

A Study on the Utilization of Natural Ventilation Systems in Institutional Buildings

OPEN ACCESS

Volume: 7
Issue: 1
Month: July
Year: 2019
ISSN: 2321-4643
Received: 27.05.2019
Accepted: 26.06.2019
Published: 01.07.2019
Citation:
Anuja, N., and N. Amutha Priya. "A Study on the Utilization of Natural Ventilation Systems in Institutional Buildings." *Shanlax International Journal of Management*, vol. 7, no. 1, 2019, pp. 73–81.
DOI:
<https://doi.org/10.34293/management.v7i1.513>



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Abstract

In Buildings, Energy Management is an important sector. Use of natural ventilation is the only way to minimise the overall energy consumption in buildings. Natural ventilation at a point can vary significantly for every second due to the climatic change. This paper has investigated energy demand problems due to ventilation in an institutional building located in India and gives satisfactory solutions to the problem. The main aim is to utilise maximum natural ventilation instead of artificial systems by reducing the energy bills in the Institutional building. Several Factors such as Wind speed, Wind pressure, Mechanical Ventilation, Air Flow Rate, Air Change Rate, Ventilation Air Change Requirements, Ventilation at various points in a Classroom are considered, and a Questionnaire Survey is conducted among the students.

Keywords: Apparent Temperature, Heat Index, Temperature Humidity Index, Thermal comfort, Thermal Resistance.

Introduction

Energy consumption is a very significant problem in each sector of the Indian economy, including agriculture, domestic, industry, transport and commercial. Energy conservation facilitates the replacement of non-renewable resources with renewable energy. Energy conservation is often the most economical solution to energy shortage. The maintenance of power is the practice of decreasing the quantity of energy used while achieving a similar outcome. This practice may increase financial capital, environmental value and human comfort. In each sector of the Indian economy including agriculture, domestic, industry, transport and commercial, the consumption of energy in all forms has been steadily rising all over the country. Energy conservation facilitates the replacement of non-renewable resources with renewable energy. It is often the most economical solution to energy shortage. The preservation of power is the practice of decreasing the quantity of energy used while achieving a similar outcome. This practice may increase fan financial capital, environmental value and human comfort. Treatment of building with thermal insulation may help in reducing domestic energy consumption. Buildings consume 50% of total human energy use; it is clear today that the building sector contributes significantly to global warming [1]. Ventilation is considered as one of the main factors in energy management. The ventilation rate needed to provide satisfactory air quality depends on ventilation effectiveness.

Ventilation effectiveness depends on the design, performance, and location of the supply outlet and returns inlet. When some of the supply air flows directly to the return inlet externally passing through the occupied zone of a room, the effectiveness of the ventilation is reduced. Air may contain a variety of possible contaminants that may or may not be harmful to human occupants.

Along with potential toxicity, contaminants can impart odours to space, and the toxicity and odour intensity are often related to the concentration of impurities. To reduce health risks and reduce objectionable odours, levels of pollutants are controlled either by dilution from outside air ventilation or by treatment of the air in an air conditioning system or by both. Proper fresh air distribution throughout a space is essential for mixing the air to achieve acceptable overall quality, and for keeping the air steadily moving around the occupants to carry away heat, moisture, and odours generated by them. Ventilation is the flow of outside air into a building and vice versa. Ventilation is mainly required to supply fresh air for respiration of occupants, to dilute inside air to prevent vitiation by body odours and to remove any products of combustion or other contaminants in air and to provide such thermal environmental as will assist in maintenance of heat, balance of the body in order to prevent discomfort and injury to health of occupants. In the worst ventilated rooms CO₂ will be high than 0.5 to 1%, by these ill effects will be produced.

