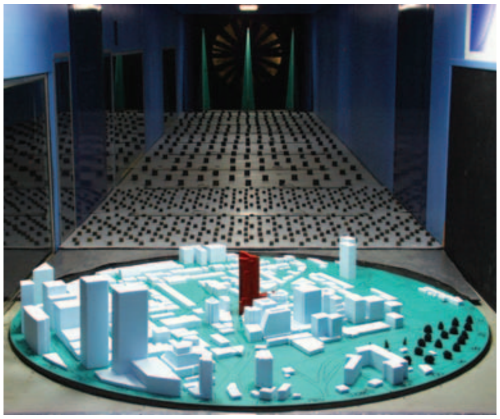


*Model with surroundings and upwind roughness.*

# Wind Tunnel Testing

## *A Breeze Through*

*By: Scott Gamble, P.Eng.*

### *I don't need a wind tunnel test; I already know the wind loads… they're right here in the code.*

In the day-to-day process of design, it is easy to confuse the minimum requirements in codes and standards with the loads produced through consideration of the important physics involved. The wind loads provided in most codes and standards are based on original academic research of a range of building shapes common 40 years ago. While these shapes are still common today, architects and engineers are becoming increasingly bold in their application of sculptural shapes, and high-tech materials and design methodologies. Codes and standards have been continuously upgraded over the years to keep abreast of new developments and experiences, but in order to keep them simple to apply they remain general in nature out of necessity.

Increasingly, we are building new structures in complex situations. In a typical instance, a fairly conventional structure is often proposed for a site where the effects of turbulence, generated by neighboring structures or terrain features, can play a major role in the loads experienced. This can be either a sheltering or a turbulent buffeting effect, which means that the code-based loads may be either too high or, on occasion, too low.

Most codes and standards recognize that wind tunnel tests can produce more reliable loading estimates, and incorporate provisions for this. An example can be found in Section C6.6 of the commentary to ASCE 7-02. Look for similar types of statements in your locally applicable code. In some locales, it is commonly understood that the code provisions are very conservative and significant savings in cost of structure and cladding can be obtained by carrying out a wind tunnel test.

### *I don't want to turn my design project into a research project!*

Although the roots of wind tunnel testing for civil/structural projects are in academia, today there are a number of highly reputable and capable wind consulting firms which specialize in providing just the kind of information you need. Testing of buildings and other structures is very different from the testing for planes, cars or university research projects. Therefore, the test facility must be set up specifically for this purpose.

The type of wind tunnel used is called a "boundary layer wind tunnel," and it incorporates a long section upwind of where the model is placed in which floor roughness and turbulence generators are present. This is to simulate the natural drag of the Earth's surface (ground, vegetation, terrain, man-made objects) on the wind flowing over it. Great care is taken to produce the correct change in wind speed and gustiness with height for each type of terrain over which the wind approaches your project. In situations where the wind approaches your project site over mountainous terrain, a parallel study, using a smaller scale model of the topography to evaluate its effect on the approaching wind, might be needed.

The wind tunnel test facility needs to have appropriate instrumentation and data acquisition in order to obtain the huge amounts of information required from the test in a reasonable length of time. These are usually in the form of simultaneous surface pressure measurements (for cladding design), high-frequency force-balances for measurement of overall structural loading, and hot-wire anemometry for measurement of wind speeds and turbulence.

Although doing a wind tunnel test is complicated, wind-consulting firms, having carried out hundreds or even thousands of these studies, make it painless for you.

