Practical Solutions

solutions for the practicing structural engineer

What are the Boundaries on Wind Testing?

By David T. Biggs, P.E., Hon. M. ASCE

Most structural engineers have heard of wind tunnel testing but few have probably been to a laboratory or used the services of a testing facility. The author had the professional honor to meet Dr. Alan G. Davenport and tour the Boundary Layer Wind Tunnel Laboratory at The University of Western Ontario in London, Ontario. Dr. Davenport is world-renowned for his pioneering work in the application of boundary layer wind tunnels to the design of wind-sensitive structures, the description of urban wind climates and other problems involving the action of wind. He also has contributed to the fields of meteorology, environmental loads, structural dynamics and earthquake loading. In addition, he also developed the world's first statistically based seismic zoning map for Canada.

The wind tunnel laboratory at Western Ontario was established in 1965 by Dr. Davenport to assist with determining the impact of wind on structures. It has been involved in the evaluation of over 1,200 structures under contract to industry and owners throughout the world. These have included the Sears Tower in Chicago, the CN Tower in Toronto, and the Walt Disney Concert Hall in Los Angeles, and the World Trade Center in New York.

Universities such as Western Ontario were the genesis of wind testing and basic wind research. Using the wind tunnel facility and solving real life design problems for the design of tall buildings, research on the prediction of wind loads and responses was carried out with and without wind tunnel testing. They provide background for the development of wind codes on the one hand, and information for the design of special structures on the other. The basic theory in wind load predictions and wind tunnel methodology were developed in the 70s and 80s and are still in use today. At Western Ontario, those services are provided by the Alan G. Davenport Wind Engineering Group (**www.blwtl.uwo.ca**).

There are also private firms that provide consulting services for wind testing and load predictions. Many designers of large buildings and specialty structures turn to these wind consultants on a regular basis.

The Development of King Abdul Aziz Mekkah in the wind tunnel. Pressure model of 7 towers, 5 of them sitting on top of an extensive podium. Structural loads were determined by integration of local pressure measurements over all surfaces of the buildings.

Pressure model of the Walt Disney Concert Hall in Los Angeles. Architect: Frank Gehry.

Why Might a Structural Engineer Want Wind Testing?

The answer lies in the development of the building codes. While codes are continually evolving, they are developed to provide information for the majority of *typical* buildings where wind tunnel testing may not be economical. While they generally err on the side of conservatism, they do not cater to problems that arise with special structures. These special structures may include those with extreme heights or lengths, slenderness ratio or special geometry. For smaller projects, these codes may result in uneconomical design; but, on large projects, unrealistic wind loads may translate into unsafe structures. Wind testing can be used to reduce the uncertainty of the effects of the wind (either too high or too low). Using curtain walls as a specific example, wind tunnel tests inherently take into account the impact of complex building geometry, wind directionality, the effect of nearby buildings and develop a more realistic modeling of the upstream terrain.

Codes may also not address specific conditions. ASCE 7 allows wind testing to take the place of analytical techniques.

Wind testing is not only for developing loadings on structures. It can be used to evaluate:

- Wind affects on pedestrians on the street.
- The deposition of snow drifting.
- The effects of topography on wind action.
- The dispersion of pollutants.
- The interaction of wind and waves on off-shore structures.
- Structure movement and the affects on occupants from wind-induced movement.

Practical Tips

The November 2003 article in STRUCTURE® magazine, *Wind Tunnel Testing, A Breeze Through* by Scott Gamble, P.Eng, offers some very valuable tips for engineers. (*To view this article, visit the 2003 archives at **www.STRUCTUREmag.org**.*)

Wind testing is most appropriate to:

a. Buildings over ten stories in hurricane areas.
b. Buildings over 22 stories in non-hurricane areas.
c. Unusual structure shapes of all types, including buildings, bridges and towers.
d. Complex surroundings. These can be urban sites, coastal regions, mountainous areas, or anywhere conditions create unique wind patterns.
e. Whenever there is a desire to optimize cost or provide greater certainty on the safety of a design.

