Literature Review on Wind induced performance analysis of Aerodynamic Modified Buildings with varied corners

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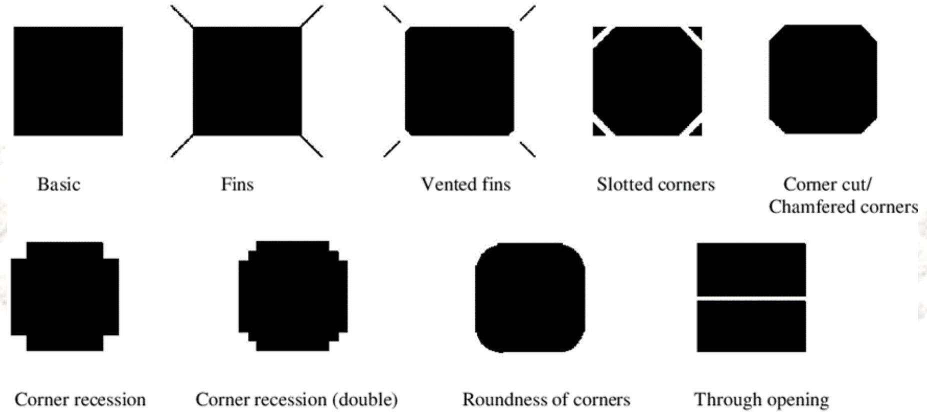
Abstract - In recent years, there has been a growing interest in understanding how wind affects buildings, especially when they are aerodynamically modified. This research focuses on reviewing previous studies related to buildings with different corner shapes: rounded, chamfered, and recessed corners. We will delve into how these studies analyzed the building's response to wind and explore other research in this area. The goal of this work is to summarize the key findings from these studies and discuss how they can influence the design of regular buildings with aerodynamic changes to better withstand wind loads. Many researchers have contributed to this field. Some have examined the changing trends in tall building design, particularly looking at aerodynamic adjustments like tapering and setbacks. Others have developed methods, like the Building Corner Aerodynamic Optimization Procedure, to reduce wind forces on tall structures. Additionally, some researchers have investigated wind effects on unconventional super-tall buildings and proposed guidelines for different building shapes. Lastly, some studies have reviewed techniques to mitigate wind effects on both low and high-rise buildings, including using computational fluid dynamics for shape optimization. By reviewing the body of work, the work aim to provide valuable insights for architects and engineers working on buildings with aerodynamic modifications to enhance their resilience against wind loads.

Index Terms – Aerodynamic modifications, aerodynamically modified building, varying geometry, varied corner