**_When should I do a test?_**

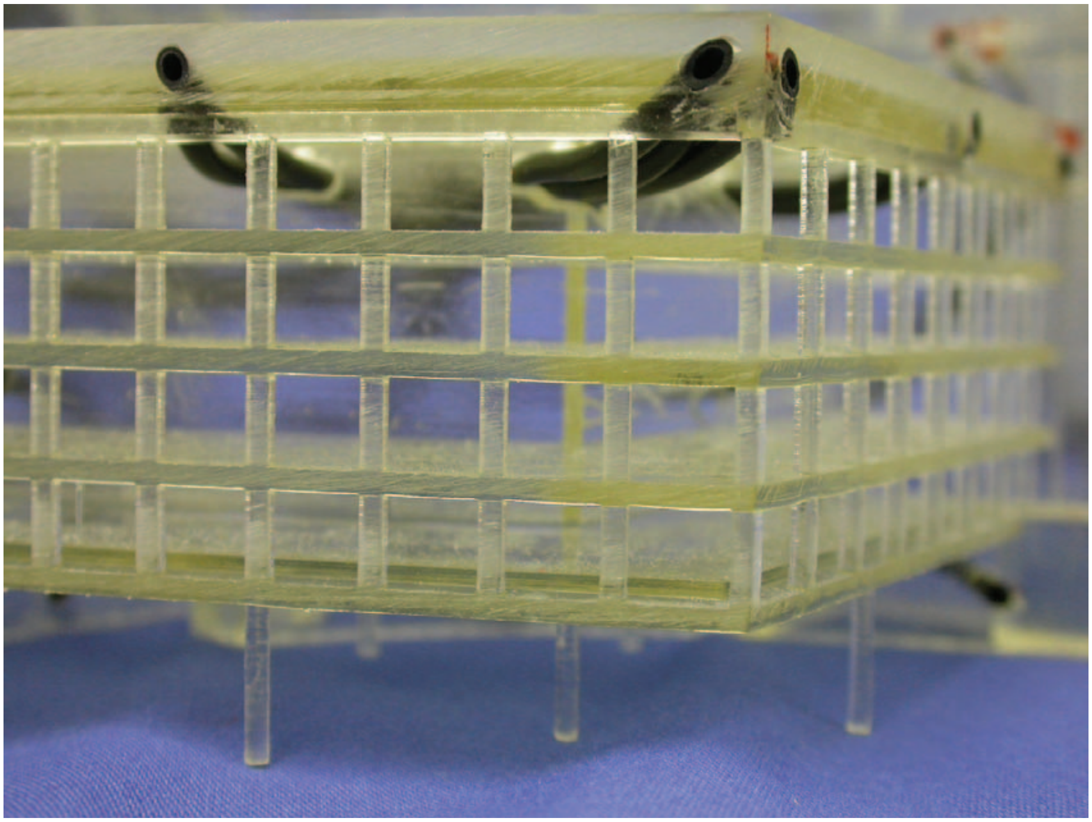
- >10 stories in hurricane areas
- >22 to 25 stories in non-hurricane areas
- Unusual Shapes
- Complex Surroundings (terrain or other structures)
- To optimize cost and safety of project

**_How do I get a test done?_**

- Contact wind consultants
- Check experience
- Send preliminary info on project
- Request proposal (i.e. Structural and Cladding)
- Discuss other issues with consultant (i.e. Pedestrian Wind and Exhaust Dispersion)

### *Wind tunnel testing will only slow down my tight schedule!*

We all know that schedules are rarely lax. Determining wind loads for designing the foundation and structure of your project must fit into the schedule properly, or the information may be of little or no use. First, wind consultants with a wealth of experience and acquired data



