NATURAL VENTILATION FOR OFFICE BUILDINGS COOLING

E. Gratia, I. Bruyère and A. De Herde.

Université Catholique de Louvain - Architecture et Climat
Place du Levant 1, B-1348 Louvain-La-Neuve, Belgium
gratia@arch.ucl.ac.be, bruyère@arch.ucl.ac.be, deherde@arch.ucl.ac.be.

ABSTRACT.

In the 1990's, concern about global warming has resulted in a resurgence of interest in naturally ventilated offices. The Belgian climate is particularly well adapted to apply cooling by natural ventilation. Indeed, except for a few hours a year, outdoor air temperature is lower than indoors. Lots of office buildings have no atrium or chimney to benefit from any stack ventilation. But natural ventilation can nevertheless be organized with only frontage windows either by single-sided ventilation or by cross ventilation. Simulations with the software TAS were made to appraise those strategies. Zone air flows and needs for cooling in an office building in various situations, as well as the impact of the wind orientation were analysed. The impact of size and location of window apertures on ventilation rates was also studied.

1 INTRODUCTION

Natural ventilation is more and more used in buildings of the tertiary sector. But it is very often associated with atrium and/or stack. But, as we try to demonstrate in this paper, it can also be organised in narrow office buildings without these equipments. That means the envelope of the building and especially window apertures have to be well studied.

Definition

We will talk about natural ventilation for cooling when its aim is to refresh the building and lower the energy consumption of the cooling system. It is qualified as "natural" because it has no energy consumption for fans as it is achieved by window openings. A distinct mechanic system ensures the hygienic ventilation.

Why use natural ventilation?

The recent advent of office equipments and the ever more important glazing surfaces have increased the overheating risk [6]. On the other hand, occupants of office buildings ask for a stimulating working environment. Mostly, that is provided by an air conditioning system. But in Belgian where climate is particularly well adapted for that, natural ventilation for cooling may furnish a great part of the cooling needs, and even sometimes be sufficient to ensure good comfort levels in occupied buildings. This will result in considerable energy and cost savings [1].

Moreover, natural ventilation seems to be very appreciated by occupants complaining about noise and health problems linked to mechanical cooling [1]. People especially appreciate the possibility of opening window [15].

Which effect on the building conception?

To be successful, the importance of ventilation for cooling must be recognised at the initial stages of the design process, before decisions are made which might make it unworkable [7, 8, 9, 10]. The driving forces, and thus the air flow rates, vary with the height of the building, with its orientation, depending on the prevailing wind direction, with the size, location and shape of openings parts of windows, on the environment … [12, 13] Thus, the efficiency of natural ventilation for cooling greatly depends on decisions taken very early in the design process of the building [1, 11].

2 METHOD

2.1 The "TAS" simulation program.

TAS is a software package for the thermal simulation of buildings. It includes a 3D modeller, a thermal energy analysis module, a systems/controls simulator and a 2D CFD package. [16].

2.2 Climatic data assumptions.

For this study we chose to analyze one sunny summer day in Uccle (Brussels, Belgium). The outside temperature evolves between 11.4°C and 23.3°C. The global solar radiation is important (see figure 1). The wind speed is close to 4m/s

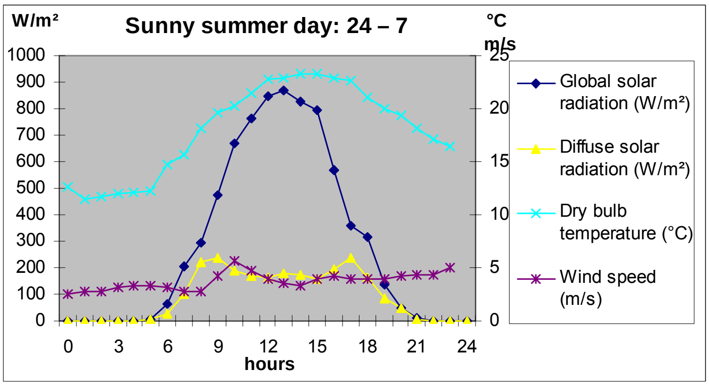


Figure 1: Climatic data of a sunny summer day in Belgium

2.3 The studied building.

We choose the narrow plan building proposed in the frame of the subtask A of the Task 27 (Performance of solar facade components) of the Internal Energy Agency which we slightly adapted to Belgian practices. It is a middle-size 5 storey office building. It consists of 150 office modules of 5.4 m depth aligned on two facades (north and south), separated by a corridor, with staircase/service spaces at both ends of the building (see figures 2, 3 and 4).

