Ask the Experts...Perception of Motion Criteria for Tall Buildings Subjected to Wind: A Panel Discussion

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Introduction

The design of tall buildings, while concerned with efficiently and effectively carrying the anticipated loads imposed upon the structure, must also consider serviceability and habitability issues. With the trend toward taller, lightweight structures, susceptibilities to the action of wind are enhanced, as a consequence of increased flexibility and potentially diminished damping. While a given design may satisfactorily carry all loads and even meet serviceability requirements, the structure may still suffer from levels of motion causing significant discomfort to its occupants and triggering responses that may include: concern, anxiety, fear, and vertigo or extreme responses of dizziness, headaches, and nausea. As a result, over recent decades, there has been a concerted effort to quantify acceleration levels that induce negative response in building occupants, though this discussion has not been free from debate. However, the rapid growth of high-rise construction worldwide has insured that the issue of motion perception will remain an urgent concern to designers, prompting the formation of this panel of experts to address the efficacy of habitability criteria and the appropriateness of the two most popular perception criteria: peak and RMS accelerations.

Origins of Perception Limits

Perception limits have been traditionally determined based on the response of individuals to tests using uni-axial motion simulators (e.g. Chen & Robertson 1973, Irwin 1981, Goto 1983), though current efforts are directed toward bi-directional motion simulation tests (Denoon et al. 2001). In most cases, such experiments rely on sinusoidal excitations, easily quantified by either peak or RMS acceleration limits. However, there appear to be some discrepancies between these testing environments and those of actual structures, since building undergo narrowband, random motions, inducing bi-axial and torsional responses. In addition, the absence of visual and audio cues in most of the test environments neglects critical stimuli, particularly for torsional motions, which are infamous for triggering visual stimulus. Hansen et al. (1973) attempted to capture a more realistic stimulus by interviewing building occupants in two tall buildings following a significant storm and establishing a tentative criterion for limiting motion, which resulted in a 5 milli-g RMS criteria for a six-year event. However, the frequency dependence of perception thresholds becomes critical, since there is evidence that, with decreasing frequency of oscillation, there is an increase in perception levels. Later work, such as Irwin's RMS criteria, known as the ISO 6897 Standard, accounted for this feature. On the other hand, AIJ has developed frequency-dependent peak acceleration curves to define acceptable motions for four types of occupancy levels. North American practice similarly uses peak accelerations, commonly limiting horizontal accelerations at the top floor to 10-15 milli-g in residential buildings and 20-25 milli-g in office buildings, based upon a 10 year return period (Isyumov 1993).

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RMS vs. Peak Accelerations

As the aforementioned perceptions limits illustrate, the international community has not agreed on a universal descriptor of acceleration, for a number of reasons. On one hand, negative reactions to motion may be the result of a sustained or ongoing phenomenon, best described by an averaged effect over some period of time, leading to the common RMS descriptor. However, others have also asserted that a person is most dramatically affected by large events – impacting the individual far more than the typical phenomenon their body had become accustomed to. Many favor the RMS index due to the ease with which it is measured experimentally or predicted analytically, citing the variability in peak acceleration measurements in wind tunnel testing as one demonstration. Further, criteria based on RMS accelerations, as opposed to peak accelerations, offer a more accurate means of combining response in different directions based on their respective correlations (Kareem 1992). However, advocates of peak acceleration criteria contend that peak resultant accelerations are difficult to estimate when RMS accelerations are used (Isyumov 1993).

Other Acceleration Descriptors

Further investigations have revealed that the jerkiness of the structural response may primarily be responsible for perception of motion. Quite simply, while humans are capable of adjusting to accelerations, any change in the acceleration will require additional adjustments for equilibrium. As a result, basing perception criteria on a measure of jerk, or the rate of change of acceleration, may better capture the stimulus defining perception thresholds under random motion. The adoption of such a criteria may altogether override the need for peak acceleration.

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