 40-storey reinforced concrete building subjected to wind and earthquake loading in accordance with Indian Standard codes. The study focused on evaluating structural performance through parameters such as base shear, displacement, drift, and acceleration.
Mohammed Elwi et al. [15]	2018	Investigated the effect of soil-structure interaction on multi-storey buildings with different foundation conditions using response spectrum analysis. The study demonstrated that both soil characteristics and foundation flexibility influence seismic response.
Ketan Bajaj et al. [16]	2013	Examined the seismic behaviour of buildings resting on different soil strata using SAP2000. The analysis showed that variations in soil properties affect important response parameters such as base shear and lateral displacement.
Amer Hassan et al. [17]	2018	Evaluated the seismic performance of base-isolated buildings considering different soil conditions. The study observed that soil flexibility affects spectral response and force distribution, thereby influencing the effectiveness of base isolation systems.
M. Roopa et al. [18]	2015	Explored soil-structure interaction effects on a G+12 reinforced concrete building founded on clayey soil. The research indicated that actual soil conditions contribute significantly to seismic response and should be considered during analysis and design.

3. Wind Load Calculation As Per Gust Factor

A Gust Factor (GF) is a parameter used in wind engineering to represent the relationship between peak gust wind speed and the corresponding mean wind speed over a specified time interval. It plays an important role in wind load estimation by accounting for the fluctuating nature of wind, which cannot be adequately represented by average wind speed alone. The magnitude of the gust factor is influenced by several parameters, including terrain roughness, exposure conditions, and atmospheric stability, building height, and surrounding topography. Variations in wind speed produce corresponding fluctuations in wind pressure and structural forces, which may contribute to increased vibrations and fatigue effects in structural components. Therefore, a proper understanding of gust characteristics is essential for the accurate evaluation of wind-induced loads on buildings and other tall structures. Recent developments in wind monitoring and data acquisition systems have enabled the collection of high-resolution wind records during extreme wind events, providing valuable information for the assessment of gust factors and turbulence characteristics used in structural design [10,13].

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

Where,

G = Gust factor

r = Roughness Factor (See 6.5 IS 875 part 3)

gv = peak factor for upwind velocity fluctuation

= 3.0 for terrain category 1 and 2

= 4.0 for terrain category 3 and 4

B_s = Background factor indicating the measure of slowly Varying component of fluctuating wind load caused by the lower frequency wind speed variation

S = size reduction factor

E = Spectrum of turbulence in the approaching wind speed

β = Damping Coefficient of building/Structure

gr = Peak Factor for resonant Response

3.1. Calculate Wind Load for Coastal Areas

Given Data:

Basic wind speed, V_b = 44 m/s

(For coastal region – Mumbai)

Risk coefficient factor, $k_1 = 1.0$

Terrain category = Category II

Class of structure = Class B

Terrain, height and structure size factor, k_2 = As per IS 875 (Part 3), varying with height

Topography factor, $k_3 = 1.0$

Type of Structure	Typical G
Low-rise rigid structures	1.0 – 1.3
Medium-rise buildings	1.3 – 2.0
Tall flexible buildings	2.0 – 3.0