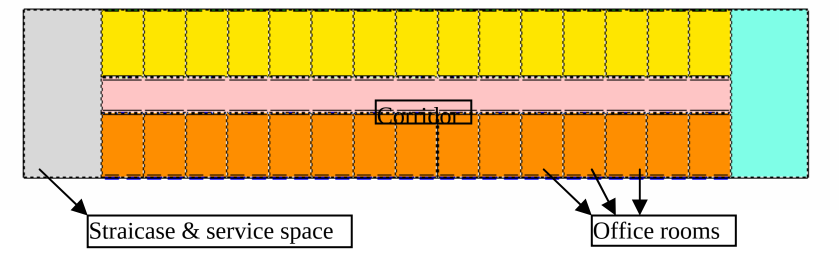


Figure 2: Each stage was divided into 5 zones. The building thus counts 25 zones

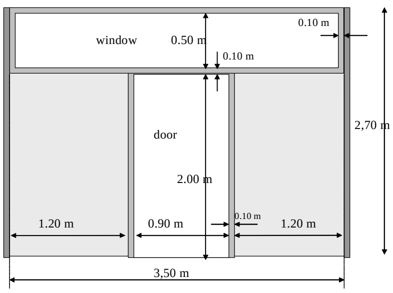


Figure 3: Cross section of an office module: View of the internal wall between office and corridor

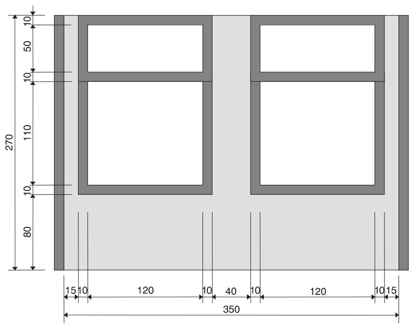


Figure 4: View of the façade Windows represent 39.5 % of the façade surface

The opaque parts of the building envelope are very well isolated (U_{roof} = 0.3 W/m²K ; U_{facade} = 0.37 W/m²K). Double glazing is low-e (U=1.8 W/m²°K, SF= 0.71). Windows are equipped with external movable sun protections on south façade. They are pulled down the entire sunny studied day.

The internals gains during occupation hours are set at 29 W/m² in offices, 0.9 W/m² in corridors and 5 W/m² in halls.

Setting temperature is 21°C for heating and 24°C for cooling all through occupation. Setting temperature at night and week-ends is 15°C for heating. There is no mechanical cooling at night or week-end. One air change per hour of hygienic air is pulsed in the building at outside temperature al trough occupation hours. The air infiltration is assumed to be constant (0.23 ach).

3 RESULTS OF SIMULATIONS

3.1 Which role does the wind have?

Two different forces drive natural ventilation: buoyancy due to temperature difference and wind [2]. To evaluate the impact of this last one, different situations were simulated with various wind speeds and directions. Windows were opened just enough to ensure a ventilation rate of 4 ach so as to limit air speed and avoid uncomfortable draughts. The internal windows on top of the office doors towards corridor were opened.

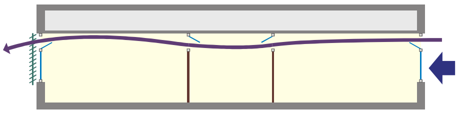


Figure 5: Cross ventilation

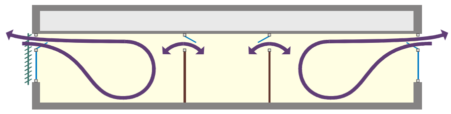


Figure 6: Single-sided ventilation

When wind is favorable, cross ventilation is set up (see figure 5). That occurs when building is not protected from wind, wind direction is not parallel to windows and wind speed is not null. The air change rate depends on wind speed and on wind direction (see table 1). But unless wind is parallel to windows, small opening of 0.05 m² is sufficient to ensure a transversal ventilation with a good air change rate (more than 2.9 ach) for a wind speed of 4 m/s. The rate of ventilation increases very slightly in higher floors. Indeed, wind speed varies with height above ground level: frictions at ground level slow the air down [4].

