VENTILATION AND COOLING
18TH AIVC CONFERENCE, ATHENS, GREECE
23-26 SEPTEMBER, 1997

Title: **Design of Low Energy Office Buildings Combining Mechanical Ventilation for IAQ Control and Night-Time Ventilation for Thermal Comfort**

Author(s): **P Wouters, D Ducarme, S Martin, J Demeester, J Schietecat, S Schouwenaars**

Affiliation: **Belgian Building Research Institute (CSTC-WTCB)
Brussels, Belgium**

Design of low energy office buildings combining mechanical ventilation for IAQ control and night time ventilation for thermal comfort

P. Wouters, D. Ducarme, S. Martin, J. Demeester, J. Schietecat, S. Schouwenaars
Division of Building Physics and Indoor Climate
Belgian Building Research Institute
WTCB - CSTC

Table of contents

Summary

The design of low-energy office buildings requires specific attention to an energy efficient concept for providing good indoor air quality conditions. With this respect, mechanical ventilation shows undeniable advantages: it can be optimally controlled (infrared detection, CO_2 control,...), heat recovery is applicable, outdoor noise and pollution penetration can be minimised.

Another crucial challenge in low-energy office buildings is the avoidance or, if impossible, the minimisation of active cooling needs. Nighttime natural ventilation can play an essential part in an overheating prevention strategy.

This paper illustrates these concepts through several consulting projects:

- *new office building to be occupied by the owner;*
- *new office building by promoter to be rented by several companies;*
- *advanced double facade building in polluted area downtown;*

1. Introduction

The use of natural ventilation in non-domestic buildings is in principle an attractive option. In practice, one observes that there is often confusion with respect to the purpose of natural ventilation and the possible advantages and disadvantages. The Belgian Building Research Institute has been involved during the last few years in several consultancy studies for new buildings as well as for retrofitting projects and was also involved in several national and European projects in which the issue of natural ventilation was studied. This paper aims to give an overview of these experiences and it also gives some critical remarks with respect to natural ventilation in general and with the challenges for the design process.

2. Various functions of natural ventilation

When people speak about a 'naturally ventilated office building', it is often not evident to have a good understanding of what they really mean :

- in a number of countries and/or for a number of people, the meaning of natural ventilation is that the air supply and exhaust is assumed to happen through cracks and leakages in the facades as well as by opening the windows and doors. It is clear that such an approach may work for not too airtight buildings in very mild climates with good outdoor conditions (no noise problems and good outdoor air quality) but it is clear that in most circumstances such a strategy can not guarantee good indoor air quality conditions;
- others understand by 'natural ventilation design' that the required supply air for indoor air quality (IAQ) control is guaranteed by specifically designed supply and exhaust openings allowing to meet the IAQ needs and at the same time to keep the energy demand within reasonable limits. This strategy can be described as '***natural ventilation for IAQ control***'.
- others understand by 'natural ventilation design' that ventilation plays a crucial role for keeping thermal comfort conditions in summer. In general, night ventilation is used for cooling down the building structure at night in order to limit the indoor temperatures at daytime. This strategy can be described as '***natural ventilation for thermal comfort control***'.

It is essential that the designers fully understand the different purposes for 'natural ventilation for IAQ control' and 'natural ventilation for thermal comfort control'. As described in the paper presented at the AIVC conference in Gothenburg[1], the energy context for both strategies is completely different and therefore also the need for optimum control. In this paper, some practical aspects of both types of natural ventilation are discussed and illustrated with a number of practical examples.

3. Practical aspects for natural ventilation for IAQ control

Among the critical barriers for natural ventilation have to be mentioned :

- Optimum control of airflow rates
  Natural ventilation is the result of pressure differences due to temperature differences and wind effect. Outdoor temperature and wind varies substantially over time. If the supply openings are not controlled, the airflow rates will strongly vary over time. The users can achieve control but it is well known that such control is not optimal. Self-regulating devices, which adapt the cross section of the openings as function of needs and/or climatic conditions, are much better. At present, the number of such components is still very limited. It is expected that more and better components will come on the market in the future.
- Heat recovery
  Minimising the energy needs can be obtained by heat recovery. This is clearly not evident for natural ventilation designs.
- Acoustics
  A large majority of office buildings is located in areas with high acoustical outdoor levels. As a result, acoustical comfort can only be guaranteed if the most of the supply openings are acoustically insulated.

