DESIGN OF VENTILATION SYSTEMS IN RESIDENTIAL BUILDINGS

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Building regulations prevailing in France made it compulsory to use specific ventilation systems in new residential buildings since 1969. Different kind of ventilation systems (mechanically powered, temperature driven, hybrid systems,...) have been developed. This paper reviews these systems and outlines their advantages and drawbacks in single family or multi-family with buildings, respect to architectural flexibility and comfort or safety requirements. In a second part, the paper introduces and discuss the scientific grounds (for instance, wind effect) which govern the ventilation rates. Results of theoretical work are given and design methods in use in France, with their influence on architecture conception, are featured. 4468

INTRODUCTION

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Ventilation systems in residential buildings are primarily intended to remove air pollutants (moisture, combustion products, odours,...) and prevent building damage due to condensations and mould growth. This was previously achieved by natural means : window opening and also air change when fireplaces are working. In the sixties, new architectural trends appeared : water-closets and bathrooms are often in a central position with no window, and fireplaces have almost disappeared in multifamily houses. On the other hand, greater concern has been paid to energy conservation and comfort matters (protection against outdoor noise and cold draught). This has led to the spread of specific ventilation systems such as : natural ventilation using vertical shafts, mechanical systems ; or new techniques such as : humidity controlled ventilation. The usual air-flow pattern, using such systems, is shown in Fig 1 :

These systems must comply with additional requirements : limit heat losses to a reasonable value, independent of climatic conditions (wind, outdoor temperature)

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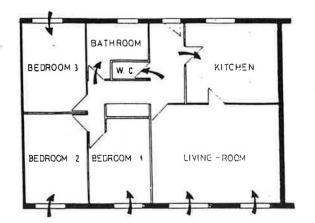


Fig 1 : airflow pattern in dwellings : Since service rooms are ventilated by exhaust vents, there are no air inlets in these rooms.

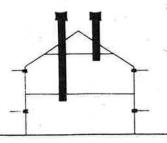
prevent acoustic annoyance, due either to noise emission or noise transmission through ventilation components; prevent reverse flow through a common ventilation network; design and install the air inlets in order to avoid cold drafts;

 avoid drift of components characteristics due to fouling or aging ; . allow access for maintenance operations and provide safety ;

in case of vented or unvented combustion appliances.

VENTILATION SYSTEMS IN USE IN FRANCE

Mechanical exhaust systems which appeared in France in the sixties are now the most commonly used systems. As opposed to natural ventilation, they provide a much greater flow rate steadiness, whatever the outdoor climatic conditions. Mechanical systems have been improved in recent years. New systems, with flow rates depending on the prevailing indoor climatic conditions, enable energy conservation and indoor air quality to be further improved indoor air quality to be further improved.



 $\underline{Fig \ 2}$: Scheme of a natural ventilation system a single family house.

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In natural exhaust systems (fig.2) the flow rate is generated by buoyancy and wind effects. Accordingly, flow rates vary a lot. Other systems (mechanical balanced systems,...) are also in use and many new systems (humidity controlled vents, hybrid systems combining natural and mechanical effect, ...) have been recently developed.

VENTILATION SYSTEMS DESIGN AND DIMENSIONING

Dimensioning of air inlets.

Air inlet sizing must lead to a good balance between air quality and energy conservation requirements. As a matter of fact, air inlets are intended to ensure as equal as possible fresh air distribution amidst the different rooms. Therefore, their sizing must be sufficient with regard to non-uniformity of flow due to building shell permeability.

On the other hand, air inlets size must be as low as possible, in order to reduce heat losses due to cross ventilation in case of wind. Calculations (6) have shown that cross ventilation heat losses are a function of the negative pressure inside the dwelling, according to the following equation :

$$Q_s = P. \frac{C}{1 + d \cdot \left(\frac{Q}{P}\right)^2}$$

where C

where :

 Q_s (m3/h) flowrate corresponding to cross ventilation

- Q P (m3/h)
- exhaust flowrate due to ventilation system operation flowrate through the building shell air leakage and air inlets (m3/h)
- when the pressure difference is 1 Pa numerical coefficients, the values of which depend on building wind exposure. e, d

Taking into account the mean air leakage values of the building shell in new buildings, the above considerations lead to a proposal that the area of air inlets should be equal to 30 cm2 in each room, when exhaust flowrate is achieved by a mechanical systems. When a natural exhaust system is used, the air inlet area must be higher.

Sizing of mechanical exhaust area.

Fig. 3 depicts an example of an airflow calculation in an exhaust network. Airflows are mainly depending on the pressure-flow rate curves of the fan, exhaust vents and network itself. However, the negative pressure in the network, (hence the flowrates at each exhaust vent), may vary considerably. As a matter of fact, thermal or wind effect may substantially increase the flowrates. Moreover, according to French regulation, it is allowed that exhaust vent aperture area may be set by the occupant either to a low value, or to a peak value. When most of the exhaust vents are at their peak value, pressure drop in the ducts increase and exhaust flow rates in other vents are lower.

