CLASSIFICATION OF HYBRID VENTILATION CONCEPTS

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ABSTRACT

This paper aims to identify major characteristics of hybrid ventilation systems, whereby a clear distinction is made between ventilation for Indoor air quality control and ventilation as part of a strategy for thermal comfort in summer. Various building projects are used as illustration for the classification.

1. INTRODUCTION

This paper intends to make a critical analysis of the various so-called hybrid ventilation concepts. The aim is to identify the major differences between the various approaches and to develop some kind of rationale.

2. WHY VENTILATION ?

Ventilation in buildings is today in most countries considered as an essential aspect in each building project. Whereas in the past, ventilation was automatically linked to indoor air quality control, there is now a growing interest in ventilation as part of an energy efficient strategy for achieving thermal comfort in summer. In order to assess ventilation components and systems, it is therefore essential to explicitly separate ventilation for indoor air quality control and ventilation as part of a thermal comfort strategy in summer (figure 1).

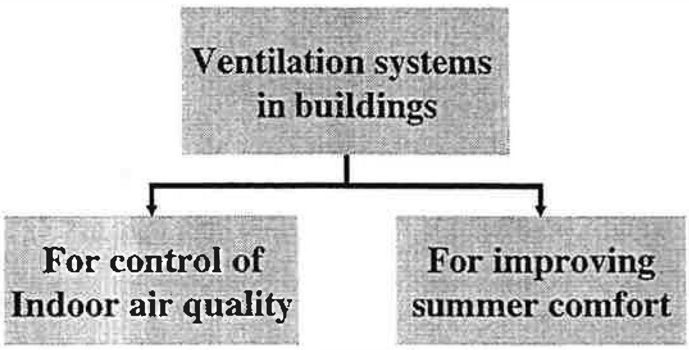

figure 1 : A correct identification of the purpose of ventilation is essential and in practice often not well expressed

As will be further discussed in the next paragraphs, the devices to be used for IAQ control and summer comfort control are in general quite different (an interesting exception is the school in Gronge (Norway) which is discussed in Annex 5). The major reason for this difference is the fact that, if compared with ventilation for IAQ control, effective night ventilation requires rather high air flow rates. As an illustration, figure 2 shows predicted air flow rates with ESP-r for a new office dwelling in Hoboken (Belgium) where intensive natural ventilation is used at night-time. The average air flow rate for IAQ is showed as well. In this project, presence detection is used for IAQ control.

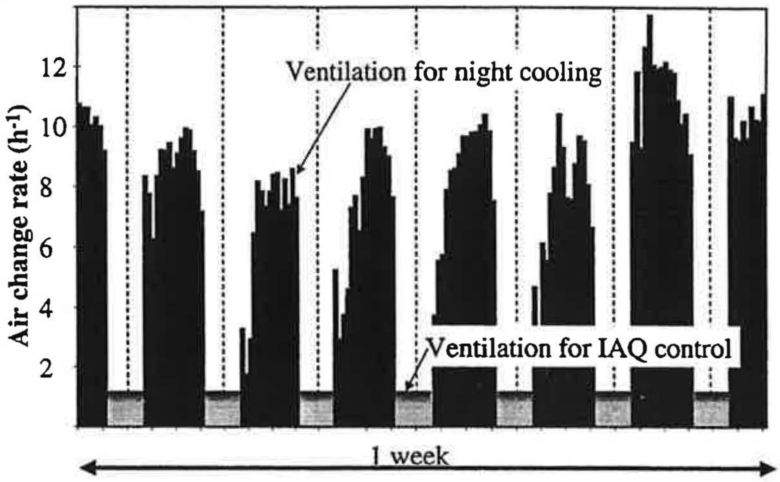

figure 2 : Ventilation for IAQ and thermal comfort : various orders of magnitude

For both types of ventilation, a successful application will only be achieved if a whole range of potential barriers and problems are solved. The next paragraph discusses the context for ventilation in relation to indoor air quality control whereas §9 focuses on potential barriers in relation to ventilation for thermal comfort control.

2.1 Ventilation as part of global strategy for indoor air quality control

In enclosed spaces, it is in most cases not possible to realise a good indoor air quality without specific provisions. Ventilation systems aim to guarantee the possibility of having acceptable indoor air quality.

At present, most standards are descriptive and there is no direct specification of the required air quality but only indirectly by specifying the required air flow rates. The primary requirement of ventilation systems is to realise an acceptable indoor air quality or, if air flow rates are specified, to meet the specified air flow rates.

In practice, a whole range of other requirements ('secondary' requirements) have to be fulfilled before one can consider that a ventilation system has good performances. The relative importance of each of these secondary requirements can vary substantially between projects. These secondary requirements include :

- Energy use : energy use should be as low as possible for the required air flow rates
- Acoustics : noise levels should be below acceptable limits
- Costs : it is evident that the cost of a ventilation system should be reasonable
- Ease of installation : a very important aspect for installers
- Space use : space use should be limited
- Ease of operation and controllability
- Ease of maintenance : the need for maintenance should be limited and such maintenance Durability : the system should work correctly over a long period of time
- Aesthetics : it must be possible to integrate the system in the building in an aesthetic way
- ...

2.2 Ventilation as part of global strategy for summer comfort control

Night ventilation is clearly part of the building tradition in hot and dry climates. It was a very common strategy in Mediterranean architecture and in hot dry climates. In certain cases, wind towers (figure 3) were used for stimulating the impact of night ventilation.

During the last decade, and also in more moderate climates, one can observe an increased interest (e.g. European projects as JOULE PASCOOL, AIOLOS, JOULE NATVENT, EC JOULE Solar House projects, IEA projects BCS Annex 28, SHC Task XIII, ...) in night ventilation strategies and this to a certain extent in parallel with a renewed interest in natural ventilation for IAQ control. In most of the existing realisations, night ventilation is achieved by natural means although there are a number of projects in which mechanical or hybrid ventilation concepts are used.

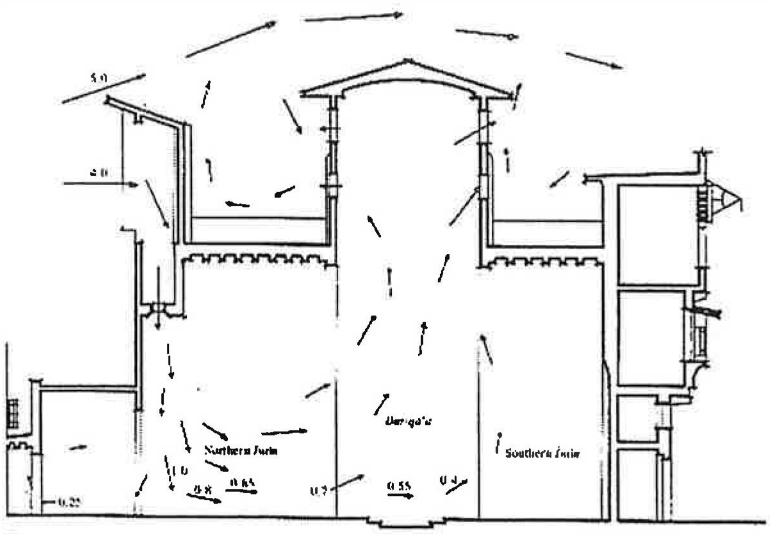

figure 3 : Section through the building, showing how the malqaf and wind produce internal air movement (m/s). Measurements made on 2 April 1973 by scholars from the Architectural Association School of Architecture in London. Source : Fathy (1986)

There are multiple motivations for this renewed interest: financial motivations (lower investment costs and/or operation costs), positive appreciation by occupants and positive impact on productivity, reduced environmental impact, some pretend an increased robustness and/or increased flexibility and adaptability.

As an illustration of the potential reduction in annual energy cost, data from CIBSE (CIBSE, 1998) can be used: in a well designed building making use of natural ventilation, a substantial energy saving can be expected because of no energy for refrigeration and a very substantial reduction in energy use for fans and pumps (figure 4).