I. INTRODUCTION

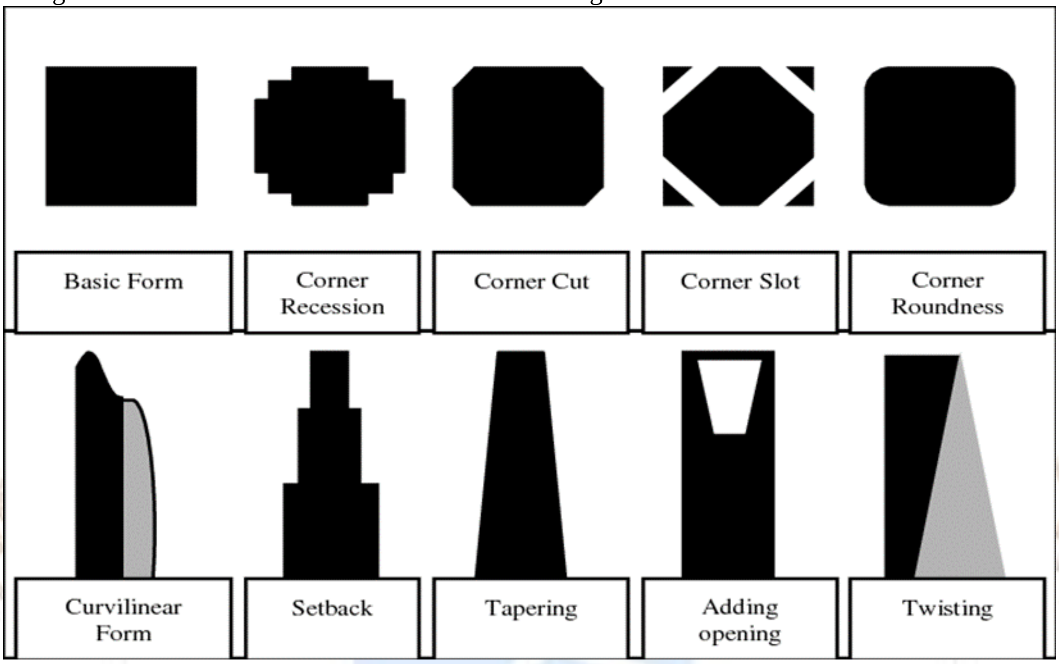
In recent years, there has been a growing interest in understanding how wind affects buildings, especially when they are aerodynamically modified. This research focuses on reviewing previous studies related to buildings with different corner shapes: rounded, chamfered, and recessed corners. We will delve into how these studies analyzed the building's response to wind and explore other research in this area. The goal of this work is to summarize the key findings from these studies and discuss how they can influence the design of regular buildings with aerodynamic changes to better withstand wind loads. Many researchers have contributed to this field. Some have examined the changing trends in tall building design, particularly looking at aerodynamic adjustments like tapering and setbacks. Others have developed methods, like the Building Corner Aerodynamic Optimization Procedure, to reduce wind forces on tall structures. Additionally, some researchers have investigated wind effects on unconventional super-tall buildings and proposed guidelines for different building shapes. Lastly, some studies have reviewed techniques to mitigate wind effects on both low and high-rise buildings, including using computational fluid dynamics for shape optimization. By reviewing the body of work, the work aim to provide valuable insights for architects and engineers working on buildings with aerodynamic modifications to enhance their resilience against wind loads.



Aerodynamic Modifications to the Shape of Building

Aerodynamic modifications to the shape of buildings play a crucial role in enhancing their resistance to wind loads and mitigating the adverse effects of dynamic forces. As modern architecture embraces taller and more flexible structures, the importance of aerodynamic design becomes paramount to ensure structural stability, occupant comfort, and overall safety. One of the primary objectives of aerodynamic modifications is to reduce wind-induced vibrations and oscillations, commonly known as aeroelastic effects, which can lead to discomfort for occupants and even structural failure in extreme cases. The first step in achieving this is to understand the complex interaction between the building and the wind flow around it. A common aerodynamic modification technique involves the introduction of corner cuts, chamfering, or rounding of corners. These adjustments help to smoothen the airflow around sharp edges, reducing the formation of vortices and turbulence. As a result, the overall wind pressure on the building is minimized, leading to reduced dynamic responses and enhancing the building's overall stability.

Horizontal and vertical slots are another effective aerodynamic modification employed in building design. By strategically incorporating these openings, the flow of wind around the building can be controlled, allowing for pressure equalization on both sides of the structure. This equalization minimizes the occurrence of differential pressures, which can cause undesirable structural motions and vibrations.
One of the primary approaches to mitigating across-wind loads is through aerodynamic shape optimization. By carefully designing the building's form and facades, engineers can manipulate the airflow around the structure to reduce wind-induced forces. This optimization involves employing techniques like tapering, corner rounding, and introducing surface modifications to minimize drag and lift forces, resulting in a more streamlined and wind-resistant building form.



Examples of micro (above) and macro (below) Aerodynamic Modifications

II. LITERATURE SURVEY

Ashutosh Sharma et al. [1] explored the evolving trend in architectural design of tall buildings, which are becoming taller and adopting unconventional shapes. The modifications of the building were divided into two categories by the author: minor modifications (e.g., corner cut, rounding, chamfer) and major modifications (e.g., taper, set-back, twist). The paper provides a comprehensive review of the recent and past aerodynamic modification techniques applied to high-rise buildings.

