Graphic and parametric tools for preliminary design stage of natural ventilation systems

Margherita Ferrucci – Université Paris-Est, IUAV University of Venice – marferit@gmail.com
Maurizio Brocato – ENSA Paris-Malaquais – maurizio.brocato@mac.com
Fabio Peron – IUAV University of Venice – fperon@iuav.it
Francesca Cappelletti – IUAV University of Venice – francesca.cappelletti@iuav.it

Abstract

In this paper we developed a simplified graphical visualization to provide a preliminary understanding of aerodynamic pressure distributions around tall buildings and to estimate the best positions for ventilation openings. This graphical model is based on a database of pressure coefficients hold by parametrical two-dimensional CFD (Computational Fluid Dynamics) simulations over several rectangular shape profiles. The pressure values are obtained by CFD simulations of a stationary flow (High Reynolds), with a K-epsilon turbulence model coupled with Navier-Stokes equations, by using Finite Elements Methods. Whilst turbulence model is well-known, the innovative application is the parameterization of the CFD simulations. The parameters considered here are the ratio between length and width of a rectangular shape and the wind direction (degrees azimuth). Our model adapts automatically to different shapes and various wind directions. Though not able to capture the same level of detail as the three-dimensional CFD simulations or experimental tests, it provides a rapid and intuitive guidance for architects at the preliminary design stage of a natural ventilation system. The final graphical visualizations, together with some simple recommendations, can be exploited by designers having no knowledge in aerodynamics.

1. Introduction

1.1 Airflow around buildings

The use of natural ventilation as a passive strategy for cooling needs reduction has been largely discussed by many authors, since free and mechanical ventilation can reduce the plant capacity and the energy consumption in air-conditioned buildings. Moreover, the use of airflow to remove indoor pollutants and to guarantee a good indoor thermal environment is quality is probably the most recognized advantage of natural ventilation. Mochida (Mochida et al. 2005) demonstrated that wind-driven natural ventilation is an effective way to maintain a comfortable and healthy indoor environment, as well as offering an energy-saving alternative to mechanical ventilation, even though its effectiveness, for a given climatic condition, is strongly affected by the position of the openings on the facades. In fact, natural ventilation, infiltration and exfiltration are affected by wind, causing variable surface pressures on envelope buildings.

The major efficacy of natural ventilation in removing pollutant is achieved when the air flows through an indoor space, determining the so-called cross-ventilation. Cross-ventilation depends on the impact of the wind over the building envelope, which produces a variable pressure field (positive and negative). This pressure difference is the driving force for the airflow through the building. So the effectiveness of wind-driven ventilation depends on the external wind conditions and on the building design (Etheridge et al., 1996).

In a tropical humid climate, for example, the speed of the airflow is used to improve the thermal comfort. Consequently, to obtain cross-ventilation, buildings are designed by choosing their location, orientation, shape, window positions and the internal partitions (Gandemer J.,1992, Olgyay V.,1973).

On the other hand, stack ventilation is driven by the difference between outdoor and indoor air density, caused by temperature difference. Also in

Part of
Baratieri, M., Corrado, V., Gasparella, A. & Patuzzi, F. (Eds.). 2015.
Building simulation applications BSA 2015. bu,press.
https://doi.org/10.13124/9788860460745

5. Acknowledgement

The first author is partially supported by *Université Franco Italienne* and *Paris-Est University*. The authors wish to thank the «*Commissariat français à l'Energie Atomique et aux énergies alternatives (CEA)*" for making Cast3M freely available.

6. Nomenclature

Symbols

H	height (m)
W	width (m)
P	perimeter (m)
r	length/width (aspect ratio)
α	azimuth angle (°)
C_p	pressure coefficient
DC_p	pressure coefficient difference

References

Journal papers

Cóstola D., Blocken B., Hensen J.L.M.. 2009. "Overview of pressure coefficient data in building energy simulation and airflow network programs." *Building and Environment* 44: 2027–2036.

Eldin AS. 2007. "A parametric model for predicting wind-induced pressures on low-rise vertical surfaces in shielded environments." S*olar Energy* 2007: 81:52–61.

Grosso M. 1992. "Wind pressure distribution around buildings: a parametrical mode." *Energy and Buildings* 18:101–31.

Katarzyna Gładyszewska-Fiedoruk, Andrzej Gajewski. 2012. "Effect of wind on stack ventilation performance." *Energy and Buildings* 51: 242–247.

Mochida A., Yoshino H., Takeda T., Kakegawa T., Miyauchi S. 2005. "Methods for controlling airflow in and around a building under cross ventilation to improve indoor thermal comfort." *Journal of Wind Engineering and Industrial Aerodynamics* 93 (2005) 437–449.

Muehleisena R. T., Patrizi S. 2013."A new parametric equation for the wind pressure coefficient for low-rise buildings." *Energy and Buildings 57: 245–249*.

Swami MV, Chandra S.1988. "Correlations for pressure distribution on buildings and calculation of natural-ventilation airflow." *ASHRAE Transactions* 94: 243–66.

Swami MV, Chandra S. 1987."Procedures for calculating natural ventilation airflow rates in buildings-Final report FSEC-CR-163-86." *Cape Canaveral: Florida Solar Energy Cente*r.

Books

ASHRAE. ASHRAE handbook – fundamentals. Atlanta: ASHRAE; 2001.

Etheridge D., Sandberg M. 1996. *Building Ventilation: Theory and Measurement.* John Wiley and Sons.

Gandemer. 1992. *Guide sur la climatisation naturellede l'habitat en climat tropical humide, Tome 1: Méthodologie de prise en compte des paramètresclimatiques dans l'habitat et conseils pratiques.* CSTB, Nantes, pp. 64–68.

Olgyay V. 1973. *Design with Climate: Bio –climatic Approach to Architecture Regionalism*, Princeton University Press, Princeton, NJ, USA pp.94–112.

Online resource

Tokyo Polytechnic University, Aerodynamic, Database of Low-RiseBuildings, http://www.wind.arch.t-Kougei.ac.jpsystem/eng/contents/code/tpu