AIR FLOW IN DWELLING HOUSES FROM AN ENERGY POINT OF VIEW (POLISH EXPERIENCE)

Marian B. Nantka
Silesian Technical University
Gliwice, Poland

Introduction

The knowledge of the amount of air flows is important not only in the determination of thermal comfort or air quality, but also in the estimation of heating requirements. Simultaneously, one of the ways of energy savings in buildings during the heating season is the correct solution of complex of problems which consist power of ventilation and airtightness of building structure.

These different factors will be reviewed in the paper. In the first part of the paper some of the results of experiments in existing buildings are presented. In the second part of the paper the way of air flow reduction by the tightening of building structures and the choice of ventilation systems has been presented.

Results of experiments

The research work has been done on about two hundred dwelling houses characteristic for the Polish Building Industry. Description of the methods used and particular results have already been presented in bibliography (1, 2, 3, 4, 5, 6). For typical indoor winter clothing (1 clo) and activity (1.2 met) Predicted Percentage of Dissatisfied vary between 15 ÷ 20 % in single family houses (SH) and 40 ÷ 50 % in multi-storey blocks (MH). The average air flow coefficient are for windows 0.8 ÷ 2.2 m^3/mhr (SH) and 1.5 ÷ 6.8 m^3/mhr (MH) at $\Delta p =$ 1daPa. The kinetic energy of the air flow in the vicinity of windows varies between 0.02 ÷ 0.22 mW/m^3. The average pressure differences equal of 0.4 to 0.7 daPa (SH) and 2.5 ÷ 7.5 daPa (MH). In this conditions air change rate as far as the whole building is 0.1 ÷ 0.4 hr^{-1} (SH) and 1.5 ÷ 2.2 hr^{-1} (MH) when the natural ventilation (NV) is installed. In the buildings with the mechanical ventilation (EMV) these values equal 0.8 ÷ 1.5 hr^{-1} (only MH). In blocks with the natural ventilation the air does not often flow into individual rooms.

For testing buildings with the NV heat losses (including air infiltration) varies between 10 ÷ 12 % (SH) and 40 ÷ 60 % (MH) from the total heat losses. In blocks with the EMV this fraction is about 60 %. The energy consumption on the ventilative requirements in heating season (for Silesia) varies between 10 ÷ 25 MWh (SH) and of 250 MWh to 450 MWh or greater (MH). After modifications of external wall (by the additional wall insulation) the fraction of ventilative heat losses are increased to the 15 ÷ 20 % (SH) and 55 ÷ 75 % (MH).

The comparison of a large number of experiments for existing buildings allows to name the main directions of continued works for elimination the excessive impact of air flow on energy losses. These works are completed by the calculation of air flows simulation. These methods were used by the author and their results prove that the conditions in the buildings are as much accidental as the necessities of building structure tightening (7, 8, 9, 10).

Method of analysis

The ventilation systems in dwelling houses not only consist power of ventilation (fan) and construction of air ducts, but also airtightness of building structure. Simultaneously, these factors are two basic ways for reduction of energy consumption in buildings.

Airtightness of the building envelope may be analysed as one of the important factors in the thermal protection of houses. The total heat losses of buildings are the sum of conductive heat flow, the air infiltration heat flow and heat requirements due to ventilation (as the results by used the duct ventilation). When the fraction of infiltration heat losses to the total heat demanded (without the ventilative heat losses) is reduced to 20 %, the average air flow coefficient of gross enclosure area can be calculated:

