BRITA in PuBs

Hybrid ventilation

EU framework programme

eco buildings

Guidelines

2007

1 Introduction

Building ventilation is considered an essential aspect of a building project in most countries today. Ventilation used to be automatically linked only to indoor air quality control. Nowadays, there is also a growing interest in ventilation as part of an energy efficient strategy for achieving thermal comfort in summer.

The expectation of experts for the near future is that the most promising systems will be based on demand-controlled hybrid ventilation technologies. Hybrid ventilation systems can be described as systems providing good IAQ and comfortable indoor environment by employing different features of natural and mechanical ventilation at different time of a day or a season of the year. The demand controlled hybrid ventilation system combine advantages of natural and mechanical ventilation with respect to the actual ventilation needs and minimisation of energy consumption.

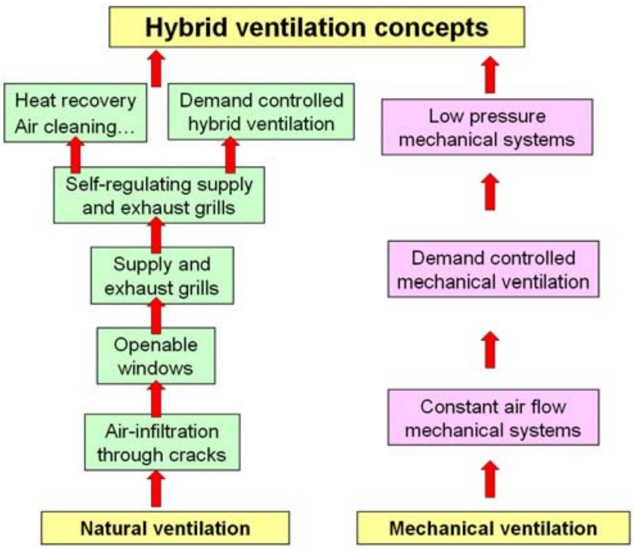

Figure1 Merging the best of natural and mechanical ventilation.

2 Requirements and regulations

There are no standards or regulations preventing the implementation of hybrid ventilation in most of the buildings in Europe. In some countries, however, the current regulations may complicate the implementation of hybrid ventilation compared with “traditional” ventilation systems. The main reason is that hybrid ventilation as such is not dealt with in current standards and regulations. It is therefore not easy to assess its performance. Many standards and regulations specify the air change rates or ventilation flow rates required for different types of ventilated spaces, levels of occupancy, activities, etc. It is rather easy to proof that a mechanical ventilation system has a capacity to meet the requirements. Demand controlled hybrid ventilation systems usually use monitoring of IAQ (mostly CO_2) and the ventilation rate is controlled with regard to the concentration of the pollutants. It is then necessary to proof that this approach leads to the same results as that using prescribed ventilation rates. New building codes, which are being developed thanks to the EPBD (Energy Performance of Building Directive), should remove these barriers. The so called Principle of Equivalence (PoE), which has already been implemented by some of the Member States, allows assessment of innovative technologies including the demand controlled hybrid ventilation systems. The future standards should focus on achieving the goals and not specifying the means. In case of ventilation the main goal is to protect human health by providing good IAQ.

Another problem closely related to the protection of life and health is fire safety. Hybrid ventilation systems, similar to other ventilation systems, have to comply with the building fire codes. Hybrid ventilation systems usually connect different fire zones and necessary measures have to be taken in order to prevent smoke and fire propagation. These measures, like installation of fire dampers, can be really painful in terms of increased pressure loss of the ductwork.

3 Current practise (what we compare with)

In the past, ventilation systems were only thought of as the means of IAQ control. Recently, the ventilation systems gain more attention also as the means of passive cooling of buildings. There are basically two categories of ventilation systems: natural ventilation systems and mechanical ventilation systems. During the last two decades, interesting developments could be observed in both categories. These developments had led to the introduction of hybrid ventilation concepts – see Figure 1.

31 Mechanical ventilation system

A balanced mechanical ventilation system with heat recovery is a commonly used mechanical system in many buildings. Some negative facts are known about mechanically ventilated buildings less than 10 years old:

- The ventilation system has a high pressure loss through the supply air system and through the extract air system.

