Measuring Air Change Rates using the PFT Technique in Residential Buildings in Northern Portugal

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ABSTRACT

Portugal has technical recommendations and standards regarding ventilation rates in natural ventilation systems. However these ventilation rates have not been fulfilled in most residential buildings recently erected in Portugal.
We believe that natural ventilation systems alone are unlikely to guarantee the recommended ventilation, and so we characterized the performance of a mixed ventilation system consisting of an air inlet through self-adjustable inlets in bedrooms and living rooms, natural exhaust in bathrooms and fan exhaust systems in kitchens.
We measured ventilation conditions in a residential complex of 94 apartments in the Porto area using the passive tracer gas method, more precisely the PFT technique. The study evaluates the façade's permeability and the respective air exchange rates per compartment using the PFT technique.
Seven flats were analyzed, six of which have a mixed ventilation system (continuous exhaust system in the kitchen and natural exhaust in the bathroom). The seventh flat has a natural ventilation system, enabling the performance of the two systems to be compared.
The experimental results allow, namely, the evaluation of the influence of insulation, a grid with low head loss and a static ventilator in the duct of the bathroom and the continuous exhaust ventilation in the kitchen.

KEYWORDS

Ventilation, dwellings, air change rate (*ACH*), PFT.

INTRODUCTION

The Portuguese standard for the natural ventilation of residential buildings, NP 1037 – 1 (2002), recommends exhaust air flow rates, corresponding to an average of one volume per hour in main rooms (bedrooms and living/dining rooms) and four volumes per hour in service rooms (kitchens and bathrooms). Most recently-built residential buildings might not comply with these rates, M Pinto (2002). "General and permanent ventilation" systems with continuous air admission through the main rooms and air exhaust in the service rooms must be implemented, Viegas (2004).

The study analyses the ventilation in seven similar flats in a four storey apartment building (Figure 1). Six of the studied flats have a mixed ventilation system (continuous fan driven exhaust system in the kitchen and natural exhaust in the bathroom). The seventh flat has a pure natural ventilation system, to enable the performance of the two systems to be compared. The flats were selected to represent different orientations and different heights above ground (see Figure 1).

Three flats with the mixed ventilation system are situated on the first floor and three on the fourth floor. The flat with the natural ventilation system is situated on the second floor.

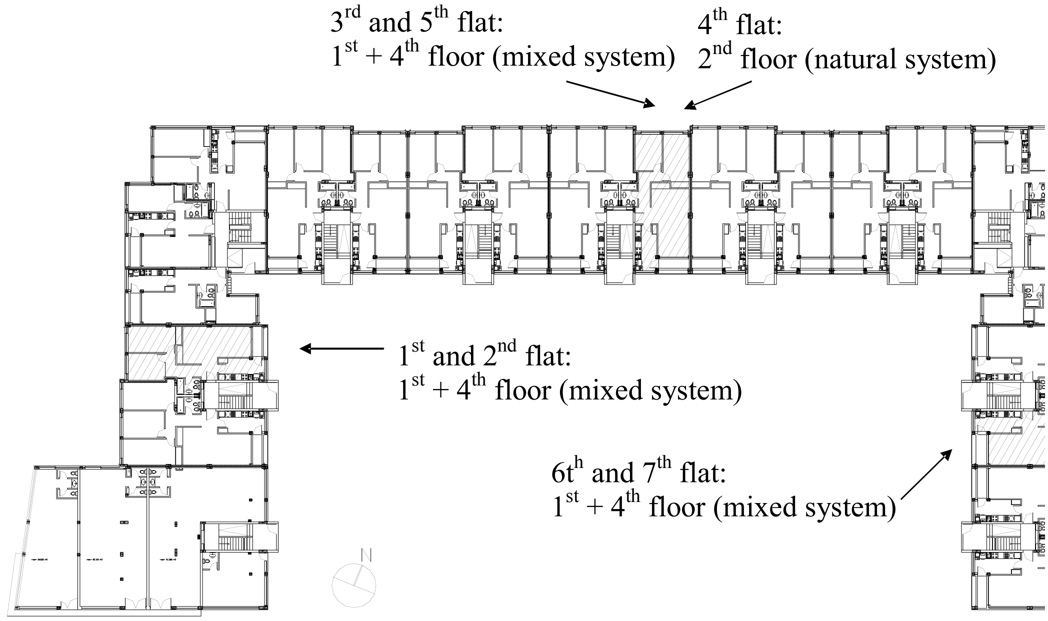


Figure 1: Residential building containing the seven flats to be tested.

