Modern Pressure Measurement Technology and Structural Design for Wind: A New Collaborative Paradigm for Wind and Structural Engineers

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ABSTRACT

A brief historical review of structural design for wind is presented that notes the progressively improved modeling of wind effects on structures and the decreasing role of their subjective estimation as measurement techniques have evolved. This progression has culminated in two developments that have improved the effectiveness of structural designs for wind in major ways: (1) the emergence of pressure scanner technology, which makes it possible to obtain and record simultaneous, phase-preserving time histories of pressure measurements at large numbers of taps on the external surfaces of structural models; and (2) the development of a computer-intensive, time-domain, iterative approach, referred to as database-assisted design (DAD), that fully exploits those measurements by determining, for any specified mean recurrence interval, (i) peak demand-to-capacity indexes directly used for member sizing, (ii) inter-story drift values, and (iii) top-floor accelerations.

The DAD approach accounts transparently for wind directionality effects and automatically achieves objective, rigorous combinations of time histories of wind effects. In particular, DAD computations confirm the theoretical finding that the use in current practice of static wind loads purported to be equivalent to the actual random, time-dependent wind loads can lead to significant errors in the estimation of demand-to-capacity indexes.

The role of the wind engineer in the final design process is to produce the requisite micrometeorological, wind climatological, and aerodynamic data in formats suitable for use by the structural engineer and for incorporation into building information modeling (BIM). Unlike in current practice, once those data are available, the interface between wind engineering and structural engineering contributions to the design entails no loss of information, and the structural engineer is in full control of the design. Finally, to the extent permitted by constructability and serviceability constraints, DAD achieves the differentiated and risk-consistent design of as many individual structural members as deemed appropriate by the structural engineer, resulting in safer and more economical structures than can be achieved by earlier practices.

At present the aerodynamic data must be measured in wind tunnels. To complete the “big data” approach inherent in DAD, efforts are underway to develop Computational Fluid Dynamics (CFD) techniques that have the potential for largely supplanting the wind tunnel as an aerodynamics or aeroelastic tool. Pending increases in available computer power, joint DAD/CFD procedures used in conjunction with the requisite wind climatological information can be anticipated to enable a full numerical approach to the design of structures for wind effects. The DAD component of the DAD/CFD combined approach is currently ready for use, and encouraging advances in the CFD component of such an approach are proceeding apace, albeit still slowly for structures susceptible of aeroelastic behavior. Some of these advances are briefly noted herein. The talk ends with a plea for intensifying the research efforts needed to enhance the safety and economy of structural design for wind by realizing the practical potential of bluff-body CFD.