Bulletin of the *Transilvania* University of Braşov
CIBv 2013 • Vol. 6 (55) Special Issue No. 1 - 2013

NATURAL VENTILATION NETWORK DESIGN OF A BUILDING

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Abstract: *In order to implement a system of natural ventilation of an amphitheater which is under completion in one of the buildings of a university was performed first a dimensioning for the air network using a methodology from local technical literature. Given the location of system input louvres, respectively exhaust resulting from this calculation was performed a simulation of the of the air network operations using Contam software. Simulation results will be validated in the future with data obtained from measurements in situ. For this, in the amphitheater will be mounted sensors and a data acquisition system. There will also be performed simulations using other numerical modeling and simulation programs.*

Key words: *air flow network simulation, wind pressure coefficients.*

1. Introduction

It is a well-known fact that carbon dioxide emitted into the classrooms reduces students' ability to concentrate and contribute to a decreased mental performance [2].

Studies from many countries in Europe show that in many cases investigated were found CO2 concentrations higher than 1000 ppm recommended [3].

One of the ways that can achieve the goals of improving indoor air quality (IAQ) and those related to energy efficiency of buildings is to adopt a mixed ventilation system – natural and mechanical, where natural ventilation and night cooling will have a leading role.

This is why this paper intends to provide a way to design a natural ventilation network for two amphitheaters of 180 seats, which is to be done in one of the university building. Figure 1 present a typical installation for achieving natural ventilation.

2. Problem Formulation

Steps which have been established for solving the application are:

a) The first stage was carried, sizing a system for natural ventilation by using local methodology of calculation of technical literature [1]

As is well known, the movement of air currents around the building is an important factor in terms of ventilation. With no local meteorological data, for calculations were used meteorological data (wind speed and direction, outside temperature) provided by the nearest weather station outside the city at a distance of 8km from the amphitheater site.

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After dimensioning the results are:

- nominal surface for the wall mounted grilles supplying fresh air from outside;
- nominal surface of the penthouse turrets for vitiated exhaust system.

Afterwards were established mounting positions of the supply and exhaust louvres. Wall mounted fresh air louvres, 16 of number (8 by each amphitheater), 1000x500 mm (Lxh), were placed on the side only exterior wall of the amphitheater, at +0.3 m from the floor.

Penthouse turrets, 8 at number (4 by each amphitheater), 1000x1000x1500 mm (Lxlxh) were placed on the amphitheater roof terrace. Figures 1 and 2 below, shows in the plan and in section, mounting positions of the two systems.

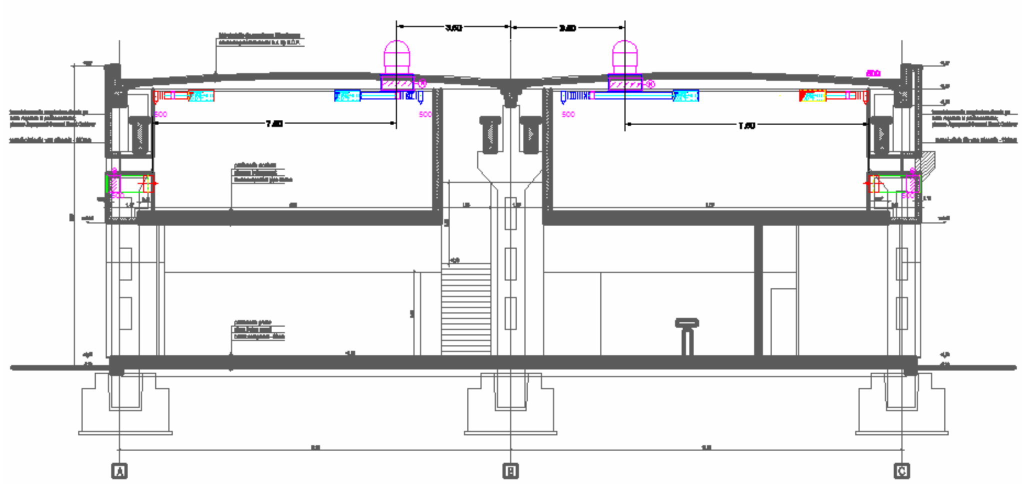

Fig. 1. *Section A-A.*

Fig. 2. *Turrets locations*

b) In the second stage, for louvres, located as shown in Figures 1 and 2, we decided to perform a simulation of air flow in the amphitheaters, to provide the ventilation rate of the amphitheaters within 5 days of the week, considering a specific running program for them. For data obtained from the simulation, to be as realistic as possible is necessary to make corrections to the calculation in terms of local wind speed and local pressure due to wind.

c) The third step is to validate the simulation results using the data obtained from measurements in situ. Therefore, in the amphitheaters is mounted a system consisting of sensors and the acquisition data logger for measuring of physical parameters, such as: temperature, humidity and air velocity in/ out in the amphitheaters and the CO_2 concentration for the indoor air.

