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NATURAL VENTILATION AT THE TRANSILVANIA UNIVERSITY RESEARCH DEVELOPMENT INSTITUTE

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Abstract: *The purpose of this paper is to present the results of the part of a broad research program that takes place within our department. The program aims to investigate the potential of natural ventilation in the Brasov climate zone. In situ research takes place in the buildings of the Transilvania University Development Research Institute in Brasov. So far, two of the four phases of the project have been covered. The results obtained regarding the airflow from natural ventilation are satisfactory and are the base of the design of the natural ventilation system of the connection spaces between the institutes laboratories.*

Key words: *natural ventilation, empirical models, numerical simulation.*

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" [1].

Natural ventilation has been defined as: "supply of fresh air to the conditioned space by natural means for the purpose of maintaining acceptable indoor air quality". Moreover, when outdoor conditions are suitable, the ventilation can also be used for cooling of the buildings, for cooling of the occupants or both [3].

In the hot season, normally, due to solar and internal heat gains, buildings can become hotter than the ambient air. This provides an opportunity for cooling the building at least partly, by using the freely available outdoor air. Though the cooling of buildings during daytime may not be possible on all days, in an year there are many days during which outdoor air can act as a heat sink for the building. Greater opportunities exist for cooling the buildings especially during the night, when the outdoor air is considerably cooler. The amount of airflow due to natural ventilation depends on:

- magnitude and direction of prevailing winds;

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- ambient air temperature;
- landscaping and adjacent structures;
- design of the building and position of windows, doors etc.

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") [2].

2. Physical Mechanisms

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

2.1. The wind effect

When wind blows over a building, a static pressure difference is created over the surface of the building. The pressure difference depends on the wind speed, wind direction, surface orientation and surrounding structures. The pressure is positive on the windward direction and negative on the leeward direction. The static pressure on the other surfaces depends upon the angle of attack. This pressure is called as wind pressure. Generally, the magnitude of the wind pressure (P_W) is proportional to the velocity pressure.

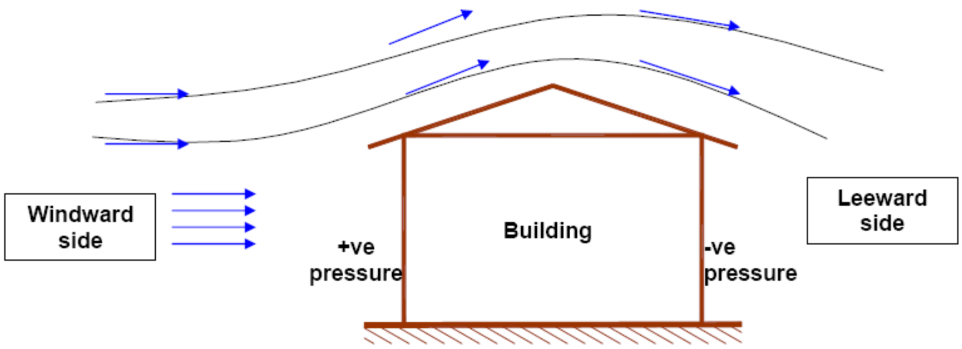

Fig. 1. *Distribution of wind pressure on windward and leeward facades of a building*

2.1. Thermal Effect

When there is a temperature difference between the indoor and outdoor, airflow takes place due to buoyancy or stack effect.

Usually, during summer, when inside is cooler compared to outside, warm outdoor air enters the building from the top openings and cold indoor air leaves the building from the bottom openings.

In our case, due to large solar gains, the indoor air is generally warmer compared to outdoor air, as a result then warm air inside the building rises due to buoyancy and leaves from the openings provided at the top, while cold outdoor air enters into the building through the openings near the base of the building.

