Wind Engineering of the 600 m Chicago Spire

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Summary

This paper discusses the analysis of the 600m Chicago Spire for wind climate of Chicago and other weather phenomenon. Tests performed by RWDI in the wind tunnel and results are discussed as well as lessons learned about some of the parameters of the building. Also discussed is the decision making process and factors that led to an Active Mass Damper being included on the project. A description of some of the special analyses performed for this unique project is also included.

Keywords: damper; motion; acceleration; stack-effect; icing; in-cloud icing; falling ice; wind tunnel; wind loads; accelerations and vortex shedding.

1. Introduction

The Chicago Spire by Santiago Calatrava is a true integration of architecture and engineering designed by him to aesthetically and technically fit in the natural world. The slow curves of nature found in items such as flowers and shells inspired Calatrava to form the elegant spiral shape of the building which then determines the building's relationship with nature. That coexistence is most evident when discussing the properties of the building's response due to the wind climate of Chicago. The 600 m tower presented the design team of Santiago Calatrava (architect and engineer), Thornton Tomasetti (engineer of record) and RWDI (wind engineering consultants) with a unique opportunity to explore how a building beyond our normal experience relates with wind.

2. Building Information Relating to Wind Engineering

The 600m Chicago Spire designed Santiago Calatrava is being developed by Shellbourne. The architect of record for the project is Perkins & Will of Chicago and the engineer of record is Thornton Tomasetti. The completely residential building is currently under construction and will be the tallest building in North America upon completion. It will sit on a prominent location on the northern bank of the Chicago River's mouth on Lake Michigan. The east side of the site is bordered by Lake Shore Drive and the north side by Ogden Slip, a man-made inlet of Lake Michigan.

3. Wind Tunnel Testing and Results – Wind-Induced Structural Responses

RWDI conducted wind tunnel studies to determine the wind loads for the overall structural design of the tower and to determine the wind-induced accelerations at the uppermost occupied floors. Three tower designs were investigated during the course of the wind tunnel test program as shown in Figure 2.

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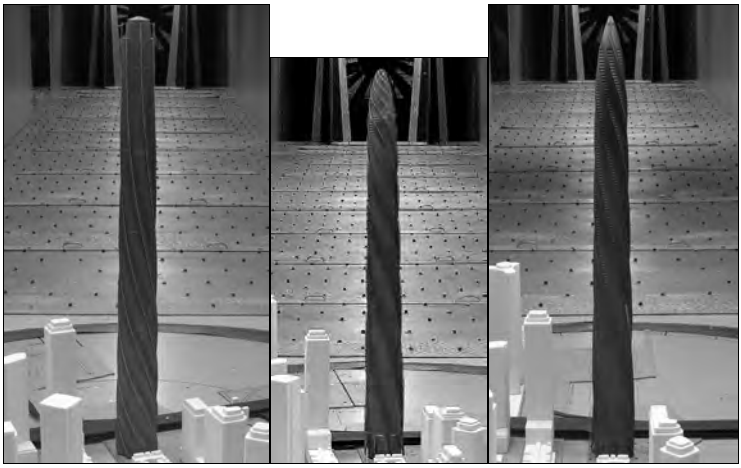
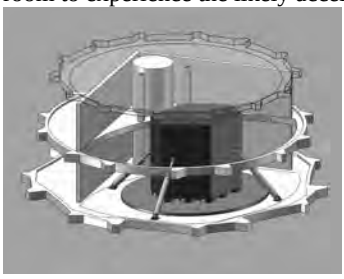


Figure 2: HFFB Wind Tunnel Test Models for Three Tower Designs

4. Building Movement and Engineering for Serviceability

A unique product of this structure is that both the primary and second order bending modes provide significant components to the overall acceleration and they must both therefore be addressed in order to achieve the desired comfort level. After studying various ideas for adding damping to the building, it was determined the best approach was to use a computer controlled active mass damper (AMD) (see Figure 4). An AMD has the benefit of being able to address both first and second order modes of vibration simultaneously. Dynamic modeling determined that a 1200 ton mass was necessary to achieve the desired comfort levels within the confines of the space allotted. When completed, the Chicago Spire AMD will be the world's largest mass damper by a considerable margin. To understand the need and effect of the AMD the project team used a motion simulating room to experience the likely accelerations first hand.



5. Other Special Studies

Other studies required by this unique project included, an in-cloud icing study, elevator cable study, and a study of the stack effect from differing air pressures through the height of the building as well as cladding wind load studies.