Wind engineering

The art of designing for the wind

With pioneering contributions from both the National Aeronautical Establishment and the Division of Building Research, wind engineering, a new field concerned with how the wind acts on objects, is broadening in scope.

Since antiquity, man has made use of the wind. It turned the sails of windmills, grinding grain and pumping water; it filled the sails of sailing ships, carrying goods across the seas.

But despite centuries of familiarity with the wind, it is only recently that scientists and engineers have begun to probe into how its restless forces affect bridges, buildings, transmission lines and other objects on the ground.

Wind engineering, as this field of enquiry is known, is new. Its first practitioner was probably Gustaf Eiffel, who designed the tower that bears his name for the Paris exhibition of 1889. Its first international conference was held in England in 1963.

It was called into being by dramatic advances in technology – such as high-strength steel and computer-aided design – which allow remarkably light and flexible structures to be built. Being light and flexible, such structures can respond to wind forces.

Architects, for example, are no longer constrained to design buildings in which strength is assured by sheer mass, but are free to erect tall, slender towers. Like stretched guitar strings, such towers can be plucked by the wind and made to vibrate, with results that are uncomfortable for the occupants, and destructive for walls and windows.

Since World War II the weight per unit volume of buildings has been quartered. In the same period, the weight of bridges per unit area of road deck has been halved. Like high-rise buildings, modern large-span bridges are light and elastic, capable of wind-induced oscillations which can be catastrophic.

The most spectacular case of destruction by wind forces on record is that of the 1 524 m long Tacoma Narrows bridge in Washington State, which collapsed on July 9, 1940. It didn't precisely *blow* down. It was torn apart by a violent twisting known as flutter, set up in its road deck by 55 km/h winds.

The action of the wind can be quite complex. Where in Canada can one find guidance on how to design for it? During the past decade, a growing volume of wind engineering problems have been tackled and solved by the Low Speed Aerodynamics Laboratory of NRC's National Aeronautical Establishment, and by the Building Structures Section of the Division of Building Research.

Aerodynamicists study the subtle play of forces set up by bodies moving through the air, or by air flowing past stationary bodies. Their science evolved primarily to answer the questions asked by aircraft designers, and their experimental tools, wind tunnels, are essentially large tubes down which air is blown and in which the forces on model aircraft can be measured.

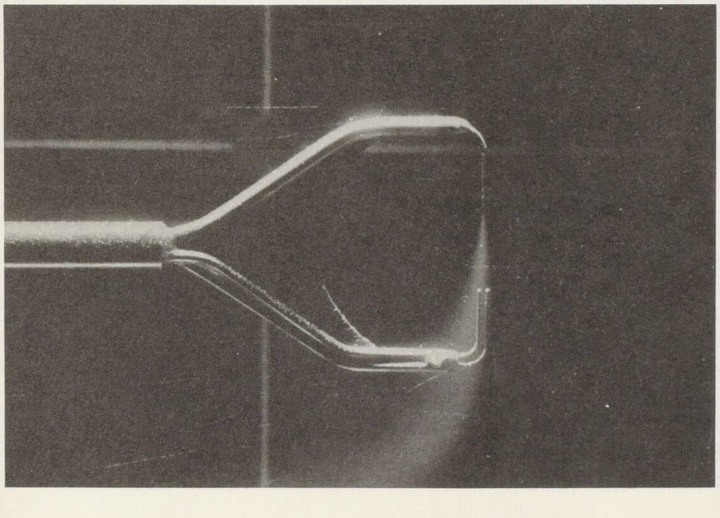
A decade ago it was not possible to study wind engineering problems in the NRC wind tunnels, all of which had been designed for aeronautical research – that is, designed to reproduce, within the laboratory, the conditions encountered by streamlined bodies (aircraft) moving relatively rapidly and smoothly through the ocean of air which surrounds our planet. But wind engineering problems involve bluff-shaped bodies and occur at the bottom of the atmospheric ocean, where conditions are quite different.

In a layer extending from about 1 000 m down to ground level, moving air is progressively slowed and made turbulent by friction with the ground.

In a major breakthrough, NRC engineers found a way to modify aeronautical wind tunnels so as to produce airflows like those in the bottom layer of the atmosphere. Just upstream of the part of the tunnel in which models are placed, they install spires (tapered so that the closer the air flowing around them is to the tunnel floor, the more it is slowed) and a stretch of rough textured, friction-inducing, surface. This ingenious system, widely copied elsewhere, has made it possible for NRC to contribute extensively to the field of wind engineering without having to build expensive special wind tunnels.

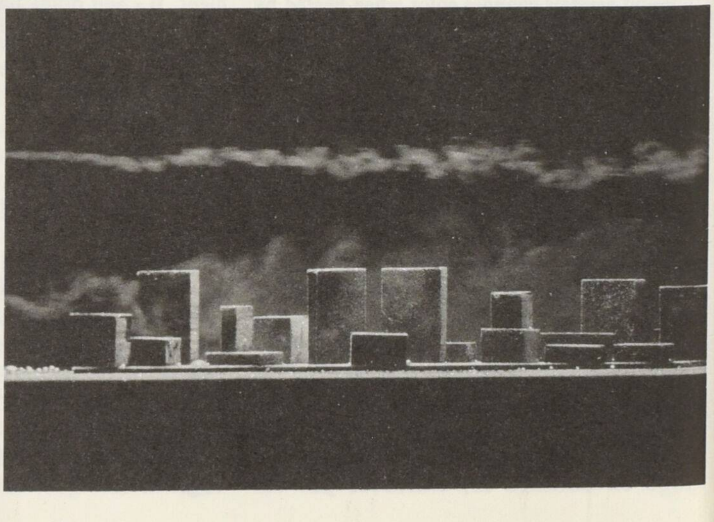
By putting detailed model buildings into these modified wind tunnels, and recording data with sensors which measure the forces of flowing air and the vibrations it induces, researchers can predict how full-size structures will respond to the wind.

In order to verify that designers can use wind tunnel predictions with confidence, the Division of Building Research has tested real buildings in a



This is a fluidics device – a flow speed sensor – working in a water tunnel. *(Photo: George Dobrodzicki, NAE)*

Cet instrument utilisé en fluidique est constitué d'un capteur et sert à mesurer la vitesse de l'écoulement dans un tunnel hydrodynamique. *(Photo: George Dobrodzicki, ÉAN)*



A windy city. To take a preliminary look at such complex subjects scientists put models and yellow colored dye into flowing water. *(Photo: George Dobrodzicki, NAE)*

Une ville exposée aux vents. Un colorant jaune ajouté à l'eau permet aux chercheurs de visualiser l'écoulement de l'air autour des maquettes. *(Photo: George Dobrodzicki, ÉAN)*