*Pressure Taps*

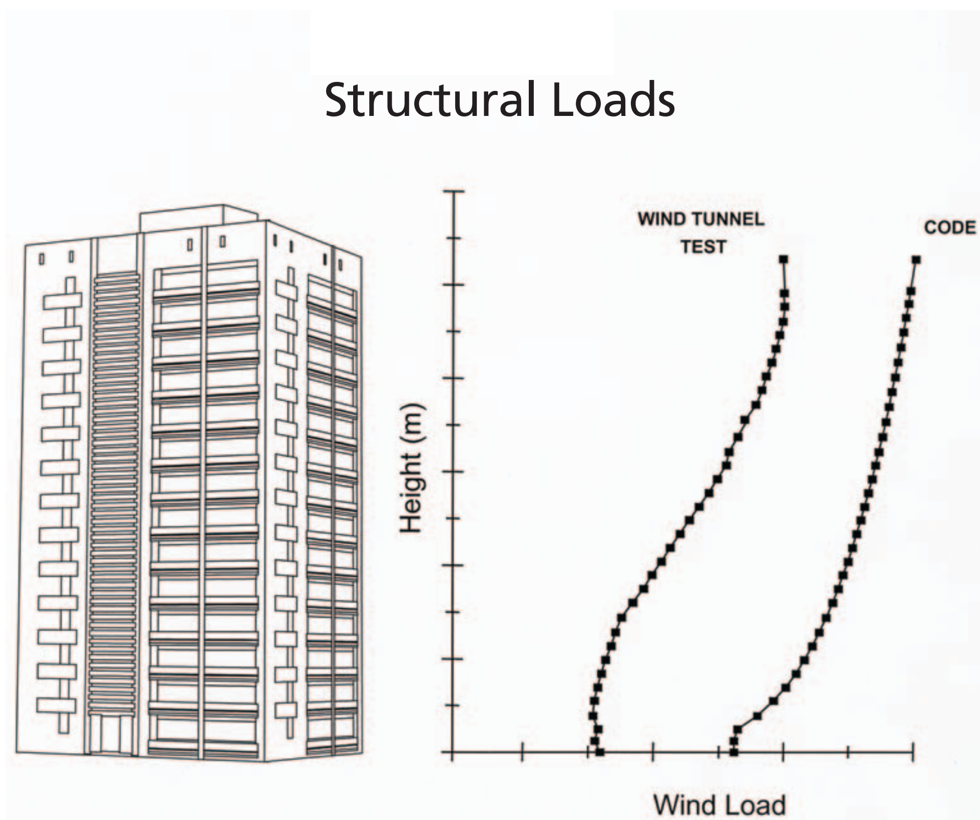
can provide input for your initial assumptions when you need it. Second, the process of wind tunnel testing may be much quicker than you think. One of the major calendar time consumers is getting the necessary information to the wind consultant so model building can get started. If the structural engineer has this available early in the process, the time frame can often be reduced.

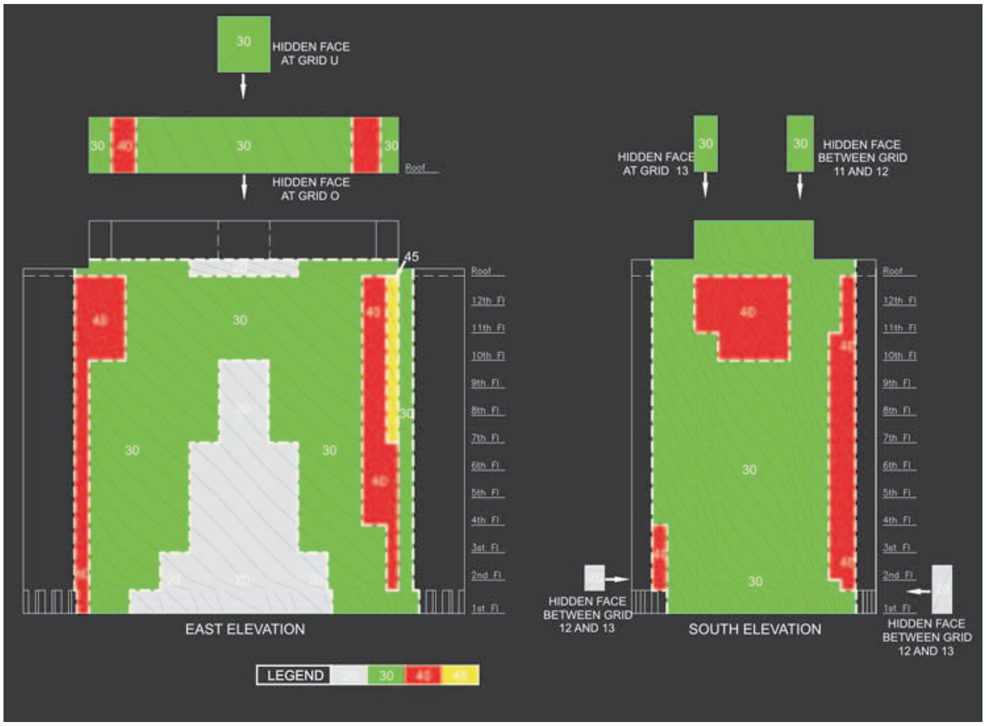
It takes some time to construct the actual study model. Most wind tunnel labs construct the model out of some form of plastic with several hundred or more surface pressure taps installed at points on the surface (where experience with wind flows dictates that the important wind pressures for design are likely to occur). For structural loads, a lightweight model usually made of balsa wood, plastic foam, or thin-walled plastic is mounted on a stiff force balance which measures the overall fluctuating wind loads on the entire structure. These lightweight models can generally be produced quickly so that the most urgently needed loads can be acquired as a priority task. Models of the surrounding buildings, usually within a radius of 1500 feet to 2500 feet of your site, are generally constructed from plastic foam. These are placed on a circular disk and set on a turntable in the wind tunnel. Rotating the turntable effectively simulates wind approaching from any direction.

