GUIDELINES TO IMPROVE EFFICIENCY OF A DOUBLE-SKIN FAÇADE IN AN OFFICE BUILDING

Elisabeth Gratia, André De Herde

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

ABSTRACT

In these last years, a great deal of interest has been devoted to double-skin façades due to the advantages claimed by this technology (in terms of energy saving in the cold season, high-tech image, protection from external noise and wind loads).

Simulations where performed on building with and without multistory double-skin facades. The operation of this one must be obligatorily related to the climatic conditions as well external as interior.

To preserve comfort and reduce cooling loads, it is important to apply natural cooling strategies among which the natural ventilation.

Some argue that double façades are designed to improve natural ventilation in buildings by stack effect, and to allow this one where this is in general not possible due to high outdoor noise levels and/or high wind speed levels.

But a faulty operation of the double-skin façade openings can generate catastrophic scenarios such as the injection of the hot air of the double-skin façade in the offices as well as a contamination of the offices of the upper stages by the polluted air from the offices of the lower stages.

This study examines how improve efficiency of a double-skin façade in an office building during the different seasons in Belgium.

KEYWORDS

Double-skin façade; Thermal modelling; Office building; Natural ventilation.

INTRODUCTION

The double-skin façade is an architectural phenomenon driven by the aesthetic desire for an all-glass façade.

The transparency is often seen as the main architectural reason for a double skin façade, because it creates close contact to the surroundings. This in fact is also derived from a client's point of view saying that physical transparency of a company gives a signal of a transparent organization with a large degree of openness (Hendriksen et al., 2000)

This "emerging technology" of heavily glazed façades is also often associated with buildings whose design goals include energy efficiency, sustainability, and a "green" image.

The success of these façades also lies in that they admit a high degree of daylight and have an outdoor uniformity and attractive aesthetics.

The costs of double-skin façades are higher than normal façades, but claims of energy and productivity savings are used to justify some of them (Poirazis, 2004).

The recent advent of computers and other office equipments increased the internal heat gains in most offices. Highly glazed façade, often with poor shading, have become very common.

This, together with the extra heat gains from the electric lighting made necessary by deep floor plans, and the wider use of false ceilings, increased the overheating risk (Gratia et al., 2003)
In the 1990's, concern about global warming has resulted in a resurgence of interest in naturally ventilated offices (Allard, 1998), (Liddament, 1996), (Dickson, 1998).
On the other hand, there is an increasing demand for higher quality office buildings. Occupants and developers of office buildings ask for a healthy and stimulating working environment (Rennie et al., 1998). Mostly, that is provided by an air conditioning system. But in many cases, with some efforts to reduce internal gains (equipment well chosen and solar protections), natural ventilation may be sufficient to ensure good comfort levels in occupied buildings.
In that case, air conditioning system will not be necessary. This will result in considerable energy and cost savings and also indirectly in a reduced burden on the environment, since the use of energy is always associated with the production of waste materials (Wong et al., 2003).

Double-skin façades are already a common feature of architectural competitions in Europe; but there are still relatively few buildings in which they have actually been realized, and there is still too little experience of their behaviour in operation. There are many unknowns: optical and thermal modelling of these systems is not routine, and coupling heat transfer and air flow from an isolated façade system to the whole building is complex. A variety of thermal coupling strategies between the façade and the whole building must be adequately simulated.
More, it is extremely difficult to find any objective data on the performance of actual buildings implementing double-skin façades. Only, subjective claims abound in the architectural literature.
So, it is important to verify if use of natural strategies is yet possible when the building is equipped with a double-skin.

METHOD

TAS program

The simulations where realized with TAS. It is a software package for the thermal analysis of buildings. It is a complete solution for the thermal simulation of a building, and a powerful design tool in the optimization of a building environmental, energy and comfort performance (Jones, 2000).

