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The Role of Infiltration for Indoor Air Quality - A Case Study in Multifamily Dwelling Houses in Poland

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THE ROLE OF INFILTRATION FOR INDOOR AIR QUALITY - A CASE STUDY IN MULTI-FAMILY DWELLING HOUSES IN POLAND

SYNOPSIS

Multifamily buildings with natural ventilation are still being built and exploited. Such buildings are often equipped with individual gas-fired water heaters located in windowless bathrooms. It implicates the possibilities of improper gas exhaust as a result of the decrease of infiltration, what could be sometimes even harmful for the occupants' health.

Based on the numerical simulations, analysis of ventilating air flows in typical multifamily dwelling house will be carried out. It will be shown that effectiveness of natural ventilation in particular flats depends not only on the active factors determining infiltration phenomenon (like wind and temperature difference) but is also strongly connected with flat location inside the complex structure of a building.

1. INTRODUCTION

Air infiltration is one of the elements that determine the process of ventilation of dwelling houses. In particular, it refers to the buildings with natural (gravity) ventilation.

The knowledge of air flows within the complex structure of a building is of interest from a few points of view. First - it is important to ensure a determined minimum rate of air change between the inside and the outside , necessary from the hygienic point of view. Secondly - the air inflow from the outside of a building (infiltration) is a prerequisite for proper course of natural ventilation process. At the same time the identification of infiltrating air flows enables to predict the infiltration caused heat losses what makes it possible to calculate heat requirements for a whole building. Thirdly - of a significance is also a question of thermal comfort. One must remember not only discomfort resulting the underheating of infiltrating air but also the directions of air flows, the latter question being of less consideration though of an importance. For example, it often occurs that the standard air change rate is satisfied, however some part of the air flows into the flat from the staircase. In this case, it is hard to admit this air change rate in the flat to be satisfactory.

Very often demands are made to minimize infiltration of the air by tightening its natural places of inflow, namely windows. The effect of such steps is, of course, positive as for heat losses, but on the other side it is conflict with postulate of correct ventilation of flats, especially in the case of natural ventilation.

2. POSSIBILITIES OF IDENTIFYING VENTILATION AIR FLOWS

To achieve information on the course of the process of ventilating flats it is required to identify air flows in the space under examination as completely as possible. The most natural and definitive way to do it seems to be measurement. Beside the methodological difficulties one must be conscious of fairly considerable randomness of the results so obtained: they are possible to be achieved in general in a limited range; it is hard to guarantee the simultaneity of measurements in different spaces; the picture obtained represents the situation of one measuring moment, i.e. for given, instantaneous conditions that force the flows.

In the case of natural ventilation we may distinguish two main driving forces of the process: wind pressure on a building and heat buoyancy. While heat buoyancy, which is determined by air temperature difference between the inside and the outside of a building, is a slow varying (e.g. in an hour cycle) quantity, then wind has definitely random character respecting both direction and velocity. It particularly refers to compactly developed lands where natural turbulent wind structure is additionally disturbed in flows around the all sorts of obstacles surrounding an examined building.

The practical way achieve full information about the ventilation air flows in multi-zone object is computer simulation. The method of mathematical modelling and numerical simulation is reliable as much as the accuracy is kept with which the phenomenon is described and the parameters are settled. The advantage of this way compared with empirical method consists, among others, in the possibility of declaring variable climate parameters, building location and location of calculation zones - according to current needs.

3. NUMERICAL PROCEDURE AND PARAMETERS OF SIMULATION

The calculation results presented below come from the simulation made by my own numerical programme TRANSVEN. This procedure allows to simulate ventilation process in multi-zone object in the quasi-dynamic course and with the time step of 1 hour. The climate parameters, which are the input of the programme, were appointed on the base of many years' meteorological observations for the south-west region of Poland [1].