Aeroelastic models, which are constructed to flex in the wind tunnel like the real structure does in response to ambient wind, are used only for exceptionally tall buildings or flexible structures such as bridges. These models require a much longer time frame to design and construct. In these cases, you should refer to the ASCE Manual of Practice for details on the method and require your wind consultant to adhere to its requirements.

### *Won't all that data from the wind tunnel be too complicated to use?*

The wind tunnel is capable of measuring a very large quantity of data. Hundreds of pressure locations can be measured hundreds of times each second and the data stored. The data are then processed to provide design information on peak loading of cladding elements, instantaneous pressure differences across parapets, canopies and across corner mullions.






*Typical cladding pressure recommendations*

Both pressures and suctions must be evaluated. Still, this sounds (and is) complicated. Structural loading tests use fluctuating forces and moments measured in the tunnel, and combine them with the structural dynamics of the building. Furthermore, measurements are generally made for 36 wind directions in 10° increments. All of this is combined with statistical models of the wind climate for the locale of your particular project. Very complicated!

But there is good news! An experienced wind consultant can boil all this down to a simple set of recommended loads, which in turn can plug into your structural design as if you used the code. The typical form of these recommendations is a set of block diagrams of design wind pressures showing pressure zones mapped on the surface of the building (to be included in a bid package) or a set of loads to apply along the height of the structure so you can evaluate the sizing of structural members.

## *If I make a change to the design, the whole wind tunnel test is useless!*

It is true that the purpose of wind tunnel testing is to get information about the loading of the actual shape of the building in its actual surroundings. If either the building or its surroundings change, the loads produced could change too. This is true of both the wind tunnel approach and code approach. However, the code gives very little guidance on how to deal with the situation. Using wind tunnel data from the earlier configuration, high quality estimates for the new configuration can often be obtained with no additional testing, depending on the nature of the change.

## *So, if I decide to do a wind tunnel test, what are the typical time and cost requirements?*

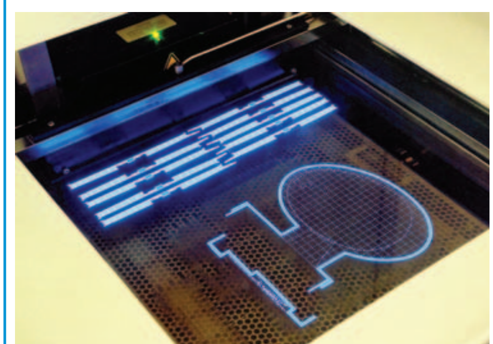
Often, the information you need first is the structural wind loading so that the design of foundation and structural framing can proceed. With all geometric information in hand and some initial structural characteristics (i.e. natural frequencies, mode shapes, mass distribution), initial structural wind loads can typically be available in four to eight weeks. In critical situations, better timing is possible. For cladding wind loads, similar timing is reasonable. The cost for wind tunnel studies, as in all things, depends on the scope of items to be studied. For example purposes, a budget of $40,000 to $60,000 (US) for a 30 story building would be reasonable. This could go higher if you add optional studies.