The concentration of indoor air contaminants and odours can be maintained below levels known to impair health or cause discomfort, by the controlled introduction of fresh air to exchange with room air. This is known as ventilation. Humans require fresh air for an adequate supply of oxygen, which is necessary for the metabolism of food to sustain life. Carbon and hydrogen in foods are oxidised to carbon dioxide and water, which are eliminated by the body as waste products. The rate at which oxygen is consumed and carbon dioxide generated depends on physical activity, and the ratio of carbohydrates, fats, and protein eaten. The sense of staleness is primarily a result of the build-up of heat, moisture, and unpleasant odours given off by the body. While high CO₂ levels are responsible for headaches and

loss of judgment, acute discomfort from smells and health problems from other sources of air contamination usually occurs long before the carbon dioxide concentration raises that high. The generally accepted safe limit is a 0.5 per cent concentration for healthy, sedentary occupants eating a regular diet. This corresponds to 2.25 CFM (cubic feet per minute) of outdoor air per person where the outdoor air contains a reasonable proportion of carbon dioxide. To allow for individual variations in health, eating habits, and activity level, and the presence of other air contaminants, with a margin of safety, ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, specifies a minimum of 15 CFM (8 L/s) of outdoor air per person.

The ventilation rate needed to provide satisfactory air quality depends on ventilation effectiveness. Ventilation effectiveness depends on the design, performance, and location of the supply outlet and returns inlet. When some of the supply air flows straight to the return inlet without passing through the occupied zone of a room, the effectiveness of the ventilation is decreased. When outdoor air passes through the system without ever being used to dilute contaminants in the occupied zone, the energy used to heat, cool, and circulate the air is also wasted. When spaces are unoccupied, ventilation is generally not required unless it is necessary to prevent accumulation within the scope of contaminants, which would be hazardous to returning occupants or harmful to the contents or structure.

In some cases, outdoor air is so polluted as to be unacceptable as ventilation air. If the concentration of contaminants in the outdoor air exceeds acceptable levels, the air must be cleaned or treated before being introduced into space. Elaborate ventilating systems with recirculation and treatment may considerably reduce pollution below current ambient levels. Except for some critical regions like hospital operating rooms, cleaning and recirculation of air within a building are permitted as long as the concentration of all contaminants of concern is maintained within specified acceptable levels. The research studies and experiments established levels of outdoor air ventilation needed to achieve satisfactory indoor air quality. Designers are now trying to make a balance between acceptable IAQ and energy conservation.

Some means of lowering energy consumption while still providing enough air-conditioning are:

- Heat recovery between exhaust and make-up outside air
- Tracking occupancy (containing only the ventilation necessary for the current number of people in the building)
- Opening outside air dampers 1 hour after occupancy (where permitted) to take advantage of the dilution capacity of large volumes of room air, and the natural dissipation of contaminants during long vacant periods
- Segregating smokers (on a separate, higher-ventilated HVAC system), preferably located in perimeter areas

When ventilation air is brought in from outdoors, it may be by mechanical or natural means. In spaces with low-density occupancy and exterior walls, sufficient outside air may be introduced by leakage through doors and windows. Interior zones and densely populated areas require the introduction of ventilated air by mechanical equipment. Also, if the outside air needs to be conditioned, it should be passed through the conditioning equipment first and then delivered to space. Whether ventilation air is brought in from outside or is predominantly recirculated, it must still be introduced at a rate sufficient to remove objectionable odours and contaminants from the space. With proper air distribution, the motion of the ventilation air blends with the room air, creating a unified thermal condition. And as the wind gently passes by the occupants, it carries away heat, humidity, and odours.

Methodology

Ventilation is the flow of outside air into a building and vice versa. Ventilation is mainly needed to supply fresh air for respiration of occupants, to dilute inside air to prevent vitiation by body odours and to remove any products of combustion or other contaminants in air and to provide such thermal environmental as will assist in maintenance of heat, balance of the body in order to stop discomfort and injury to health of occupants. In the worst ventilated rooms CO₂ will be high than 0.5 to 1%, by these ill effects will be produced.

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unacceptable as ventilation air. If the concentration of contaminants in the outdoor air exceeds acceptable levels, the air must be cleaned or treated before being introduced into space. Elaborate ventilating systems with recirculation and treatment may considerably reduce pollution below current ambient levels. Except for some critical regions like hospital operating rooms, cleaning and recirculation of air within a building are permitted as long as the concentration of all contaminants of concern is maintained within specified acceptable levels.