- There is constant and high airflow rate for ventilation during hours of occupancy as most systems are CAV (Constant Air Volume).
- High consumption of electricity by fans.
- About 1-2 ºC increase in supply air temperature through the supply air system, which mean less possibility to utilise “free cooling”.
- Most ductworks cannot be easily inspected and cleaned.
- Noise from central air handling unit and from air inlet diffusers.

Innovations in mechanical ventilation

As far as mechanical ventilation systems are concerned, demand controlled ventilation systems have received a lot of attention in last two decades. Decreasing costs of pollutant and presence sensors together with interconnection of different building services by means of the Building Management Systems (BMS) help to implement demand controlled ventilation strategies based on occupancy or IAQ monitoring. Much effort has been spent, in last couple of years, on optimising the energy use of such systems. As a result low pressure ventilation systems with high-efficiency fans have been developed. Exploitation of renewable energy for energy saving in ventilation begins to play an important role.

32 Natural ventilation systems

Typical natural ventilation system is a passive stack ventilation system with purpose provided air supply openings in the building envelope. Two main problems are related to these systems

- ventilation rate is dependant on weather conditions
- draft risk problems occur in the vicinity of air supply devices

Innovations in natural ventilation

New models of wind cowls – devices using wind in order to contribute to the stack effect – are being developed. Solar radiation induced flow is being studied in order to increase the performance of natural ventilation system on hot sunny days in summer. Self-regulating devices, such as air inlets and exhausts, are used to deal with the varying weather conditions. The use of such devices reduces the draft risk and increases comfort of the occupants. Features like air cleaning and heat recovery at low pressure differences have been developed for natural ventilation systems. More recently, demand controlled natural ventilation systems, where advanced electronic control is applied are becoming available. Fan assisted systems have been developed in order to compensate for the lack of sufficient pressure differences during certain time periods.

4 Overview of different types

Concept 1: There is a hybrid ventilation system based on mechanical exhaust system In Figure 2. The system has been designed to operate partly naturally during the heating season by using buoyancy forces. Wall-mounted radiators provide heating of the supply air and thus reduce draft risk.

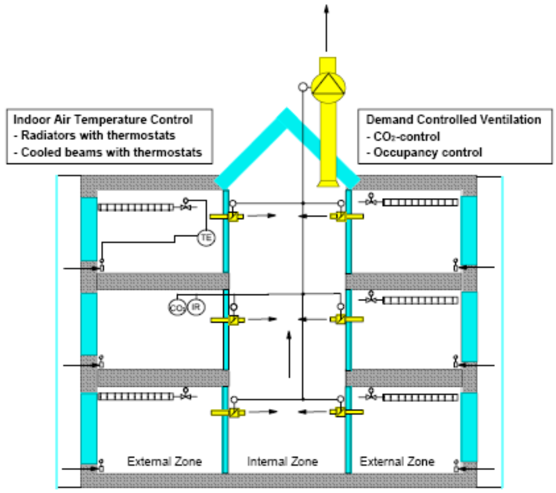

Figure 2 Hybrid ventilation concept 1 based on mechanical exhaust (Heinonen and Kosonen, 2000)

During cooling and mild climate period the ventilation is based on mechanical exhaust and window ventilation. The airflow rate of each space is controlled with CO_2 and occupancy sensors. Supply and exhaust air dampers are closed when the space is not occupied.

The mechanical exhaust systems are quite common in many types of buildings throughout Europe. Therefore, this concept of hybrid ventilation can be adopted during retrofitting. Some of these building do not have purpose provided air supply openings and the mechanical exhaust systems rely on air-leakage of the building envelope. Retrofitting usually involves improvement of the airtightness of the envelope (window gaskets, replacement of windows, etc.), therefore, some way of air supply has to be provided.

Concept 2: Figure 3 shows a hybrid ventilation system with air supply ducts where ventilation air is supplied into the building through an air handling unit (AHU) only during heating and cooling season. During mild climate season the supply air bypasses AHU and flows into the building naturally. A combined heating and cooling coil is integrated with a supply air device. Supply air is discharged the nozzles into the device, and through slots flows into a room. Air discharged from the nozzles induces air around it, and causes air circulation in a room by a combined heating and cooling coil. The extract air flows through the heat recovery coil during heating season. The airflow rates are controlled in the same way as in concept 1.