3. Problem Solution

For the natural ventilation system showed in Figures 1 and 2 has been done a functional simulation using CONTAM program.

3.1. Simulation of air network using accounting CONTAM software

First, corrections were made for the calculation of the wind speed and local pressure. Relationship to calculate local wind speed[4]:

$$V_H = V_{met} \cdot A_0 \left(\frac{H}{Z_{met}}\right)^{\alpha} \tag{1}$$

Where:

V_H – local wind speed, in site (where we make the calculations);

H – altitude site [m];

A_0 – coefficient describing local terrain barriers from the site.

Terrain coefficients for wind speed calculation method used in CONTAM are presented in Table 1.

Table 1

Terrain type	Coefficient (A_0)	Exponent (α)
Urban	0,35	0,40
Suburban	0,60	0,28
Airport	1,00	0,15

In CONTAM, airflow through open windows and doors is simulated by Bernoulli's equation[4]:

$$\Delta P = \left(P_1 + \frac{\rho V_1^2}{2}\right) - \left(P_2 + \frac{\rho V_2^2}{2}\right) + \rho g (z_1 - z_2) + P_w \tag{2}$$

Where:

ΔP – pressure drop between points 1 and 2;

P_1 , P_2 – static pressure at the inlet and outlet;

V_1 , V_2 – input and output speeds;

Z_1 , Z_2 – hydrostatic height;

P_w – wind pressure.

In CONTAM wind pressure is calculated using a method presented in ASHRAE 1993. The relationship is also provided by Dols 2000.

$$P_w = \rho \frac{V_{met}^2}{2} C_h f(\theta) \tag{3}$$

$$C_h = \rho \frac{V_H^2}{2} = A_0^2 \left(\frac{H}{Z_{met}}\right)^{2\alpha} \tag{4}$$

After that it was created a model for the amphitheater airflow in Contam. So in Contam amphitheater is treated as a collection of nodes representing parts of the amphitheater and elements of air flow represented by supply and exhaust louvres. The louvres were modeled as simple openings. It have been established an estimated opening program for the air volume damper wall mounted, different for the five days of the week. To estimate CO_2 emissions in the amphitheater was considered a different occupation in the five days of the week, between 60% and 80%. Emission of a person has been considered as the corresponding sedentary work, 0.3 [l / min].

Regarding the ventilation model, was chosen the least complex model described in specialty literature, respectively the model "power law". Within it, the air flow is given by:
(Dols 2006, LBNL 2007)

$$Q = C \times \Delta P^n \quad (5)$$

Where:
C – flow coeficient;
n – flow exponent.

As the windows (grilles) which are fully open are described as simple vertical openings, it is assumed that the flow velocity of air based on the opening height is given by the orifice equation:
(LBNL 2007)

$$V(y) = C_d\sqrt{2\frac{P_n(y) - P_m(y)}{\rho}} \quad (6)$$

Where:
$V(y)$ - viteza fluxului de aer;
C_d – coeficientul de descărcare;
P_n , P_m – presiunile de referință ale celor două zone aflate de o parte și de alta a deschiderii.

To estimate the CO_2 level, as an alternative to solving differential equations of mass balance was used equation (7):

$$C_t = \left[\frac{QC_{ext}+q}{Q}\right]\left[1 - e^{-\frac{Qt}{V}}\right] + C_0 e^{-\frac{Qt}{V}} \quad (7)$$

The ventilation rate used in equation (7) have been simulated with the CONTAM for a set of input parameters.

In order to check (determine) whether the model is sufficiently acceptable to apply to the entire building, tests were carried out first on a more simple building (a room). Thereby was chosen for the test a rectangular room with aspect ratio 4:1.

In Figure 3 is represented the CONTAM model for this room wich has two openeings for entry/exit of the air one on the north wall, the other in the south.

