WIND TURBULENCE AND VENTILATION

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An appropriate way to identify the most efficient ventilation systems and improve their design is to use design codes for ventilation rates.

These rates are strongly influenced by spatial and temporal fluctuations in wind pressure on the facade and roof. The influence of the effects of wind on ventilation was studied using a model which includes air compressibility, together with the pressure field measured on a model in a boundary layer wind tunnel.

The simulation results obtained are analyzed using a design code. The effect of wind fluctuations on the quality of ventilation is evaluated using the concentration of a polluting agent as an indicator.

INTRODUCTION

One of the mainsprings of ventilation in buildings is the pressure due to wind. Because of its fluctuating character, wind produces a pressure field around a building which is also fluctuating (1, 2). However, most multi-zone numerical models for air transfer disregard this phenomenon by using a certain number of simplifying hypotheses including that of air incompressibility and that of the steadiness of wind pressure during the same period of time.

These simplifications lead to erroneous conclusions in certain cases. For example, when the pressure inside a room is equal to the wind pressure on the façade, taking temporal wind fluctuations into account produces an air flow rate which is not equal to zero. Similarly, when a room only communicates with the outside via a single opening, the air transfers are not zero, if both the air compressibility and temporal wind fluctuations are considered.

NUMERICAL STUDY

Model making

The SIREN 2 code is used (see figure 1) to evaluate the movement of air between zones within the same building under given temperature and wind pressure conditions and for ventilation installations and buildings with given characteristics. The pressure fields are determined (see figure 2) by taking measurements in a boundary layer wind tunnel on a 1/150 scale model [4].

