Buildings Undergoing Complex Motions: Accelerations and Human Comfort

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The design of tall buildings, while concerned with efficiently and effectively carrying the anticipated loads imposed upon the structures, is largely concerned with serviceability and habitability issues. The latter issue may still require attention, even for buildings designed to meet lateral drift requirements (Kareem et al. 1999). As such, structural accelerations, as a function of return period, must be considered to ensure acceptable occupancy comfort in buildings. The international community, however, has not agreed as to whether RMS or peak values should serve as a universal descriptor of acceleration (Tall Buildings Committee/SEI: www.nd.edu/~dynamo). On one hand, negative reactions by occupants may be a result of a sustained motion, best described by an averaged effect like RMS. The other viewpoint asserts that perception and reaction to motion is most dramatically affected by large events better characterized by peak values. While humans are capable of adjusting to accelerations, any change in the acceleration will require additional adjustments for equilibrium. For this reason, ergonomical studies concerning vibration and comfort suggest that motions containing impulsive vibration or shocks may lead to higher discomfort. Furthermore the transient nature of such impulsive motions repeated at frequent intervals may compound this effect. As a result, basing perception criteria on a measure of jerk, or rate of change in acceleration, may better capture the stimulus defining perception thresholds under random motion. The adoption of such a criterion may altogether override the need for the peak acceleration criteria.

Unfortunately, the quantification of peak accelerations associated with perception issues becomes more challenging in buildings with either complex geometric shapes or structural systems with non-coincident centers of mass and resistance, or both (Chen and Kareem 2005). Such buildings may undergo three-dimensional (3-D) coupled motions when exposed to spatiotemporally varying dynamic wind loads. As there is evidence that, with decreasing frequency of oscillation, there is a concomitant increase in perception levels, buildings undergoing complex motions at different frequencies may present different thresholds. This further complicates the assessment of human comfort in actual buildings.

In this study, the authors present a representative tall building with 3-D mode shapes and closely-spaced frequencies and utilize an analysis framework that takes into account the correlation among wind loads in principle directions and inter-modal coupling of response components to estimate the acceleration response statistics (Chen and Kareem 2004). These predicted responses are evaluated against full-scale acceleration values to demonstrate the efficacy of this coupled response framework. The resulting acceleration data set is then examined to investigate the nature of the motion waveform: its peakedness and level of transience, characterized in terms of statistical measures. More importantly, the time of residence above a specific motion threshold is examined.

Utilizing anecdotal information concerning motion perception and reaction, correlation between the stimulus and occupants' perception and reaction to motion is offered. The authors also explore the issue of frequency-dependent perception thresholds in buildings with coupled motions through the introduction of frequency-dependent transfer functions of human biodynamic motion sensitivity to dispense appropriate weighting functions to responses at various frequencies.

References

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