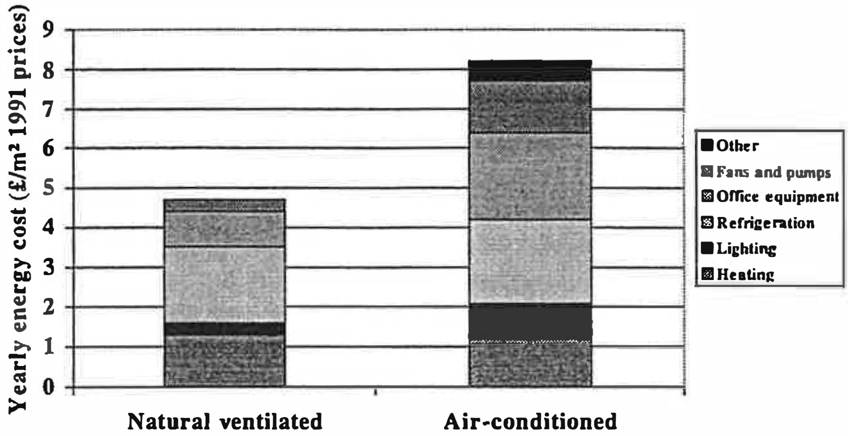

**figure 4 : Typical energy consumption for different types of office buildings
Source : CIBSE(1998)**

Quantification of the impact on productivity is less evident. However, there are several studies indicating the potential for such improvements. As an illustration, figure 5 shows the perceived productivity as function of the degree of control. The larger the degree of control, the better the perceived productivity. A building with a concept of night cooling and passive cooling techniques may be contributing to a better degree of control and therefore a better productivity.

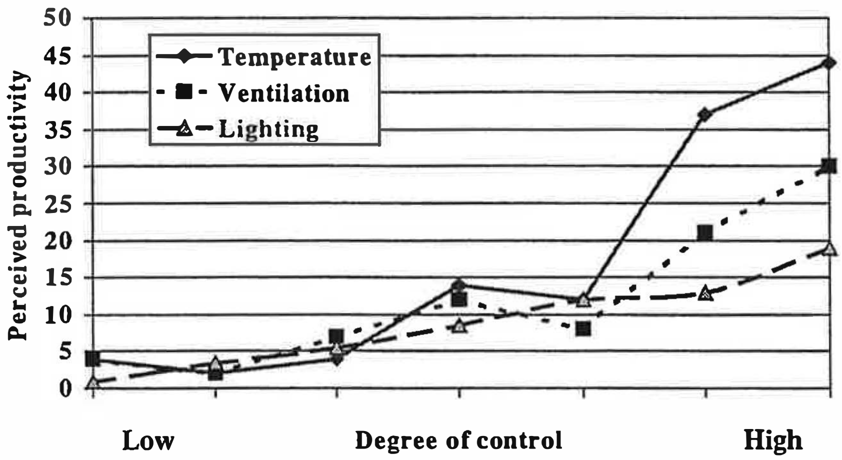

figure 5 : Impact of degree of control on temperature, ventilation and lighting on perceived productivity Source : CIBSE (1998)

A successful night cooling design requires much more than the achievement of the required air flow rates. A whole range of potential barriers can be identified (figure 6).

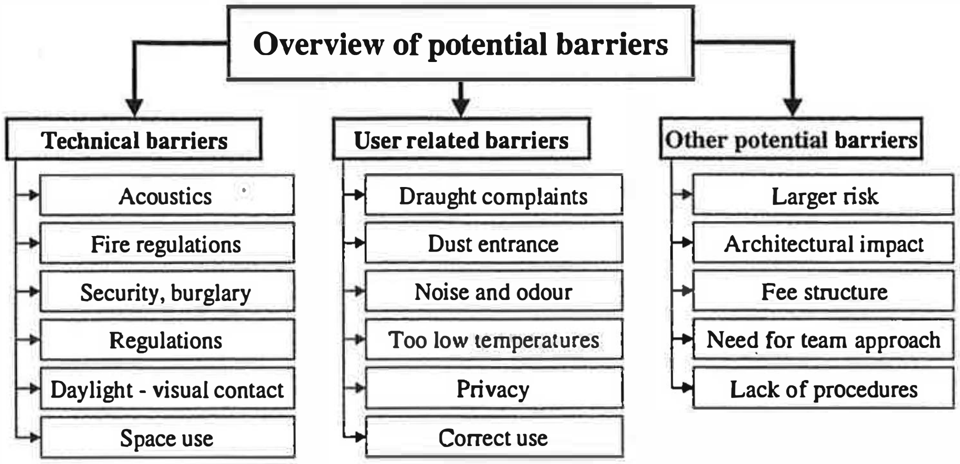

figure 6 : Successful night ventilation for summer comfort requires handling of a whole range of potential barriers

3. HYBRID VENTILATION

In the past, ventilation systems were in general only used for IAQ control and they were classified in 2 categories : (constant air flow) mechanical ventilation systems and (manual controlled) natural ventilation systems.

During the last 2 decades, interesting developments can be observed for both categories (see figure 7):

- As far as mechanical ventilation systems are concerned, demand controlled ventilation systems have received quite a lot of attention (as was found in IEA Annex 18 'Demand controlled ventilation'). The last years, specific efforts are done for optimising the energy use of such systems by developing low pressure ventilation systems in combination with high efficiency fans, e.g. the EC JOULE-TIPVENT project;
- As far as natural ventilation systems are concerned, supply, transfer and exhaust grills have become quite common in many countries. Self-regulated devices allow to better take into account varying weather conditions. A further optimisation is obtained (e.g. air cleaning at low pressure differences, heat recovery systems. More recently, demand controlled natural ventilation systems, whereby advanced electronic control is applied are becoming available. In order to compensate during certain periods of time the lack of sufficient pressure differences, fan assisted systems have been developed.

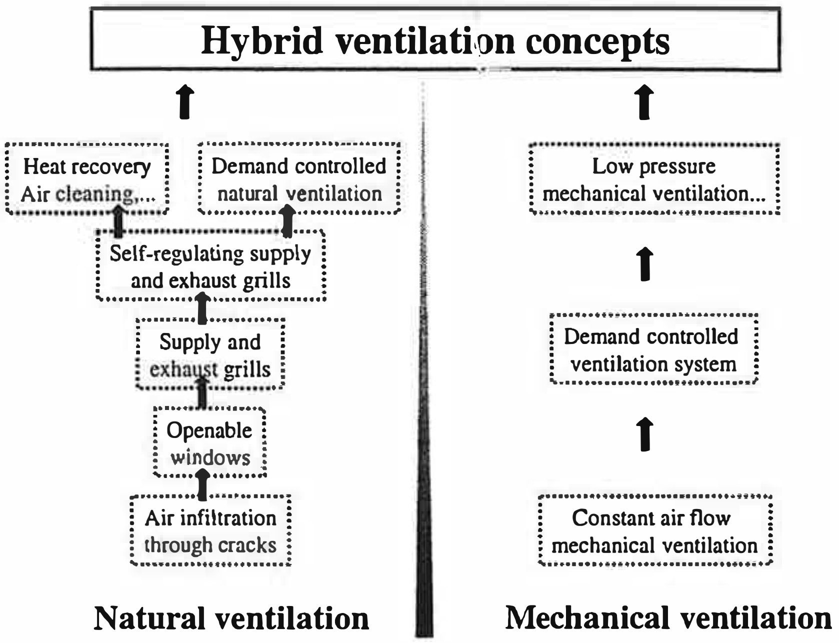

figure 7 : The future ?: merging the best of natural and mechanical ventilation...

As a result, the splitting between natural and mechanical ventilation is becoming in many cases rather weak. More fundamentally, one observes that there is a tendency for combining the best of both technologies : intelligent natural ventilation if appropriate, efficient mechanical ventilation if required. This tendency is valid also for ventilation in relation to thermal comfort in summer.

This new tendency is called hybrid ventilation. It is the subject of IEA annex 35 'HYBVENT'.