Basing the analyses of ventilation efficiency on the time runs seems to be more useful than calculation at steady climate data. Then, it becomes possible to analyse the variation of ventilation conditions in a given time period with the variation of climate parameters. Especially, it concerns the variation of velocity and direction of wind. Such type simulations

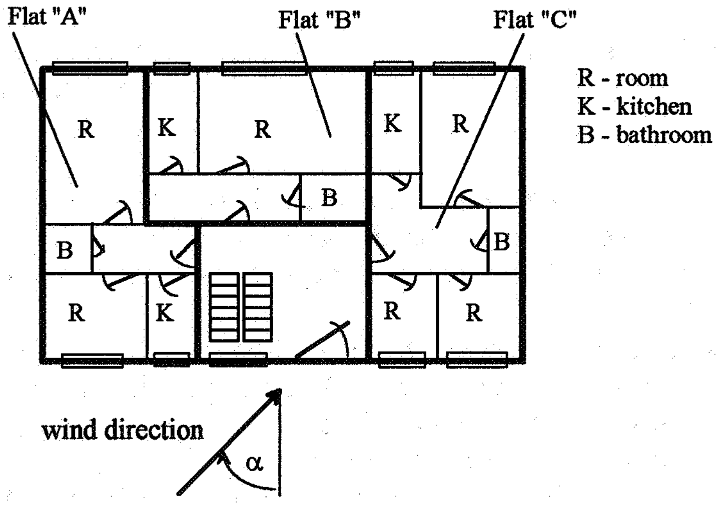


Fig. 1. Plan of a storey of the examined building.

open up good possibilities for analysing a great amount of individual cases, delivering material for generalization of statistical nature.

The calculations were made for a 5-storyed dwelling house with 3 flats on each floor. All flats were equipped with gas-fired water heaters placed in bathrooms without windows. Air change in the flats could occur thanks to individual gravity ventilation ducts and also exhaust ducts. The simulations were carried out for climate parameters representing the transition period of winter and spring (3 weeks of March) for the average temperature of this period approximately -1.3°C and wind velocity 3.3 m/s.

4. SIMULATION RESULTS AND DISCUSSION

While making a design of ventilation system of a building one should meet the need of essential from hygienic point of view air change rate. It is commonly assumed to be approximately 1 air change rate per hour for dwellings. The realization of this postulate mostly means to design the ventilation ducts that make such air flows possible.

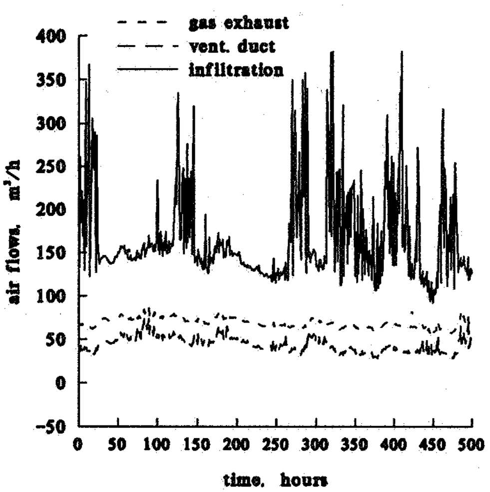


Fig. 2. Ventilation air flows in the flat "A" on the 1st floor.

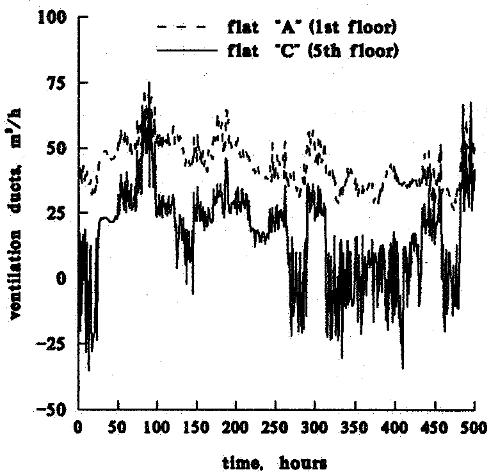


Fig. 3. Comparison of ventilating air flows in the flat "A" and "C".

For the analysed building cubage (approx. 4400 m^3), in the time period the calculations dealt with the air change rate in the whole building amounts, on average, to the level 0.5 air changes per hour. This value is thought to be a minimum air change rate (in hygienic aspect) [2].