Table 2 Wind Load for Coastal Areas-1

HEIGHT	K1	K2	K3	K4	Vb	Vz	Pz	Cf	Gust	Ae	FZ	Force in Kn
7.5	1	1.00	1	1	44	44.00	26.40	0.02	2.70	135	192.5755	0.19
10.5	1	1.01	1	1	44	44.34	26.61	0.02	2.66	189	267.1097	0.27
13.5	1	1.02	1	1	44	44.68	26.81	0.02	2.62	243	341.3893	0.34
16.5	1	1.02	1	1	44	45.03	27.02	0.02	2.59	297	415.6522	0.42
19.5	1	1.03	1	1	44	45.37	27.22	0.02	2.56	351	490.046	0.49
22.5	1	1.04	1	1	44	45.71	27.43	0.02	2.54	405	564.6687	0.56
25.5	1	1.05	1	1	44	46.05	27.63	0.02	2.52	459	639.5893	0.64
28.5	1	1.05	1	1	44	46.40	27.84	0.02	2.50	513	714.8588	0.71
31.5	1	1.06	1	1	44	46.74	28.04	0.02	2.49	567	790.5163	0.79
34.5	1	1.07	1	1	44	47.08	28.25	0.02	2.47	621	866.5927	0.87
37.5	1	1.08	1	1	44	47.42	28.45	0.02	2.46	675	943.1135	0.94
40.5	1	1.09	1	1	44	47.77	28.66	0.02	2.44	729	1020.1	1.02
43.5	1	1.09	1	1	44	48.11	28.87	0.02	2.43	783	1097.571	1.10
46.5	1	1.10	1	1	44	48.45	29.07	0.02	2.42	837	1175.542	1.18
49.5	1	1.11	1	1	44	48.79	29.28	0.02	2.40	891	1254.027	1.25
52.5	1	1.12	1	1	44	49.14	29.48	0.02	2.39	945	1333.04	1.33
55.5	1	1.12	1	1	44	49.48	29.69	0.02	2.38	999	1412.59	1.41
58.5	1	1.13	1	1	44	49.82	29.89	0.02	2.37	1053	1492.689	1.49
61.5	1	1.14	1	1	44	50.16	30.10	0.02	2.36	1107	1573.346	1.57
64.5	1	1.15	1	1	44	50.51	30.30	0.02	2.35	1161	1654.569	1.65
67.5	1	1.16	1	1	44	50.85	30.51	0.02	2.34	1215	1736.366	1.74
70.5	1	1.16	1	1	44	51.19	30.72	0.02	2.33	1269	1818.744	1.82
73.5	1	1.17	1	1	44	51.53	30.92	0.02	2.32	1323	1901.709	1.90
76.5	1	1.18	1	1	44	51.88	31.13	0.02	2.32	1377	1985.268	1.99

79.5	1	1.19	1	1	44	52.22	31.33	0.02	2.31	1431	2069.426	2.07
82.5	1	1.19	1	1	44	52.56	31.54	0.02	2.30	1485	2154.187	2.15
85.5	1	1.20	1	1	44	52.90	31.74	0.02	2.29	1539	2239.558	2.24
88.5	1	1.21	1	1	44	53.25	31.95	0.02	2.28	1593	2325.541	2.33
91.5	1	1.22	1	1	44	53.59	32.15	0.02	2.28	1647	2412.14	2.41
94.5	1	1.23	1	1	44	53.93	32.36	0.02	2.27	1701	2499.36	2.50

4. Conclusion

Buildings perform better due to symmetry, while irregular buildings experience higher torsion and drift. The addition of soft storey further amplifies these effects, making it a critical parameter in design. The use of advanced software tools has improved the accuracy of analysis, but there is still a need to integrate codal provisions with practical modelling approaches.

This review highlights the importance of considering building geometry and vertical irregularities in wind analysis of high-rise structures. It emphasizes the need for comprehensive studies focusing on coastal environments, where wind effects are more severe. Future research should aim at combining analytical, numerical, and experimental approaches to develop optimized and safe design solutions.

Most existing research focuses on square or rectangular buildings, with very few comparative studies on irregular shapes such as L, C, and T under strong coastal wind environments.

Previous studies mainly consider soft storey at the ground floor, whereas limited research is available on soft storey located at higher levels (15th, 20th, 25th floors) and their influence on dynamic wind response.

Studies either focus on building geometry or soft storey, but not both together. There is a gap in understanding how different shapes behave when soft storey is introduced at multiple levels in the same height profile.

Although the GF method is recommended in codes, many researchers rely only on static wind pressure or simplified wind analysis, leading to a gap in accurate prediction of dynamic wind effects.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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