Hybrid ventilation systems are in the framework of IEA 35 defined as (Heiselberg, 1998):

> *"Hybrid ventilation systems can be described as systems providing a comfortable internal environment using different features of both natural ventilation and mechanical systems at different times of the day or season of the year. It is a ventilation system where mechanical and natural forces are combined in a two-mode system. The main difference between conventional ventilation systems and hybrid systems is the fact that the latter are intelligent systems with control systems that automatically can switch between natural and mechanical mode in order to minimise energy consumption and maintain a satisfactory indoor environment. "*

4. BUILDING EXAMPLES

In this report , 7 buildings are used as illustration. It must be stressed that the fact that these buildings are included in this report not necessarily mean that they are excellent buildings with respect to indoor climate and energy efficiency. The major reason why they are included is their innovative ideas with respect to ventilation for IAQ and/or thermal comfort.

Three leading building examples:

- The *Commerzbank* in Frankfurt (Germany), arch. N. Foster
- The *Inland Revenue building* in Nottingham (UK), arch. M. Hopkins
- The *New Parliament Building* in London (UK), arch. Richard Rogers Partnership
- The *Millennium Dome* in London (UK), arch. Richard Rogers Partnership

Besides these 'high-profile' buildings, there are also 3 more classical buildings :

- The Primary *school in Gronge* (Norway), arch. Letnes

- The *PROBE building* at BBRI (Belgium), architect (renovation) Y. Wauthy
- The *IVEG building* in Hoboken (Belgium), arch. Lemaire & Musse

A brief description of these buildings is given in annex A.

5. OPTIMISATION CHALLENGES

A fundamental difference between ventilation for IAQ and ventilation for summer comfort is the optimisation challenge:

- In case of ventilation for IAQ control, the challenge is during periods of heating and cooling demand to achieve an optimal equilibrium between IAQ needs and energy use. Balancing of systems, demand controlled ventilation,... are therefore important issues;
- In case of ventilation as part of a strategy of energy efficient cooling, maximisation of the air flow rates without creating comfort problems (e.g. undercooling in the morning,..) is the challenge and there is in most projects no heavy demand on air flow optimisation.
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5.1 Ventilation for IAQ

As indicated above, optimisation between IAQ and energy use is important during the heating season. Outdoor the heating season, there is no real optimisation challenge, the more ventilation (with clean outdoor air), the better for the indoor air quality.

During heating season	Outside heating season
▪ Limiting pollution sources ▪ Choice of appropriate IAQ targets and related air flow rates ▪ Optimum air supply to occupants (ventilation efficiency) ▪ Adapting air flow rates to IAQ needs (demand controlled ventilation,...) ▪ Minimising energy use (heat recovery,...)	▪ Limiting pollution sources ▪ Air flow rates may be higher than during heating season ▪ Optimum air distribution still important ▪ No need for adapting air flow rates to needs ▪ Fan energy

table 1 : Issues of concern for ventilation in relation to IAQ control

5.2 Ventilation for summer comfort

Ventilation as part in a strategy for summer comfort means in most cases the use of night ventilation, whereby the aim is to cool down the thermal mass. The major issues of concern are avoidance of too low temperature at the start of the working hours (this may be a problem if the weather conditions suddenly change) and an appropriate control strategy of the ventilation devices.

6. VENTILATION FOR IAQ CONTROL

There is a whole range of hybrid ventilation strategies. Hybrid ventilation can mean :

- a switching in time between natural ventilation and mechanical ventilation (§6.1);
- mainly a natural ventilation system but with support of mechanical ventilation (fan assisted) if the pressure differences are not enough (§6.2);
- mainly a mechanical ventilation system, but whereby the available natural forces are optimal used (§6.3).

6.1 Alternative use of natural and mechanical ventilation

- Concept

  The ventilation strategy is based on the combination of 2 fully autonomous systems whereby the control strategy consists in a switching between both systems.

- Example

  An example is the *Commerzbank* in Frankfurt. The objective is that during the largest part of the year, the IAQ control is done by means of natural ventilation. However, if there is too much wind, if it is too hot,... use is made of a mechanical ventilation system. Both systems are completely separated.

6.2 Fan assisted natural ventilation

- Concept

  The ventilation strategy is aimed to be essentially a natural ventilation concept. However, during periods of lack of the required pressure differences and/or during periods of increased demands, there is fan assistance. In case the ductwork distribution system is a low pressure concept, low pressure fans can be applied which, if advanced control strategies are used, allow to make optimal use of the available pressure differences due to stack and wind effect.

- Example

  The *school in Gronge* is an interesting example of such fan assisted natural ventilation system. Most of the time, the system works fully natural.

  There are also a number of interesting Swedish school projects which make use of such hybrid ventilation concept.

6.3 Stack and wind supported mechanical ventilation

- Concept

  The ventilation strategy is based that there is mechanical ventilation during periods that air supply is required. However, the system design counts on an a maximum use of the available pressure differences from wind and stack effect.

- Example

  The Norwegian Building Research Institute has developed in the framework of the EC JOULE-NATVENT project an air to air heat recovery system whereby optimal use of the available natural forces is made. (figure 8).

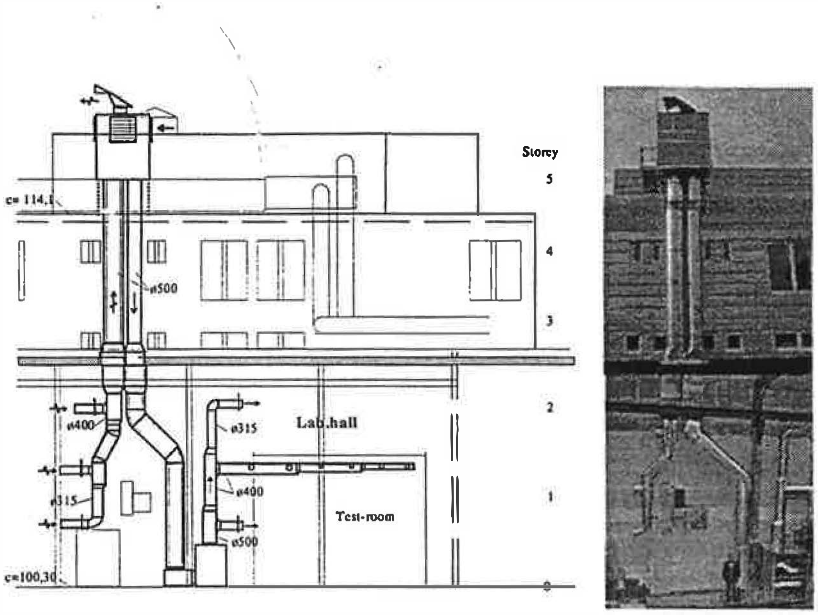


figure 8 : Concept of static heat recovery system developed by NBI

As shown in figure 9, the required fan power is rather well correlated with the available pressure differences due to stack and wind effect.

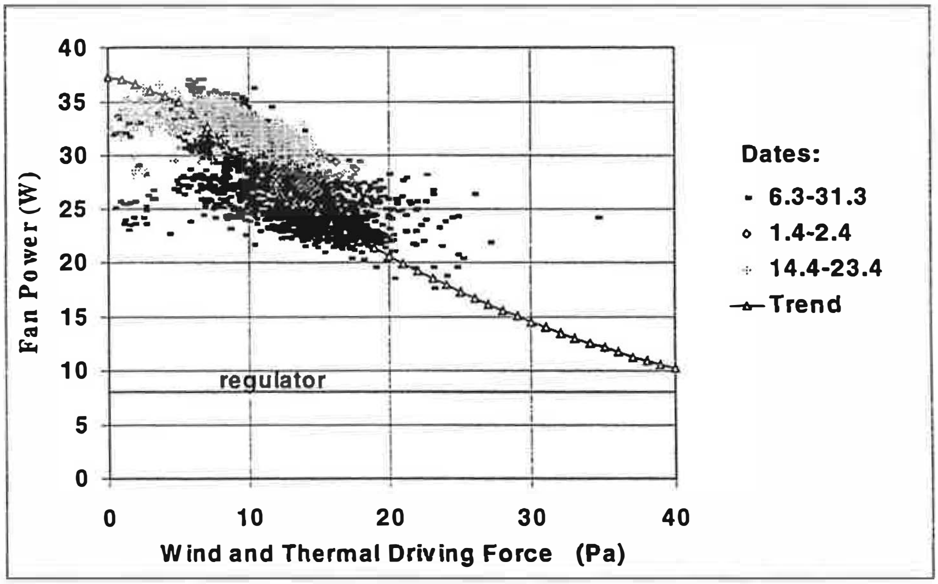


figure 9 : Fan power versus available pressure difference dut to wind and stack effect

7. VENTILATION FOR SUMMER COMFORT

7.1 Passive cooling concepts

- Concept

  The objective is to achieve acceptable thermal comfort conditions by making use of only passive means, whereby intensive (night-time) ventilation is a crucial part of the strategy.