Studied building

The simulations where realized on the building proposed in the frame of the subtask A of the Task 27 (Performance of solar façade components) of the International Energy Agency, Solar Heating and Cooling Program. Some modifications were made to adapt this one to the practices of Belgium.

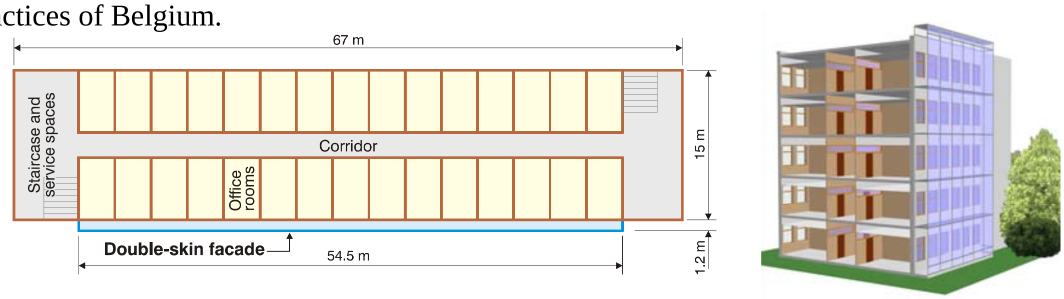
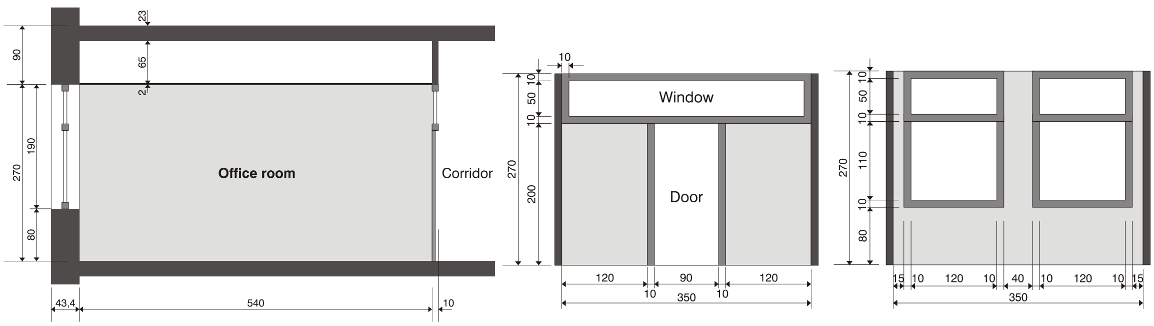


Fig. 1. View of the office building studied.

The building is a middle-size office building with office modules aligned on two façades, separated by a central corridor, with staircase/service spaces at both ends of the building.
The office building comprises 150 office modules, distributed over 5 floors and 2 orientations: 15 office modules per floor at each of the two orientations. The schemes are shown in Fig. 1.
Geometrical data of the office building are described here. Vertical cross section of office module with main measures is shown in Fig. 2.
The internal wall between office module and corridor has an openable window above the door to facilitate the air flow between northern and southern spaces (the false floor is not comprised in the drawing).
Each office has four windows (two top and two below) to allow natural day or night ventilation.



Vertical cross section of office module. Internal wall between office module and corridor. External wall of the office.

Fig. 2. Geometrical data of the office building.

Thermal characteristics:

Building envelope: Roof: U = 0.3 W m^{-2} $°K^{-1,}$ Ground floor: U = 0.379 W m^{-2} $°K^{-1,}$ Opaque part of façade: U = 0.373 W m^{-2} $°K^{-1}$
Low-e double glazing: U=1.8 W m^{-2} $°K^{-1}$, direct solar transmission: 0.62, total solar transmission: 0.708
Double skin: Clear single glass, U-value = 5.33 W m^{-2} $°K^{-1}$, shading factor = 0.76.
Width of the air cavity: 1.2m.
H (double-skin façade) = H (building) + 1m.
Internal gains in the offices: 29.37 W $m^{-2.}$

Climatic data assumptions.