A. Elshaer et al. [2] investigated wind-induced loads and motions on tall buildings, which influence the design of lateral load resisting systems. Authors proposed a Building Corner Aerodynamic Optimization Procedure (AOP) to reduce wind loads by using an optimization algorithm, Large Eddy Simulation (LES), and an Artificial Neural Network (ANN) based surrogate model. The study demonstrated corner mitigation as an effective method to reduce wind loads without significantly impacting the building's structural and architectural design. The researchers presented two aerodynamic optimization examples focusing on drag and lift minimization, taking into account wind directionality and turbulence. For instance, the authors achieved significant reductions of more than 30% in both along-wind and across-wind responses by applying a two-surface chamfering, which was constrained to 20% of the building's width. This highlighted the potential of aerodynamic optimization techniques to improve the wind performance of tall buildings.

Y.C. Kim et al. [3] investigated wind loads on atypical super-tall buildings, which include along-wind, across-wind, and torsional loads occurring simultaneously in time and space. To appropriately combine these loads, pressure measurements were taken on the buildings using a simplified reference model with four columns. Analyzing the data in the time domain, the study proposes combination rules based on a concept called the combination factor. The combination factor for a square model is approximately 0.5, while for atypical models, it varies depending on the building shape. The study also presented two methods for determining the combination factors, and the comparison between peak normal stresses obtained from the analysis and combination factor shows a relatively good agreement, mostly within ±5%. This research contributed to understanding wind load combinations for atypical super-tall buildings.

Maryam Asghari Mooneghi et al. [4] reviewed various aerodynamic mitigation techniques applied to both low-rise and high-rise buildings, including modifications to shapes and simple architectural elements. Additionally, the study presented aerodynamic shape optimization techniques specifically aimed at reducing wind loads on tall buildings. Computational Fluid Dynamics (CFD) was discussed as a tool for this purpose, along with gradient-based and non-gradient-based optimization methods. The research aimed to spark interest in using aerodynamic shapes and considering wind performance in the early stages of building design. It also serves as a valuable resource for different approaches to reduce wind loads on buildings.

F.A. Johann et al. [5] addressed the issue of comfort performance during wind-induced motions in building design. The authors found that there were disagreements among different authors and normative codes regarding comfort evaluation criteria. These discrepancies included the use of peak acceleration instead of root-mean-square (rms) acceleration, the impact of waveform on comfort evaluation, and the consideration of users' perception and complaints. The paper proposed an alternative approach to comfort assessment, suggesting that in the future, users should be aware of building motions and educated to cope with them. As long as the building's structural integrity and safety are not compromised, the study suggested assessing sustained vibration for factors like nausea, task performance reduction, and other compensatory behaviours. This approach could potentially lead to less conservative structural designs while still ensuring human comfort during wind-induced motion.

Kim Yong Chul et al. [6] conducted aeroelastic wind tunnel experiments using conventional and tapered super-tall building models. Authors investigated how tapering affected fundamental aeroelastic behaviors under different incident flows. Three types of incident flows were simulated: turbulent boundary-layer flow representing urban areas, low-turbulent flow, and grid-generated flow. The results showed that introducing taper significantly suppressed responses in low-turbulence and boundary-layer flows. However, in the grid-generated flow, the response became larger than that of the square model when the wind was applied normal to the surface. The study clearly demonstrated the effects of taper and incident flows on normalized responses, power spectra, stability diagrams, and probability functions. These findings provide valuable insights into the impact of taper on aeroelastic behaviors in various wind conditions.

Deng Ting et al. [7] conducted wind tunnel tests on tapered super high-rise buildings with a square cross-section, using synchronous pressure measurement technology. Authors investigated the effects of a global strategy involving chamfered modification on aerodynamic loads and wind-induced responses. Additionally, they carried out local aerodynamic strategies by opening a ventilation slot in the corner of equipment and refuge floors. The results showed that the global strategy of tapered elevation increased the vortex shedding frequency while reducing vortex shedding energy, leading to a reduction in across-wind aerodynamic loads and responses. Chamfered modification effectively suppressed the across-wind vortex shedding effect on tapered buildings. Opening the ventilation slot further mitigated the strength of vortex shedding and reduced the residual energy associated with vortex shedding in the aerodynamic loads of chamfered buildings. Based on the findings of researchers, the researchers suggested optimized locations for implementing local aerodynamic strategies. These findings provide valuable insights into how specific modifications can influence aerodynamic performance and wind-induced responses in tapered high-rise buildings.