- Examples
  - The <u>PROBE</u> building in Limelette is fully counting on passive measures for achieving thermal comfort in summer. The hybrid ventilation aspect in this building consist in the combination of a purely natural ventilation system for summer comfort with a purely mechanical ventilation for IAQ control.

- In another Belgian building (Keppekouter building in Aalst), the natural supply concept is very similar as in the PROBE building, but large roof fans are used for air extraction. These fans are installed instead of natural ventilation ducts because of the minimal space use of the fans.

7.2 Combination of passive and active cooling

- Concept

  The objective is to achieve during most of the time acceptable comfort conditions by using night time ventilation and without the use of active cooling. However, active cooling (often with limited cooling capacity) can be applied during extreme weather conditions.

- Examples

  - In the *IVEG* building, the objective is to achieve thermal comfort by making use of passive measures. During the design phase, the possibility of a limited active cooling power has been considered, whereby the air flow rate for IAQ control can be cooled down and dehumidified. This active cooling power allows a 2 K temperature reduction during extreme weather conditions. This active cooling system is not installed from the beginning. Only in case of comfort complaints, the cooling unit will be added to the air distribution system.
  - In the *Commerzbank*, there is a combination of passive control measures (open windows, minimisation of internal loads,...) and active cooling (cold ceilings) during extreme conditions.

8. VARIOUS TYPE OF COMPONENTS FOR HYBRID VENTILATION CONCEPTS

As such, there are no real hybrid ventilation components. A hybrid ventilation system in nearly all cases exist of a combination of components which can be used in purely natural systems or purely mechanical systems.

However, in order to allow a correct design and functioning of a hybrid ventilation system, the availability of appropriate components is essential. In this paragraph, just 3 examples of components are briefly described.

- Low pressure ductwork

  In order to allow a combination of natural and mechanical forces in air distribution system, it is essential that a low pressure ductwork design is choosen and implemented.

- Low pressure fans with advanced control mechanism

  In order to allow a combination of natural and mechanical forces in air distribution system, it is also essential to use fans which operate under low pressure differences and which have an advanced control mechanism : frequency controlled, air flow controlled,....

- Low pressure static heat exchanger

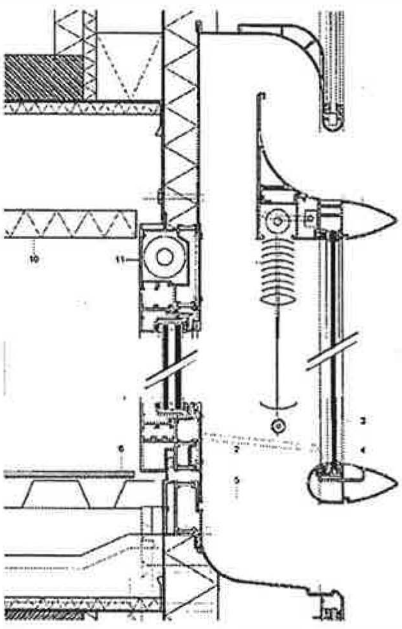
  In order to allow a combination of natural and mechanical forces in an air distribution system with heat recovery system, it is essential that the heat exchanger has a low pressure drop. The Norwegian design (figure 8) is an example of such approach.

9. SPECIFIC BOUNDARY CONDITIONS

As indicated in §2, a successful application of ventilation for IAQ control and for summer comfort control requires that a whole range of potential barriers is correctly handled. In this chapter, some of these potential barriers is briefly reviewed and examples are presented.

9.1 Draught control

Draught control is a major reason for not using ventilation devices or for closing them. An interesting example for minimising draught problems is the façade design in the Commerzbank. See figure at the right.



9.2 Security

Risk of burglary or a feeling of lack of security may also lead to the closing of certain ventilation devices. The use of louvres can be an appropriate solution for limiting the risk of burglary and therefore increasing the possibility for a correct system operation. Another approach is to situate the air intake at secure locations as is done in e.g. the New Parliament building in London.

9.3 Air preheating

Especially in cold climates, too low supply temperatures may be a major reason for non use of the air supply devices. The solution applied in e.g. the Gronge school is allows to avoid such draught complaints.

9.4 Outdoor air pollution

It is important that the air supply is of good quality. Since it was in the case of the New Parliament building not evident to guarantee a good air quality at street level, air intake at roof level was applied.

9.5 Acoustical problems

In case the outdoor noise levels are too high during operation hours of the building, there is a major risk that the ventilation devices will not be used.

9.6 Fire regulations

Fire prevention imposes compartmentation, which can limit the efficiency of natural or hybrid ventilation, specially for night cooling.

10. LEVELS OF DESIGN INTEGRATION AND INDUSTRIALISATION

Hybrid ventilation concepts can vary widely in the level of integration and industrialisation.

10.1 Industrial hybrid ventilation system with limited building impact

The Norwegian concept of static heat recovery can be considered (once produced in industrial conditions) as an industrial system, which has limited interaction with the building design.

10.2 Fully integrated design of hybrid building

The other extreme is e.g. the Gronge school, where the whole architecture and installation design is fully linked and integrated. In this case, a very close collaboration between architects and mechanical engineers is essential.

10.3 Moderate integration level

An example of a more moderate integration level between the work of architects and mechanical engineers is e.g. the IVEG building. Essential in the architectural design was the concept for louvres in the façade and the 2 large chimneys.

10.4 Marginal integration level

In case of the PROBE building, there is almost no interaction between the design considerations for the IAQ control and the summer comfort control.

11. SYNTHESIS

Hybrid ventilation systems cover a very wide range of technologies and designs.

All the buildings presented in this paragraph make use of natural ventilation during at least certain parts of the year. Moreover, in all buildings, there is use of fan assisted ventilation and there is also the use of advanced technology. In some of the buildings, active cooling is foreseen.

In figure 10, the ventilation strategies applied in 4 of these buildings are schematically represented. It clearly shows that hybrid ventilation is not a single concept but that it covers a whole range of strategies.

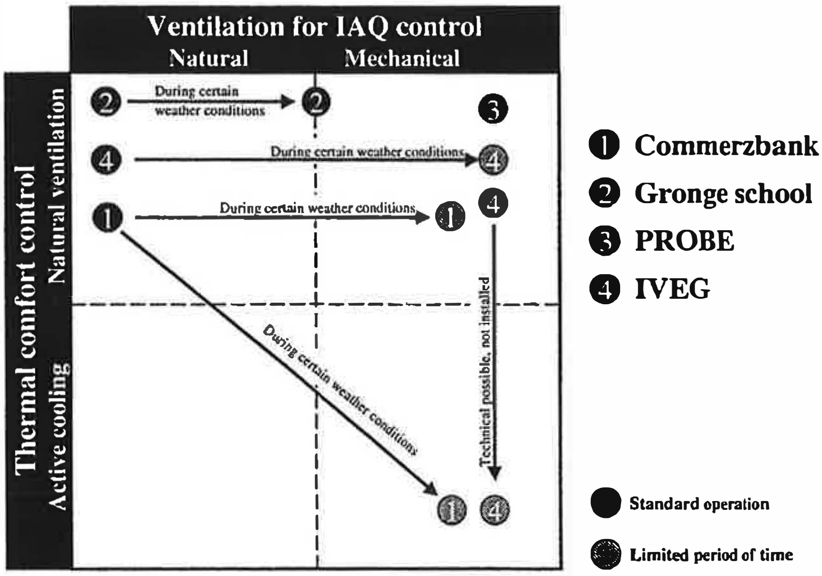


figure 10 : Synthesis of ventilation strategies for 4 of the buildings discussed in this paragraph

12. ACKNOWLEDGEMENTS

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Annex : Brief description of buildings mentioned in this report

The buildings which are used in this paper as examples are in this annex briefly described. It must be stressed that the fact that these buildings are included in this paper does not necessarily mean that they are excellent buildings with respect to indoor climate and energy efficiency. The major reason why they are included is their innovative ideas with respect to ventilation for IAQ and/or thermal comfort.