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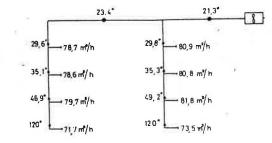


Fig. 3 : Mechanical exhaust network :

This figure depicts calculated flowrates and temperatures (6) in an exhaust network. The exhaust vents of the first floor are linked to vented gas appliances, the flue temperature of which is assumed to be equal to 120° C.

The pressure variation inside the network may be, as illustrated in Fig. 4, quite important and cause either noise production, when the pressure is high, or unsufficient ventilation, when this pressure is low. The allowed values of noise production (acoustic pressure level) in the kitchen is 35 dB(A), which can be usually achieved, provided the negative pressure in the network does not exceed a value, which usually is in the range of 120 to 140 Pa. On the other hand, the pressure must be high enough to limit flowrate variations due to wind or thermal effect. Moreover, the exhaust vent aperture area must not be too large in order to reduce noise transmission from one flat to another one.

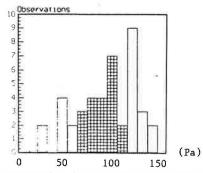


Fig. 4 : pressure variation in a mechanical exhaust network :

This histogramme shows the distribution of negative pressure which were measured in an exhaust mechanical system. Crossed lines indicate the range of pressure for which air flow and acoustic requirements of the exhaust vent are met. A large number of measured values are not in the authorized range; the sizing of this particular exhaust network must therefore be improved.

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For all these reasons, a typical pressure range is 70 - 120 Pa. Most of the exhaust vents in use in France are designed to meet the flowrate steadiness and noise requirements in this range of pressure.

The design principle of mechanical exhaust systems in multifamily buildings is therefore to dimension the network in such a way that the pressure drop of exhaust vents remains in the authorized range of values, regardless of the climatic data and the occupant behaviour. This is generally achieved either by using purpose-designed fans or, preferably, in using ducts with sufficiently large diameters, which allow accommodation of the pressure drop variation due to human behaviour. accommodation of the pressure drop variation due to human behaviour (i.e : variation of required exhaust flowrate). A design method (2), based on this principle, is under preparation and will hopefully help designers improve exhaust network sizing. State Street Laws

Dimensioning of natural ventilation systems.

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Proper dimensioning of natural ventilation system is a delicate matter, because the airflow is dependent, to a great extent, on the outdoor temperature and also on the wind effect, which still needs a lot of investigation. The need for more research can be illustrated by considering the example of shunt ducts which were in common use in multi-family buildings in the sixties : As it appears in Fig. 5, the shunt duct is a double duct composed of a small duct used for individual air exhaust of each building and a larger one used to collect individual airflows up to the top, where a cowl is installed to transform wind velocity into pressure head. From an architectural point of view, the shunt duct makes it possible, compared with individual ducts, to save space and decrease the building cost. On the other hand, it may lead to higher likelihood of reverse flow (4).

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60 cm ²	- 32 m ³ /h	60 cm ²	1-17 "	2/h
60 cm²	36 m ³ /h	60 cm ²	1 On	2/h
60 cm²	1-41 m ² /h	60 cm ²	16 1	2/h
60 cm ²	46 m ³ /h	60 cm ²	23 1	2/h
60 cm ²	52 m ³ /h	60 cm ²	29 m	3/h
30 cm ²	11_31 m ³ /h	30 cm2	18 1	2/h
30 cm ²	11 34 m3 /1	30 cm2	21 0	P/h

Fig.5 : Shunt ducts : influence of wind velocity and outdoor temperature on exhaust flowrates.

first column : outdoor temperature : 0°C ; wind velocity : 0 m/s second column : outdoor temperature : 10°C ; wind pressure : -3 Pa



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It may be noticed that reverse flow rates occur under unfavourable climatic conditions. These reverse flow rates may be alleviated using high performance cowls. A practical difficulty is that, for a given cowl, the negative pressure caused by the wind is a complex function of wind velocity and air flow rate, thus making design calculation difficult to handle. Gonzalez (3) investigated that point, and showed that a relationship exist between two non-dimensional quantities. More work is still needed, to correlate flow rate test results on commercially available cowls with theoretical analyses.

A last difficulty arises from wind turbulence. Computer simulations (1) (5) showed that taking account wind turbulence makes it possible to explain reverse flow at the upper floor.

CONCLUSION

Design methods based on computer codes makes it possible to improve the design of ventilation systems. More research work is still needed in order to ascertain results relevant to natural ventilation.

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ACKNOWLEDGEMENTS

The author wish to express his thanks to R.MOUNAJED who developped computer models, J.GANDEMER who provided wind data and J. RIBERON for general assistance. Participation of AFME, France, to research support is gratefully acknowledged.

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