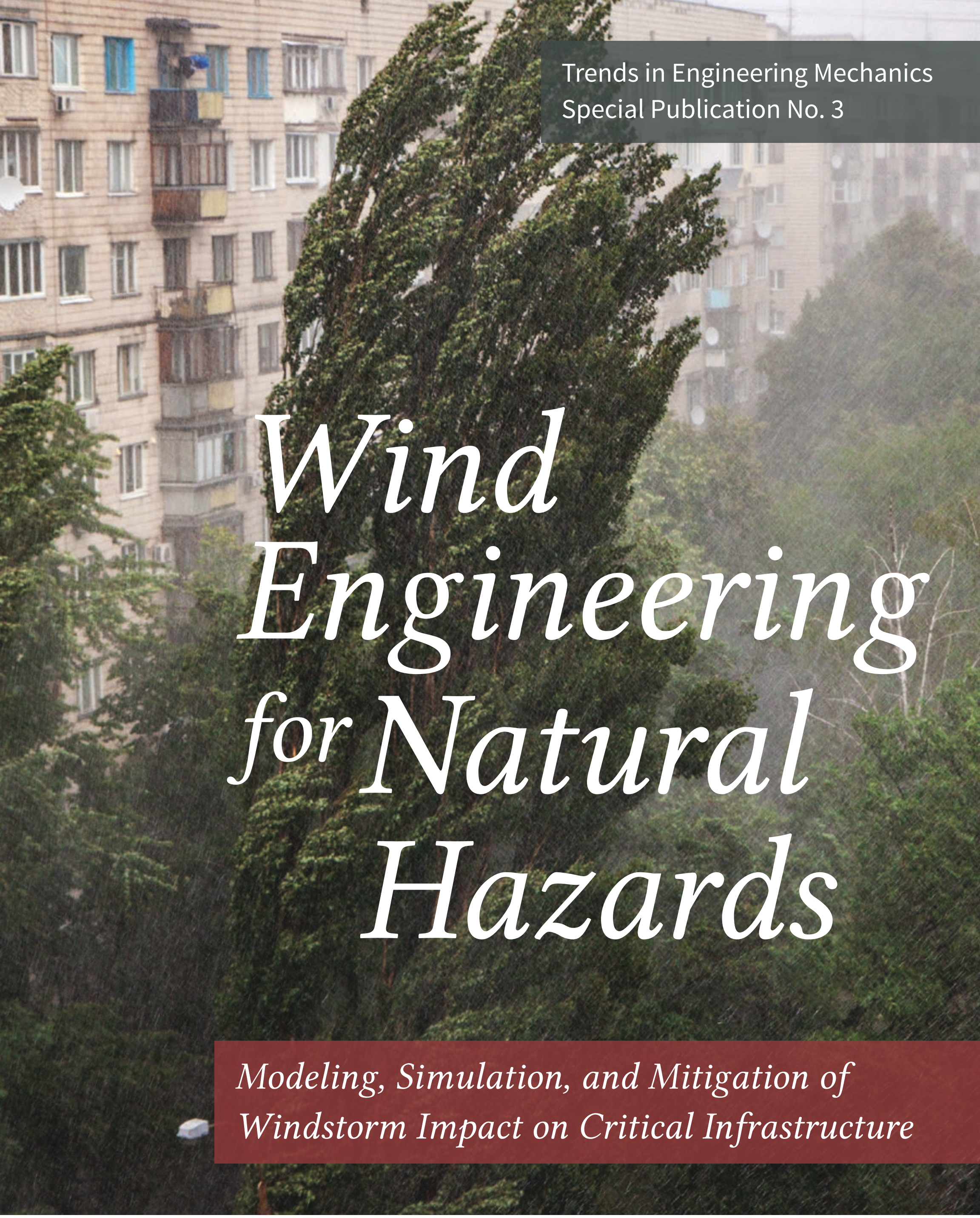

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Wind Engineering for Natural Hazards

Modeling, Simulation, and Mitigation of Windstorm Impact on Critical Infrastructure

Fluids Dynamics Committee

Edited by
Aly Mousaad Aly, Ph.D.

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Preface

Although wind itself may not be visible to the human eye, its effect on the built environment can be seen readily, and the hazards that it brings are of tremendous impact, both on life and critical infrastructure. Climate change has increased the risks of wind hazards among other natural hazards, and understanding the often-encountered hurricanes, tornadoes, and other types of nonsynoptic winds and large-scale wind storms became crucial for realistically predicting the wind impact on the built environment.

Wind engineering is a multidisciplinary research area that lies at the intersection of different disciplines: fluid mechanics, structural dynamics, mathematics, atmospheric science, and computer science, among other technical areas. The physics involved in the processes of atmospheric boundary layer (ABL) and the interaction with the built environment are indispensable for the understanding of wind-induced loads and the response of the infrastructure. The tools employed in wind engineering include atmospheric modeling, boundary layer wind tunnels, computational fluid dynamics (CFD), and full-scale data collection, among others.

This publication addresses the challenge of modeling and understanding windstorms' impact on the built environment to mitigate natural hazard threats on high-rise buildings, long-span bridges, power transmission lines, and other critical infrastructure. It also addresses the complexity of simulating nonsynoptic and synoptic wind flows, owing to the need for high-resolution flow characteristics.

Several research topics in wind engineering are currently progressing at the National Institute of Standards and Technology (NIST). The contribution by Duthinh et al., "Recent and Current Wind Engineering Research at the National Institute of Standards and Technology," reviews previous and current NIST research projects aimed at improving standard provisions and advancing structural design practice for wind loads.