4. Practical aspects for natural ventilation for thermal comfort control

Natural ventilation for thermal comfort in summer is a very attractive option. The cooling potential is in principle very large, especially at night, but very large air quantities are needed since the thermal capacity of the air is very small (an outdoor air flow rate of 100 m^3/h gives only 30 W/K cooling power).

Among the critical aspects have to be mentioned :

- Acoustics
  Intensive ventilation during working hours through open windows is not evident in urban areas for buildings in the vicinity of traffic roads, airports,... Night time ventilation is often not a problem since there will be no or only a very limited occupation and since the outdoor noise levels are in general lower than during the working hours.
- Outdoor pollution
  Traffic can create outdoor pollution problems due to which intensive ventilation through open windows at the streetside is not evident. At nighttime, pollution levels are in general lower and moreover no occupants.
- Burglary and insects
  At daytime and even more at nighttime, ventilation through open windows may not substantially increase the risk of burglary and the entrance of insects. Use of appropriate protection systems can guarantee this.
- Thermal mass
  Night ventilation can be an attractive option but a requirement is a minimum amount of thermal mass.
- Minimisation of thermal load (solar and internal)
  Even in buildings with a high thermal mass, thermal comfort without active cooling can only be guaranteed if the thermal load is reasonable. In practice, this often means good control of solar gains (by appropriate shading devices) and reasonable internal gains (efficient lighting, energy efficient computers and controls,...)

5. Design examples

5.1 General

A brief overview of some of the projects in which we were involved over the past few years is given in table 1.

	IVEG	Keppekouter	Pointcaré	Waregem	PROBE
Type of project	New building	New building	Renovation	Renovation	Renovation
Number of stories	3	3	6	2	2
Delivery	End 1998	Summer 1997	-	Summer 1997	Summer 1997
Architects	Lemaire & Musse	Declerck	Ph. Samyn & Partners		Y. Wauthy
Characteristics in relation to IAQ control					
• Ventilation strategy	Mechanical balanced	Mechanical balanced	Mechanical balanced	Natural	Mechanical supply
• Heat recovery	yes	Yes	Yes	No	No
• Noisy/polluted environment	yes	Yes	Yes	No	No
• Demand controlled ventilation	Yes	No	No	No	Yes
Characteristics in relation to temperature control in summer					
• Façade louvres for night ventilation	Yes, automatic	Yes	Rear façade	Yes	Yes
• Exhaust	Chimney	Extraction fan	Chimney	Chimney	-
• Solar protection	External screens	External screens	Double façade	External fixed	External screens
• Double façade ventilation	No	No	Yes	No	No

table 1 : overview of key features designs

In all these projects, the following features are found :

- Very good thermal insulation
  A very good thermal insulation is important, not only for minimising the heating demand in wintertime but also for limiting the solar gains through opaque components in summer time.
- Good solar protection
  Thermal comfort in summer with no or limited cooling power is only possible by minimising the solar gains. Therefore, solar protection systems are applied in all projects with g-values of the order of 0.10 or lower.
- Efficient intelligent lighting
  In all projects, the use of high efficient fluorescent lamps with electronic ballast is foreseen resulting in installed lighting powers of the order of 10 W/m² (for 400 lux). Several projects make use of daylight compensated luminaries and in some cases also presence detection. These technologies have become mature technologies at reasonable additional costs.

In the next paragraphs, a more detailed description of the first 3 buildings in table 1 is given.

5.2 IVEG building

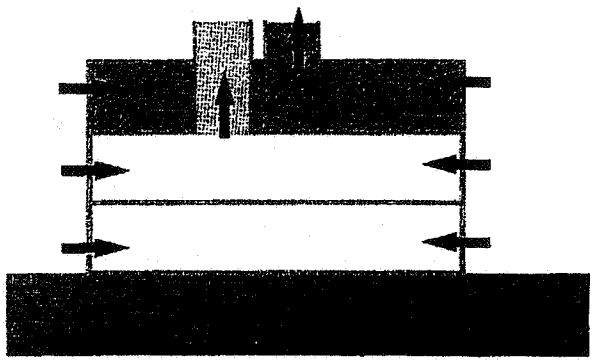
5.2.1 The context of the project and partners