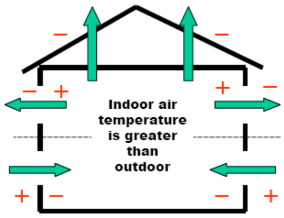

Fig. 2. *Stack driving flows in our building* [4]

3. Stages of Our Project

The present project is a real one and was developed by our team for the access and connection spaces between the 12 buildings, designated as research laboratories, of the Transilvana University of Brasov Development Research Institute (ICDT). These are:

- two identical Spines, with a surface of 480 m^2, a volume of 2040 m^3, and an average height of 4.25 m each;
- an Atrium, with a surface of 630 m^2, a volume of 6400 m^3 and an average height of 10.20 m.

Fig. 3. *The access and connection spaces between the 12 buildings of the Institute*

In the design phase of the institute, 2009-2010, the ventilation and cooling of these spaces was treated with superficiality, or even ignored. Obviously, the consequence is the overheating of the spaces during the warm season, as shown in the photographs below, made on July 24, 2017.

Fig. 4. *Temperature and humidity sensor*

Today, 6 years after the institute was put into operation, our solution is a natural ventilation and cooling system, the only solution that could be implemented in the present situation.

Having the opportunity to carry out this project, our team has set out to develop a broader research program on the subject in the future. The stages of this program are:

1. Calculation of the number of operable windows and them positioning;
2. Calculation of airflow from natural ventilation using empirical models;
3. Modelling and numerical simulation of natural ventilation in this case (implicitly optimizing the location of the operating windows, to get the best ventilation);
4. Measuring natural ventilation parameters by installing a sensors system (temperature, relative humidity, air velocity, CO_2 concentration).

3.1. Calculation of the number of operable windows and them positioning

First we calculated the actual air intake/outlet areas for the opening configuration of the selected operating windows, shown in the figure below.

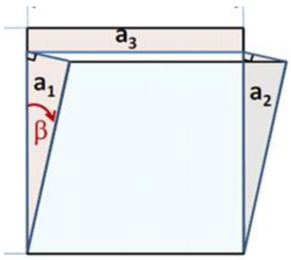

Fig. 5. *The geometry of the operable windows*

$$A = a_1+a_2+a_3 = (H\sin\beta\cos\beta+L-L\cos\beta) \quad (1)$$

For the Spines:

- air inlet area, A=0.7(0.7·0.259·0.966 +1.5−1.5·0.966)=0.124 m^2
- air outlet area, A=0.43(0.43·0.259·0.966 +1.5−1.5·0.966)=0.124 m^2

For Atrium:

- air inlet area, A=0.75(0.75·0.259·0.966 +1.5−1.5·0.966)=0.178 m^2
- air outlet area = air inlet area = 0.178 m2

According to the number of windows that could become operable and their layout, we have proposed to get an air exchange: n=1.2 [h^{-1}]. They result as follows:

For each Spine

- the number of air inlet windows: 13
- the number of air exit windows: 9

For Atrium

- the number of air inlet windows: 12
- the number of air exit windows: 12

The location of the operating windows for the two Spines is shown in Figure 4 below.

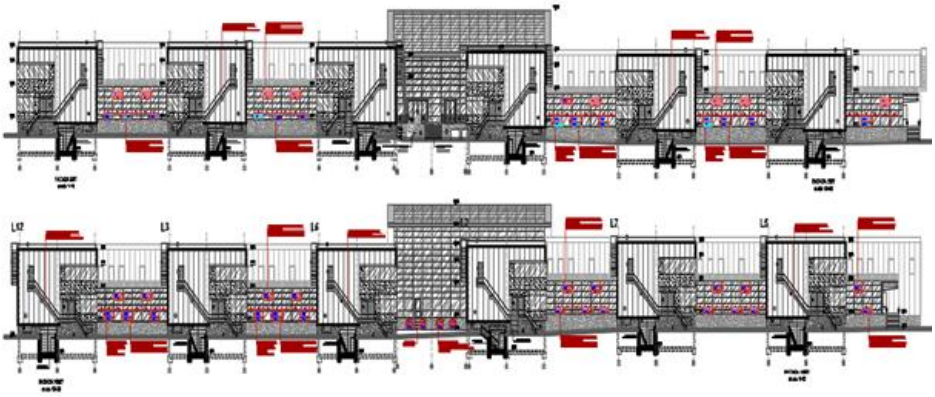

Fig. 6. *The west and east façades where the operable windows for Spine were placed*