We chose to analyze Belgian standard days (week day). Each modelled day is preceded by the simulation of ten previous days to take account of the effect of inertia.

RESULT OF RESEARCH – WHAT SHOULD BE DONE IN PRACTICE.

Sunny winter day (outside temperature evolves between 0°C and 5.8°C)

Building without double-skin takes directly profit from the solar gains and air exchanges between the sunny and no sunny zones can be privileged.
Heating demand is 539 kWh per day.

In building with double-skin, heating of South offices is useless except 1 or 2 hours the morning. Temperature in the closed DP is
- 34.5°C if shading devices are up
- 41°C if shading devices are down.

If overheating is observed in South offices, shading devices are sufficient to restore comfort.
A very small opening (slit of 2.5 cm) up and down in the double-skin generates great air flows and makes it possible to recover ±11 000 m³/h at 25-26°C. This air can be used as ventilation air of the no sunny zones.
The extraction of the air of the offices via the double-skin makes it possible to recover to air with ± 32°C, but this one must forward by an exchanger whose efficiency is about 0.5. This solution is slightly less profitable than the preceding one.
Heating demand is 438 kWh per day.

Cloudy winter day (outside temperature evolves between 0.8°C and 6.3°C)

In the two building, air exchanges between South and North zones imply a light increase in heating consumptions.
In building without double-skin, heating demand is 647 kWh per day.

In building with double-facade, double-skin must remain closed and temperature in the closed DP is 2°C moreover than the outside temperature. This air layer decreases the losses by transmission of the interior façade and protects this one from the losses by infra-red radiation.
Heating demand is 566 kWh per day.

Sunny spring day (outside temperature evolves between 8°C and 14.6°C)

Building without double-skin takes directly profit from solar gains and air exchanges between sunny and no sunny zones can be privileged.
If overheating is observed shading devices are sufficient to restore comfort. If necessary, little day ventilation removes the cooling need.
Heating demand is 95 kWh per day.

In building with double-skin, heating of South offices is useless due to the hot air layer provided by the double-skin. Indeed, temperature in the closed DP is
- 28°C if shading devices are up
- 32°C if shading devices are down.

Air exchanges between zones S and N allow to remove heating of North offices except 1 or 2 hours the morning. Shading devices are necessary when there are overheating.
Double-skin air can be used to ventilate the halls (only spaces having to be heated between 10 a. m. and 4 p. m.).
Day ventilation increase eliminates cooling needs,
- in southern offices: 3ach from 9 a. m. to 6 p. m.
- in northern offices: 2 ach from 12 a. m. to 2 p. m.

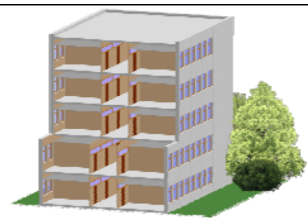
Heating demand is 45 kWh per day.

Sunny summer day (outside temperature evolves between 11.4°C and 23.3°C)

The table 1 compares the cooling load of the office building with and without double-skin façade. We suppose that the openings are adjusted to obtain a day ventilation of 4 ach and a night ventilation of 8 ach at all the floors.

TABLE 1

Comparison of the cooling load of the office building with and without double-skin façade.

		
No cooling strategies	1033kWh/day	1147kWh/day
Shading devices	685kWh/day	Closed double-skin: 911 kWh/day Opened double-skin: 850 kWh/day
Day ventilation	Single-sided ventilation: 474 kWh/day. Cross ventilation: 608 kWh/day	Double-skin top windows opened: 805 kWh/day. Double-skin top and down windows opened: 771 kWh/day.
Night ventilation	Single-sided ventilation: 403 kWh/day. Cross ventilation: 425 kWh/day	Double-skin top windows opened: 721 kWh/day. Double-skin top and down windows opened: 665 kWh/day.
Day and night ventilation	Single-sided ventilation: 252 kWh/day. Cross ventilation: 358 kWh/day.	Double-skin top and down windows opened: 513 kWh/day.