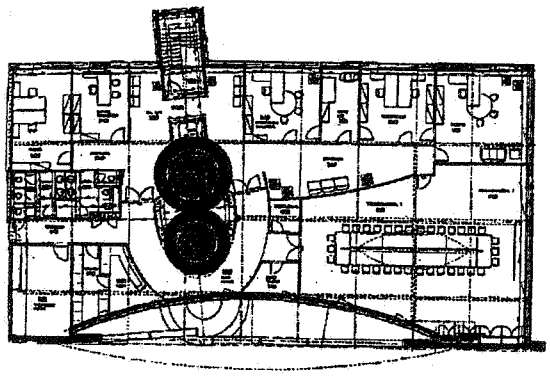
This building will be the new head office of IVEG, which is public company for gas and distribution, which has some 70.000 clients in a number of villages in the region of Antwerp. A relatively long preparation period was possible (about 18 months) and the owner was very strongly motivated for realising a low energy building with good indoor climate conditions. Therefore, for a number of design decisions they were ready to take full responsibility and this of course simplifies certain decisions.

5.2.2 The overall design

It is a 3-story building with a total floor area of about 1.800 m². The plan of the top floor is shown in the figure.

5.2.3 Specific features relevant for this article



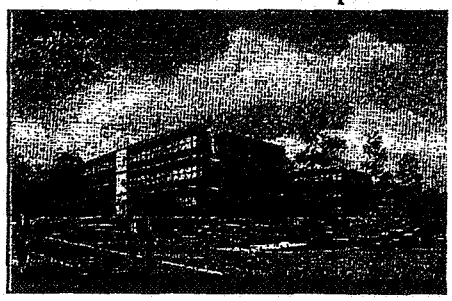


- Fire regulations
  The Belgian fire regulations specify that it is not allowed to have more than 2 stories in 1 fire compartment. The original scheme of 1 large central chimney for night ventilation had to be modified. As a result, 2 chimneys are now foreseen. An additional advantage of this scheme is that the ventilation of the top floor is substantially improved. In the original design, the neutral level was situated close to the middle height of the top floor whereas in the new design, it is situated above roof level.
- Design of chimney
  The net sections of both chimney openings are about 5 m² and the top of the chimneys is about 3 meter above roof level. Opening and closing of the chimneys is done automatically. These chimneys also allow the entrance of daylight.
- Top cooling as emergency
  Detailed dynamical simulations indicate that the applied strategies should result in acceptable thermal comfort in summer time. However, it is possible that the building use will change in time and/or that some of the assumptions are too optimistic. Therefore, the possibility for having in a later phase top-cooling is foreseen by having the supply ductwork insulated during the construction and by reserving the required space in the technical room for a chiller. Simulations indicate that top cooling will result in a 2...3°C temperature reduction and of course a lower relative humidity level.

5.3 Project 'Keppekouter'

5.3.1 The context of the project and partners

Specific for this project is that it is project by a building promoter and that space will be rented. Therefore a very pragmatic approach with specific attention for the cost implications was essential. The building is situated at a distance of about 50 meters from the highway Brussels –Oostende and open windows during working hours is not evident.



5.3.2 The overall design

It is a 3-story building. The spaces will be rented for office use, no details concerning the organisation of the space were available during the design phase. Landscape offices as well as cellular offices are possible.

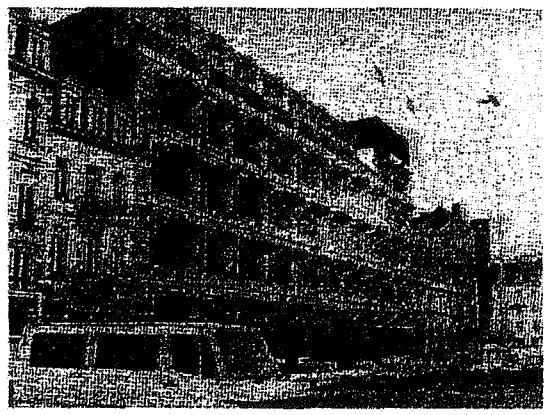
5.3.3 Specific features relevant for this article

- As a result of the consultancy work, the thermal insulation of the building has been drastically improved and external solar shading is installed;
- Mechanical extraction for night ventilation, mainly because of budgetary reasons
  Night ventilation is applied by having ventilation grills in slicing windows. BBRI proposed the use of natural extraction ducts, cross section 2 ducts of about 1 m^2 each per floor area. This results in loss of space, which can be rented or sold. The promoter came with the proposal to have mechanical extraction fans at roof level. Since they are only used at nighttime, the acoustical problem is marginal and the investment cost and space use rather low. The running costs of the fan seem to be acceptable.
- Thermal mass
  The fact of having landscape offices strongly reduces the possibility of thermal mass in the separation walls. Moreover, the promoter wanted a false ceiling. Access to the thermal mass in the false ceiling is realised by having in the 4 corners of each room ceiling panels with each 9 openings 18 x 18 cm^2.