3.2. Calculation of airflow from natural ventilation using empirical models

For the Spines

- Natural ventilation due to wind

$$Q_w = C \cdot R \cdot A \cdot v_w \left[\frac{m^3}{s}\right] = 0.3 \cdot 1 \cdot 1.0 \cdot 2.2 \cdot 3600 = 2347 \left[\frac{m^3}{h}\right] \quad (2)$$

Where: $C = 0.3$ (a constant that takes the value of 0.30 for oblique winds); $R = 1$ (factor that is function of inlet and outlet areas); $A = 1.0$ (effective air intake area); $v_w = 2.2$ (average wind speed in summer).

- Natural ventilation due to stack effect

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$$Q_{st} = C \cdot A\sqrt{h\frac{\Delta T}{T_w}} \left[\frac{m^3}{s}\right] = 0.0707 \cdot 1.0\sqrt{2.8\frac{277}{295}} \cdot 3600 = 407 \left[\frac{m^3}{h}\right] \quad (3)$$

Where: $C = 0.0707$ (a constant that takes a value of 0.0707 when inlets and outlets are optimal, about 65% effective); $A = 1.0$ (effective air intake area); $h = 2.8$ (the vertical distance between the axes of the inlet/outlet windows); $\Delta T = 277$ (indoor/outdoor temperature difference); $T_w = 295$ (indoor air temperature).

- Natural ventilation due to combined wind and stack effect

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$$Q_{total} = \sqrt{Q_w^2 + Q_{st}^2} = \sqrt{2347^2 + 407^2} = 2382 \left[\frac{m^3}{h}\right] \quad (4)$$

$$ACH_{total} = \frac{Q_{total}}{V} = \frac{2382}{2040} = 1.27\ [h^{-1}] \quad (5)$$

For Atrium

- Natural ventilation due to wind

$$Q_w = C \cdot R \cdot A \cdot v_w \left[\frac{m^3}{s}\right] = 0.3 \cdot 1 \cdot 2.14 \cdot 2.2 \cdot 3600 = 5076 \left[\frac{m^3}{h}\right] \quad (6)$$

Where: $= 0.3$; $R = 1$; $A = 2.14$; $v_w = 2.2$.

- Natural ventilation due to stack effect

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$$Q_{st} = C \cdot A\sqrt{h\frac{\Delta T}{T_w}}\left[\frac{m^3}{s}\right] = 0.0707 \cdot 2.14\sqrt{8.6\frac{277}{295}} \cdot 3600 = 4392\left[\frac{m^3}{h}\right] \quad (7)$$

Where: $C = 0.0707$; $A = 2.14$; $h = 8.6$; $\Delta T = 277$; $T_w = 295$.

- Natural ventilation due to combined wind and stack effect

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$$Q_{total} = \sqrt{Q_w^2 + Q_{st}^2} = \sqrt{5076^2 + 4392^2} = 6712\left[\frac{m^3}{h}\right] \quad (8)$$

$$ACH_{total} = \frac{Q_{total}}{V} = \frac{6712}{6400} = 1.05\ [h^{-1}] \quad (9)$$

4. Conclusions

This paper presents part of an extensive research program developed by our department, having as main purpose the investigation of the potential of natural ventilation in the Brașov climate zone. The program was generated by the opportunity I had to offer a solution for night ventilation and cooling for the access and connection spaces between the 12 buildings, designated as research laboratories, of the Transilvana University of Brasov Development Research Institute (ICDT). So far, two of the four phases of the project have been completed, the third one is ongoing and the last part of the project will be carried out after the implementation of the natural ventilation and cooling system designed by us.

At this stage, an empirical calculation model, consisting of expressions that provide the ventilation rate due to wind velocity and temperature difference, was used. The application of such a model is very simple, and the results obtained regarding the air flow from the natural ventilation are satisfactory. But it should also be kept in mind that these results are valid for the climate data in which the expressions of air flow have been obtained. Therefore, it is necessary to validate the results and the climate data in the Brasov area, which will be carried out in the fourth phase of the project.

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