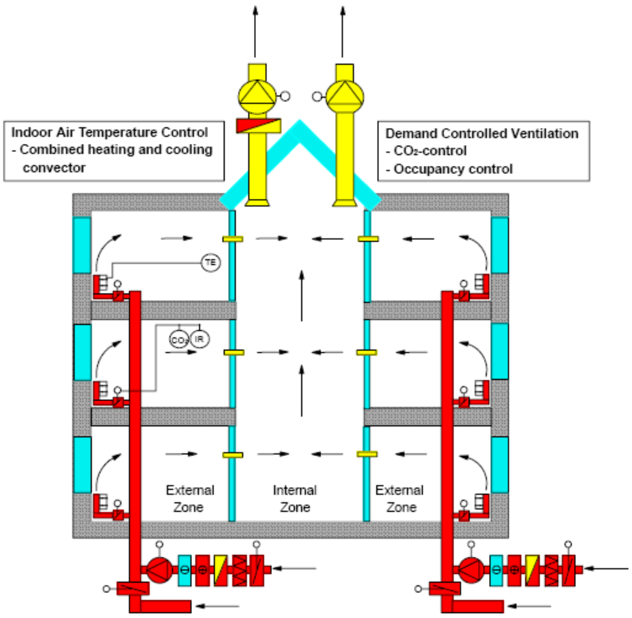

Figure 3 Hybrid ventilation concept 2 with supply air duct (Heinonen and Kosonen, 2000).

Concept 3: Figure 4 presents a hybrid concept based on a low-pressure balanced ventilation system. The system operates in mechanical mode during heating and cooling season. Filtering of supply air is possible in mechanical mode, but filters have to have a low pressure drop (e.g. electrostatic filters). A low pressure system has low air velocities in the ducts what leads to the reduction of aerodynamic noise. On the other hand the application of noise transfer reducing measures in the ductwork (noise transfer from a fan, or between different rooms) is limited by the requirement of very low overall pressure drop. Supply air can be taken directly from outside to the external zones through walls or windows during mild weather seasons.
Since the concept 3 is based on a low pressure mechanical system it can make use of natural driving forces (passive stack, contribution of wind) even when operating in a mechanical mode. Energy consumption of fans can be reduced this way.

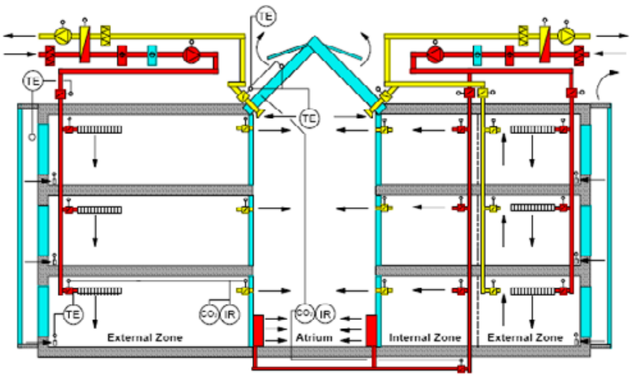

Figure 4. Hybrid ventilation concept 3 based on balanced ventilation (Heinonen and Kosonen, 2000).

The concepts 2 and 3 can be combined with earth-to-air heat exchangers (usually underground ducts or culverts) for pre-heating and/or pre-cooling of supply air. The contribution of ground exchangers to the energy savings very much depends on the climatic conditions. The use of underground culverts increases investment and maintenance costs, therefore, application of such measures should be thoroughly analysed.