Alas, the way in which the building with double-skin is crossed by the ventilation air is a function of the wind orientation and speed.

If double skin is on the windward side, the air flow in the building is due to the wind effect and the movement is reversed except at the lower stages where the stack effect dominates when only the top window of the double-skin is opened. In that case, the upper stages are partially contaminated by the air providing from the lower stages and the cooling loads are important. The cooling consumption for this sunny summer day is 986 kWh/day.

To improve the situation, top opening must be leeward oriented. Knowing the orientation of the wind, just open the window being in depression to improve cross ventilation in the good direction.

Fig. 3 gives the evolution (morning, midday, afternoon) of the zone air change rate during the day in each office for the various floors. When the air change rate is negative, the air flow is done in opposite direction.

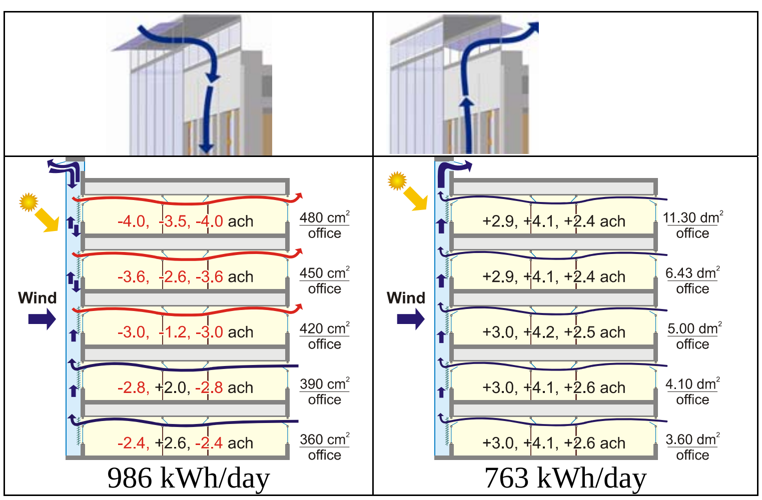


Fig. 3. Office air change rate and air movement when the sunny double skin is on windward side.

During the night, the cross ventilation is totally effective even if the direction of air flow in the building is reversed. Indeed, it is not important since the double-skin temperature is nearly the same than the outside temperature and since the reuse of the air arising from other offices is not a problem since they are not occupied and so not polluted during night.

Cloudy summer day (outside temperature evolves between 14.3°C and 18.1°C)

In the two cases, shading devices are not used because that would diminish daylighting.
With the application of the cooling strategies (day ventilation and night ventilation) cooling demand can be cancelled in building without double-skin.

In building with double-skin, cross day ventilation is effective if DP top opening is leeward oriented. Cross night ventilation is effective even if the direction of air flow is reversed. Indeed, it is not important since the double-skin temperature is the same than the outside temperature. Cooling demand is 181 kWh per day.

Sunny autumn day (outside temperature evolves between 15°C and 26.7°C)

In the two cases, external shading devices must be used, day ventilation is to prevent since outside temperature is upper than 24°C between 11.30 a.m. and 5 p.m. and night ventilation (8 ach) is effective.
In building without double-skin, cooling demand is 395 kWh per day.
In building with double-skin, the double-façade must be largely open (temperature in DP passes from 67°C to 31°C if there is an opening of 50 cm). So the cooling demand is 624 kWh per day.

CONCLUSIONS.

In winter, the air layer decreases the losses by transmission of the interior façade and protects this one from the losses by infra-red radiation
Moreover, if the double-skin is sunny, the air temperatures increase very quickly. This air can be used as ventilation air of the no sunny zones.

During the summer, when the sun is shining, it is difficult to apply the strategy of day natural ventilation. Indeed, cross day ventilation by extraction through the double-skin is delicate and is a function of the wind orientation and of the building wind protection.

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