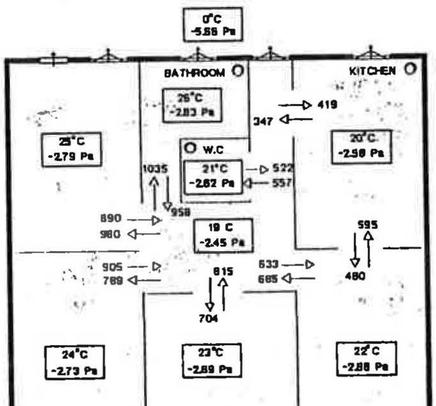


Fig. 1 :
Computed flow rates (in kg/h) in a dwelling with mechanical ventilation

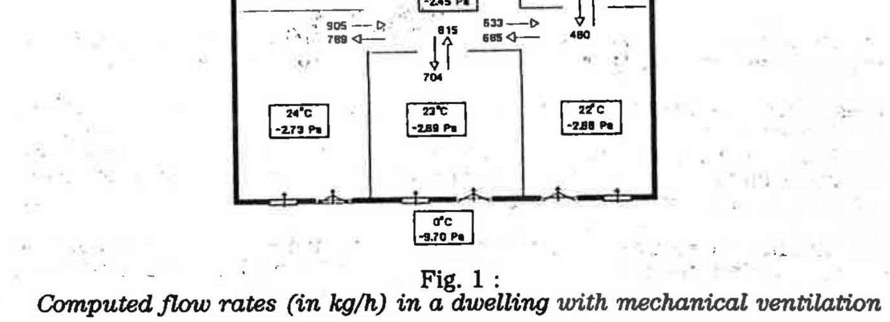


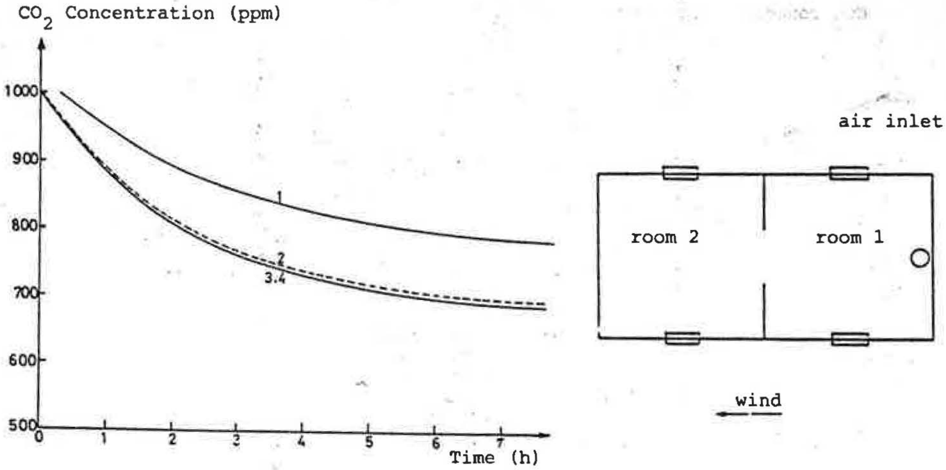
Fig. 2 : *Examples of spatial and temporal fluctuations in wind pressure*

Effect of wind turbulence on single-family houses

Air transfers are calculated according to different hypotheses depending on whether spatial and temporal fluctuations in the wind pressure and air compressibility are taken into account. In order to ascertain the effect of these hypotheses on the results, a pollution indicator is used i.e. the carbon dioxide concentration. Two cases were examined:

<u>First case</u> : study of a two-room house

The CO_2 concentrations were calculated in each of the two rooms for different wind angles and with the communication door closed and open. Figure 3, for example, shows the result of a simulation where the wind is parallel to the facades, the communication door is open and there is a constant flow of pollutant in room n° 1.



1 : incompressible air, constant wind pressure
2 : incompressible air, temporal wind fluctuations
3 : incompressible air, spatial and temporal wind fluctuations
4 : compressible air, spatial and temporal wind fluctuations

Fig. 3 : *Changes in the carbon dioxide concentration in room n° 2 as a function of time. Wind is parallel to the facades and communication door open.*

The results show that, unlike the air compressibility, the effect of wind turbulence cannot be ignored. The effect of temporal wind fluctuations on the ventilation is particularly important when the wind is parallel to the main facades (see figure 3) ; ignoring this can produce errors of up to 35 % in the CO2 concentration. However, the possible error committed by ignoring spatial fluctuations in pressure is less than 10 %.

Second case : study of a single room house

The case of a house with single exposure and no special ventilating system was considered. The air from the facade passes through a free section of 200 cm^2, while the opening in the opposite facade, corresponding to defective airtightness, is only 10 cm^2. It is assumed that no carbon monoxide is emitted inside the house and that the initial concentration is 1000 ppm.

Figure 4 shows the changes in the carbon dioxide concentration as a function of time for various hypotheses. It can be noted that, unlike the previous example, the hypothesis of air compressibility is a determining factor. This is explained by the large disproportion between the sections of the two air passages (ratio of 1 to 20).