5 Advantages/disadvantages

Each of the above mentioned concepts has some advantages and disadvantages for both retrofitting and installation in new buildings. A concept finally implemented in an actual building will probably use certain features from all three concepts in order to comply with the requirements. All three concepts use demand control of airflows to guarantee the efficient usage of energy. The building can be divided into zones with respect to the occupancy schemes. Ventilation can be shut down when a zone is not unoccupied. The efficient heating and cooling of supply air in cold climates should be carried out in a centralised way (Concept 2 and 3).
The Concept 1 is suitable for retrofitting of buildings with passive stack ventilation or mechanical exhaust ventilation systems, where the installation costs can be much lower than if a balanced mechanical ventilation system was installed. This concept can be adopted in buildings, where there is not enough space for air supply ductwork or this ductwork cannot be installed for other reasons (e.g. cultural heritage protection). The concept 1 can also be employed for night cooling of buildings by intensive ventilation. Mechanical cooling (if needed) is provided by a separate system. This can be a split system, a VRV (Variable Refrigerant Volume) system, or thermally activated building elements (like cooled beams in Figure 2). Heat recovery by means of a heat pump is possible in Concept 1.
The Concept 2 is a suitable solution when fan coil units were used in a building before retrofitting. The significant part of the “infrastructure” of a hybrid ventilation system already was in the building before retrofitting (piping for the fan coils, air supply ductwork). The implementation of the hybrid ventilation concept 2 in such a case does not require a “from scratch” approach and reduces installation costs. The Concept 2 is suitable when the ventilation system is supposed to provide cooling and heating. Heat recovery by means of a heat pump can be employed in the Concept 2.
The concept 3 is suitable in situations where heating or cooling is used for a significant time of the year. Low pressure drop heat exchangers can be employed for air-to-air heat recovery with the Concept 3.

6 Costs and energy saving potential

A hybrid ventilation system has in general higher investment costs than a natural ventilation system or a simple mechanical ventilation system. A hybrid ventilation system needs sophisticated control algorithms in order to effectively combine advantages of natural and mechanical ventilation. Some hybrid ventilation systems are actually two independent ventilation systems, one natural and one mechanical, and the control system alternates between natural and mechanical ventilation in order to minimize energy consumption. The control strategies very often involve monitoring of air quality in rooms and other parameters, for which purpose relatively expensive sensors are needed.

It would not make sense to compare the investment costs of a hybrid ventilation system to costs of simple natural ventilation. In case of a building with natural ventilation by window opening the investment costs of a “ventilation system” are close to zero. Even the earlier mentioned passive stack ventilation systems with purpose provided air supply openings are significantly cheaper than a hybrid ventilation system. Higher investment costs of a hybrid ventilation system bring much higher level of comfort for the occupants and better indoor air quality. Such improvements are very difficult to evaluate in terms of money.

If we compare a hybrid ventilation system to a balanced mechanical ventilation system using similar demand control strategy (e.g. monitoring of CO_2 concentrations) the investments costs of a hybrid ventilation system will not be much higher than the costs of a mechanical system (by some 10 to 20 percent). The higher investments costs will be made up for in lower energy consumption during operation. The savings will be higher when a hybrid ventilation system incorporates passive/night cooling strategy.

It is very important to point out that some components of the hybrid ventilation systems have multiple purposes (e.g. motorized windows or skylights). Only a part of the cost of such components should be included in the investment costs of the ventilation system. The same applies for wiring and other parts of the system. Some sensors and actuators of a hybrid ventilation system can share wiring with other systems when LonWorks(R) or LAN technologies are used for communication.

A number of buildings with hybrid ventilation systems were studied within the framework of the ANNEX 35 HybVent of the International Energy Agency [8]. The installation costs of the hybrid ventilation system in the ANNEX 35 case study buildings varied from 99 Euro/m^2 to 790 Euro/m^2. The installation costs of the hybrid ventilation system made, in majority of buildings, less than 20 percent of the total cost of a building. The case study buildings in warm climates showed significant reduction of electricity consumption due to use of passive cooling.

Higher energy savings can generally be achieved when hybrid ventilation is used in new buildings and when it is introduced in the early stage of the building design. The configuration of the building can be designed or modified to fully exploit advantages of hybrid ventilation. The floor plans can be designed in a way to minimise the length of horizontal ventilation ducts. The building shape and orientation can make use of wind and solar radiation for ventilation.

