Hybrid ventilation systems

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One of the main parts in the energy consumption of building service systems is mechanical ventilation. There is a minimum ventilation rate for several reasons like removing of inner moisture source or people produced Carbon Dioxide. There are two options: Control less natural ventilation or Mechanical system with heat recovery. By heat recovery the energy consumption of the heat load could be reduced. But new energy budgets are introduced: Power consumption of a fan, additional energy consumption because of not demand controlled ventilation. There is a minimum of ventilation rate is defined by the requirements of a building construction and occupancy. By changing the idea of an easy to use fun concept, the energy consumption of a mechanical ventilation system considerably could be reduced.

SUMMARY

The primary purpose of ventilation is to provide acceptable indoor air quality and indoor temperatures. Hybrid ventilation takes advantage of natural ventilation forces, using mechanical forces only when natural forces do not suffice. In natural ventilation the forces of wind and air density differences are used to move air through the building. The old concept of natural ventilation could be as a grate potential for new ventilation concept by combination of the natural ventilation potential and modern design techniques, materials and control strategies.

DEVELOPING TECHNOLOGY

That modernized technique for designing new buildings and retrofitting is requiring more integrated design of building construction, developed thermal insulation, reduced non controlled filtration and controlled mechanical ventilation system with heat recovery. Also on optimal use of sustainable technologies such as passive solar gains, delighting and natural ventilation and cooling. Also important factor is the impact of the outdoor air and internal contaminant sources on the indoor air quality. Today higher indoor air quality is required, so mechanical ventilation systems consume considerable amounts of electric energy for fans and heat through the heating coils. It is possible to simple apply traditional natural ventilation systems but because it is control less does not provide the acceptable comfort level for the occupancy and consumes a large amounts of energy to heat the fresh air.

So the solution is the hybrid ventilation systems that combine natural and mechanical driving forces. This has made it possible to satisfy relatively strict indoor air quality requirements for most of the time. A hybrid ventilation system can be described as 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.

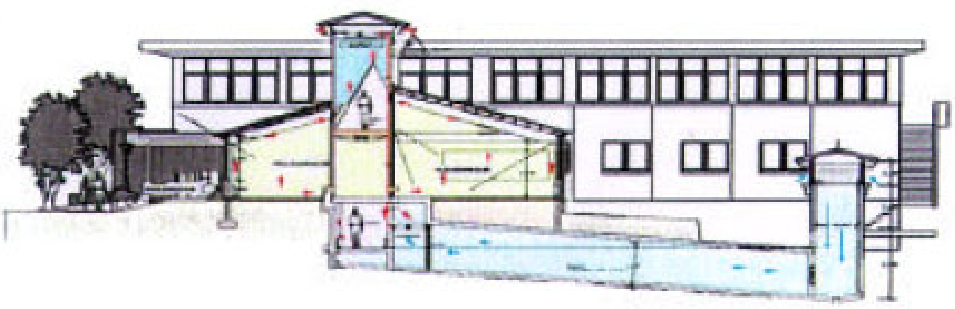

Figure 1. *Primary school in Norway with stack effect based ventilation system and ground cooling mass for night ventilation*

The basic philosophy is to maintain a satisfactory indoor environment by alternating between and combining these two modes to avoid the cost, the energy penalty and the consequential environmental effects of year-round air conditioning. The operating mode varies according to the season and within individual days; thus the current mode reflects the external environment and takes maximum advantage of ambient conditions at any point in time.

HYBRID VENTILATION

Hybrid Ventilation is a two-mode system which is controlled to minimize the energy consumption while maintaining acceptable indoor air quality and thermal comfort. The two modes refer to natural and mechanical driving forces. The purpose of its control system is to establish the desired air change rate but lowest possible energy consumption. The demand control is based on **I**ndoor **A**ir **Q**uality, where the most influencing parameter is CO_2 . The more traditional thermal comfort control is based on temperature monitoring, but a predicting intelligence. Lighting is also demand controlled based luminary sensors. And of course opening of the window, operating shading device is controlled by demand. The building shell is airtight, well insulated. Underground duct and culvers are applied for pre cooling or preheating the incoming air.

Designing of low pressure drop duct system is also a crucial point. With low pressure drop advantage could be taken on natural driving forces like stack effect and wind effect. Low pressure duct system could be ensured by applying larger diameter, low pressure active and passive mechanical elements (silencer filters etc.), less fittings as possible, and distribution system which does not requires high kinetic energy, like displacement ventilation.