Four leading building examples:

- A.1. The Commerzbank in Frankfurt (Germany), arch. N. Foster
- A.2. The Inland Revenue building in Nottingham (UK), arch. M. Hopkins
- A.3. The New Parliament Building in London (UK), arch. Richard Rogers Partnership
- A.4. The Millenium Dome in London(UK), arch. Richard Rogers Partnership

Besides these 'high-profile' buildings, there are also 3 more classical buildings :

- A.5. The Primary school in Gronge (Norway), arch. Letnes
- A.6. The PROBE building at BBRI (Belgium), arch. (renovation) Y. Wauthy
- A.7. The new headquarters of IVEG in Hoboken (Belgium), arch. Lemaire

A.1. The Commerzbank in Frankfurt (Germany) by Sir Norman Foster

This Commerzbank is the tallest building in Europe and, with a floor area of about 70.000 m² provides working space to 2.500 employees. It is remarkable that the brief of 1991 mentioned the requirement to design one of the first naturally lit and naturally ventilated skyscrapers in the world.

It is interesting to include this building in the discussion in relation to the global environmental context, its energy concept and the role of technology for low-energy buildings.

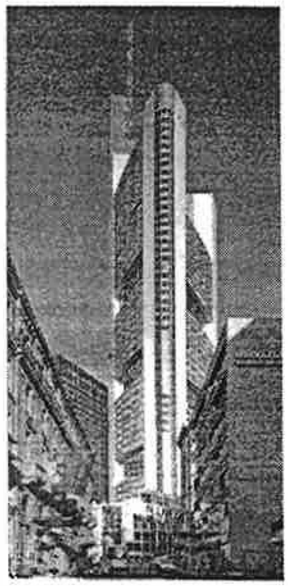


figure 11 : The Commerzbank, arch. Sir Norman Foster

- Overall energy context

  It is essential that the discussion on energy use is not limited to heating, cooling, lighting,... Besides the energy related to the building operation, there is the energy used for the building construction and the energy use for the transportation of its employees. A tall building as the Commerzbank is surely not very efficient with respect to the energy use for construction. However, a tall building allows in a city centre as Frankfurt easy use of public transportation systems. Car use is not stimulated since only 300 car parks are available for a total of 2500 employees and a large number of visitors.

- Ventilation principles

  The ventilation concept of the building is not only essential for the IAQ control but also for the thermal comfort control during most of the year.

- Because of the height of the building, natural ventilation can not always be applied (e.g. when high wind speeds) and therefore mechanical ventilation as well as active cooling systems are also provided.
- The central atrium (divided in 12-storey high atria) and the 4-storey high atrium-gardens play also an essential role in the ventilation concept.
- The building has a hybrid HVAC concept : a mixture of natural ventilation for IAQ and thermal comfort control, mechanical ventilation for IAQ control and cold ceilings for summer comfort control. This is illustrated in figure 12.

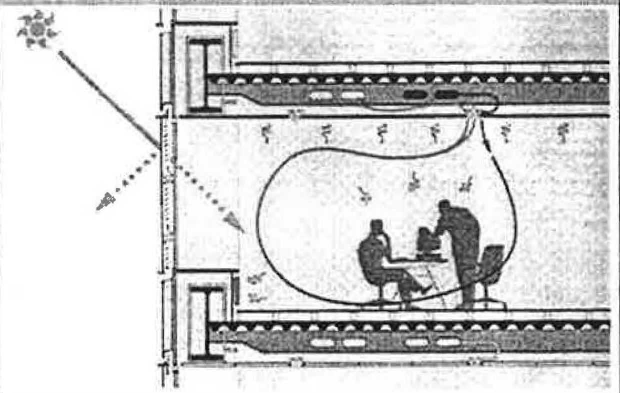
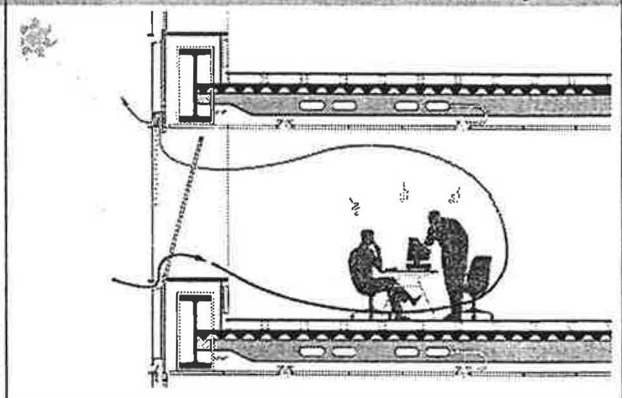
If weather is either too hot or too cool for natural air circulation	If weather is suitable, ventilation and cooling systems close down automatically
	
Air is provided for ventilation only, with extra heating or cooling provided by standard radiators or cooled ceiling panels	*A light on the control panel then indicates that the windows can be opened to ventilate the room natural*

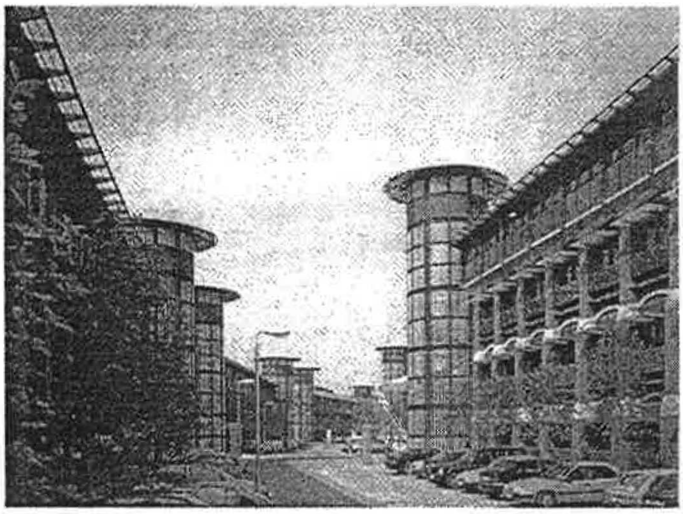
figure 12 : Two typical operation modes of offices in Commerzbank Source : Davies (1998)

- Use of advanced control technology

  Given the fact that the ventilation systems are to a large extent automatically controlled, it is evident that the ventilation concept of the building largely depend on advanced control technology

A.2. The Inland Revenue building in Nottingham by Michael Hopkins & Partners

This building complex has a total floor area of about 40.000 m² and consists of 6 office buildings (figure 13) and 1 common building. It provides work space for some 1.800 employees. It is a very good example of a project with great attention for optimal use of the environment : ventilation, solar control, daylighting,... A particular element in the ventilation concept are the staircases, which act as natural ventilation chimneys. This is illustrated in figure 13. In figure 14, one can see a number of the measures taken in relation to solar control, daylight and ventilation. It is interesting to notice that the air supply at room level is fan assisted and therefore one can consider this concept as some kind of hybrid ventilation.