When a hybrid ventilation system is to be used in retrofitting, the possible concepts are restricted by the configuration of a building. This can increase the design costs because more complicated arrangements and control strategies have to be used.

7 Maintenance and service

Maintenance of a hybrid ventilation system is usually a more complex task (not necessarily more expensive) than maintenance of a balanced mechanical ventilation system. The maintenance of a balanced mechanical ventilation system mostly involves the maintenance of its main part - an air handling unit. The components of a hybrid ventilation system are usually distributed all around a building, and some of them (like motorized windows) may not represent “standard” components of ventilation systems.

It is very important to look at a hybrid ventilation system as an integral part of a building, because demand controlled hybrid ventilation systems can use inputs from other building systems integrated in the BMS (access system, fire alarm, etc.). The inspection, maintenance, and service of a hybrid ventilation system are an important part of facility management. A maintenance manual should be prepared, where the inspection and maintenance of different parts of the hybrid ventilation system is described. It is useful to point out in the manual what impact a failure of one part of the system has on its performance (e.g. air supply inlet stuck in the open position increases ventilation heat loss). In case of large buildings with complex hybrid ventilation systems different parts of the system can be inspected and maintained by different specialist, but all the findings have to be reported to a person responsible for a hybrid ventilation system as a whole (HVAC operating engineer, facility manager, etc.).

The requirement of low pressure drop of the ductwork in case of hybrid ventilation systems brings advantage in its inspection and cleaning. In order to have small pressure drop the ducts have to be short with a minimum of bends, dumpers, and other obstructions to air flow.

Many components of hybrid ventilation systems are easy to inspect and their failure can be observed and reported by occupants (e.g. stuck air supply inlets). The behaviour of occupants plays very important role in the efficient operation of the system.

Since hybrid ventilation systems consist of many components operating rather independently, a failure of one component usually does not bring about the failure of the system as a whole.

8 Design guidelines, tools

The hybrid ventilation process is very dependent on the outdoor climate, the microclimate around a building and a building itself. All these factors have to be considered when a hybrid ventilation concept is being prepared. It is important to keep in mind that the design process is not a strait line and that it may (and very probably will) be necessary to repeat some design steps in cycles in order to find an optimal solution. Before making a first draft of a hybrid ventilation concept the following questions have to be answered:

Is it possible to modify a building design?

If it is still possible to modify the design of a building (orientation, shape, number of stories, floor plans, etc.) it is easier to design hybrid ventilation system as an integral part of a building. A building can be designed in a way to make use of the prevailing wind direction for ventilation. Solar radiation can be employed in order to increase natural driving force (solar chimneys, double skin facades). Dual-purpose energy saving measures like atria and light-wells can be integrated in the building design. An atria or a light well providing daylight for otherwise windowless parts of a building can also be employed for natural ventilation.

What purpose will a hybrid ventilation system be used for? Will it be used only for indoor air quality control or also for passive cooling of a building?

Passive cooling by intensive ventilation has a potential to reduce energy consumption for cooling under relatively dry climatic conditions. Passive cooling, however, is not a suitable technique in moist climates, where most of energy for cooling is related to dehumidifying (latent heat removal). Passive cooling requires much higher air change rates than ventilation for indoor air quality control. Large area air supply openings in the building envelope are usually needed to provide sufficient air change rates.

What natural driving forces are available?

Available natural driving forces depend very much on the climatic conditions. Passive stack effect is available nearly all the time in cold and severe climates, where the indoor air temperature is more than 90 percent of the time higher than the outdoor air temperature. Stack effect can be employed to reduce the energy consumption of fans in case that the Concept 3 is used. In warm climates the stack effect due to the indoor - outdoor temperature difference can be very small and wind and/or solar radiation have to be employed in order to increase the natural driving force.

When the above mentioned questions are answered the basic concept of a hybrid ventilation system can be drawn. There are many possible configurations of hybrid ventilation systems for different buildings. To simplify the matter we will refer only to the three earlier mentioned basic concepts and their combinations.

1. Selection of the basic concept

If a building design is not yet finished, all three concepts and their combinations can be used. The climatic conditions are the most important factor influencing the selection of the concept. The building design can be modified in order to exploit the dominant driving forces (wind and/or buoyancy).