The air permeability of building components and the air permeability of the envelope were both investigated. The *ACH* at 50 Pa of a flat is approximately 5.6 h^{-1} which is in the mid-range of whole building air permeability in Portugal, A Pinto (2005).

DESCRIPTION OF THE FLATS AND THE VENTILATION SYSTEM

Figure 2 shows a standard apartment (mixed type) and the location of the various ventilation system devices.

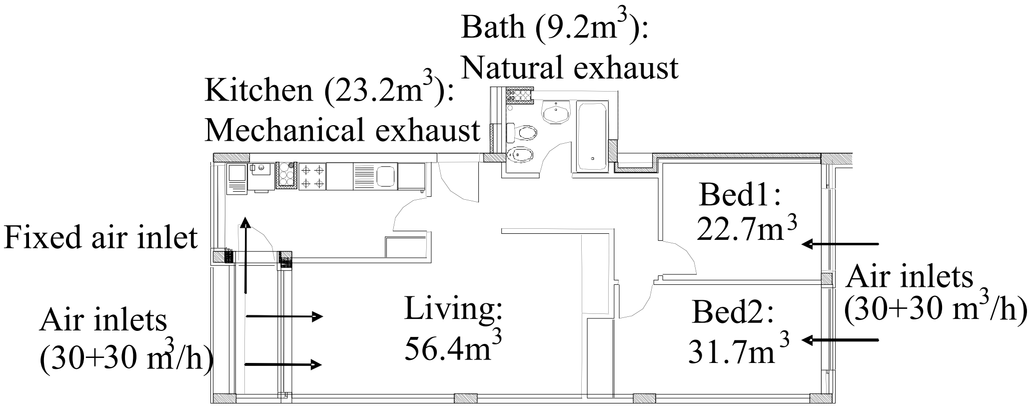


Figure 2: Standard flat tested.

The ventilation system layout is as follows:

- Four self regulated air inlets (30 m^3/h at 20 Pa) are placed in the living room and the bedrooms as shown in Figure 2, fitted above the windows;
- The diameter of the bathroom ducts in the flats on the west and north wings of the building is 110 mm while those on the east wing is 125 mm;
- The diameter of the mechanical (and natural) exhaust duct in the kitchen is 150 mm (metal);
- The diameter of a collective water heater appliance duct serving three kitchens on the same vertical plane is 175 mm (metal). The appliance ducts from the 4^{th} floor are individual with a diameter of 125 mm. The fresh air requirement for the heater is about 4.3×heating power ≈ 100 m^3/h.

The layout of the natural system implemented in the 4^{th} flat (2^{nd} floor) is similar to that described above for flats 1, 2, 3 and 5, except for the absence of a mechanical extract in the kitchen.

In the six flats equipped with a mixed ventilation system, two parallel exhaust ducts (PVC) were installed to ventilate the bathroom. They both had a diameter of 110 mm (or 125 mm in the two flats on the east wing), but one was modified with insulation on the exterior with polyurethane foam of approximately 3 cm and was equipped with a reduced head-loss grid and a static ventilator on the roof.

One of the aims of the tests was to compare the performance of the two natural exhaust ducts, i.e. determine the influence of the insulation, the reduced head-loss grid and the static ventilator.

VENTILATION MEASUREMENT TECHNIQUE

The PFT technique is a passive tracer gas technique for ventilation measurement in which perfluorinated hydrocarbons are used as tracers. The tracer gas is continuously infused into the room air at a low and constant rate from miniature containers via built-in capillary tubes. Air is sampled using passive diffusive samplers filled with a charcoal sorbent. The amount of tracer trapped in the samplers during the exposure time is analysed using gas chromatography with an electron capture detector.

In homogeneous emission techniques, used to monitor the ventilation performance in this study, the tracer gas emission rates from the sources are arranged to yield an equal emission rate per volume unit in the measurement object. The emission rate from a source can be adjusted by a metal wire extending to different depths in the capillary tube. The local tracer concentration will be proportional to the "local mean age of air (τ_p[h])". Using passive samplers positioned in different rooms, it is therefore possible to get an idea of how the ventilation air is distributed within the measurement object. The inverted value of the local mean age of air can be interpreted as a "local air change rate" (ACH_{local}), Stymne (1994).