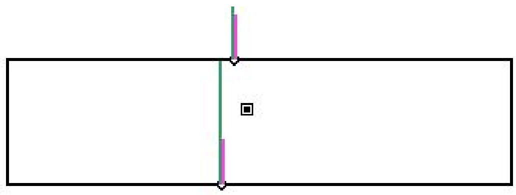

Fig. 3. *Air penetration paths in the test building*

Also is indicated if possible, as meteorological data (wind speed and direction, outside air temperature, solar radiation and atmospheric pressure) to be those in situ. As we stated, in this application are used data from a weather station nearby that were corrected in terms of speed and wind pressure.

Figure 3 shows the ventilation rate of the amphitheater (corresponding to a set of input data entered into the simulation program) for its entire five days of the week.

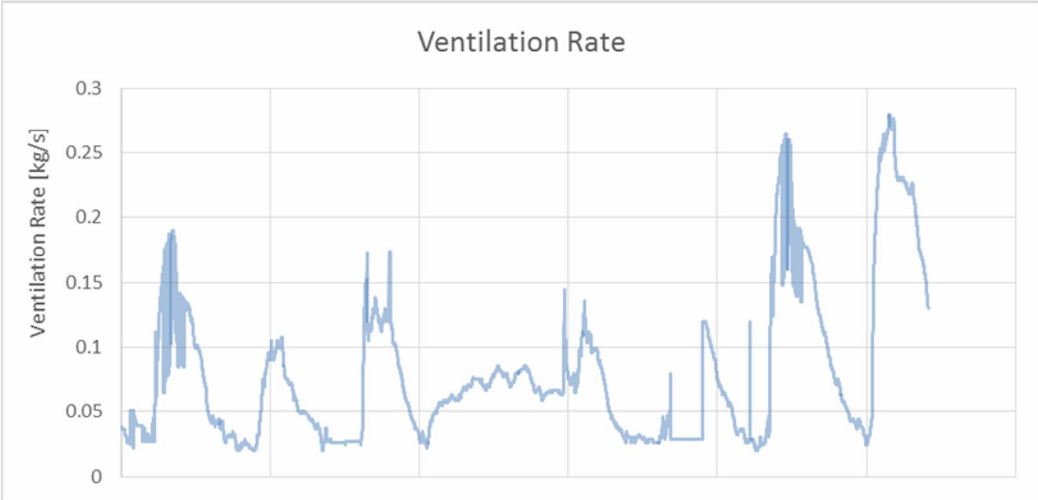

Fig. 3. *Ventilation rate of the amphitheatre*

3.2. Validation of simulation results

To compare data from simulation with real amphitheater measurements will be installed a complete acquisition system, monitoring/ recording of physical parameters that interest us, namely:

- sensors to measure CO_2 concentration at both occupants level and of the exhaust damper level.
- sensors for measuring air temperature inside at both occupants level and of the exhaust damper level.
- sensors for measuring the temperature of the fresh air introduced and for the evacuated one
- alarm sensors to record opening time and opening introduction of exhaust dampers

The system is "Saveris" from TESTO. Documentation and monitoring is done via wireless probes. For the needs of this application, the system comprising:

- Radio probe with external sensor temperature and humidity - 2 pcs;
- Radio probe with internal NTC sensor - 1 pc;
- Radio probe with output channel current / voltage - 3 pieces;
- Air velocity transmitter - 2 pcs;
- Hot wire probe for air speed - 2 pcs;
- Transmitter for CO_2 concentration - 1 pc.

Fig. 4. *The central unit of the integrated monitoring / recording data acquisition system*

Fig. 5. *Sensors*

4. Conclusion

Today, the amphitheater is the stage of completion. Obviously, the data that we obtained from measurements in situ we calibrate simulations so that the simulation results become a useful tool in achieving any network design for natural ventilation air to a building.

Also in the future we will do simulations with other modeling and numerical simulation programs to determine which one provides results closest to the actual operation of a natural ventilation air system.

References

1. Facilities Handbook – Ventilation and air conditioning 2002 ARTECNO Bucureşti 2002, ISBN 973-85936-2-X
2. DFES. 2003. Building Bulletin 87, Guidelines for Environmental Design in Schools, London: DFES.EU. 2002.
3. BRE, 2006. Ventilation and Indoor Air Quality in Schools Guidance Report 202825, Building Research Establishment Technical Report.
4. Dutton S., Li Shao, Riffat S. 2008. Validation and Parametric Analysis of Energyplus: Air Flow Network Model Using Contam.. University of Nottingham. De Montfort University, Leicester, UK. Third National Conference of IBPSA-USA, Berkeley, California, 2008.