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MODELLING METHOD FOR MONO FAÇADE NATURAL VENTILATION

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Abstract: *Natural ventilation is an effective measure to save energy consumed in buildings and to improve indoor air quality. The controlled opening of windows, as a passive cooling method, allow interior cooling by introducing fresh outdoor air, without energy consumption. For this, however, it is necessary to understand specific phenomena and establish tools for estimating ventilation flow according to external conditions and opening configuration. This work presents the physical mechanisms that determine air circulation and the methods of modeling natural ventilation mono-facade.*

Key words: natural ventilation, save energy, modeling natural ventilation mono-façade.

1. Introduction

It is well known the fact that inside the office buildings which are equipped with mechanical ventilation and air conditioning systems the opening of windows is strictly forbidden ("closed buildings"). It is known that the operable windows create a comfort much more appreciated by the occupants, compared with the one from „closed buildings" [3].

In this regard, the controlled opening of windows as a passive cooling method represent an interesting and rational perspective for the limitation of discomfort and to reduce the running time of mechanical ventilation and air conditioning systems. Indeed, opening windows allow interior cooling by introducing fresh outdoor air, without energy consumption ("free cooling"). But to take into account the cooling through natural ventilation is necessary to understand specific phenomena more complex than with mechanical ventilation and to have reliable tools to estimate the ventilation flow in the external conditions and opening configuration.

2. Physical Mechanisms

In a real situation, the air flow in the natural ventilation mono-facade is caused by two mechanisms: thermal effect created by the temperature difference and the effect caused by the wind.

2.1. Thermal Effect

In the absence of wind, the air flow is caused by air pressure difference caused by the temperature difference between inside and outside.

If we consider a room with a large opening height H (see Figure 1), the uniform indoor temperature is higher than

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the outside temperature, interior and exterior pressure profiles some distance opening can be represented as two straight , each having a slope depending on the density of the air at the appropriate temperature.

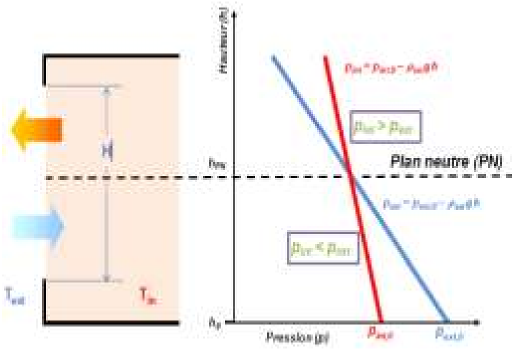

Fig. 1. *Representation of heat circulation*

The two lines intersect at a height h_{PN} which corresponds to a plane in which the inside pressure coincides with the outside (the neutral plane). Under the neutral plane the inner pressure is less than the external pressure, which causes air to enter through this area in the room. Above the neutral plane the external pressure is greater than the inner one, which causes the air to get outside the room.

It can be argued that in this case, of a single opening, the neutral plane is going through the center opening height, and the airflow rate is set to:

$$q_{th} = \frac{1}{3} \cdot \cdot A \cdot C_D \cdot \sqrt{\frac{\Delta T \cdot H \cdot G}{\tau}} \qquad (1)$$

where:
A,H - area, opening height;
C_D – the coefficient of discharge, the value of which is generally 0.6
ΔT - difference between indoor and outdoor temperature
τ – the average between the interior and exterior temperature

2.2. The Wind Effect

The wind also contributes to the air flow in the case of natural ventilation mono-facade. Schematically, we can separate the environmental effect of the wind on the movement in two components: one due to media pressure difference created by the wind and another due to turbulence created by fluctuations in speed and pressure near the opening.

The first effect is relatively low, in the case of natural ventilation mono - facade , due to the fact that the difference in pressure between the different parts of the same openings , or between the various openings located on a facade , is generally low.

As regards turbulence, we can distinguish generally two effects: turbulent diffusion and pressure fluctuations [5]. Turbulent diffusion is the result of interaction between the opening and the air boundary layer formed along the building wall (see Figure 2a), which causes the inputs and outputs to and from the room air. Pressure fluctuations due to turbulence near the opening also lead to the creation of an exchange of air between the inside and outside by pulses (see Figure 2b)

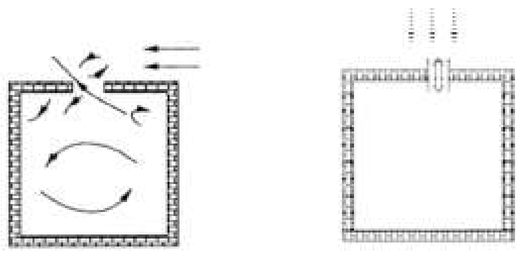

Fig. 2. *The wind turbulences effect in mono façade natural ventilation*

A distinction between the two effects is quite difficult, because both are created by turbulence and it is hard to be separated. They cause an unsteady three-dimensional flow, which had been proposed several analytical models [5]. These designs, however, require many inputs that detailed values of speed and pressure fluctuations that are not generally available, making them difficult to use in practice.