However, owing to complicated path of air flows it turns out that air infiltration is markedly varied in a complex structure of individual storeys. This fact can be illustrated by comparison of ventilation air flows in the flat "A" on the first floor (Fig. 2) and in the flat "C" on the fifth floor. Outdoor air infiltration, which decides the air change, is in the flat "A" about 2.5 times greater than in the flat "C" at the same climate conditions. At the comparable cubages of both those types of flats, it implicates the difference of twice as large air change rate being absolute too little. The effect of such low level of infiltration is respectively worsened operation conditions of ventilation and exhaust ducts. It can be noticed that in some time periods there occur backflows in ventilation ducts in the flat "C" (Fig. 3). They are particularly dangerous for occupiers' health and even life. A situation like this takes places mainly in the flat "C" perpendicular, appearing more rarely on its lower floors.

Observations of the utilization of such type buildings confirm the above presented simulation results. In Polish foothills, where foehn type winds occur in some seasons, cases of poisoning of the occupiers took places many a time in consequence of inadmissible carbon monoxide concentration in bathrooms with gas-fired water heaters. Death cases were also stated.

For finding those climate conditions in which backflows in ducts can occur the flow rates in ventilation ducts of the flat "C" were settled in function of variable wind velocity and ambient temperature. Fig. 4 shows space picture of this variation in a wide range of climate parameters. It can be noticed that the most disadvantageous operation conditions take place at the wind velocity 4÷7 m/s and ambient temperature 0÷5 °C. These values of climate parameters are typical for the transition period (winter - spring) in heat season in Poland.

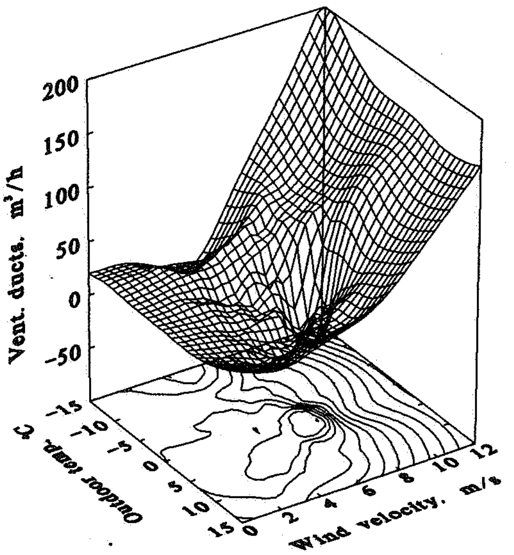


Fig. 4. Spatial picture of changeability of air flows through the ventilation duct in the flat "C" on the 5th floor.

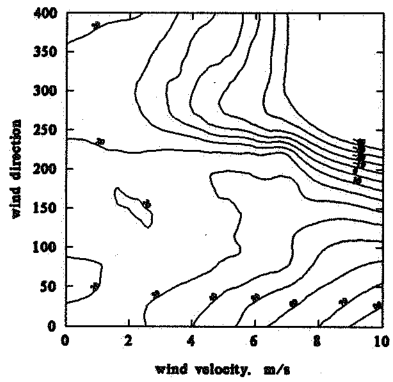
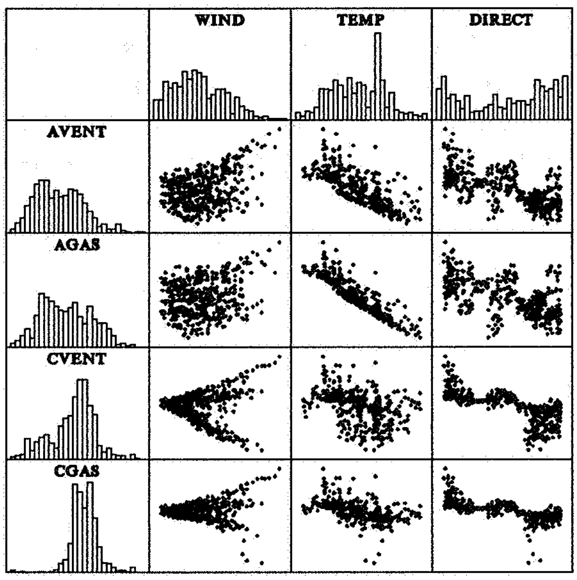


Fig. 5. Isolines of the air flow rate in the flat "C" as a function of wind direction and velocity.