Wind direction	N or S	NNE/NNW or SSW/SSE	NE /NW or SW /SE	ENE /WNW or WSW/ESE	E or W
Ventilation rate (ach)	4.6	4.5	4	2.9	0.15
Type of ventilation	Cross ventilation				Single-sided ventilation

Table 1: Ventilation rate in the third floor for various wind directions
(Wind speed = 4m/s, 0.05 m² window opening on façade)

When wind is not favourable, single sided ventilation is set up (see figure 6). It is caused by temperature difference between inside and outside air, usually called the stack effect [2]. That occurs when:

- the building is protected from wind,
- or wind speed is null (That occurs very seldom in Belgium : we measure less than 50 hours a year with a wind speed lower than 0.5 m/s)
- or when wind direction is parallel to windows. That occurs in Belgium from around 6% of time (facades NE and SW) to 20% of time (façade NNW and SSE).

Window openings have to be much more important: around 0.6 m² to reach 4 ach for day ventilation and around 1.2 m² to reach 8 ach for night ventilation.

3.2 How much energy does natural ventilation save?

To evaluate efficiency of natural ventilation for cooling, the thermal comportment of the building was simulated in 5 different situations. For day ventilation, the air change rate was limited at 4 ach to avoid uncomfortable draughts. For night ventilation it was limited at 8 ach. Although there is no comfort concern during night, air speed should nevertheless be limited at 1.5 m/s to avoid paper blows off desks [4].

	Cooling demand
▶ Standard air conditioning ("reference" building)	685 kWh/day
▶ single sided day ventilation for cooling	474 kWh/day
▶ Cross day ventilation for cooling	608 kWh/day
▶ single sided night ventilation for cooling	403 kWh/day
▶ cross night ventilation for cooling	425 kWh/day

Table 2: Cooling load for the building without and with ventilation. External sunscreens are pulled down.

During the day, single-sided ventilation is much more efficient than cross ventilation (see table 2). Indeed with cross ventilation, the air enters the building at outside temperature, is partly heated in a first office and enters then in a second office. That one is so cooled with air at higher temperature. The total quantity of air entering the building is double in the case of single-sided ventilation.

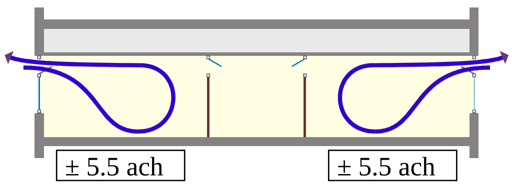
During the night, cross ventilation is almost as effective as single-sided ventilation (see table 2). It is due to the fact that the outside temperatures are rather low and that the period of ventilation is long.

3.3 Which positions choose for openings?

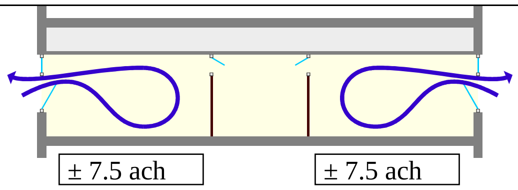
As we've seen, it is no problem to ensure sufficient air ventilation rate with very small openings when wind is favorable. But when it is not the case (wind speed is null, building protected or wind direction parallel to openings), window openings have to be more important. They should then be optimized.

Five solutions of open windows were compared (see table 3). In each case, the opening area is the same (1.2 m² per office on each side of the building). The temperature difference between inside and outside is around 2°C. There is no wind.

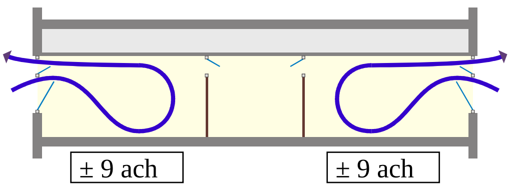
1. Top windows (100%)



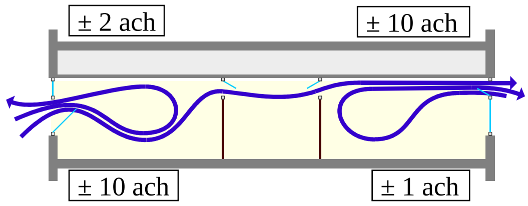
2. Bottom windows (45%)