$$a_m = 0.7\ k_m (\Delta p_m)^{-\alpha} \quad m^3/m^2hr \qquad (1)$$

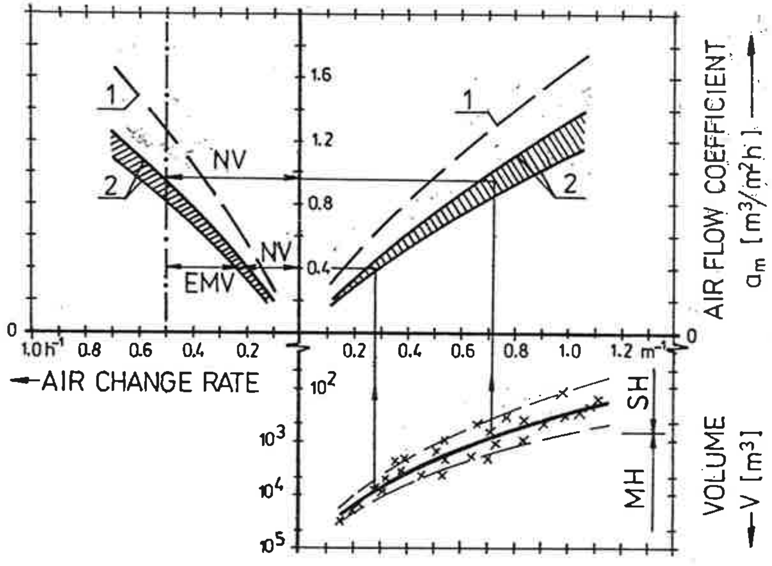
where k_m - value is the average thermal transmittance of gross enclosure area ($W/m^2 K$), Δp_m is the average pressure difference for the winter conditions and the areas of the all perpendicular walls, bottom and top seperation (daPa) and α is the air flow exponent (most often is equal 0.65 ÷ 0.70). The pressure difference may be calculated by determining of weight mean from pressures on the all external walls of buildings. In this case, the a_m - values are results of heat transmition through external walls and heat flow due to the natural air flow from outside as of wind and thermal driving. Some results of these calculations are illustrated on Fig. 1. Buildings are divided by the ratio of the gross area of the enclosure to the building's volume (D). The a_m - values vary between 0.3 ÷ 0.8 m^3/m^2hr (MH) and greater than 0.8 ÷ 1.0 m^3/m^2hr (SH). For these values the air change rate varies between 0.1 ÷ 0.3 hr^{-1} (MH) and greater than 0.4 ÷ 0.5 hr^{-1} (SH). As it shows for buildings from the ratio D lower than 0.6 ÷ 0.7 m^{-1}, the air change rate is also lower than minimal fresh air requirements. These buildings are excessively hermetic and the controlled ventilation system must be installed. In general, the additional air change rate (reduced to the minimum fresh air requirements - 0.5 hr^{-1}) is the function of building largeness (by the ratio D). The natural ventilation can be installed in dwellind houses if volume is lower than about 1000 m^3 (1 ÷ 3 floor levels). When the buildings volume is greater than the mentioned value the mechanical ventilation must be installed. Energy may be held not only by tightening the building envelope or mechanical ventilation, but also by heat recovery from exhausted air. In high - rise buildings with the supply - exhaust mechanical system (SEMV) and tight houses structure, both the indoor air quality, thermal comfort and energy consumption are independent on the weather. In the average winter conditions (0°C, 5 m/s) reduction of ventilative heat losses by tightening the building envelope is higher than 30 ÷ 40 % (MH). The higher energy saving (about 70 %) may be received if the waste heat recovery is applied. These results have been made for windows only opened for short periods in the case of extreme bad air quality.

On the basis of these analyses for different buildings it can be defined both the limit of tightening and the type of ventilation system to apply.

1. For building volume lower than 1000 m^3 ($D > 0.6 ÷ 0.7\ m^{-1}$) the natural ventilation may be applied. The a_m - values is about 1.2 m^3/m^2hr.

2. If buildings volume is lower than about 5000 m^3 ($0.5 < D < 0.7\ m^{-1}$) the exhaust mechanical ventilation must be installed. The a_m - values are about 0.8 m^3/m^2hr. These buildings are multi - family houses from 4 ÷ 6 floor levels.

Fig. 1. The illustration of the method proposed for the determination of tightening of buildings envelope and choice of ventilation systems in dwelling houses (1 - for k_m - values from measurements; 2 - for k_m - values from Polish Standard Norms).



3. In buildings with volume lower than 10000 m^3 ($0.3 < D < 0.5\ m^{-1}$) it is neccesary to supply - exhaust mechanical ventilation (they are multi - family houses from 8 ÷12 floor levels). The a_m - values is about 0.6 m^3/m^2hr.

4. For high - rise buildings ($D \leq 0.2\ m^{-1}$) the supply - exhaust systems with waste heat recovery is recomended. The a_m -values are about 0.4 m^3/m^2hr. When the heat efficience equals 0.5, a good thermal comfort, indoor air quality and reduction of the heat demanded can be maintained.

Finally, the energy reduction by eliminating excessive air flow through the building envelope may be limitted to about 20 % of the total heat demanded in all Polish dwelling houses. This reduction corresponds to the lowering in the air change rate from 1.5 hr^{-1} to 0.5 hr^{-1}. The increase of air rate goes together with the increase of this fraction (i.e. 20 %), but these changes are of periodical character (two or four hours in the day as the results of experiments and questionaries in existing buildings). These changes consider the regulation of ventilation systems.