3. The Modeling of Natural Ventilation Mono-Façade

For modeling natural ventilation mono-facade they have been proposed several models that can be grouped into four categories:

- empirical models, as correlations;
- mono-zone nodal models ;
- zonal models ;
- Computational Fluid Dynamics, CFD

3.1. Empirical models

Empirical models are best used for modeling natural ventilation, due to their simplicity and speed of calculation. These models are based on empirical relationships derived from theoretical or experimental reasons. Waren Correlation: Waren and Parkins (1995) propose two distinct expressions for calculating ventilation flow due to the effect of heat and wind. Airflow due to thermal effect is calculated using the expression (1) above. Wind effect is taken into 1 that air flow is parallel to the wall opening. Local speed u_L is considered uniform and depends on wind speed and direction. In this case, the flow acts as a mixed layer two-dimensional (see Figure 3).

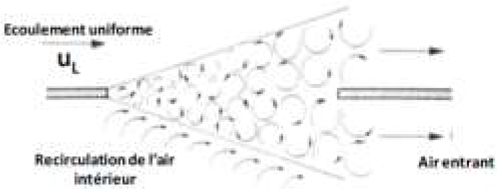

Fig. 3. *Schematic representation of a boundary layer of mixture, the two-dimensional*

Ignoring turbulence, the authors provide for air flow rate of ventilation, expression:

$$q_{wind,Waren} = 0{,}025 \cdot A \cdot v_{wind} \quad (2)$$

where:
v_{wind} – speed of wind.

In order to combine thermal effect and the wind, the authors propose considering the greater of the two values of the flow, calculated:

$$q_{War} = \max\left(q_{th,War}; q_{wind,War}\right) \quad (3)$$

According to the authors, this reflects the fact that one of the two effects is always mono- dominant natural ventilation facade. Waren correlation is used in practical guidelines for evaluating performance mono- front natural ventilation, such as CIBSE 2005, CIBSE 2006.

Phaff et De Gids Correlation: Phaff et De Gids [3] propose an empirical expression that takes into account both the thermal and wind at namely:

$$q_{p\,si\,DG} = \frac{1}{2} \cdot A \cdot v_{equiv} \quad (4)$$

where:
$\frac{1}{2} \cdot A$, it comes from the fact that the air enters the room through the half of the opening and out through the other half-
v_{equiv} – equivalent wind speed, which is calculated with:

$$v_{equiv} = \sqrt{C_1 w_{wind}^2} + \sqrt{C_2 H|\Delta T| + C_3} \quad (5)$$

where:
C_1 C_2 şi C_3 – empirical coefficients

Terms under radical corresponding pressure differences caused by wind ($C_1 w_{wind}^2$), by the thermal effect

($C_2 H|\Delta T| + C$) and by turbulence (C_3).

The value of the three coefficients were determined on the basis of measurements on the first floor , two actual buildings. Their values, which minimizes the differences between correlation and experiment are:

$$C_1 = 0{,}001, C_2 = 0{,}0035, C_3 = 0{,}01 \qquad (6)$$

3.2. Nodal models

Within nodal model, building is represented as a set of homogenous areas characterized by constant temperature and pressure (Feustel 1990). Each area is linked to other external and aeraulic lines (see Figure 4) representing the input and output modes of air in/from the area: the tire leaks, large openings (doors, windows) and systems of mechanical ventilation.

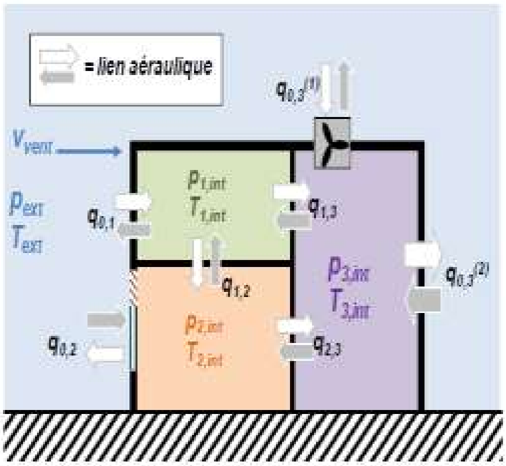

Fig. 4. *Schematic representation of a nodal model multizone*

Each line of air system is mathematically described by a characteristic function which expresses the airflow rate dependence of the pressure difference between the two adjacent areas.