Sharma et al. [8] conducted wind tunnel tests on 13 super-tall buildings with different polygonal cross-sections, including straight and helical shapes. The main focus of the authors was to investigate how the number of sides influenced response characteristics in straight super-tall buildings and the effect of helical shape on polygonal section super-tall buildings. The results revealed that as the number of sides increased, the overturning moment coefficients, spectral values, and responses decreased. The straight triangular model showed the largest mean and fluctuating overturning moments, while the straight square model exhibited the highest spectral values and responses. For annual design wind speed, the largest peak accelerations were similar when the buildings had more than 5 sides, but variations were observed in the largest maximum displacements among models. The study also found that the effect of helical shape on response characteristics diminished as the number of sides increased. Generally, the impact of helical shape became smaller when the number of sides reached 5 or more. These findings shed light on how the building's shape influences its response to wind forces.

Jiming Xie [9] focused on improving the safety and serviceability of super-tall buildings in strong winds through aerodynamic optimization of building shapes. This approach addressed the wind-related issues at the source, unlike structural optimization which focuses on increasing structural resistance to winds. However, there were challenges in implementing aerodynamic optimization in design practice, related to conflicts with other design aspects and cost-effectiveness. To overcome these challenges, the researchers emphasized the importance of conducting aerodynamic studies early in the design stage to assess different optimization options effectively. The paper summarized successful aerodynamic approaches used in building designs and discussed their principles and effectiveness. Furthermore, to guide preliminary design, the paper proposed a practical approach to assess the effectiveness of tapering, twisting, and stepping – the three common schemes of aerodynamic optimization in super-tall building design. This research provides valuable insights and guidelines for optimizing building shapes for enhanced wind performance.

S. Lamb et al. [10] used a longitudinal within-subjects design to examine how wind-induced motion in tall buildings affected occupant wellbeing and work performance. They collected survey data from 47 office workers in wind-sensitive buildings and 53 control participants over 8 months and various wind conditions.
The findings revealed that the effects of building motion emerged gradually, with motion sickness developing after prolonged exposure. Symptoms of sopite syndrome, such as tiredness, low motivation, distraction from work, and low mood, were prevalent at 2–3 times the baseline rates. As motion sickness increased, work performance significantly decreased by 0.76–0.90 standard deviations below the baseline. Affected individuals coped with discomfort by seeking to work in different locations during motion, taking longer breaks, and using analgesics for self-medication. While humans showed adaptability, most occupants experienced reduced levels of performance and comfort during building motion. The study suggests that design criteria for tall buildings should focus on minimizing the environmental stress of motion on work performance and wellbeing, rather than merely addressing motion tolerance or formal complaints to building owners. These insights can inform future building design and occupant well-being in tall structures affected by wind-induced motion.

Y.C. Kim et al. [11] conducted wind tunnel tests on 13 super-tall building models with atypical shape under urban area flow. The main goal of the authors was to compare the wind load effects on these atypical super-tall buildings directly. Time history analyses were performed using a frame model with local wind forces applied at each floor's center. The results revealed that the square model experienced the highest peak normal stresses among all tested models. The setback model showed the smallest peak normal stresses among single modification models, while the CC+TP+360Hel model displayed the smallest peak normal stresses among multiple modification models. Bending moments contributed approximately 20% of the total, with axial forces being the main factor in peak normal stresses. The increase in bending moment in the across-wind direction was more significant as the damping ratio decreased. Moreover, the helical and multiple modification models exhibited less sensitivity to damping ratio compared to other models. The study also found that, under various loading conditions, the largest contribution of bending moment was in the along-wind direction, while the impact of torsional moment was almost negligible. These findings provide valuable insights into the wind load effects and structural behavior of atypical super-tall buildings.

Chiara Pozzuoli et al. [12] conducted an extensive experimental campaign on a continuous equivalent aeroelastic model of a regular square-section tall building. Measurements included surface pressures, forces, displacements, and accelerations in both across-wind and along-wind directions. Aeroelastic effects on the across-wind response were evaluated through aerodynamic damping using an experimental-numerical procedure. The study proposes a general procedure for wind risk assessment of tall buildings concerning comfort, following the Performance-Based Design (PBD) approach and the PEER (Pacific Earthquake Engineering Research) equation. This procedure was applied to a case-study building with known aeroelastic response from wind tunnel tests. The research provides valuable insights into assessing wind-induced discomfort in tall buildings, supporting more informed design decisions in the future.