5.4 Project Pointcaré

5.4.1 The context of the project

This design for this renovation was prepared in the framework of an architectural competition. The design office Ph. Samyn and Partners (architects & engineers), wanted a low energy building with good indoor climate conditions. Specific attention is given to daylight features and summer comfort with minimum active cooling.



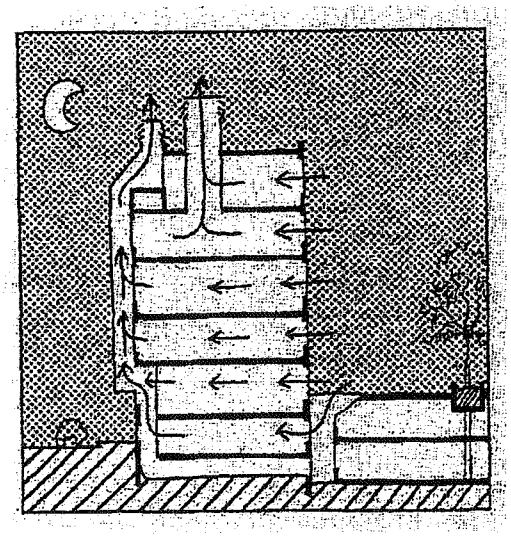
Proposed façade by Ph. Samyn and partners for Pointcaré building

5.4.2 The overall design

The building is situated in Brussels along a road with very intensive traffic. The TGV station is at a distance of a few hundred meters. A complete renovation of the 6-story building is required.

5.4.3 Specific features relevant for this article

- Double façade with various functions
  The acoustical outdoor levels and the outdoor air quality do not allow the opening of the windows at street side. On the contrary, the noise and air quality levels are quite satisfactory at the garden side. A double façade concept has been adopted in order to combine various functions :
  - efficient solar shading without specific maintenance problem
  - very good acoustical insulation of the street façade;
  - preheating of ventilation air during the heating season;
  - evacuation of room air during intensive night ventilation

  The operation mode in summer at night-time is shown in the figure above.
- Avoidance of false ceilings in order to maximise thermal mass and use of daylight
  The high floor to ceiling height and the concrete floors are attractive conditions for use of thermal mass and daylight.
- Balanced ventilation with heat recovery for IAQ
  In order to combine good IAQ with low energy demand, a balanced ventilation system with heat recovery was proposed. The supply can only be used for top cooling if needed.

6. Conclusions

1. Natural ventilation for IAQ control requires completely different provisions than natural ventilation for thermal comfort control in summer.
2. The use of natural ventilation for IAQ control in low-energy offices is of course possible but it is not necessarily the best choice in all circumstances.
3. Achieving an optimum balance between IAQ and energy use is for not evident with the natural ventilation devices on the market today. This situation may change in the future if self regulating devices become more widely available.
4. It is especially for summer ventilation very important that the issue of night ventilation is seriously considered from the beginning of the design process.
5. It is very important to have in the design process the appropriate knowledge, which allows quick decisions. Detailed simulations can be done afterwards for optimisation purposes and/of for checking if the proposed designs are feasible.
6. Optimising the airflow rate for thermal comfort in summer is in general from a numerical point of view not a real challenge. The higher the ventilation rate, the better the performances (unless draught problems occur). The real challenge for summer comfort is a combined design and analysis of solar and internal gains, thermal mass, thermal insulation, solar protection, ventilation,....
7. Further research is needed which focusses on the delivery of very practical design guides/rules to be used by designers in daily practice. The CIBSE guide on Natural ventilation in non-domestic buildings. Applications Manual AM10 : 1997.

7. Acknowledgements

The experiences reported in this report have been carried out in the framework of various research projects : The Flemish Impulse Programme for Energy Technology (VLIET), the EC JOULE project NATVENT and the EC Altener project AIOLOS. Also the support received in the framework of the Belgian Technical Advisory service was very helpful. The authors wish to thank the other project partners for their contributions in these projects. Moreover, specific thanks goes to the owners, users and designers of the buildings reported in this paper.

8. References

1. Ventilation requirements in non-domestic buildings and energy efficiency, 17th AIVC Conference Gothenburg 1996.
2. NATVENT brochure : A better way to work. Overcoming barriers to natural ventilation, 1977.
3. The CIBSE guide on Natural ventilation in non-domestic buildings. Applications Manual AM10 : 1997