Natural ventilation in buildings engineering essay

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Proper design of energy conscious buildings requires a balance between two things:

The thermal performance of the building envelope and the appropriate selection of techniques for heating, cooling and day lighting;

An acceptable quality of the indoor climate in terms of thermal comfort, ventilation effectiveness or indoor air quality.

Over the past years in all the western countries and more especially Europe, there has been a conscious limit of the availability of energy since the oil crisis of 1973. The main result of this crisis in term of the construction industry was therefore to reduce significantly global energy consumption, mainly used for heating and air-conditioning while neglecting its impact on the comfort and health of its occupants. During these periods, new regulations were made to regulate these, which also so the birth of real development of building research in western countries. However, these strict regulations on energy reduction in buildings was accompanied by an increasing number of disorders, mainly due to humidity condensation and the growth of mould, which affected the health of the occupants leading to SBS and building related sickness among the occupants, to overheating in the summer or in intermediate seasons, which affected the thermal comfort of the occupants and finally poor indoor air quality (IAQ) die to low air-change rates.

The evolution began in the 1990s and it is now clear that energy conservation cannot be disassociated from the quality of the indoor and outdoor environment. These environmental criteria have even led to major modifications in manufacturing and technology, such as the abandonment of CFCs in HVAC. These criteria also highlight the necessity of full integration of the building site characteristics and potential in the design and this leads naturally to a focus on more integration of passive concepts on heating, cooling or more generally indoor climate conditions. (1)

1. Santamouris and Asimakopoulos, Passive Cooling of Buildings (1996)

With these various aspects taken into account, natural ventilation appears to be a very attractive solution to ensure both good indoor quality and acceptable comfort conditions in many regions. Further more, natural ventilation seems to provide an answer to many complaints from users concerning mechanical ventilation, which appears to be noisy, to create health problems, to require routine maintenance and to consume energy. In contrast, natural ventilation is preferred by the occupants since it is energy efficient (no need of mechanical system), it can be easily integrated into buildings and it provides a healthier and more comfortable environment if integrated correctly. (2)

Fundamentals of Natural Ventilation

The magnitude and pattern of natural air movement through a building depends on the strength and direction of the natural driving forces and the resistance of the flow path. Good design involves the appropriate application of fundamental principles to the general strategies described in the following sub-sections. The driving forces for natural ventilation are wind and density difference.

Wind

Wind driven ventilation is caused by differences in pressures acting across the external surface of a building. The distribution of pressure depends on:

the type of terrain surrounding the building (open country/city centre) and the presence of any obstructions (other buildings, tree belts etc) which provide opportunity for site layout and landscaping to enhance wind driven ventilation

the wind speed and its direction relative to the building, and

the shape of the building; this provides the opportunity for the architectural form and detailing to enhance the potential for wind driven ventilation.

2. Liddament, M. A Guide to Energy Efficient Ventilation. (1996)

Air will flow through a building from areas of high surface pressure to areas of low pressure as shown in figure 2. 5. In general terms, building surfaces facing into the wind will experience positive pressures; leeward surfaces and those parallel to the wind direction will experience negative pressures (suction)

Source: Whole Building Design Guide

Figure 2. 1 Wind pressure field around a building

Careful orientation of a building in relation to the topography of the site can maximise the potential for wind driven ventilation. This potential can be enhanced by landscaping, such as tree planting.

Density differences

Warm air is less dense than colder air. If two columns of air at different temperatures are separated by a boundary, there will be a difference in pressure across that boundary due to the different pressure gradients on either side. Normally, where it is warmer inside the building than outside, the pressure difference acts inwards at lower levels of the building and outwards at high level. When openings are placed in the boundary separating the two air columns, an upward air flow will be created through the building, exhausting warm air at high level and replacing it by cooler air at low level. This is known as the ‘ stack effect’.

These stack -driven flows rise vertically through a building, but will induce horizontal flows in spaces connected to the column of air rising. These horizontal flows replenish the warm air which is exhausted from the shaft. The shaft can take a variety of forms (see 2. 3. 3), but Figure 2. 2 below illustrates the general principles associated with stack driven flows in an atrium.

Source: Caroline Rock, Coventry University

Fig. 2. 2 Stack driven flows in an atrium

Strategies for Natural Ventilation

Wind and buoyancy, the driving forces for natural ventilation, may be used for different ventilation strategies: wind variation-induced single sided ventilation, wind pressure-driven cross ventilation and stack ventilation.

Single-sided ventilation

Single-sided ventilation relies on opening(s) being on only one side of the ventilated enclosure. A close approximation is a cellular building with opening windows on one side and closed internal doors on the other side.

Single opening

With a single ventilation opening in the room, the main driving force for natural ventilation in summer is wind turbulence. Compared with other strategies, lower ventilation rates are generated, and the ventilating air does not penetrate so far into the space

Source: Dyer environmental controls

Fig 2. 3 Single-sided single opening ventilation

Double opening

Where ventilation openings are provided at different heights within the façade, the ventilation rate can be enhanced by stack effect. The ventilation rate will be further enhanced by any wind pressures acting on the ventilation opening. As well as enhancing the ventilation rate, double opening increases the penetration of fresh air into the space. Effective to a depth of about 2. 5 times the floor to ceiling height.

Source: Dyer environmental controls

Fig 2. 4 Single-sided double opening ventilation

Cross ventilation

Cross ventilation occurs where there are ventilation openings on both sides of a space. Air flows from one side of the building to the other and leaves through for example another window or door. Cross ventilation is usually wind driven. As the air moves across an occupied space, it picks up heat and pollutants. Cross ventilation is effective up to 5 times the floor to ceiling height

Source: Dyer environmental controls

Fig 2. 5 Cross ventilation

Stack ventilation

This term is used to describe those ventilation strategies where the driving forces promote an outflow from the building, thereby drawing in fresh cool air via ventilation openings at low level. The strategy makes use of the difference in density between a column of warm air and the surrounding cooler air. Because air flows into the building at low level, then up to a high level exhaust point, great care has to be taken into account when determining the

different sizes of ventilation opening on each floor of the building. For equal ventilation rates, the ventilation openings at lower floors need to be smaller than those nearer to the top of the building.

The effectiveness of natural ventilation can be enhanced by designing the stack outlet to be in a region of wind-induced negative pressure. The air may flow across the whole width of the building and be exhausted via a chimney, or it may flow from the edges to the middle to be exhausted via a central chimney and or atrium. e. g. Lanchester Library, Coventry University.

Fig 2. 6 Stack Ventilation strategy at Lanchester Library, Coventry

Fig 2. 7 Air exhaust via perimeter chimneys, light wells and the central atrium at Lanchester Library, Coventry

Source: Pat Non, Coventry University

Double Skin Façade

A double façade construction consists of a normal concrete or glass wall combined with a glass structure outside the actual wall. Double skin facades offer several advantages. They can act as buffer zones between the internal and external environment, reducing heat loss in winter and heat gain in summer. In combination with ventilation of the space between the two facades, the passive thermal effects can be used to best advantage. Opening windows in the inner skin can draw air from the buffer zone into the building. The stack effect of thermal air currents in tall buildings offer advantages over lower buildings.

Night Ventilation

Night ventilation is not an additional mode of ventilation; it is simply a different operational strategy. It takes advantage of the natural diurnal variations in temperature to promote cooling. Night ventilation offers many advantages like cooling the fabric of the building at night and also ventilating during unoccupied periods