S. Lamb et al. [13] surveyed 1014 central business district workers in Wellington, New Zealand, about their experiences with wind-induced building motion, susceptibility to motion sickness, and compensatory behaviours. Approximately 41.7% of respondents reported feeling wind-induced building motion, with 41.6% experiencing perceptible motion at least once a month. Difficulty concentrating was the most frequently reported effect among those who felt building motion.
The study indicated that early onset motion sickness was common among building occupants. Surprisingly, despite a strong preference to avoid tall buildings, highly susceptible individuals were equally likely to work on high floors, exposing themselves more to building motion and reporting more symptoms of motion sickness. The findings have implications for occupant comfort, motion sickness, rates of complaint, and compensatory behaviours in tall buildings. The research highlights the importance of understanding and addressing the impact of wind-induced building motion on occupants' wellbeing.

Yong Chul Kim et al. [14] explored the spatio-temporal characteristics of pressure fluctuations on tall buildings with irregular and unconventional shapes. They focused on the effectiveness of aerodynamic modification methods, which are commonly used to suppress across-wind responses in tall buildings for safety and habitability. The results revealed that taper and set-back influenced the bandwidth of power spectra and the position of peak frequencies. These modifications also caused changes in the height at which vortices begin to form and shed. Due to the smaller building dimensions, the vortices formed at that height shed more frequently before an inverted conical vortex formed over the entire height. The study provides valuable insights into the effects of aerodynamic modifications on pressure fluctuations in tall buildings with irregular shapes. This understanding can contribute to the design and safety considerations of such structures in windy conditions.

H. Tanaka et al. [15] conducted a series of wind tunnel experiments on square-plan tall building models with different configurations, such as corner cuts, setbacks, and helical shapes. The experiments provided valuable insights into the aerodynamic characteristics of tall buildings with various configurations, contributing to a comprehensive understanding of their behavior in windy conditions.

B. Bhattacharyya et al. [16] presented a detailed study on an E-plan-shaped building under wind excitation. Wind angles varied from 0° to 330°. The study used wind-tunnel experiments and numerical simulations (CFD) with k-ε and SST k-ω models. Results showed good agreement between experimental and numerical data. The SST k-ω model performed better in computing mean pressure coefficients. Maximum positive and negative mean pressures occurred at skew wind angles. A comparison with a symmetrical E-plan-shaped building (same area) showed significant pressure variation due to small aerodynamic modification.

Xu-Liang Han et al. [17] investigated aerodynamic forces on a 600-m-high supertall building using field measurements during Super Typhoon Mangkhut and wind tunnel tests on a 1∶500 scaled model. Comparative analysis showed wind tunnel tests provided conservative mean local drag coefficients and RMS local lift coefficients. However, model experiments predicted smaller RMS local drag coefficients at higher levels than onsite measurements. Reynolds number effects on local wind forces and the Strouhal number were explored. The study aimed to enhance understanding of aerodynamic forces on high-rise buildings during strong windstorms and provide valuable information for wind-resistant design of supertall buildings.

X. J. Wang et al. [18] examined wind-induced pressures on a low-rise building with gable roof and roof overhang during Typhoons Mujigae and Sarika through full-scale measurements. Wind tunnel tests on a 1∶100 scale model were also conducted under various upstream exposure conditions. Comparisons with aerodynamic database and field measurements showed reasonable agreement in mean and RMS wind pressure coefficients on the roof. An improved peak pressure estimate approach was proposed and validated. The combined study aimed to enhance understanding of wind effects on low-rise buildings during typhoons and improve their wind-resistant design.

Xu Cheng et al. [19] investigated the impact of architectural facades on wind loads of tall buildings, considering balconies, mullions, shading boards, and ribs. Multiple point pressure measurements and high-frequency force balance experiments were conducted for buildings with various facades. The study revealed that facades have a significant influence on local wind pressure and aerodynamic force, and may also experience larger forces themselves.