In response, research studies and experiments established levels of outdoor air ventilation needed to achieve acceptable indoor air quality. Designers are now trying to make a balance between energy conservation and acceptable IAQ. Some means of decreasing energy consumption while still providing adequate ventilation are:

- Heat recovery between exhaust and make-up outside air
- Tracking occupancy (containing only the ventilation necessary for the current number of people in the building)
- Opening outside air dampers 1 hour after occupancy to take advantage of the dilution capacity of large volumes of room air, and the natural dissipation of contaminants during long vacant periods
- Segregating smokers, preferably located in perimeter areas.

When ventilation air is brought in from outdoors, it may be by either mechanical (active) or natural (passive) means. In spaces with low-density occupancy and exterior walls, sufficient outside air may be introduced by leakage through doors and windows. Interior zones and densely populated areas require the introduction of ventilated air by mechanical equipment. Furthermore, if the outside air needs to be conditioned, it should be passed through the conditioning equipment first and then delivered to space. Whether ventilation air is brought in from outside or is predominantly recirculated, it must still be introduced at a rate sufficient to remove objectionable odours and contaminants from the space. With conventional air distribution, the motion of the ventilation air blends with the room air, creating a unified thermal condition. And as the wind

gently passes by the occupants, it carries away heat, humidity, and odours.

Objective

The main objective of this paper is to utilise the natural ventilation to the maximum by reducing the use of artificial systems (fan, air conditioner, more relaxed, etc.) in the Institutional buildings. It minimises the electric power consumption. The energy diagnosis aims at determining the current conditions of the facility, from energy use, identifying problems and recommending possible solutions. The Theoretical and Experimental Analysis Case method is used here. The analysis is performed in the institutional building located in India. The building in which the study is carried out is oriented in East-West direction. Air Flow Meter is used to measure the speed of air. The values are calculated using formula and also obtained through measurements. Finally, both the calculations were compared by plotting the values in the form of graphs using MS Excel and MS Word.

Factors to be considered for ventilation

- Wind speed
- Wind pressure
- Mechanical Ventilation
- Air Flow Rate
- Air Change Rate
- Ventilation Air Change Requirements
- Ventilation at various points in a Classroom
- Questionnaire Survey

Experiments with discussions

Wind speed

Wind speed is the movement of air or any other gases in the atmosphere. It is compared and found from Table in IS: 3362 – 1977. It ranges from 0.6 to 1.2m above the floor. According to ASHRAE Standard 55, the average airflow velocity is generally lower than 0.2 m/s in HVAC buildings as a rule, while in naturally ventilated buildings it can exceed that limit. Speed on the body surface is more economical than 0.8 m/s, and it satisfies the essential requirement for thermal comfort. Figure 1 illustrates the variation of wind speed with time for three different days. It is found that on 4th March, wind speed is decreased

and then it increases. But on 6th and 8th March wind speed increases and then it goes on decreasing when the time passes.

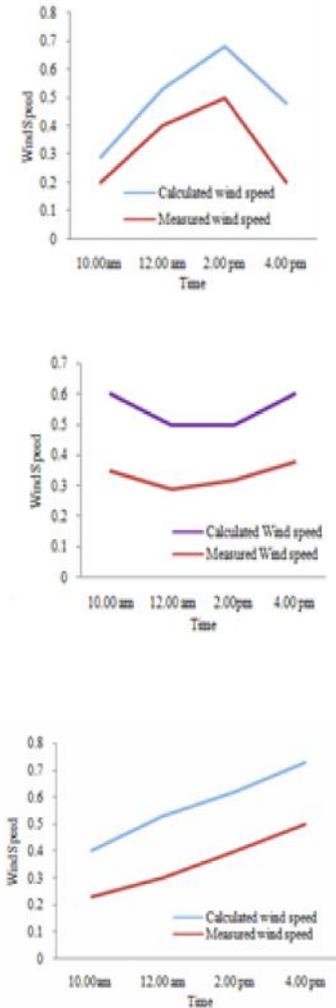


Figure 1 Variation of Wind Speed with Time on 4/3/2018, 6/3/2018 and 8/3/2018

Wind pressure

Wind causes pressure or suction normal to the surface of a building or structure. The nature and magnitude of these pressures/suctions are dependent upon a large number of variables, namely, the geometry, the kind of the incident wind, the direction of wind incidence, point of separation etc., which determine the quality of wind flow over or around a building/structure. The total force exerted upon a composition by wind is known as the wind pressure.

