WIND DESIGN

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Contents

Summary

Designers of every age have taken into account wind effects on their structures. Wind effects are specific to each site and each structure. Wind-structure interaction can be foreseen in several cases. For complex cases a scaled model is necessary.

1. Introduction

Today, as ever, the design of a plant has to begin with a good perception of the environment and its constraints. Wind effects are representative of these constraints: indeed every structure above ground level is subject to some small or large wind pressure.

2. Historical Background

In the antiquity, the wind was respected and feared: it was the origin of the energy necessary for the ships' movement or for the milling of wheat. The first studies regarding the wind concerned its nature. Aristotle (384-322 BC) wrote the book whose title was "Meteorology" and Theophrastus (371-286 BC) wrote "About weather and wind". However, these books were more philosophical than practical.

Leonardo da Vinci (1452-1519 AD) described natural phenomena more physically and was the origin of a better use of the wind (i.e. discovery of the parachute and weathercock).

In the next two centuries, Galileo (1565-1612 AD) and Newton (1642-1727 AD) wrote basic principles of mechanics. Indeed, Newton wrote the law describing the effort induced in a body surrounded by a flowing fluid.

Subsequently, Bernouilli, d'Alembert, Poisson and Stokes emphasized the aspects of fluid mechanics. Analytical estimation of the effects of the wind over constructions was studied also and in 1883 Reynolds determined the equations of the movement of a turbulent fluid.

In 1893, Irminger's tests were the beginning of the studies of wind effects in aerodynamic tunnels; he determined the distribution of wind pressures on buildings models. A better knowledge of the wind was then very necessary due to several accidents, such as the collapse of bridges (i.e. Firth of Tay in 1879).

At that time, Eiffel built his tower in Paris. Deflection at the top of the tower, due to a wind of 128 km h^{-1} was calculated as 20 cm and Eiffel estimated that the vibrations of the tower would be very slow and not perceptible for visitors. This was confirmed, after completion of the tower, by multiple measurements.

Subsequently, progress was very quick; in 1930 Irminger and Nîkkentved conducted a study about trials of building models in tunnels. This kind of research was carried out in several countries, i.e. in Belgium by professors Vandeperre and Baes. Simultaneously, the theoretical basis of fluid theory was improved. This theory was most necessary and allowed analysis of the results of laboratory models. Prandl studied turbulent flows, Taylor developed a statistical theory of turbulence and von Karman worked on scale problems between the laboratory model and the actual structure in case of turbulent flows. In 1950, von Karman published "Aerodynamics and the art of the engineer".

In 1961, Davenpoort used statistics for the first time to describe wind effects. Models in the laboratory were improved by the use of "aerolastical" models which scale both the strength and the deformability of buildings.

From 1963, the International Association for Wind Engineering organized several congresses to allow international exchange of the results from research in the field of wind engineering.

3. Wind Speed to be Considered on a Site

Wind is an air movement trying to equilibrate differential air pressure coming from an unequal heating of the atmosphere by solar radiation, due among other reasons to differences in latitude and ground cover. Rotation of the earth, gravity effects and shear on the ground affect also the wind speed. Shear on the ground, itself a function of the ground rugosity, is the origin of turbulent exchanges between atmospheric layers.

The design wind speed is the wind velocity which the designer must use to calculate the loading due to wind in accordance with the local standard code of practice. The design wind speed will depend upon the district where the structure is to be erected (meteorological considerations), the local topography (building on top of a hill, in a valley, etc.), the roughness of the surrounding terrain (flat country, wooded area, suburbs, center of town), the size of the building, its anticipated lifetime and required degree of safety, and the duration of the gust which is likely to be significant.

Most, if not all, of these factors are taken into account in the various international codes of practice for the design of buildings. ECCM (1987), for example, defines a basic wind speed which is the maximum 10 s gust speed likely to be exceeded only once in 50 years at 10 m above the ground in open level country. The design wind speed is then obtained by multiplying the basic wind speed by factors which take into consideration the above mentioned parameters. Figure 1 shows the evolution of the wind speed with the height above ground level.