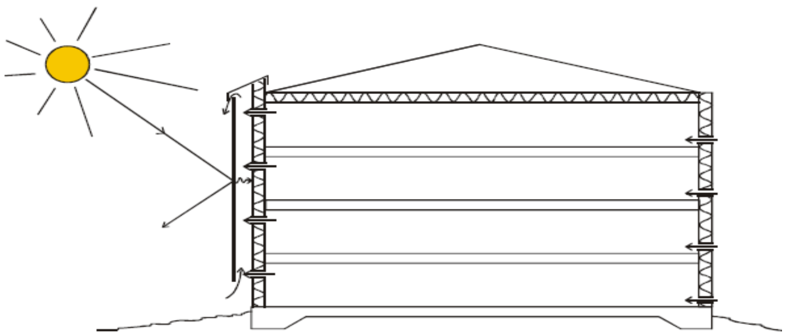

Figure 2. *Natural ventilation concept based on* ***solar chimney*** *with combination of* ***photovoltaic cell****.*

CONTROLL

Control and controlled parameters have to be chosen with regard to the control strategy being implemented and the technical feasibility of the measurements, as well as economic considerations. Various parameters may be measured depending on the objectives of the control strategy. In stead of traditional control strategies in hybrid ventilation systems new, more accurate and more demand dependent control strategies are applied, based on thermal comfort (Predicted Mean Vote and Predicted Percentages of Dissatisfied) or Level of the Indoor Air Quality. Indoor air pollutants - particulates, gases and vapors – result from both outdoor and indoor sources. CO_2 level may be considered as an indicator of the number of occupants, in nonsmoking areas. The concentration limit for CO_2 control is about 1000 ppm while the concentration in a rural area is about 300 ppm. CO can be a useful index where tobacco smoke is predominant. The concentration limit varies from 11 ppm to 35 ppm, depending on the exposure time. H_2O, though not exactly an air pollutant, is frequently used to control the air flow rates in order to avoid moisture in wet rooms. A so called *multicriterial approach* could be applied in order to optimize the above mentioned parameters. Advanced fuzzy control or logical control techniques are available to optimize several control parameters at the same time with application of fitness functions. An example of such a fitness function could be:

$$\Phi = \alpha \cdot \left(PMV_{+} - 0.5 \right) + \beta \cdot \left(-PMV_{-} - 0.5 \right) + \chi \cdot \left(CO_2 - CO_{2\,max} \right) + \delta \cdot \Xi_{cons}$$

This fitness function structure supposes that:

- PMV has to be maintained within [-0.5 : +0.5]
- CO_2 concentration has to be maintained below a $CO_{2\,max}$ concentration (800 ppm)
- The energy consumption Ξ_{cons} is minimized

The various coefficients of the fitness function have to be defined by expert knowledge. Their values have a major impact on the efficiency of the multicriterial control strategy. In the example given above, preference could be given either on comfort or on energy efficiency.

EXAMPLE OF A POSSIBLE CONCEPT FOR CONSERVATION OF ENERGY

Hybrid Ventilation is natural ventilation plus mechanical ventilation with the side condition that natural ventilation shall be used as much as possible to minimize the energy use. During the season with high solar irradiation cooling of buildings is required. At the same time the outdoor temperature is relatively high and subsequently the cooling capacity of outdoor air is low. The low cooling capacity can be compensated by high air velocities. This requires supply of high flow rates of air to the building by a solar chimney can be used to provide a sufficient stack effect. The solar chimney is based absorbing the solar radiation, see **Fig. 2.** An external surface of the solar chimney photovoltaic cell could be applied for producing electric energy for the cooling. But passive methods for pre-cooling could be applied in the following manner:

1. Providing the module with an air gap that allows air to flow behind the module. Heat is transferred by convection to the air and transported away by the airflow.
2. Connect the module to heat sinks (bodies with lower temperature). Heat is transported by conduction to heat sinks.
3. Provide the back surface of module with a coating of a suitable emissivity so heat is transported by radiation to neighboring colder surfaces.

In the context of hybrid ventilation it is natural to use the ventilation air for cooling of the cells. The temperature of the cells will be minimized by maximizing the flow rate in the air gap. This is in consort with the requirements of supply of high flow rates to meet the comfort requirements. There is an optimum with of the solar chimney which depends on the solar gain and the volume flow rate [1]. The total conversion of the solar energy is around 15%, so the rest heats the solar chimney.

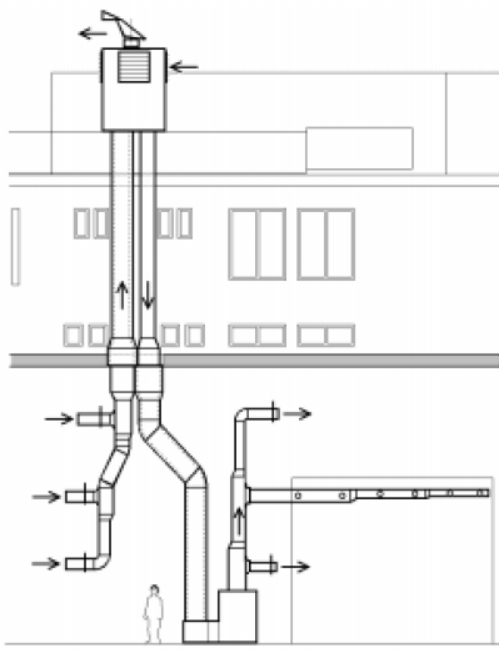

Figure 3. *Natural ventilation concept based on stack pressure and wind effect (Existing system at Norwegian Building Research Institute)*