The wind pressure at any height above means ground level shall be obtained by the following relationship between wind pressure and wind speed using Equation (1). The mean pressures measured at various points on the building were generally in the range of $0 \pm$ two psf. It ranges from 0 ± 0.0052 .

$$P_w = 0.612 \times V^2 \quad (1)$$

where P_w = wind pressure in N/m^2 and V = design wind speed in m/s

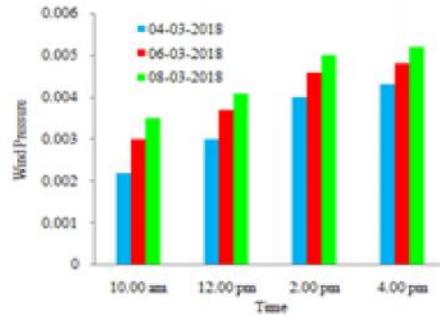


Figure 2 Variation of Wind Pressure with Time for three different days

Figure 2 shows the variation of wind pressure for three different days. It is found that from 10.00 am to 4.00pm; it goes on increasing. There is a tremendous variation in wind pressure.

Mechanical ventilation

A mode of assisted or controlled ventilation using mechanical devices that cycle automatically to generate airway pressure. It is the process of supply of outside air either by positive ventilation or by infiltration by reduction of pressure inside due to exhaust of breath, or by a combination of positive ventilation and exhaust of air. Usually, it ranges from 0 to 1. The area of the inlet opening is 13.8078 m^2 . The variation of mechanical ventilation with time for three different days is shown in Figure 3 and is calculated using Equation (2).

$$Q = AV \quad (2)$$

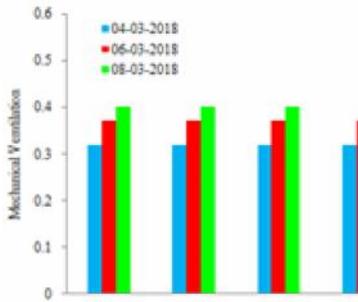


Figure 3 Variation of Mechanical Ventilation with Time for three different days

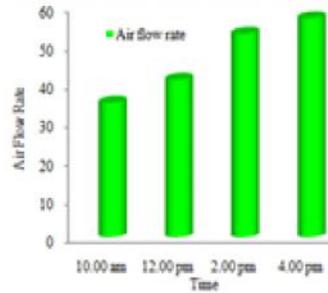


Figure 4 Variation of Air Flow Rate with Time on 4/3/2018, 6/3/2018 and 8/3/2018

There is an increase in the air flow rate for the three different days from 10.00am to 4.00pm.

Air Flow Rate

Air Flow rate is the rate at which the wind comes within 45° of the direction of the prevailing wind. Usually, it ranges from 30 to 60m³/h per m². The air flow rate with time is depicted form Figure 4 and is calculated using Equation (3).