3. Both top and bottom windows : the top windows are opened at 50% and the bottom windows are opened at 22.5%



4. Bottom window on one side (45%), top window on the other side (100%)



5. Both top and bottom windows on one side (50% on top, 22.5% at bottom), only the top window on the other side (100%)

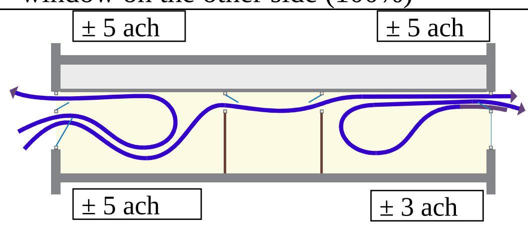


Table 3: Natural ventilation for 5 various window aperture situations

We noted that :

- if window openings are identical on both sides of the building (same surface, same height) a single-sided ventilation is set up. In that case, two openings at different height are very much more efficient than one single opening (9 ach instead of 7.5 or 5.5 ach). And the greater is the difference of height, the more important will be the stack effect. One can use, for example sash windows.

- to create a cross ventilation when there is no wind, window openings on both sides of the building have to be at different heights. In these cases, a main cross ventilation is set up, but with some single-sided ventilation. Opening two apertures on one side instead of one is in that case no more necessary. Indeed, the 5th case is not more efficient than the 4th one (see table 3): there is 10 ach in the first office instead of 12 and 8 ach instead of 11 in the second one.

4 DISCUSSION

If the external environment is favourable (not noisy nor smelly, temperate climates), natural ventilation for cooling provides a simple approach for narrow buildings studied in this paper. But driving forces, and thus air flow rates, vary constantly with the weather [5, 14]. Most of the time, with cold or windy weather, the ventilation rate necessary to ensure a good thermal comfort will easily be reached. But on a calm summer day, when most cooling is likely to be required, the cooling capability of natural ventilation is limited by the small temperature difference between inside and outside air [2]. In general, but particularly for these days, natural ventilation has to be taken into account very early in conception of the building.

Two solutions can be considered:

1 Night ventilation

Night ventilation is more efficient than day ventilation (see table 2), but it must take into account the risk of intrusion (windows granted with grilles or replaced by vents, security service). Moreover, some form of automatic control system is desirable [15] to prevent the ingress of rain and over cooling. If the overnight ventilation is not stopped early enough, rooms will be too cold at the beginning of the occupancy period.

During night, cross ventilation is almost as efficient as single-sided ventilation. That type of ventilation will then be preferred if opening between offices and corridor can easily be organised (permanent opening, manual opening). Indeed, cross ventilation can operate with much smaller opening areas. That means less intrusion risk, less openable windows or vents to install and to control automatically. To ensure a cross ventilation, openings should be at different high on both facades.

2 Diurnal ventilation

That solution will be chosen when fully secured all-night cooling is impractical or when the building has very few thermal mass (false floors, false ceilings …)

As ventilation is organised during occupation hours, windows or vents can be driven manually [15]. In that case, a cross ventilation can hardly be organised: ventilation in one office will depend on the presence or the good willing of another occupant on the other side of the building… Single-sided ventilation should then be considered. To be as efficient as possible, windows opening should then be divided in two parts (a top and a bottom aperture).

An automatic control can also be considered. Transversal ventilation can then be organised most of the time, when wind is favourable. A single aperture is so sufficient. A single-sided ventilation will anyway be set up when wind is not favourable. The automatic control which will open windows at the right time will partly compensate the lack of efficiency due to a single opening instead of two.

The modelling work suggests that early morning cooling, for a few hours, may be worthwhile. That will be easily organised with an automatic control of windows. With manual window openings, that could be done by cleaners when they open the building.

The interest of day ventilation could even be more important if one takes into account the impact of air speed on occupants comfort. Indeed air speed around 0.8 m/s permits to maintain a space about 2°C warmer [1].

5. CONCLUSION

Even without any stack or atrium, efficient natural ventilation in narrow office buildings is possible. But since wind and temperature differences are the driving forces causing air flows through the building, the envelope has to be well studied in the early stage of the design. In some cases, mechanical cooling could even be avoided. For northern European climates, natural ventilation can be considered for cooling loads in the range 10-35 W/m² [3]. Building conception should then be carried out even more carefully to limit the cooling loads. The orientation, solar protection, installed lighting power, size of windows and so on should be chosen with that goal in mind.

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