Principle of Building of Norwegian Building Research Institute:

The system makes maximum use of available stack pressure and wind. Fan assistance is needed because the total system pressure drop is about 50Pa at the design flow rate of 400 l/s, so natural ventilation alone would be insufficient. The fresh air intake is a wind scoop, with carefully balanced flaps in each of 4 directional intakes that open only on the intake sides that are facing the wind. The exhaust air is also wind-boosted to create suction. There is an electrostatic filter with relatively low pressure loss coefficient. Flow rate is kept constant by automatic control of the fan speed. There is run-around heat recovery. To maximize the stack pressure, the part of the return duct outside the building is insulated, and the length of supply duct inside the building is likewise insulated. The axial fans are particularly efficient, with a low voltage DC motor. At design flow rate, the fan speed is less than 50% of maximum, to ensure low noise and power consumption. The pressure drop in the ducts can be about 0.15 Pa/m, which translates to a velocity at a low ranges. The fans are automatically controlled to maintain constant 400 l/s volume flow rate, based on signals from in-duct anemometers.

Overall performance on energy conservation: Each fan's power ranges between 18W and 37W depending on the available driving forces. With the two assisting fans running at 28W each, on average, the specific fan power is about 5% of a typical mechanical ventilation system today. The heat exchanger efficiency is approx. 50%.

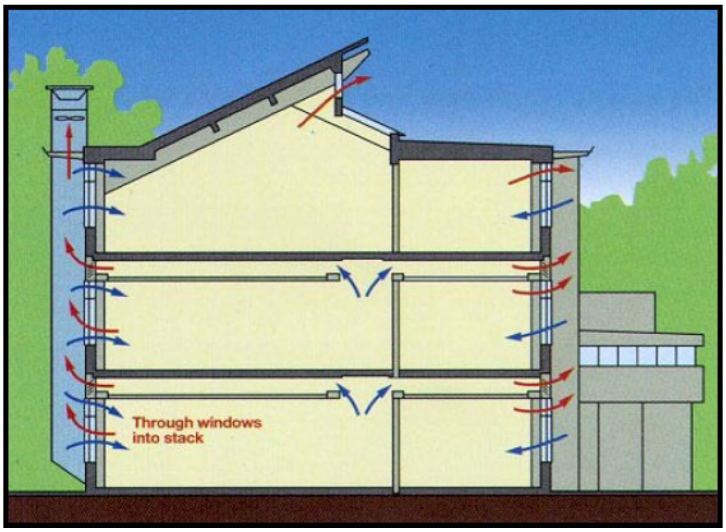

Figure 4. *Natural ventilation concept based on solar chimney driven stack pressure and night ventilation (Existing system at UK BRE Environmental Office)*

About 45% of the south façade is glazed and has adjustable external shading providing solar and glare control. Ground and first floor ceilings are formed from a sinusoidal concrete slab – this acts to provide high thermal mass and a channel for air flow deep into the building (and building services). A combination of night cooling, single sided and cross ventilation is used. For still summer days solar ventilation chimneys (fronted with glass blocks) encourage stack ventilation. Fans are also fitted in the chimneys for use when natural driving forces are insufficient. The second floor, instead of the waveform ceiling and connection to the stacks, has a monolith roof rising to clerestory glazing at 5m - this creates its own stack effect.
A sophisticated controls ventilation opening, fans, winter trickle ventilation, heating and cooling and lighting in an integrated manner, but also allows occupant adjustment. Winter ventilation is via the vents opening on to the ducts formed by the concrete waveform ceiling - this acts to preheat the air before it reaches the office space.

Principle of hybrid ventilation: A combination of single sided, cross, passive stack and fan assisted ventilation is used in the building. The main components of the ventilation system are open-able windows and vents, ventilation towers and fans fitted within the ventilation towers to assist air flow for night cooling or peak summer conditions. The outside air is transferred to deep into the office spaces by means of ducts cast into the concrete ceiling. The ceiling is formed from sinusoidal slabs and the ducts are contained within the troughs of these slabs. This provides a large area of thermal mass to ameliorate the effects of heat gains in the building. Components used to solve main issues or problems.

Overall performance: The winter performance shows that comfort conditions are maintained and acceptable air change rates are achieved. The average supply of fresh air being approximately 0.75 ach. This resulted in internal CO2 concentrations of just over 1000ppm. In the summer fresh air supply rates averaged about 2-3 ach and rates of 10 ach were achieved at times of high internal temperatures. The consequent levels of CO_2 were lower than in winter at about 600-800ppm. The internal peak design temperature of 28°C was not exceeded at all and the lower 25°C threshold was only recorded on three occasions.

CONCLUSIONS

In order to achieve energy conservation by Hybrid Ventilations systems integrated concepts should be developed. Integrated concept and also integrating different areas in building construction. Mechanical engineer, architect and civil engineer and building physics have to cooperate by the building design. This is the only way of building ventilation system by operating considerable less energy than the traditional ventilation and air-conditions systems.

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