FIELD EXPERIMENTS

Two series of measurements were carried out, one during summer conditions in August 2005, the other during winter conditions in January/February 2006. During both periods the flats were unoccupied. Passive samplers were placed in all rooms of the flats and were left to sample the air for one-week periods. During summer conditions only one period (2/8-9/8) was run, while two periods (12/1-19/1 and 26/1-2/2) were run during winter conditions. Indoor and outdoor temperatures, wind speed and wind directions were measured (see Table 1).

Summer conditions

In the summer test, the mechanical exhaust schedule in the kitchen was: 12 noon-2.00 pm and 6.30 pm-9.30 pm at ≈ 120 m^3/h and the rest of the time at ≈ 60 m^3/h (average flow of ≈ 70 m^3/h). In the mixed ventilation system the modified duct (isolated) was used in bathrooms.

In relation to the indoor thermal conditions (vacant flats), Table 1 shows that, as was expected, the flats with the temperature extremes are those on the ground floor and the top floor, with an average difference of 3ºC (it was not possible to obtain values for flat 5). It may be concluded that the ambient temperatures follow the outside temperature and can lead to situations of discomfort.

The outside climatic conditions (obtained in the roof) feature low wind speeds (wind speed average per octant between 1.3 m/s and 3.6 m/s), bearing approximately perpendicular to flats 3 to 5, that is, in the N-NW (predominant octants in the afternoon and evening) and SE octant (predominantly in the morning) and high temperatures.

Winter conditions

In the winter test, the mechanical exhaust schedule in the kitchen was: 12 noon-2.00 pm and 6.30 pm-9.30 pm at ≈ 110 m^3/h and the rest of the time at ≈ 90 m^3/h (average flow of ≈ 95 m^3/h).

Two tests periods were carried out in January and February 2006. In the first week there was some heating (2400 W radiators) in flat 2 and the ducts in the bathrooms were the modified (isolated) ones. In the second week there was some heating (radiators) in flat 4 (natural ventilation) and the ducts in the bathrooms were the normal ones (unisolated).

In relation to the indoor thermal conditions, Table 1 shows that the flats had very low temperatures (the flats were vacant). A slight increase can be seen in the 2^{nd} (1^{st} week) and in the 4^{th} (2^{nd} week) flats because of the radiators.

The outside climatic conditions feature low wind speeds (wind speed average per octant between 1.0 m/s and 3.2 m/s), predominantly in the same octants as the summer test (N, S and SE).

Table 1. Situation of the investigated flats and climatic conditions during the three measurement periods

Flat	Floor	Location*	Vent.	2/8 - 9/8	12/1 - 19/1	26/1 - 2/2
				T_{in} ºC average		
1	1st	W	mixed	23.8	12.5	10.0
2	4th	W	mixed	25.9	***15.5***	9.1
3	1st	N	mixed	23.1	11.6	13.4
4	2nd	N	natural	24.0	11.2	***16.8***
5	4th	N	mixed	unspec.	10.5	10.5
6	1st	E	mixed	23.6	10.9	10.2
7	4th	E	mixed	25.7	9.7	9.2
Average flat indoor temperature ºC				24.4	11.1***	10.4***
Average outdoor temperature ºC				25.4	8.8	6.0
Average wind speed m/s				1.9	1.4	1.7
Average wind direction				N+NW=34% SE=18%	S+SE=51%	N+SE=36%
note : *flats located at the west, north or east part of building, ** flat heated with radiators, ***without the heated flat						

RESULTS

In Figures 3, 4 and 5 the measured local *ACH* (inverted value of the local mean age of air) in the bathrooms and kitchens as well as the average *ACH* of the flats (computed from the inverted value of the volume weighted local mean ages of all rooms in the object) are displayed for the three measurement periods.