For high-rise buildings, it may be astute to design cladding and components using a shorter recurrence period wind load than that of the main force resisting system (structural frames). The paper by Tamura and Yang, "Interrogation of Relation between Design Load Level and Lifetime of Individual Building and Its Element," strongly recommends that the optimal design wind load level in Japan involve a group of buildings, rather than attempting to optimize the life-cycle cost (LCC) of individual buildings.

The simulation of the stochastic dynamics of high-rise buildings, under turbulent wind loads, is imperative for investigating the wind-induced damage of high-rise buildings. In the paper by Caracoglia, "Investigation on a Generalized Intervention Cost Function to Examine Wind-Induced Damage on Tall

Buildings," the author takes into consideration the influence of the cross-wind modal response on the damage and the simultaneity of the structural response along the two directions of the investigated building model.

Moreover, high-rise buildings are susceptible to wind-induced loads; therefore, their design is frequently dominated by the wind governing loads. In the work by Jeong and Tarrant, "Wind Loading on Tall Building Structures in Consideration of Performance-based Design," the authors show that the "heavy-headed, light-tailed" probabilistic distributions of wind speeds, as well as building aerodynamic characteristics, can generate high loads in service level winds, which diminishes the application of performance-based design (PBD) to tall building wind design.

Wind fairings, based on principles of wind-adaptable design (WAD), is a promising approach to optimize buildings' aerodynamic properties. In their paper, "Application of Wind Fairings for Building Aerodynamic Optimization," Xu and Xie achieve a reduction of about 20% in design wind loads by properly designed wind fairings adapted for buildings.

Multiple-tuned mass dampers (MTMDs) are effective devices for response control in high-rise buildings. The paper by Elias and Matsagar, "Wind Response Control of Tall Buildings with Flexible Foundation using Tuned Mass Dampers," analyzes the response of high-rise buildings equipped by MTMDs, accounting for soil-structure interaction (SSI). The authors' findings suggest that the type of soil may influence tuning parameters, and the MTMDs show better effectiveness, compared to the single-tuned mass dampers.

Secondary axial flow on inclined bridge stay cables contributes to the intensity of wind-induced vibrations. The work by Wang et al., "Simulating the Role of Axial Flow in Stay Cable Vibrations via a Perforated Wake Splitter Plate," proposes a solid wake splitter plate for achieving a symmetric surface pressure distribution pattern and a weaker von Kármán vortex shedding strength, leading to reductions in the lift and drag forces, which may affect the wind-induced vibrations.

Long-span bridges may exhibit diverse aeroelastic phenomena, and the shape of the deck plays an important role in governing the aerodynamic stability. In the paper by Haque et al., "Bottom Plate Slope Effects on Aerodynamic Behaviour of Hexagonal Cross-Section Bridge Deck," the authors carry out detailed numerical investigations on the bottom plate web slope effect on flow behavior of a hexagonal bridge deck, using a two-dimensional finite volume code with the RANS turbulence model, and they compare the results with those obtained from the study of a pentagonal shape.

Long-span slender structures, such as transmission lines, may be subjected to a unique load because of the spatial localization of the downburst, which is different from synoptic winds. In their paper, "Longitudinal Forces on Transmission Towers due to Non-Symmetric Downburst Ground Wire Loads," Elawady and El Damatty develop a simplified approach to estimate downburst-induced forces for ground wires of transmission lines.

It can be challenging to capture the characteristics of the wind field during a tornado event, especially in the near ground region. In the paper by Yuan et al., "Effects of Chamber Shape on Simulation of Tornado-like Flow in a Laboratory," the authors produce tornado-like vortices, employing three simulators with different geometric shapes, to systematically study and understand the violent tornadic wind field and its effect on civil engineering structures.

Computational wind engineering is a promising area of research that has received significant attention in recent years. The paper by Yeo and Shi, "Computational vs. Wind Tunnel Simulation of Atmospheric Boundary Layer Flow for Structural Engineering Applications," presents atmospheric boundary layer computational simulation used to assess its suitability for structural wind engineering applications.

We hope that this book reveals the knowledge shown with the most recent advances and applications in wind/structural engineering and thus is of interest to numerous researchers looking to pursue further investigations leading to major improvements of design approaches, with the intent of creating more resilient and sustainable infrastructures. This is imperative per the current climate change and population growth.

Last, but not least, we would like to thank all the authors for their contributions, as well as the reviewers for their support and helpful critiques, which made this publication possible. Many thanks to Dr. Chaker, Dr. Hajj, Dr. Diplas, and members of the EMI Fluid Dynamics Committee for their collaboration.

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CHAPTER 1

Recent and Current Wind Engineering Research at the National Institute of Standards and Technology

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Abstract: *This paper briefly reviews recent and current National Institute of Standards and Technology (NIST) research aimed at improving standard provisions and advancing structural design practice for wind loads. The research covers: (i) New wind speed maps for the conterminous United States; (ii) Risk-consistent estimation of wind load factors for use with the wind tunnel procedure; (iii) Modern peaks-over-threshold approaches to estimation of peak wind effects; (iv) User-friendly procedures for the database-assisted design of rigid and flexible structures; (v) Novel approaches to codification of pressures on cladding and components; (vi) Modern modeling of synoptic storm planetary boundary layers and its implications for super-tall building design; (vii) Computational Wind Engineering (CWE); (viii) Tornado climatology and development of tornado-resistant design*

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