# THE IMPACT OF WIND TURBULENCE ON THE PRECISION OF A NUMERICAL MODELLING STUDY

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## ABSTRACT

The aim of this study is to illustrate the importance of the effects of wind turbulence on air change in buildings. Using two simple configurations, tested over a short period, two approaches are compared.

The tests are performed using an experimental house which is fully exposed to the wind. The air flow rate is measured over 15 minutes for two configurations: natural ventilation via two openings positioned on two opposing facades, and mechanical exhaust ventilation with two natural air openings.

A code simulates this phenomenon using three numerical solutions based on the frequency of wind-related measurements:
- use of the experimental meteorological file,
- average of the experimental meteorological file at a frequency of 1 Hz,
- average of the experimental meteorological file in order to obtain one value.

The simulation with the one-value file reduces the rate of real air change by around 20%. The other two simulations offer greater precision: less than 2% for the natural ventilation configuration and around 6% for the mechanical ventilation one.

This study demonstrates the importance of the effects of wind turbulence. Where numerical modeling is concerned, it would appear necessary to take into account the wind fluctuations related to turbulence in the field of high frequencies.

## INTRODUCTION

The wind is an important factor in building air change. The nature of the wind plays a predominant role. Measurements show that the wind speed is the combination of an average speed and a fluctuating speed.

An example of spectral decomposition of the kinetic energy of the fluctuations causes two peaks to appear (fig. 1): energy at low frequencies is centered on a period of 4 days, and energy at high frequencies is centered on a period of 1 minute.

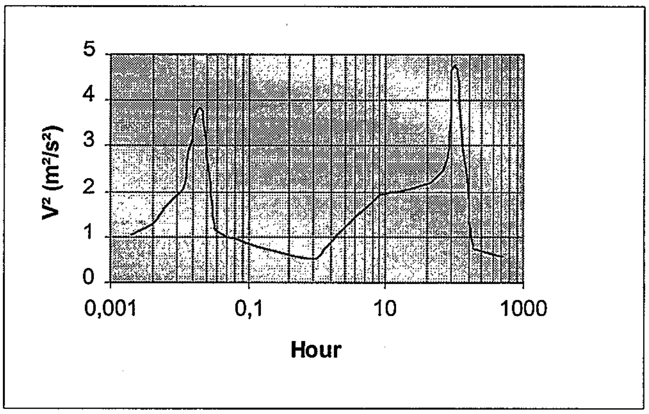


**Figure 1: An example of wind speed spectrum**

Traditionally, codes used for building heat science use one-hour-step meteorological files. Therefore wind speeds on these files only represent the low frequencies section while hiding the field of high frequencies. Therefore, the effect of wind is only partially taken into account and may lead to an incorrect evaluation of the air change rate.

The aim of this study is to quantify these errors using simple configurations.

## METHOD

Two approaches are used and compared for the evaluation of the average air flow rate of a house over a short period: an experimental approach and a numerical approach.

### The experimental approach

The experimental house used for the tests is located in Bouin (north Atlantic coast, France). It consists of a single volume (close to 90 $m^3$). The site is totally exposed to the wind, which remains quite stable over long periods in terms of both amplitude and direction. Airtightness of the building envelope was deliberately improved: the residual leakage value is very low (less than 0,3 ach[1] under 150 Pascal of depression).

The air flow rate is obtained by measuring the reduction in the level of a tracer gas (ethane) previously injected into the room and homogenized using fans. This method allows a good precision for the valuation of the air flow rate.

The external pressure is measured near the openings. An average internal pressure is measured. The wind velocity and wind direction are measured at the top of the house. All this measurements are taken at a frequency of 5 or 10 Hz in order to be sure of representing most of the energy contained in the wind. The testing duration is about 15 minutes.

Two test configurations are used:

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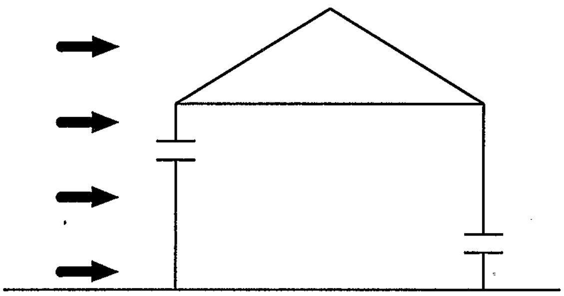
[1] Air Change per Hour.

Configuration 1: natural ventilation through two openings

Two openings of 200 cm² are positioned on two opposing facades. The opening on the windward side is placed in the upper part, the opening on the leeward side in the lower part.