Conclusions

The knowledge about the airtihgtness and ventilation of Polish buildings has been significantly increased during the last four years. Both experimentally and theoretically the correlation between airtightness, air change rates and thermal performance in different buildings was shown by the application of simple method. This method is helpful for definition of both the limitation of tightening buildings and for choice of the type of ventilation systems. But there are still problems to be solved. Areas which need supplementary research are:

- determining of airtightness requirements from biological demands (due to different building materials, odours of man's body, air humidity, etc.)
- air change rates in various rooms and possibility of regulation demands of ventilation systems
- increasing of co-operation structural and HVAC engineers in the design and construction of buildings.

These all factors, however, tend to ignore the main point which is a good ventilation, but good ventilation cannot be obtained without tight structure and correct realization of thermal insulation of buildings. On the other hand - cannot ignore the energetic point of view from heat consumption on the air requirements of buildings. Requirements and standards on these problems will be further discussed.

References

(1). Nantka, M.B. Ventilation and Heat Demanded in Dwelling Houses. Silesian Technical University Reports, 1980, 1981 (unpublished).

(2). Nantka, M.B. Air Infiltration and Heat Losses in Typical Buildings. 1981, Proc. of the meeting of Polish Scientific Academy.

(3). Nantka, M.B. and Majerski, S. Effectiveness of Ventilation Functioning in Many - Storey Residential Houses, 1981, C.O.W. nr 6.

(4). Nantka, M.B. Heat demands of dwelling houses and possibilities of their reduction. 1982, C.O.W. nr 5.

(5). Nantka, M.B. Tightness of pre-fabricated outer walls and its influence on heat demanded in apartment buildings. 1983, Air Infiltration Review, nr 2.

(6). Nantka, M.B. Theoretical and experimental study of heat flows due to the air infiltration and ventilation. 1984, Proc. of the International Conference, Praque.

(7). Nantka, M.B. Ventilation and air infiltration in relation to the indoor air quality and energy consumption. 1984, 3-rd International Congress - Air Quality, Stocholm.

(8). Nantka, M.B. Calculation methods for the natural and mechanical ventilation in dwelling houses. 1984, C.O.W. (in print).

(9). Nantka, M.B. Airtightness problems and consequences from energetic point of view. Arch. Energ. (in print).

(10). Nantka, M.B. Main directions developing low energy heating and ventilation systems in apartment buildings, 1984, Proc. of the International Conference, Wroclaw.

SUMMARY

M.B.Nantka: Air flow in dwelling houses from energetic point of view (Polish experience). The present paper reviews the important ways of reduction the excessive impact of air flow on energy losses in dwelling houses and the quality of the air. In the first part of the paper some results of the experience in the existing houses have been presented. In the second part the simple method to make possible correct solution of energy reduction by organisation of air change in different construction of houses is described. The aim of this method is the decrease of the average air coefficients of grass enclosure area of building to demand values and determination of the heat criteria for type of ventilation systems selection. In conclusion of the paper the main directions of further analyses are presented.

RESUME

M.B.Nantka: Les mouvements d'air dans les maisons egsistantes au point de vue energetique (experience de Pologne).Dans ce rapport on examina les chemins principales que mènent à'la borner d'excessif d'influence d'èchanger de l'air sur demandes de chaud des maisons residentiels et sur qualité de l'air d'intérieur. Dans la premiere partie on reprèsenta quelques resultats de mesurage lesquels on mena dans les bâtiments egsistants. Dans la deuxiéme partie on decrit la methode qui rendre possible correcte solution pour diminuation de consomation d'energie dans diverses bâtiments par convenable organisation d'echange de l'air. De point de mire de cette methode est recevoir de correcte mouvements d'air, qui sons determineè plus precisiment dans la ventilation. La methode permetee ausii sur determination des criteries energetiques au choix des systemes de ventilation dans les bâtiments. En conclusion on presentra les directions principales des essais et mesurage futures.

KURZFASSUNG

M.B.Nantka: Die Lüftströmungen in den Wohngebäuden vom energetischen Standpunkte aus (Die polnischen Erfahrungen). In der vorgenstellten Bearbeitung werden die Hauptwege besprachen, die fur die Einschrankung des übermässigen Einflusses auf den Warmebedarfe der Wohnungbäuden und auf die Güte des inneren Lufts führen. In ersten Teil werden die einingen Ergebnisse der in der bestehenden Gebäuden durchgeführten messungen vorgestellt. Im zweiten Teil des Berichts werden die einfachen Methoden beschrieben die Korrekte Lösung im Umfang der Verüngensung des Energieverbrauchs durch die richtige Organisation Luftwechsels in den Verschiedenen Gebauden ermöglicht. Der Zweck diser Methode is die Verkleinerung der mittleren Luftdurchgangszahlen durch die ausserlichen Verschläge zu den erforder lichen Werten und die Luftungssystems. Im Schluss werden die Hauptrichtungen der Künftingen Untersuchungen und Messungen vorgestellt.