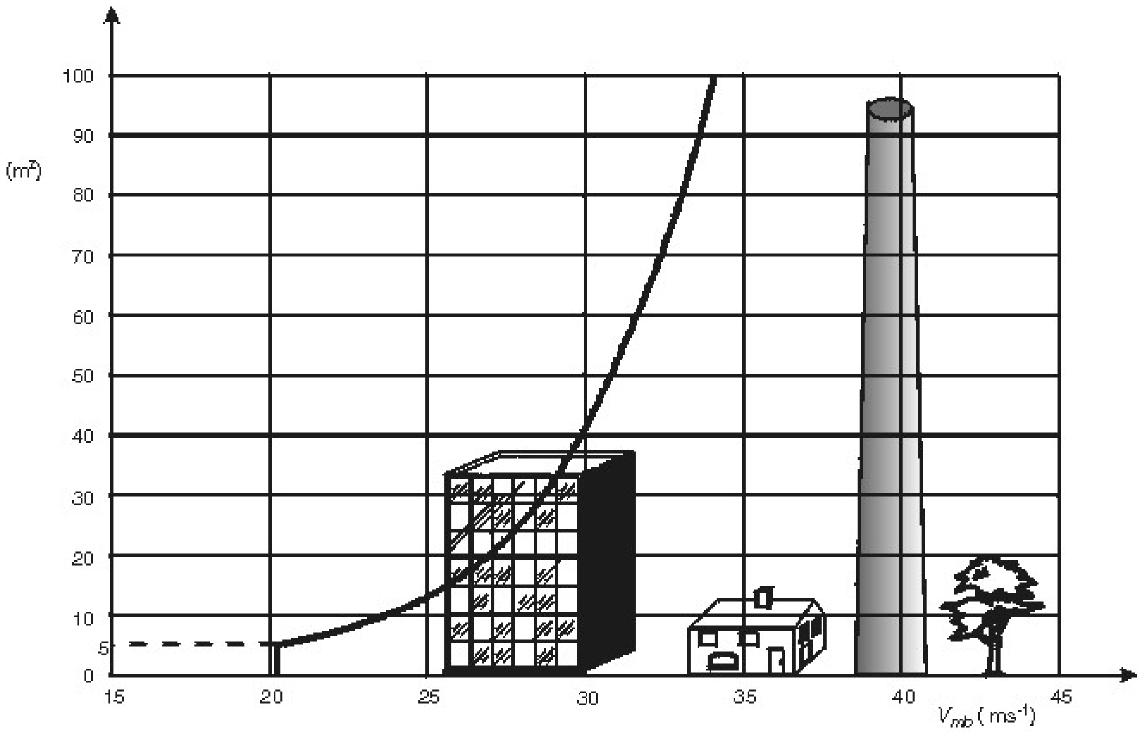

Figure 1. Evolution of wind speed above ground floor.

Very sensitive structures or equipment can be protected against the effects of winds with a higher speed than the design wind speed as described in IAEA (1987) and NRC (1974).

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Bibliography and Suggestions for further study

American Institute of Architects. 1998. Workbook, Buildings at Risk: Wind Design Basics For Practising Architects. New York: AIA Press.

American Institute of Architects. Buildings at Risk: Wind. Washington, D.C.: AIA Press, 1996.

ANSI (1972) *Minimum Design Loads for Buildings and Other Structures*. ANSI A-58-1. New York: American National Standards Institution.

Aysan, Yasmin. 1991. "Disasters and the Small Dwelling: Conference Held at the Disaster Management Centre, Oxford Polytechnic, 2-5 September, 1990." Disasters 15(1): 78-81.

Baird, B. 1976. "Disaster Relief in Honduras: The Plitical Response to Hurricane Fifi; Field Report to the Organization of American States." Disasters 3(3): 49.

Bentley, Mace and Steven L. Horstmeyer. 1999. "Monstrous Mitch: (Destruction in Honduras and Nicaragua)." Weatherwise 5(2): 14-18.

Chiu, Arthur et al. Hurricane Iniki's Impact on Kauai. A Report for the National Science Foundation, December 1995. Springfield, VA: National Technical Information Service, 1995. (Grant number BCS-9300961)

Denhartog J P (1960) *Vibrations Mécaniques*. Paris: Dunod.

ECCM (1987) Recommandations for Calculating the Effects of Wind on Constructions. Publication no. 52. Brussels: European Convention for Constructional Steelworks.

Eurocode 1 Part 2.4. (1995) *Wind Actions*. ENV 1991-2-4. Brussels: European Committee for Standardization.

Eurocode 3 Part 3.2. (1997) *Chimneys*. ENV 1993-3-2. Brussels: European Committee for Standardization.

IAEA (1983) *Extremal Meteorological Phenomena Safety Guide*. 50-SG-S11A. Vienna: International Agency of Atomic Energy.

Melaragno, Michele. Wind in Architectural and Environmental Design. New York: Van Nostrand Reinhold, 1982.

NBN (1988) Actions du vent sur les constructions. NBN B 03-002. Brussels: Institut Belge de Normalisation.

NRC (1974) *Design Basis Tornado for Nuclear Power Plant Regulatory Guide 1.76*. Washington: US Atomic Energy Commission.

Simiu E (1996) *Wind Effects on Structures*. New York: Wiley-Interscience.