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Estimation of Extreme Wind Load Effects with Various Mean Recurrence Intervals: Nonlinear, Uncertainty and Wind Directionality Effects

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Crosswind response often dominates wind-resistant design of tall buildings and flexible structures. This talk will discuss the estimation of extreme and fatigue responses of crosswind excited tall buildings and flexible structures at the vicinity of vortex lock-in wind speed, where nonlinear negative aerodynamic damping effect is significant. The aerodynamic damping is modeled as a nonlinear function of time-varying velocity and/or displacement of vibration based on motion-induced aerodynamic force information derived from forced-vibration model testing in wind tunnel. The method of equivalent nonlinear equation is used to determine the crosswind response statistics, extreme value distribution and fatigue damage. Correction factors as functions of response kurtosis are also introduced to facilitate the calculation of extreme and fatigue damage from those of traditional Gaussian predictions. The effectiveness and accuracy of the proposed frameworks are illustrated by crosswind response of a square-shaped tall building and by full-scale vibration measurement data of a traffic-signal-support-structure.

The performance-based design of wind-excited structures requires estimation of extreme wind load effects with various mean recurrence intervals (MRIs). This talk will discuss a fully probabilistic framework of estimating the annual extreme (maximum) response distribution through synthesizing distribution of extreme response conditional on mean wind speed and the distribution of annual maximum wind speed. A closed-from framework will be presented for estimating the wind load effects with given MRI directly from the statistics of wind speed and response of both rigid and flexible structures. The design response for a target MRI is readily defined with an improved accuracy than the widely used Cook-Mayne coefficient. It also highlights the advantage of direct use of wind speeds with various MRIs in predicting responses as adopted in newest version of ASCE 7-10 and other modern codes over the traditional practice of using a single load factor. This talk will also discuss the wind directionality effects. The limitations of existing approaches are highlighted. A unified framework is introduced to account for directionality and uncertainty for estimating extreme wind load effects with various MRIs. A new thinking of avoiding use of single directionality factor as specified in current ASCE 7-10 is provided.