## *I can get the same thing from CFD at a lower price…*

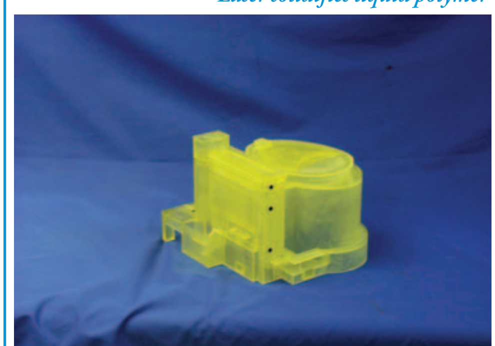
Computational Fluid Dynamics, or CFD as it is known commonly, is an entirely computed assessment of fluid flows. No physical models are used. While used extensively in the aircraft, internal ventilation and industrial process industries, boundary layer wind flows are so complex that CFD's applicability for this purpose is still not verified. Be careful about claims of CFD proponents. Running one or two wind directions in a computer model is not sufficient to gain the necessary information to make important design decisions.

### *Modern Rapid Prototyping (SLA)*

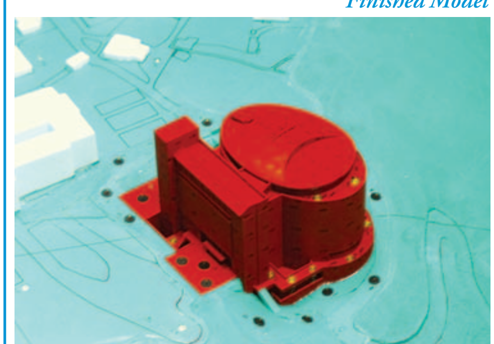
- "Grows" a model from 3D CADD
- By solidifying liquid polymer
- By laser light, in hours not days



*Laser solidifies liquid polymer*



*Finished Model*



*Instrumented for wind tunnel testing*

### *Are there any other advantages to doing a wind tunnel test?*

Once a scale model is constructed, there are many optional tests and analyses that can be of great benefit to the design, such as: parametric analysis of structural loads (changes in stiffness, mass, damping), differential loads on adjacent elements, loading of secondary structural members, effects of other buildings in phased projects, loads during construction phases, pedestrian wind environment, snow loading, roof paver lift off, gravel scour, flow visualization and measurement of exhaust re-entrainment, sliding snow and ice, and rain infiltration under canopies. More detailed studies such as aeroelastic studies, which may be necessary for bridges, large span roofs, spires and cantilevered features where vortex shedding or instabilities are possible, can also be undertaken.

While complicated to carry out, initiating a wind tunnel test and using the results are not rocket science for a structural designer. Even projects which, at first examination, look entirely "code-like" can benefit greatly from incorporating the physics of the situation through a wind tunnel test.

*Aero Bridge Model 1*

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# noteworthy news and events

## *Article Ideas for 2004…*

STRUCTURE magazine's Editorial Board and publishing staff will be meeting at the NCSEA Winter Institute in Scottsdale, AZ, January 23-24, 2004. (See page 37 of this issue for Winter Institute details.) The publishing staff would love to talk to anyone with articles ideas for 2004.

Please email **publisher@structuremag.org** and we will try to set up a time to chat!

Also, watch for copies of STRUCTURE magazine at these upcoming conferences:

NAHB
January 19-22, Las Vegas, NV

World of Concrete,
February 17-20, Orlando, FL

Visit our Events page at
**www.structuremag.org**
for more on upcoming conferences!

## *Correction…*

Please note the following important correction to the *Indian River Inlet Bridge* article in the October issue of STRUCTURE magazine. In the second to the last paragraph, first column, page 18, the final sentence should read:

"Therefore, the selected arch dimensions and design criteria are such that cracking level stresses ($7.5\sqrt{f'c}$) are **not** permitted, even under the factored load combinations."