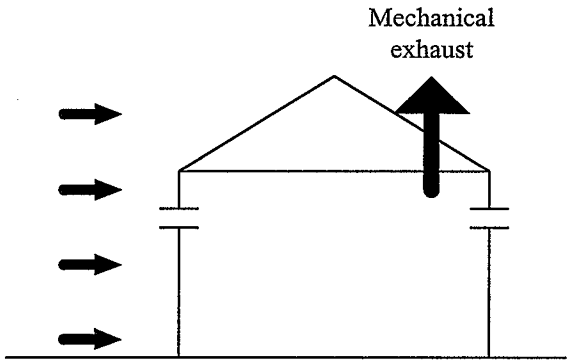
The measurement of wind speed is taken at a frequency of 5 Hz. The average wind speed is about 5 m/s. Its direction is perpendicular to the wall.



Configuration 2: mechanical ventilation

A mechanical ventilation system extracts a constant air flow from the building. Two openings of 200 cm² are installed in the upper part, on two opposing façades (the windward side and the leeward side).

The measurement of wind speed is taken at a frequency of 10 Hz. The average wind speed varies from 4 to 6 m/s. Its direction is perpendicular to the wall.




**The numerical approach**

The CLIM 2000 code is used. This software, which is developed by the EDF Research and Development Division, allows dynamic modeling of the thermal behavior of buildings. The volumes of air are linked together by thermal resistance (representing the walls) and specific models of exchange of mass or energy.

In France, one-hour-step meteorological files are used for a complete heating period. The values represented by the wind vector correspond to time averages calculated over the 10 minutes period just preceding the hour, and on the basis of 10 measurements taken every minute. These values are therefore a sample of the wind vector.

The experimental site described above was modeled using CLIM 2000. The principal hypothesis are:

- air is incompressible,
- the volume of air is homogenous in both temperature and pressure,
- an opening is represented by the following law: $Q_m = k \times \Delta P^N$ where $Q_m$ is the air mass flow, $\Delta P$ the deviation in upstream/downstream pressure, k and N two coefficients[2].
- mechanical exhaust is represented by a mass transfer at a constant air volume flow fixed by the operator.

[2] The coefficients k and N are given by the characteristic curve of the opening ($Q_m$ in function of $\Delta P$) determined in a laboratory in steady state.

For the taking into account of the experimental meteorological data, particularly wind-related measurements, three solutions are adopted:

Solution 1: simulation with a one-value meteorological file

The statistical average of all the values recorded on the experimental site is calculated in order to obtain a one-value file.

Solution 2: simulation with the experimental meteorological file

The file of values recorded on the experimental site is used. This simulation requires additional development work on the standard version of the code.

Solution 3: average at 1 Hz

The average of 5 successive points from the 5 Hz file (or 10 successive points from the 10 Hz file) is calculated in order to obtain a frequency of 1 Hz compatible with the code. In this case, it is not yet certain that all the effects of high frequencies have been fully taken into account.

## RESULTS

The following two tables show the deviations between the different solutions for an average air change per hour calculated over 15 minutes.

| Origin of results | Average air change per hour | Relative error | Observations |
|---|---|---|---|
| **Configuration 1: natural ventilation through two openings** | | | |
| Experimentation | 2.49 | - | - |
| Simulation with a one-value file (solution 1) | 1.98 | -20% | Large deviation |
| Simulation with a 5 Hz file (solution 2) | 2.48 | -0.4% | Good correlation |
| Simulation with a 1 Hz file (solution 3) | 2.44 | -2% | Degradation of precision |
| **Configuration 2: mechanical ventilation** | | | |
| Experimentation | 3.25 | - | Part linked to mechanical ventilation: 37% |
| Simulation with a one-value file (solution 1) | 2.53 | -22% | Large deviation |
| Simulation with a 10 Hz file (solution 2) | 3.05 | -6% | Poor correlation |
| Simulation with a 1 Hz file (solution 3) | 3.02 | -7% | Poor correlation |

## DISCUSSION

For the tests performed, the simulation with a one-value file is not adapted. It reduces the rate of average air flow rate by around 20%. This bad precision cannot be due to the measurement errors.

The simulations performed at 1 Hz or with the experimental meteorological file offer greater precision, although the correlation remains poor for the second configuration (mechanical ventilation). For the first configuration (natural ventilation), an average at 1 Hz of the experimental meteorological file provides a satisfactory solution. But the wind speed of the second configuration is not so stable than the wind speed of the first one. It could explain that even the simulation with the experimental meteorological file for the second configuration is not so efficient.

This analysis concerns two particular cases but the aim is to show the importance of wind turbulence in buildings air change. The impact on energy consumption is considerable: the proportion of air change in french residential buildings represents around 30% of heating consumption. Although the impact of some assumptions cannot be ignored (such as the air incompressibility hypothesis or the way to model the aerodynamic opening law), this study should lead us to change our simulation techniques with a view to improving the taking into account of wind fluctuations linked to turbulence in meteorological files.

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