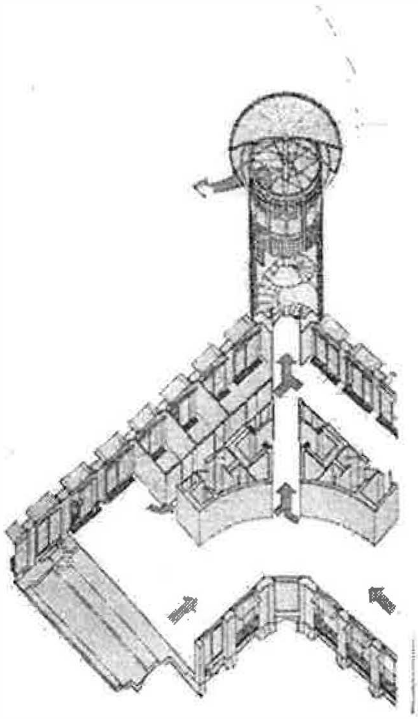


figure 13 : Inland Revenue Building in Nottingham (arch. M. Hopkins) : global view and global ventilation concept

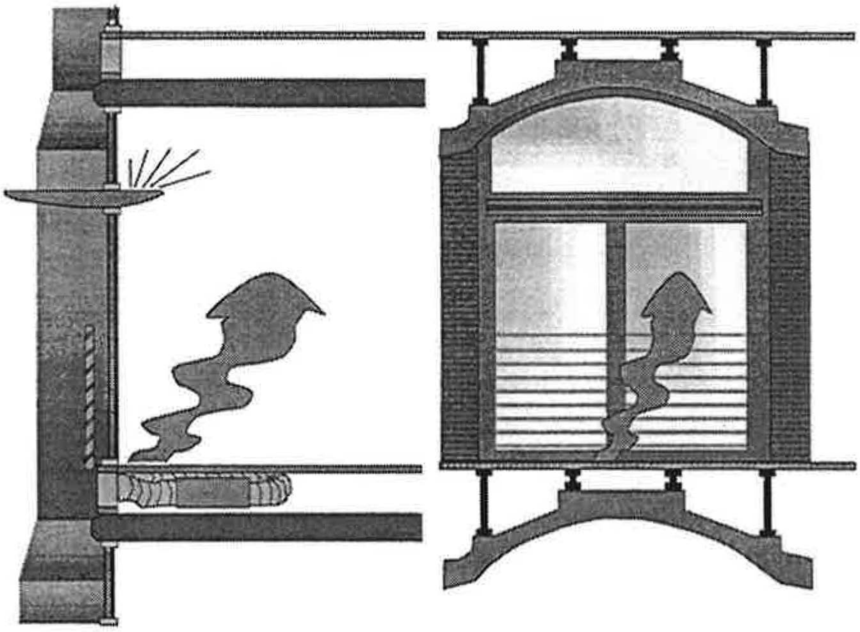


figure 14 : Mechanical air supply in floor void in Inland Revenue Building (arch. M. Hopkins)

Effective use of night ventilation as part of a summer comfort strategy is not evident if there is only a marginal amount of thermal mass.

In the Inland Revenue Building, accessibility to thermal mass is optimal at ceiling level (figure 14): there is no suspended ceiling and moreover the contact area of the ceiling is enlarged by the curved ceiling form.

This is achieved by use of prefabricated concrete elements. The floor void is used for all installations.

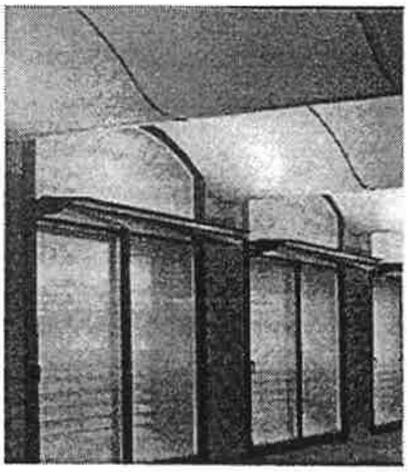


figure 15 :Curved ceiling form

A.3. The New Parliament Building in London by Richard Rogers Partnership

The New Parliament building is an interesting example of a complicated concept of hybrid ventilation. Moreover, it is interesting since it clearly refers to the original concept of natural ventilation used in the Parliament building itself.

Because of several reasons (security reasons, air pollution,...), air supply at street level was not possible and is therefore situated at the top of the building. Large chimneys aim to make optimum use of stack and wind effect.. Due to insufficient pressure differences, fan assisted ventilation is applied.

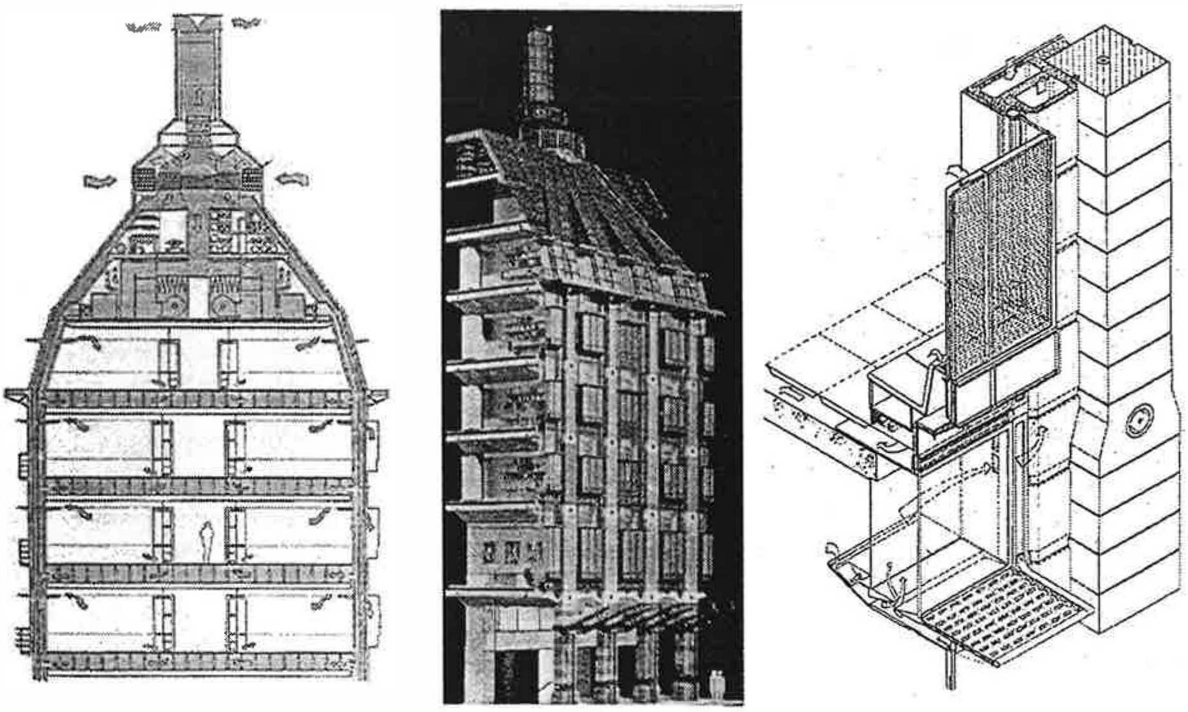


figure 16 : New Parliament building, London Architect : Richard Rogers Partnership

A.4. The Millennium Dome in London by Richard Rogers Partnership

The Millennium Dome is one of the World's largest enclosed spaces, built up for the Millennium celebrations.

Up to 35000 people can gather under this umbrella of 320m of diameter and 50m of height.

Incontestably, the thermal comfort and the IAQ are main issues of concerns.

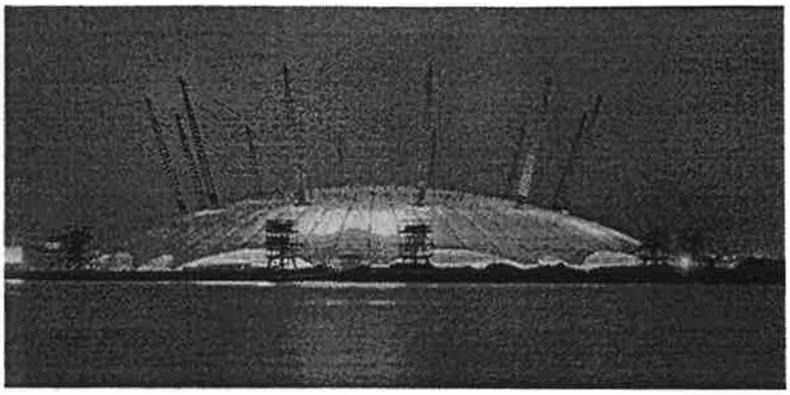


figure 17: The Millennium Dome

In order to achieve a good indoor climate, the air change is designed to one volume per hour. Figure 18 explains the Dome's hybrid ventilation strategy. The entire space is not conditioned, but air movement of around 1-2 m/s is provided to give a strong perception of coolness and some evaporative cooling during the summer period.