Nodal models have been implemented in many simulation programs air system, of which the best known are COMIS (Feustel et al, 2001) and accounting (Walton and Dols, 2005). These programs are aimed mainly dispersion of contaminating substances in a building [2]

Nodal models can be coupled with the thermal simulation program TRNSYS (TRNSYS 2007) to perform thermo-aeraulic simulations of buildings that have complex ventilation strategies (ventilation between floors, fireplaces or heating atrium etc.). It can be said that these models are today the most advanced simulation of buildings thermal air system (Chen, 2009).

Concerning mono-facade natural ventilation, nodal models have the drawback that take no account of the turbulence created by the wind, which is one of the main engines of natural ventilation mono-façade.

3.3. Zonal models

Zonal models is an intermediate approach between the nodal models end CFD models. Within each area zonal patterns air system is then divided into several sub- areas in rectangular form, which they apply the laws of conservation of mass and energy.

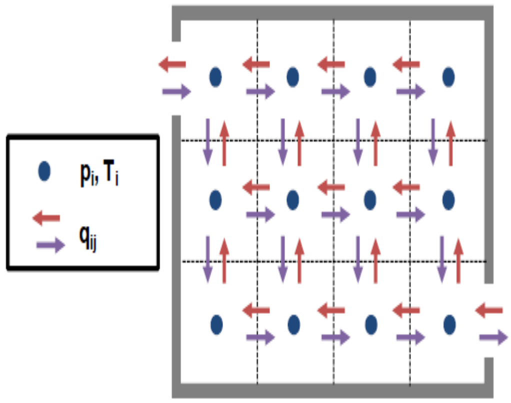

Fig. 5. *Schematic representation of a zonal model*

Without going into details, although it requires a smaller amount of calculation than the one required for CFD models, the latter are preferred today because of the growing computing power available today.

3.4. Computation fluid dynamics CFD

Computational Fluid Dynamics, CFD consists of numerical solving the Navier - Stukes equations, respectively equations of conservation of mass , the amount of movement and energy. For this field of study is divided into a large number of small volumes. The equations are then simplified and applied to each small volume discretized. Solving equations is iterative and can take several hours or even days of computing, for which CFD methods are used mainly in research projects related to the natural ventilation of buildings.

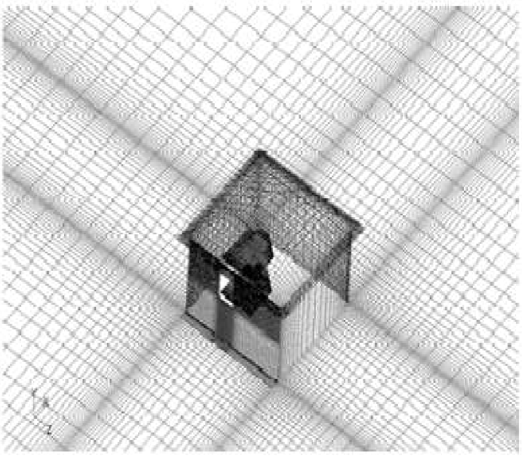

Fig. 6. *Field computing and simulation discrediting natural ventilation mono-facade*

CFD methods applied to natural ventilation is quite complicated. Field calculation must include inside and outside the building (see Figure 6). Moreover, in case of natural ventilation mono-facade, turbulence is a mechanism for the exchange of air very important to be modeled accurately. For this we have two ways: statistical simulation of turbulence (Reynolds averaged Navier-Stokes, RANS) and simulation of large eddies (Large Eddy Simulation, LES)

CFD methods validity of the results depends heavily on the accuracy of boundary conditions imposed on the mesh and turbulence model adopted. Therefore, it is generally necessary experimental validation of the results.

With this method systematic studies have been conducted by Jiang and Chen (2001, 2003) and Jiang et al (2003) [1]. Within these studies were conducted comparisons between simulation RANS, LES simulations and experimental results obtained in wind tunnel models reduced. The conclusion of these studies was that turbulence simulation with method LES lead to more accurate results regarding prediction of speeds and air flows.

4. Conclusions

Empirical models are expressions which provide ventilation flow due to the difference in temperature, wind speed and possibly its direction. Application is very simple, but their validity is generally assessed on the basis of data that they have been developed. Therefore, evaluation of their joint database is uncertain.

Nodal models are currently the reference models for the simulation of multi-zone air system. For the evaluation of complex ventilation systems, they are often coupled with thermal models. However, their application to natural mono-facade ventilation is limited because they do not take into account turbulence.

Zonal models are models whose use is limited and that in terms of wind, it is difficult to impose boundary conditions. Therefore, the CFD models are preferred.

CFD models are based on direct solution of the Navier-Stokes equations, imposing appropriate boundary conditions and turbulence model properly. Their application, however, requires important calculation and preparation time, which makes it rather difficult to use any practical application. Which is why today they are mainly applied in research projects.

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