If a building is already designed, possible configurations of a hybrid ventilation system will be to some extent limited. One of the above mentioned concepts can then be adapted to fit the building. The issues like night cooling potential, noise and air pollution in the surroundings as well as fire safety and security have to be taken into consideration when selecting a basic concept.

If a hybrid ventilation system is to be used for passive/night cooling a concept similar to the Concept 1 or the Concept 3 is the most suitable. Ventilation air for passive cooling is drawn into a building directly from the outside through the special air inlets, windows, or both. High air change rates can be achieved this way. The Concept 2 uses air supply ducts all year round, and it would require more energy to achieve high air change rates in this case. It is however possible to add air supply openings in the building envelope to the Concept 2. These openings would increase air change rate in passive cooling mode. The Concept 2 and the Concept 3 can be combined with earth-to-air heat exchangers for pre-cooling of ventilation air.

2. Development of the ventilation concept

In the development phase of the concept the location and size of air supply openings as well as features to enhance the driving forces as solar chimneys and thermal stacks are designed. Passive methods to heat and/or cool the outdoor air are designed as well as heat recovery and filtering.

3. Design of mechanical systems

In step three the necessary mechanical systems to fulfil the comfort and energy requirements are designed. These can range from simple mechanical exhaust fans to enhance the driving forces to balanced mechanical ventilation or air conditioning systems.

The crucial part of the effective and efficient operation of a hybrid ventilation system is a good control strategy. All three basic concepts use IAQ monitoring for ventilation rate control. The hybrid ventilation and corresponding whole system control strategy are determined to optimise the energy consumption while maintaining acceptable comfort conditions.

Close cooperation of all involved parties (property owner, architect, civil engineers, HVAC engineers) is necessary throughout the design process. Every step of the hybrid ventilation system design requires many calculations and if possible also annual performance simulations.

Calculation and simulation techniques used in design of hybrid ventilation systems have to take into account many factors. Beside outdoor weather conditions, which can change quite quickly and which very much influence the performance of the system in the natural ventilation mode, there is a number of parameters influencing the control (occupancy profile, activity of people, etc.). The calculation techniques based on monthly or daily averages are not detailed enough to asses the performance of the system. Hour by hour or even sub-hourly simulation may be needed to asses the performance correctly. A number of simulation tools are available for this purpose. A multizone air flow model COMIS (Conjunction of Multizone Infiltration Specialists) was developed and tested within the framework of the ANNEX 23 of the International Energy Agency. This tool can be employed for calculation of air flow rates in case of hybrid ventilation.

Many other simulation tools for whole building performance are also available.

9 Best practise examples

One of the best practise examples of application of hybrid ventilation in public buildings is a Mediå School in Grong, Norway. This single-storey building with the floor area of 1000 m^2 was built in 1998. The hybrid ventilation system

in the Mediå School is based on the fan assisted natural ventilation principle. The system involves many interesting features like an underground culvert for preheating of outdoor air, a heat recovery system with heat exchangers connected by means of a fluid loop, and displacement ventilation.
A hybrid ventilation system was also designed for one of the demonstration buildings of the BRITA in PuBs project – the “Brewery” in the Czech Republic. A building, which used to be a brewery, was converted into a social and culture centre for students and academics. The centre provides accommodation services and the hybrid ventilation system is used in the guest rooms. The demand control of the system is based on the indoor air quality monitoring. When air pollution in a room reaches a set point the air inlet in the room opens and so does the damper in the air exhaust. If the concentration of pollutants in the room begins to decrease after opening of the air supply inlet and the exhaust damper the system operates in a natural ventilation mode. If after opening of the air supply inlet and the exhaust damper ventilation flow rate is not sufficient to remove the pollutants an assisting exhaust fan is switched on. Figure 5 shows the air supply inlets in the guest rooms. The inlets are installed in the wooden frame of the window.

Figure 5. Air supply inlets of a hybrid ventilation system

10 References

101 Compilation

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The authors are Miroslav Jicha and Pavel Charvat from the Brno University of Technology, Czech Republic. The professional editing was closed in May 2007.

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11 Disclaimer