Full-Scale Validation of the Wind-Induced Response of Tall Buildings: Preliminary Results of the Chicago Monitoring Project

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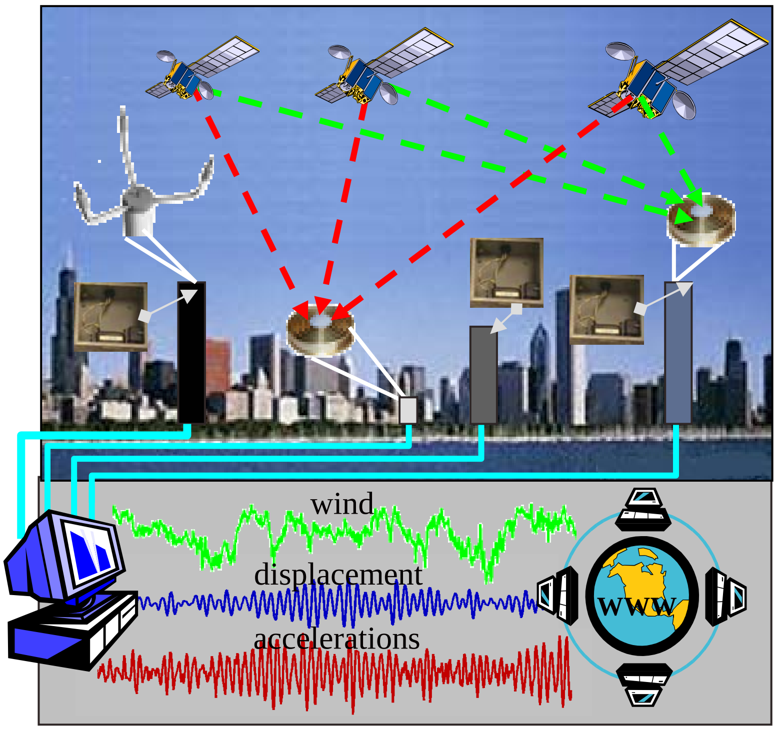

Figure 1. Overview of Instrumentation Program for Chicago Full-Scale Monitoring Project.

Abstract

While high-rise construction serves as one of the most challenging projects undertaken by society each year, tall buildings are one of the few constructed facilities whose design relies solely upon analytical and scaled models, which, though based upon fundamental mechanics and years of research and experience, has yet to be systematically validated in full-scale. In response to this deficiency, a full-scale monitoring project was initiated through the combined efforts of members of academe (University of Notre Dame), practicing design firms (Skidmore, Owings and Merrill, Chicago) and commercial testing laboratories (Boundary Layer Wind Tunnel Laboratory, University of Western Ontario). Currently, the monitoring program includes two tall buildings in Chicago: one steel and one concrete. A third tall steel building in Chicago will be instrumented in the near future to provide a suite of tall buildings, among the world's 25 tallest buildings, with structural systems common to high-rise construction. This paper overviews the monitoring program, instrumentation and preliminary results of this ongoing full-scale investigation.

Instrumentation

The buildings are each instrumented with four servo, force-balance accelerometers geared to monitor low-amplitude, low-frequency motions with minimal noise. Two pairs of orthogonal

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accelerometers are mounted at opposite corners of each building at the highest floor possible, providing a means to determine accelerations along both building axes and in torsion. Data is collected from these accelerometers at 8.33 Hz and statistical records are generated every 10 minutes and archived in an on-site data logger. When the accelerations of the building exceed a pre-determined threshold specific to each structure, continuous time histories of the accelerations are recorded for the duration of one hour and stored in the data loggers for subsequent download and analysis to extract dynamic properties of the building. In addition, the monitoring system is supplemented by a high-precision Global Positioning System (GPS) to measure static and dynamic displacements of one of the buildings, requiring the use of a nearby reference station to increase the accuracy of GPS displacement estimates (Kijewski and Kareem, 2003).

Though wind speed measurements are currently being retrieved from Chicago's O'Hare International and Midway Airports and a lakefront monitoring station, the team is coordinating efforts to install an ultrasonic anemometer on one of the monitored structures, at a height well above the aerodynamic influence of the roof, to provide an accurate description of the gradient height wind climate of the city of Chicago. Finally, the data collected in the study is archived off-site and integrated into a web-interface to allow for secured access by the project team and building owners and management in their diverse geographic locations, as overviewed in the schematic in Figure 1.

Data Analysis

The analysis of data collected in this study will provide valuable insight into a variety of response characteristics for tall buildings and permit the systematic validation of existing design practice through the comparison of analytical and wind tunnel response estimates with full-scale observations. To date, a limited number of field measurements have been recorded. However, from these observations, structural properties such as the periods of vibration of the building in the fundamental modes and the structural damping are being estimated and will be documented in this study, providing a better indication of in-situ dynamic properties and the adequacy of current design assumptions. Based upon these preliminary results and future collected response data, modern design approaches and wind tunnel testing procedures will be calibrated systematically for the first time using full-scale data in order to provide more reliable predictions for future design. Note that the wind tunnel data used for this calibration was generated using updated testing of 1:500-scale models of the buildings to include surrounding structures built subsequent to the completion of the buildings being monitored in this study. Wind speed and acceleration response observed in full-scale will be compared with those predicted from the wind tunnel tests at the Boundary Layer Wind Tunnel Laboratory, as will the variation of rms acceleration with wind direction.

References

Kijewski, T., and Kareem, A., "**GPS for Monitoring the Dynamic Response of Tall Buildings: Experimental Verification and Full-Scale Application**", *Proceedings of 2003 Structures Congress & Exhibition*, ASCE, 29 May-1 June, 2003, Seattle.