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Review on Building Structures Subjected to Wind Loads

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Abstract- The review paper delves into the intricate realm of wind load analysis in building structures, offering a comprehensive exploration of historical developments, contemporary methodologies, and emerging trends. Tracing the evolution from empirical approaches to advanced computational simulations, the review highlights pivotal milestones, including the establishment of international standards and the integration of computational fluid dynamics. Real-world case studies illustrate the practical implications of wind load analysis, shedding light on the performance of structures during extreme weather events. While showcasing the achievements in understanding and mitigating wind-induced forces, the paper underscores the imperative of adapting design strategies to meet the challenges posed by climate change. As the built environment faces an era of heightened environmental uncertainty, the synthesis of historical knowledge and cutting-edge advancements emerges as a crucial paradigm for ensuring the resilience, safety, and sustainability of building structures in the face of dynamic wind forces.

Index Terms- Weld Joint, Fatigue Life, Safety Factor, ANSYS

I. INTRODUCTION

The wind load significantly influences building stability through a complex interplay of lateral, vertical, and dynamic forces. The lateral forces induce structural sway, while dynamic effects such as wind-induced vibrations can lead to resonance and structural fatigue. Building components, including facades, cladding, and roofs, are susceptible to wind pressures, potentially compromising their integrity. Moreover, the vertical loads transferred to the foundation, coupled with soil-structure interaction, can impact the overall stability of the structure. Torsional effects, particularly on tall or asymmetric buildings, may result in twisting movements, demanding careful consideration in the design phase. Local wind effects, influenced by topography and urban features, contribute to uneven wind distribution, creating localized high-pressure zones that can affect specific areas of the building. Recognizing the multifaceted nature of wind-induced forces is paramount in ensuring the structural resilience and long-term stability of buildings against the dynamic forces of nature.

II. LITERATURE REVIEW

Early approaches to understanding wind effects on structures involved empirical methods, often reliant on simplified models and wind tunnel experiments. Notable contributions in the mid-20th century saw the emergence of more sophisticated analytical techniques, with researchers exploring fluid dynamics principles to predict wind loads more accurately.
Significant developments in wind load standards, such as those established by organizations like ASCE (American Society of Civil Engineers) and ISO (International Organization for Standardization), have played a pivotal role in shaping the industry's response to wind-induced forces. These standards provide a framework for assessing wind loads on various building types, offering guidance on factors like wind speed, building geometry, and topographical considerations.
The advent of computational tools and technologies has ushered in a new era in wind load analysis. Computational Fluid Dynamics (CFD) simulations have enabled engineers to model complex wind interactions with structures, providing a more detailed understanding of aerodynamic forces. Additionally, advancements in meteorological data collection and numerical modeling techniques have enhanced the accuracy of predicting extreme wind events, contributing to the refinement of building codes and standards.

Yi et al. (2012) conducted an experimental study on the interference effect of high-rise buildings arranged in a staggered arrangement and found that the interference amplification effect of twisting towers in the middle position was very evident.

Xiaobing et al. (2021) carried out wind tunnel tests on parallel three-square columns and studied the variation law of drag coefficient, wind pressure coefficient and Strouhal number of parallel three-square columns with spacing. An experimental study on the wind load characteristics of parallel three-square columns was conducted, and the results showed that columns arranged systemically on both sides could significantly interfere and increase the dynamic load of disturbed columns in the middle.

Bharat Singh et al. (2022) adopted high-rise buildings with rectangular sections as research objects and discussed the change of airflow pattern caused by the presence of disturbing buildings, thus leading to the change of wind pressure distribution.

Kunyang et al. (2021) studied the average wind pressure around a single square column with different spacing ratios and showed that with changing wind angle, the average wind pressure distribution of each square column was similar to that of a single square column, and the average wind pressure coefficient in adjacent planes between square columns changed significantly.

Yaling et al. (2021) conducted a wind tunnel comparison test on super tall buildings, studied the static and dynamic interference effects of wind load on the main structure of the distributed high-rise buildings array and the interference effects of the envelope structure, and analyzed the interference mechanism combined with the Computational Fluid Dynamics calculation results and the basement bending moment spectrum.

Rongqiang et al. (2022) numerically simulated the interference effect of cross-shaped super high-rise buildings, and the results showed that the surface shape coefficient of cross-shaped buildings was significantly affected by building spacing (Rongqiang et al., 2022).

Liguo et al. (2021) performed a wind tunnel test on a high-rise building complex in the coastal area of Shenzhen and analyzed the mechanism of disturbance caused by the project building.

Dongmei et al. (2012) used the World Financial Center in the Lujiazui area of Shanghai as a research object to conduct a wind tunnel test and studied the amplitude characteristics of the surface wind pressure coefficient and wind coefficient of each layer of super high-rise buildings under the interference from surrounding buildings.

Lam et al. (2008) used wind tunnel test method to study the interference effect of a row of square high-rise buildings arranged nearby. The study showed that when the wind direction was about 30º, the wind flowed through the narrow building gap at high speed, thus generating a high negative pressure on the relevant building walls. Buildings in a row, therefore, did not exhibit a resonant response to wind at reduced velocities around 10 as an isolated square-plan tall building.

Li & Li (2022) used CFD numerical simulation to study the influence of multi-highrise buildings on the surface wind load characteristics of low-rise buildings. The research showed that wind pressure distribution on target low-rise buildings was very sensitive to changes in height ratio and space ratio. The average wind pressure coefficient and influence factor of low-rise buildings decreased with increasing height ratio and increase with increasing space ratio. The fluctuating pressure coefficient of the target low-rise building increased with the increasing height ratio, and the fluctuating pressure coefficient reaches the maximum when the height ratio was 8.

Nagar et al. (2022) studied the interference effect of two buildings based on the mean interference factor and the root-meansquare interference factor, and the research showed that the maximum value of the mean interference factor was 4, 9 and 13, respectively, in the case of full blocking, half block and no block. In the case of complete blockage, the sidewall suction force was reduced by about 65 %. In all interference cases, the root-mean-square interference factor value was less than 1.

Weifeng et al. (2022) studied the aerodynamic and structural dynamic characteristics of super-tall twin towers and compared them with isolated single towers. Research showed that when the twin towers were side by side in the wind, if the relative spacing was about 1.0 or less, the beneficial effect was pronounced, but when the relative spacing reached 2.0, it could be ignored. When towers were configured in conjunction with the wind, the beneficial effect would remain in effect until the maximum relative spacing tested was 2.0

Chun yan et al. (2011) numerically simulated the static interference effect of shaped buildings under a specific inflow direction and studied the distribution law of wind pressure interference factors on the surface of the disturbed buildings.

III. CONCLUSION

The comprehensive review of literature on wind load analysis in building structures reveals a dynamic evolution from empirical methods to advanced computational simulations, driven by a continuous quest for accuracy and resilience.

Historical milestones, such as the development of international standards and the integration of computational fluid dynamics, have significantly shaped the field, providing a robust foundation for contemporary design practices. Real-world case studies underscore the practical implications of wind load analysis, offering valuable insights into the performance of structures under extreme weather conditions.

However, the review also emphasizes the pressing challenges posed by climate change, necessitating adaptive design strategies and ongoing research to address the evolving nature of wind-induced forces. As we navigate a future marked by unpredictable environmental dynamics, the synthesis of historical knowledge and cutting-edge advancements will be pivotal in ensuring the structural integrity, safety, and sustainability of building structures against the formidable forces of the wind.

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