Xu Cheng et al. [20] investigated the use of performance-based wind design (PBWD) to reduce induced dynamic forces in tall and slender buildings. They found that if the reduced wind load is smaller than the aerodynamic forces, it may not ensure proper inelastic wind design. To avoid huge ductility demand due to damage accumulation, the yield strength for structural systems with zero-to-modest post-yield stiffness must be larger than the aerodynamic forces. For systems with large post-yield stiffness, it would be advisable to consider upper limits of aerodynamic forces due to uncertainty in the number of occurrences of peak aerodynamic loads applied to a structure during a wind event. The authors concluded that, for structural systems with zero-to-modest post-yield stiffness, the yield strength must be larger than the aerodynamic forces to avoid huge ductility demand.

III. CONCLUSIONS

[1]. The research landscape reveals a wide array of studies on aerodynamic building modifications conducted by various researchers.
[2]. Recent architectural trends have demonstrated a strong preference for incorporating aerodynamic features like tapering and setbacks in the design of tall buildings.
[3]. The introduction of innovative methods, such as the Building Corner Aerodynamic Optimization Procedure, shows promise in effectively reducing wind loads on tall structures.
[4]. Investigations into wind loads on atypical super-tall buildings emphasize the need for flexible design guidelines tailored to diverse building shapes.
[5]. Studies spanning low and high-rise buildings highlight the potential benefits of shape optimization through computational fluid dynamics (CFD) in mitigating wind-induced challenges.
[6]. In-depth examinations of human comfort during wind-induced motions propose alternative assessment approaches and advocate for aeroelastic wind tunnel experiments on models of tapered super-tall buildings.
[7]. The influence of global and local aerodynamic strategies on tall building wind-induced responses underscores their importance in structural performance under windy conditions.
[8]. Wind tunnel tests conducted on various polygonal cross-section super-tall buildings provide valuable insights, suggesting a necessity for further exploration of pressure fluctuations in unconventional tall buildings with aerodynamic modifications.
[9]. There exists significant potential for future research endeavors involving aeroelastic tall building models, aiming to comprehensively evaluate wind risk and enhance safety considerations in windy conditions.
[10]. Collectively, these findings contribute significantly to advancing safety and wind resilience in the context of buildings with aerodynamic modifications.

In conclusion, the reviewed literature presents a diverse and comprehensive body of research on the effects of aerodynamic modifications on building structures. It highlights evolving architectural trends favoring features like tapering and setbacks in tall building design, while also introducing innovative methods such as the Building Corner Aerodynamic Optimization Procedure to mitigate wind loads. From examinations of human comfort during wind-induced motions to wind tunnel tests on various building shapes, these studies collectively emphasize the significance of considering aerodynamics in building design. The authors point towards a promising future in wind engineering research, emphasizing the need for aeroelastic models, pressure fluctuations, and further experimentation with unconventional building shapes. Ultimately, this body of work contributes to the broader goal of enhancing safety and resilience in the face of wind-related challenges, guiding architects and engineers toward creating structures that harmoniously balance aesthetics with structural robustness in varying wind conditions