What is also important here is the location of a given flat in building structure and resulting from it the orientation of windows towards the predominant directions of wind. Unadvantageous influence of the wind velocity above 4 m/s is confirmed, but backflows in ducts occur at the wind directions from the range of 180 ÷ 360 ° by starting counting from the building facade. The phenomenon of backflows in ducts practically does not exist in the "A" type flats, although the total length of their window gaps is comparable to the case of the flats "C", thus the conditions of infiltration from this point of view are similar. Such an effect is explained by inner structure of both types of flats; a major role is played here by the location of kitchen in which an inlet to the ventilation duct is placed.

The influence of the layout of individual flats particularly becomes apparent when making statistical analyses. While having a great amount of simulations at one's disposal (in the case under consideration - 450) it is possible to search a correlation between ventilation air flow rates and variable climate parameters. The results achieved are illustrated by scattering matrix (Fig. 6). In the "A" type flats, of considerable importance is the influence of the



Legend:
A[C]VENT - air flows in vent. duct in the flat "A"[C];
A[C]GAS - air flows through the gas exhaust in the flat "A"[C];
WIND - wind velocity;
TEMP - outdoor temperature;
DIRECT - wind direction.

Fig. 6. Comparison of wind and outdoor temperature effect on ventilating air flows.

temperature difference between the outside and the inside of a building; the correlation coefficient is here from -0.65 to -0.75. Whereas the influence of wind direction and velocity is of less significance (correlation coefficient 0.4 ÷ 0.6). In the flat "C", what is primary for duct operation is wind direction (correlation coefficient -0.65 ÷ -0.8).

The simulation results point to good agreement of the proposed model of infiltration with actually occurring air flows in existing buildings [3,4].

The benefit of the simulation works as presented below seems to be the possibility of obtaining quantitative relationships between ventilation driving forces of infiltration and resulting ventilation air streams. It may be useful in better predicting ventilation efficiency.

5. CONCLUSIONS

Natural air change in multi-family buildings essentially depends on infiltration what means, among others, that it is formed spontaneously and is imperfectly predictable.

Providing ventilation ducts of a suitable flow rates cannot be the only way to satisfy proper conditions for air change in natural ventilation. The results reported above show that as early as initial design stage one should take account of location of a building in a given area considering its wind rose. Of a great importance is also the layout of flats within a storey and the location of window openings in definite walls of a building. It is necessary to resign applying gas-fired water heaters because it is not always in the system of natural ventilation that one can be sure of the entire exhausting of flue gases.

An important aspect of quantification of flow processes and natural exchange of the air is the matter of wind modelling as being one of the deciding driving factors of those phenomena. Development of simulation models should tend to dynamical calculations, the climate generators being chosen adequately. Averaging the results yielded in this means seems to be more reliable than that in the case of the calculations made for steady climate conditions.

REFERENCES

1. BARANOWSKI, A.
"Natural Ventilation in Multifamily Dwelling Houses at Simulated Heat Season Climate Conditions - Numerical Prediction and Analysis"
Proceedings of IAQ Conf.: "Indoor Air Quality Problems", Warsaw, 1993.
2. BARANOWSKI, A
"Effect of Infiltration on Natural Ventilation of Multi-Storey Buildings" (in Polish)
Proceedings of the Conference "Building Physics in Theory and Practice", Łódź, 1993.
3. NANTKA, M.B. and BARANOWSKI, A.
"Investigation of Air Backflow Conditions: Case Study of Multifamily Dwelling Houses".
Proceedings of Fourth International Conference "ROOMVENT '94", Cracow, 1994
4. NANTKA, M.B. and BARANOWSKI, A.
"Action of Canals of Waste Gases in Multifamily Dwelling Houses with the Natural Ventilation" (in Polish)
COW, No.8, 1992.