How Can Engineers Learn More About Wind Design and Wind Testing?

There are many continuing education opportunities for structural engineers. ASCE has several seminars that offer a wide range of criteria on wind. These seminars come in various forms: live workshops, live interactive web seminars and web seminars on CD. Workshops vary in length; each seminar is one hour in duration. (*Visit* ***www.asce.org/conted/distancelearning/*** *for more information.*)

The specific wind related education opportunities include:

Wind Loads

This course is an online version of a popular ASCE workshop. Topics include wind effects (e.g., Bernoulli's equation, patterns over buildings, and effects of roof geometry), basic design wind speed, design wind loads, how to use the ASCE-7 standard (plus three worked solutions), frequently asked questions, other codes, and where to get further information. After completing this course, engineers will be able to: explain basic air flow concepts and the effects of wind on structures; describe and calculate different wind speed measures; describe and calculate the parameters of the design wind speed equations, and; use the standard to calculate design wind loads.

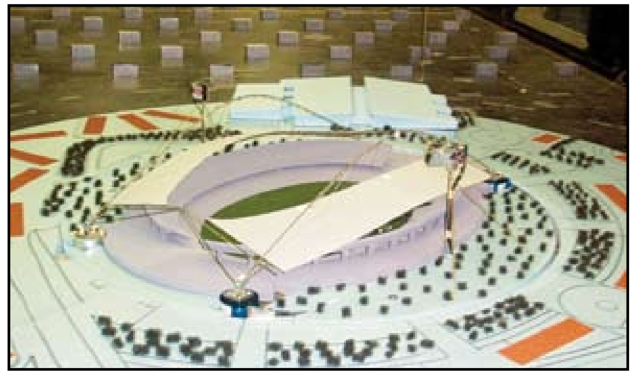
The Cyberport Cybercenter in Hong Kong. Hybrid pressure model using acrylic and ABS plastic using rapid prototyping technique. The building is curvilinear with a fabric roof.

Wind Loads - 4 Part Series

Presented in this four part series of webinars-on-CD is an overview of the provisions, examples problems, and a look behind the equations that will increase your intuition about how to properly apply the provisions. The series is designed for engineers, architects and building officials who need to understand the latest requirements in wind loads. The newest building codes (IBC, NFPA, and Florida) reference the wind provisions of ASCE 7 Standard – Minimum Design Loads for Buildings and Other Structures. Chapter 6 – Wind Loads from the 2002 edition will be the basis for this series. All four parts take four hours.

Wind Tunnel Testing for Wind Loads on Structures

The wind load provisions of IBC 2000 and ASCE 7 permit wind tunnel testing to define wind loads to replace those of the analytic provisions. This seminar presents the types of wind tunnel tests that are typically performed, the results to be expected, the typical benefits of the tests, guidance on when testing is beneficial, and costs. The webinar-on-CD is based on ASCE publications "Minimum Design Loads on Buildings and Other Structures (ASCE 7)" and "Wind Tunnel Model Studies of Buildings and Structures (ASCE Manual of Practice Number 67)".▪



Aeroelastic model of the Athens Olympic Stadium shown in the wind tunnel. Long spanning structures such as roofs and bridges often require aeroelastic modeling to take into account the effects of wind-induced motion.

The author greatly acknowledges the assistance in preparing this article provided by the Boundary Layer Wind Tunnel Laboratory at The University of Western Ontario, including R. Tom Edey, Director of Operations and Eric Ho, Research Director. Alan G. Davenport, Founding Director, is acknowledged for his inspiration for the article.

David Biggs is with Ryan-Biggs Associates, a structural engineering firm in New York and Pennsylvania. He specializes in the design, evaluation, and restoration of masonry structures, forensic engineering, and the development of new masonry products. David currently serves on the STRUCTURE® Editorial Board.

ADVERTISEMENT – For Advertiser Information, visit **www.STRUCTUREmag.org**