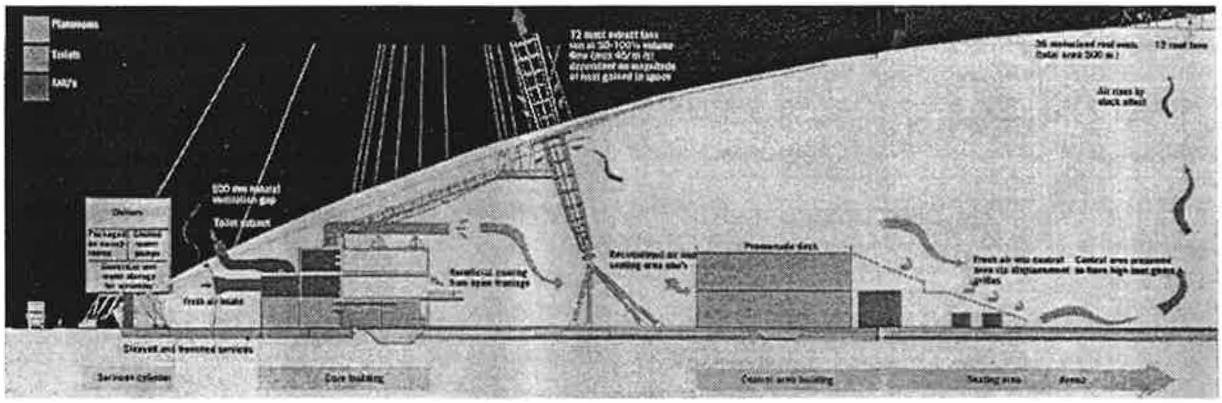


figure 18: Millennium Dome's hybrid ventilation

Fresh air is supplied and conditioned by air handling units (12 x 25 m^3/s) and by a 500 mm gap in the perimeter wall.

The air is afterwards recycled into the inner square in order to refresh the seat decking and the performance area at the centre of the Dome.

The hot air is extracted by 12 fans located in the 12 steel masts (12 x 45 m^3/s) (figure 19), by 12 fans in the dome cap (12 x 5 m^3/s), and/or by 36 motorised roof vents (figure 20).

The fans in the masts extract two times the mechanical ventilation supply : the natural ventilation must provide the remainder.

Under normal circumstances, the 36 vents are open. In case of rain, they automatically close and the 12 extract fans can be operated manually. In the heating season, the recirculation can raise up to 50 % if heating is not sufficient. Under very hot circumstances, the system can adopt a 100 % cooling strategy via a cooling coil.

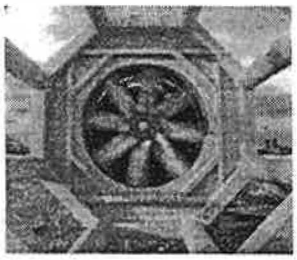


figure 19: extract fan in a mast (before erection)

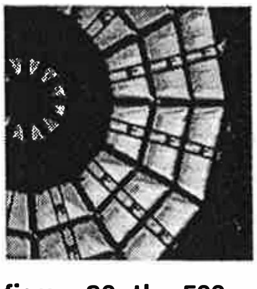
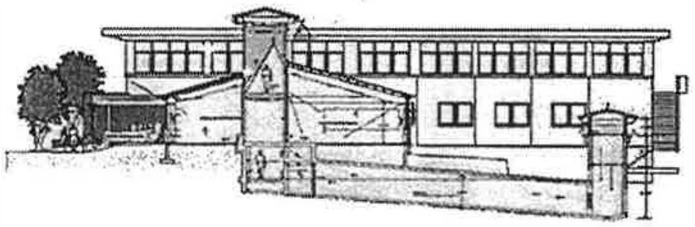


figure 20: the 500 m^2 vents in the foof

A.5. Primary school in Gronge (Norway) by Letnes Arkitektkontor

This school, which is studied in the framework of IEA annex 35 'HYBVENT', is a very interesting example of hybrid ventilation in a rather cold climate (middle of Norway).



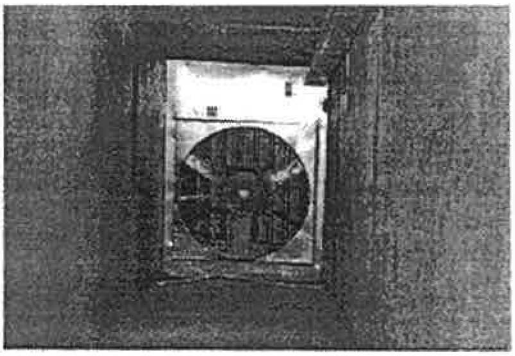


figure 21 : low pressure supply fan

The same ventilation system is used for IAQ and summer comfort control. Interesting features are:

- a large underground well insulated concrete ductwork (size 2 x 2 cm²), which act as air supply;
- large, low pressure fans in supply and exhaust are only used if stack and wind effect is not sufficient (see picture);
- a water-air heat recovery system between supply and exhaust allows to preheat the air in winter time;
- room air is brought in at floor level and its functioning is based on the principle of displacement ventilation (figure 22);
- the air flow rate at classroom level is controlled by a CO_2-sensor, which controls the small openable windows which are connected to the upper duct (see figure 24);
- The large extraction duct also acts as daylight supply to the classrooms (figure 24)

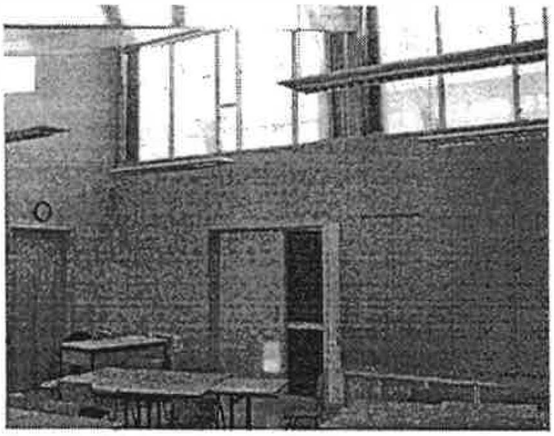


figure 22 : Classroom view

During the heating season, the air flow rate is controlled as function of the CO_2-concentration.

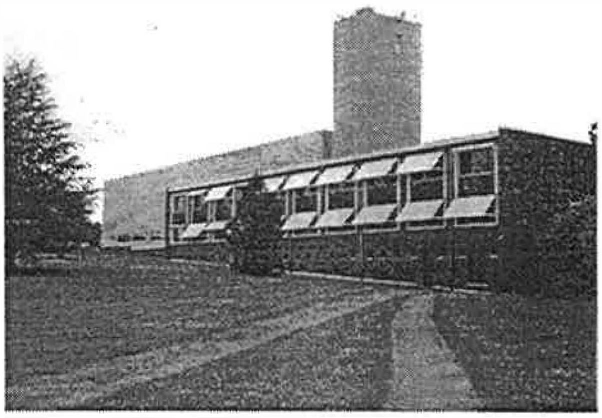
Outside the heating season, the air flow rates are in most cases above the required air flow rates. The concept of intensive ventilation is used as part of a strategy for avoiding overheating.

figure 23 : co_2 sensor

figure 24 : air extraction duct

A.6. The PROBE building at BBRI, Limelette (Belgium), arch. Y. Wauthy

The PROBE building has two ventilation systems with total different objectives:



- An infrared controlled mechanical ventilation system: This ventilation system controls the internal air quality (IAQ) in the offices. Fresh air is pulsed in the offices (7 dm^3/s.person) and extracted from the toilets. Every office has its own infrared sensor. There is only a supply when the infrared sensor detects presence. Air supply is stopped if no occupancy detected for more than 15 minutes.

  In this way the quantity of fresh air is adapted to the ventilation demand. This leads to a reduction of ventilation losses and fan energy of 35%. An airtight ductwork and a well-regulated fan are important conditions for the good operation of this system. (Ducarme,1997)

- A system for intensive night ventilation: the building can be naturally ventilated by means of large louvres at both sides of the building (figure 22). The objective of this intensive night ventilation it to cool down the internal mass of the building with cold external air to obtain a better thermal comfort in summer time.