Figure 3: Display of measured *ACH* during the summer conditions 2/8-9/8

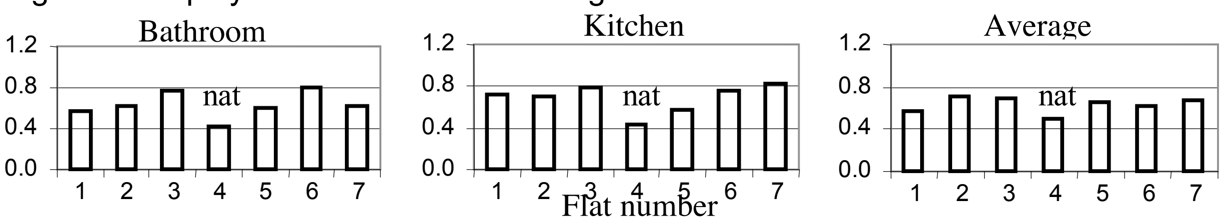


Figure 4: Display of measured *ACH* during the first winter week 12/1-19/1

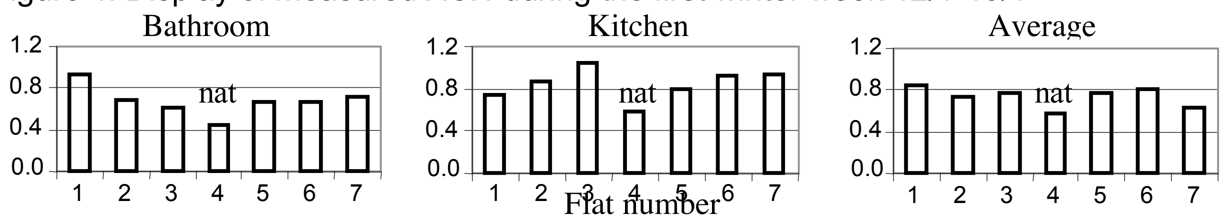
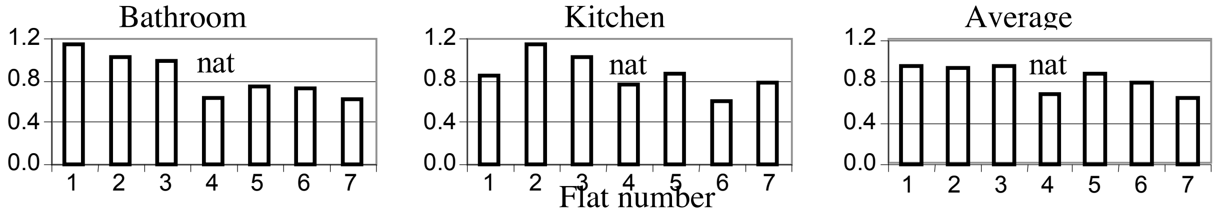


Figure 5: Display of measured *ACH* during the second winter week 26/1-2/2



MAIN CONCLUSIONS

Regarding the *ACH* obtained, the main conclusions are:

- The use of a static ventilator, insulation and a low head-loss grids (ΔP_{total}- 45 m^3/h = 2 Pa) is significant for obtaining meaningful increases (≈ 60%) in *ACH*, comparing with the bathroom of flat 4, which does not have these devices;
- The use of the Φ125 mm diameter in the bathroom duct in flats 6 and 7 does not increase the extracted flow;
- The wind speed is important to achieve higher *ACH*, especially in the bathroom. We can see this by comparing the *ACHs* for the 1st and 2nd weeks in the winter test (the average speed increased 21% and the $ACH_{globall}$ increased 14%);
- The higher inside temperature and wind speed in the 2nd week of the winter test is fundamental to increasing the extraction flows in flat 4, with natural ventilation (≈ 21%);
- The increase in the average mechanical flow in the kitchen, between summer and winter, is about 36%, and the increase in the ACH_{global} is 25%;
- The average ACH_{global} for the flats with a mixed system can be regarded as reasonable (0.65 in the summer and 0.81 in the winter). This varies slightly with location in terms of height and the orientation of the flats, but it is always greater than the average ACH_{global} for the flat with the natural ventilation system (0.51 in the summer and 0.63 in the winter).

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REFERENCES

IPQ (2002). NP 1037-1: Ventilation and evacuation of combustion products from places with gas appliances. Part 1: Dwellings. Natural ventilation (in Portuguese), *Portuguese Institute of Quality*, Lisbon, Portugal.

Pinto, A. (2005). Criteria to define limits for building airtightness. Airtightness of some Portuguese dwellings, *26th AIVC Conference*, Brussels, Belgium.

Pinto, M. and Freitas V. (2002). Characterization of natural ventilation systems in residential buildings in Portugal. The importance of standardization, *XXX IAHS Congress*, Coimbra, Portugal.

Stymne, H. and Boman, C. (1994). Measurement of ventilation and air distribution using the homogeneous emission technique. A validation, *4th Healthy Buildings Conference*, Budapest, Hungary.

Viegas, J.; Matias, L. and Pinto, A. (2004). Natural ventilation of an apartment: a case study, *9th Roomvent Conference*, Coimbra, Portugal.