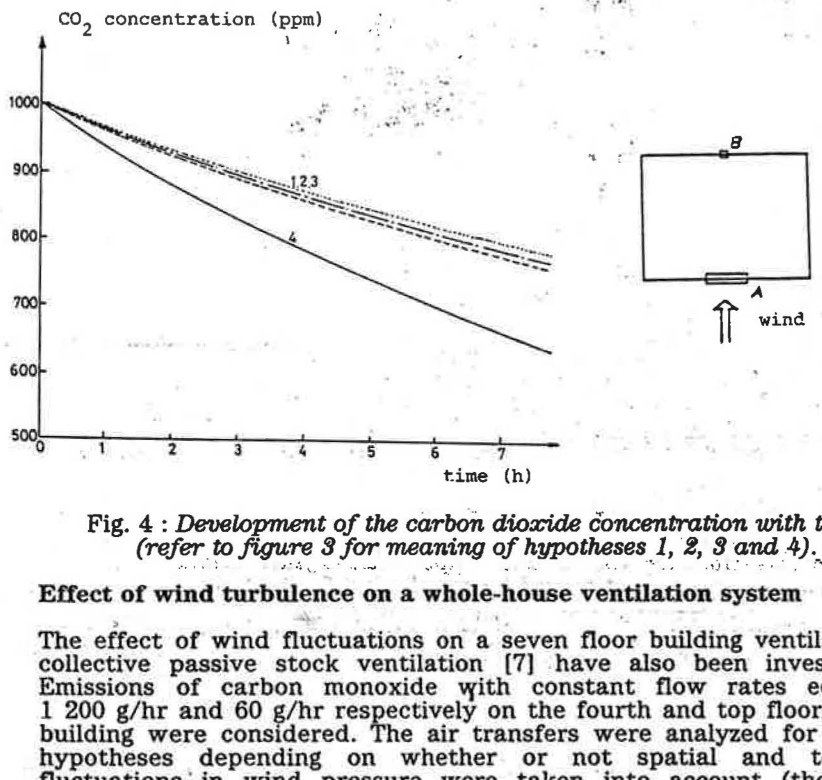


Fig. 4 : *Development of the carbon dioxide concentration with time (refer to figure 3 for meaning of hypotheses 1, 2, 3 and 4).*

Effect of wind turbulence on a whole-house ventilation system

The effect of wind fluctuations on a seven floor building ventilated by collective passive stock ventilation [7] have also been investigated. Emissions of carbon monoxide with constant flow rates equal to 1 200 g/hr and 60 g/hr respectively on the fourth and top floors of the building were considered. The air transfers were analyzed for various hypotheses depending on whether or not spatial and temporal fluctuations in wind pressure were taken into account (the air is considered to be incompressible). The results show that taking the wind fluctuations into account considerably modifies the instant flow rates and can explain why the air flow is reversed on the top floor when the network head loss is high (figure 5).

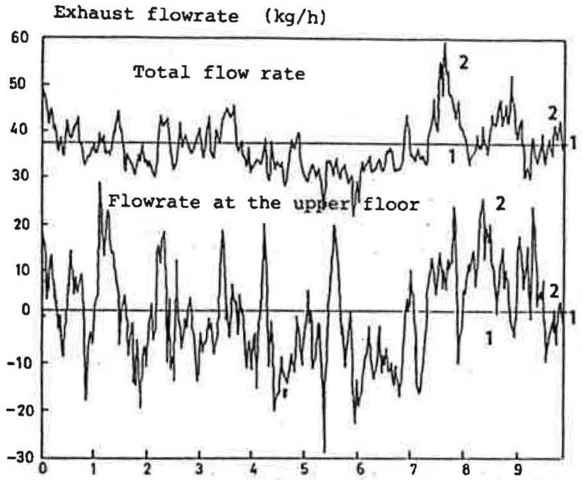


Fig. 5 : *Computed flowrates in a shunt duct*

1 : flowrates are calculated using time averaged wind pressure
2 : flowrates are calculated using actual wind pressure records

EXPERIMENTAL STUDY

An experimental house was designed to globally validate the design codes by dealing with problems which it is impossible to simulate on a scale model in a boundary layer wind tunnel due to the lack of similitude. This is the case when determining the effective ventilation rates in a house, because the head loss is not a linear function of the flowrate.

Particular care has been taken to make the walls of the house perfectly airtight so that air will only pass through the required areas.

Pressure tapping points are distributed along the outside surface of the walls, and next to the air inlet and outlet orifices. The speed and direction of the wind are recorded in synchronization with all the measurements taken in the laboratory. The ventilation rate is measured in the conventional way using the tracer gas method. This instrumentation is completed by a chain of rapid response (40 Hz) measurements (8), (9) currently being installed and designed to instantaneously measure the flow of air entering or leaving the orifices or walls.

CONCLUSION

Due to the fact that the phenomena governing the air transfers in a building are not linear, the treatment of wind fluctuations results in discrepancies with respect to calculations made when using an average wind pressure value.

Simulation results show the need to take temporal wind fluctuations into account as well as air compressibility for evaluating the air change in a flat with air passages mainly located on one facade. Experimental study is currently done in order to ascertain this finding.

The wind turbulence can also result in reverse flow occuring in ventilation ducts when they are connected to several floors. Further research will be devoted to studying this problem by incorporating the influence of the mechanical inertia of the air mass present in the pipe.

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