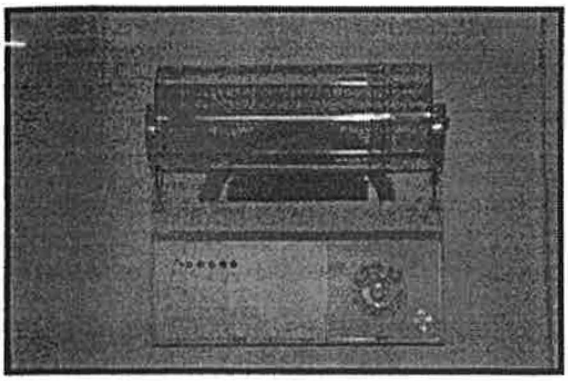


figure 25 : Supply grill with presence detection

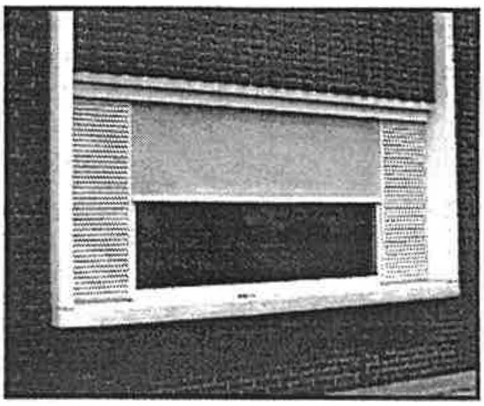


figure 26 : Louvres for intensive ventilation

A.7. IVEG building in Hoboken (Belgium) by Lemaire & Musse

In the IVEG building, the hybrid ventilation concept consists of the following elements :

- A mechanical air supply system with presence detectors integrated in each supply grill. The air distribution can also act during hot periods as an active cooling system whereby the required air flow rate for IAQ control can be cooled and dehumidified;
- A night ventilation concept which is fully natural.

With respect to the night ventilation concept, we were during the design phase confronted with a (potential) barrier concerning the fire regulations.

- Originally, it was the intention to use a fully natural ventilation design, which was largely stack driven (figure 27).
- However, the fire regulations impose that a compartment is limited to 2 floors. Therefore, a modified concept has been used (figure 28) requiring 2 large chimneys.

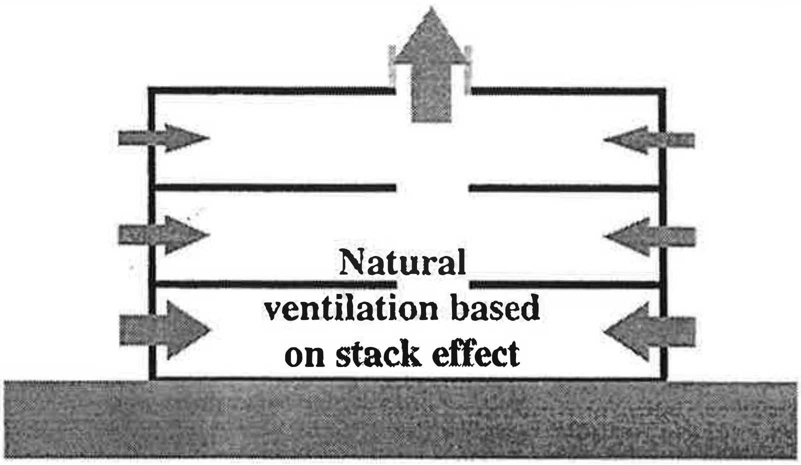


figure 27 : Original concept for night ventilation in IVEG building

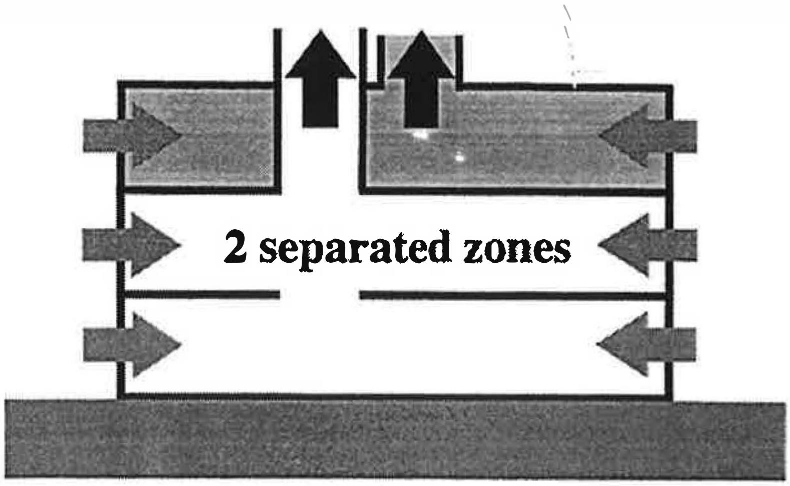


figure 28 : Modified concept for IVEG building due to fire regulations

- This 2nd concept is not only in line with the fire regulations but also has a much better air flow performance:
  - In case of only one chimney, there probably will be no air intake at the top floor but air exhaust only. This will clearly reduce the cooling potential for the top floor.
  - With the '2 chimneys' design, there is also air intake in the top floor windows. The architectural integration is presented in figure 29.
- On the second floor, the walls of the chimney of the lower floors consist of fire resistant glazing, which should improve the visual comfort conditions.

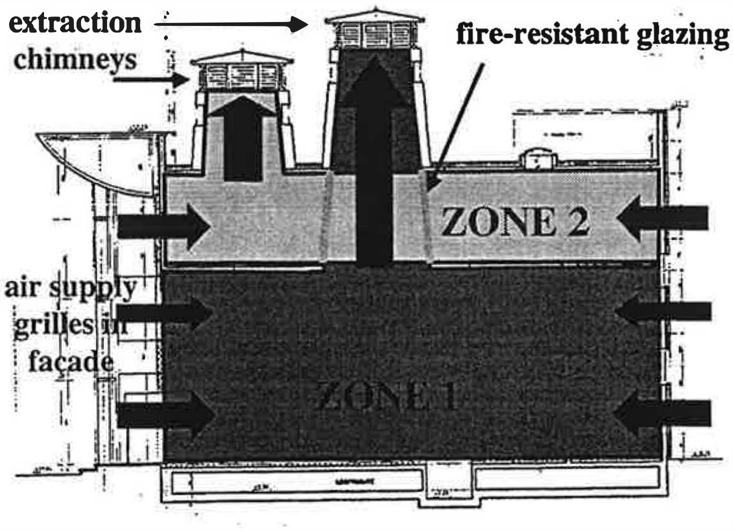


figure 29 : Integration of night ventilation concept in building design

Air supply is achieved by means of large louvres in the facades. These louvres are automatically controlled. (figure 30).

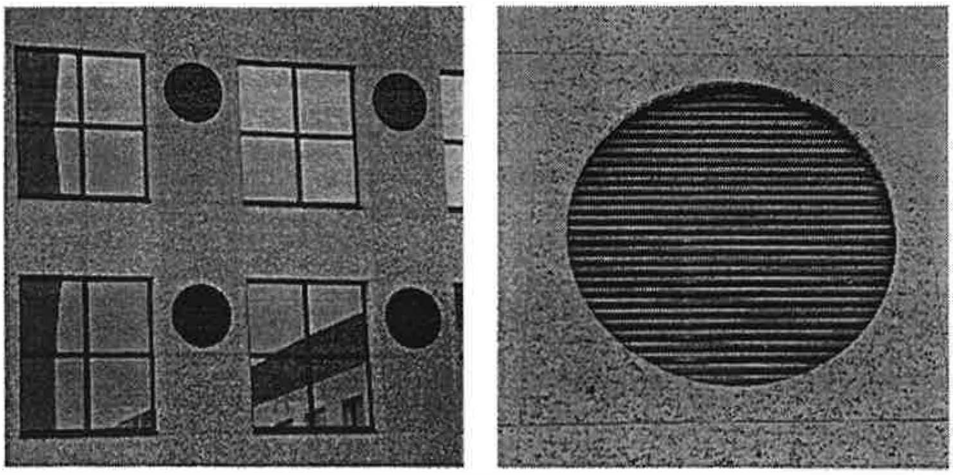


figure 30 : Concept of natural air supply for night ventilation in IVEG building (arch. Lemaire & Musse)