[11]. REFERENCES

[1]. Ashutosh Sharmaa , Hemant Mittala , Ajay Gairola “Mitigation of wind load on tall buildings through aerodynamic modifications: Review” Journal of Building Engineering (2018).
[2]. A. Elshaer, G. Bitsuamlak, A. El Damatty, “Enhancing wind performance of tall buildings using corner aerodynamic optimization”, Engineering Structures(2017).
[3]. Y.C. Kim, Y. Tamura, S. Kim, “Wind load combinations of atypical supertall buildings”, Journal of Structural Engineering (2016).
[4]. M. Asghari, R. Kargarmoakhar, “Aerodynamic mitigation and shape optimization of buildings: review”, Journal of Building Engineering (2016).
[5]. F.A. Johann, M.E.N. Carlos, F.L.S. Ricardo, “Wind-induced motion on tall buildings; a comfort criteria overview”, Journal of Wind Engineering and Industrial Aerodynamics (2015).
[6]. Y.C. Kim, Y. Tamura, S. Yoon, “Effect of taper on fundamental aeroelastic behaviors of super-tall buildings”, Wind and Structure International Journal (2015)
[7]. T. Deng, X. Yu, Z. Xie, “Aerodynamic measurements of across-wind loads and responses of tapered super high-rise buildings”, Wind and Structure (2015).
[8]. Y.C. Kim, E.K. Bandi, A. Yoshida, Y. Tamura, “Response characteristics of super-tall buildings – Effects of number of sides and helical angle”, Journal of Wind Engineering and Industrial Aerodynamics. (2015).
[9]. Jiming Xie, “Aerodynamic optimization of super-tall buildings and its effectiveness assessment” Journal of Wind Engineering and Industrial Aerodynamics (2014).
[10]. S. Lamb, K.C.S. Kwok, D. Walton, “A longitudinal field study of the effects of wind induced building motion on occupant wellbeing and work performance”, Journal of Wind Engineering and Industrial Aerodynamics (2014).
[11]. Y.C. Kim, Y. Tamura, H. Tanaka, K. Ohtake, E.K. Bandi, A. Yoshida, “Wind- induced responses of super-tall buildings with various atypical building shapes”, Journal of Wind Engineering and Industrial Aerodynamics (2014).
[12]. C. Pozzuoli, G. Bartoli, U. Peil, M. Clobes, “Serviceability wind risk assessment of tall buildings including aeroelastic effects”, Journal of Wind Engineering and Industrial Aerodynamics (2013).
[13]. S. Lamb, K.C.S. Kwok, D. Walton, “Occupant comfort in wind-excited tall buildings: Motion sickness, compensatory behaviours and complaint”, Journal of Wind Engineering and Industrial Aerodynamics.
[14]. Yong Chul Kim, Jun Kanda, “Wind pressures on tapered and set-back tall buildings”, Journal of Fluids and Structures
[15]. Hideyuki Tanaka, Yukio Tamura, Kazuo Ohtake, Masayoshi Nakai, “Experimental investigation of aerodynamic forces and wind pressures acting on tall buildings with various unconventional configurations”, Journal of Wind Engineering and Industrial Aerodynamics
[16]. Biswarup Bhattacharyya, Sujit Kumar Dalui, “Experimental and Numerical Study of Wind-Pressure Distribution on Irregular-Plan-Shaped Building”, Journal of Structural Engineering
[17]. Xu-Liang Han, Qiu-Sheng Li, Kang Zhou, Ming Li, “Investigation of the Aerodynamic Forces on a 600-m-High Supertall Building by Field Measurements and Wind Tunnel Test”, Journal of Structural Engineering
[18]. X. J. Wang, Q. S. Li, B. W. Yan, “Full-Scale Measurements of Wind Pressures on a Low-Rise Building during Typhoons and Comparison with Wind Tunnel Test Results and Aerodynamic Database”, Journal of Structural Engineering

[19]. Ke Yuan, Z.Q. Chen, "Effects of facade appurtenances on the local pressure of high-rise building", Journal of Wind Engineering and Industrial Aerodynamics
[20]. Mingfeng Huang, C.M. Chan, "Optimal performance-based design of wind sensitive tall buildings considering uncertainties", Journal of computers and structures
[21]. S. Lamb, K.C.S. Kwok, D. Walton, "Occupant comfort in wind-excited tall buildings: motion Sickness, compensotary behaviour and complaint", Journal of Wind Engineering and Industrial Aerodynamics (2013).
[22]. Y.C. Kim, J. Kanda, "Wind pressures on tapered and set-back tall buildings", Journal of Fluids and Structures (2013).
[23]. H. Tanaka, Y. Tamura, K. Ohtake, M. Nakai, Y. Chul Kim, "Experimental investigation of aerodynamic forces and wind pressures acting on tall buildings with various unconventional configurations", Journal of Wind Engineering and Industrial Aerodynamics (2012).
[24]. Dr.Prem Krishna, Dr. Krishen Kumar, Dr. N.M. Bhandari, IS: 875(Part3): Wind Loads on Buildings and Structures - Proposed Draft & Commentary, IIT Kanpur.
[25]. Muhanad M. Maied, DR. P. Srinivasa Rao, 2021, A Comparative Study of Wind Forces on Tall Building as Per Is 875-Part-III (1987) and Draft Code (2011) using Gust Factor Method