$$Q = KAV \quad (3)$$

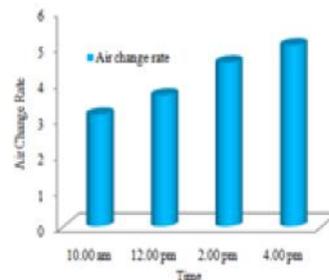
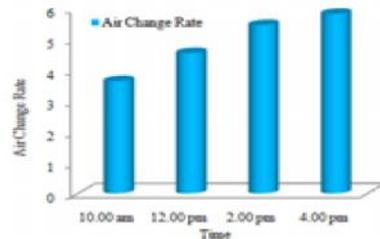
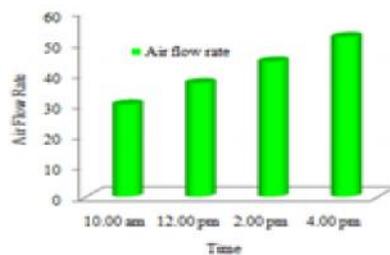
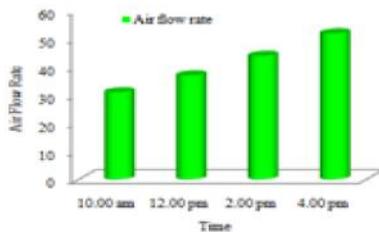
Where, Q – the rate of air flow in m³/h, K – coefficient (0.6 when the wind blows perpendicular to openings and 0.3 when the wind blows at an angle of 45° to openings, A – a free area of inlet openings in m² and V – wind speed in m/h.

Air Change Rate

Air Change Rate as the ratio of the volumetric flow rate of air into space to the interior volume of the space. For classrooms, it ranges from 3-6 ACH. Figure 5 illustrates the variation of air change rate with time and is calculated using Equation (4).

$$n = 3600 q / V \quad (4)$$

There is an increase in the air flow rate for the three different days from 10.00am to 4.00pm.



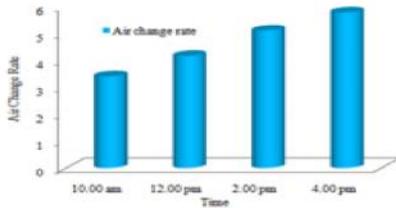


Figure 5 Variation of Air Change Rate with Time on 4/3/2018, 6/3/2018 and 8/3/2018

Ventilation Air Change Requirements

In developing this standard, ASHRAE recognised that there were many different kinds of buildings, many different climates, and many different styles of constructions. To accommodate these differences, the critical requirements were designed with several alternate paths to allow users flexibility. Some conditions are performance-based, with specific prescriptive alternatives. The standard recognises that there are several different ways to achieve the specified ventilation rate and allows both mechanical and natural methods. The first things people tend to look at in a ventilation standard are the rates, specifically the full ventilation rates of the building. Here according to the ASHRAE 62.2P, the ventilation air change requirements are found by plotting the air change rate against the floor area of different classrooms. Here the air change rate for five different classes with varying regions of the floor has been found. From the above graph, we come to know that the air change rate decreases with the increase in the floor area. Thus the air change rate requirement will vary by the size of the building and the occupancy. Figure 6 explains in detail about the air change rate for the different floor area.

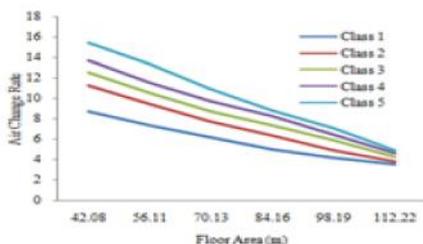


Figure 6 Variation of Air Change Rate with Different Floor Area

Ventilation at Various Points in a Classroom

The ventilation rate changes for every second due to the climatic variation. Here the variety of ventilation rate at various points in a classroom was considered. At each location, there will be a slight variation in the value. Proper fresh air distribution throughout a space is essential for mixing the air to achieve acceptable overall quality, and for keeping the air steadily moving around the occupants to carry away heat, moisture, and odours generated by them.

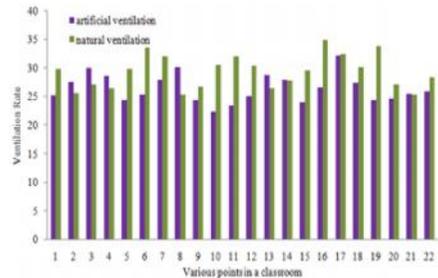


Figure 7 Variation of Natural and Artificial Ventilation at various points in a Classroom

By plotting the graph for multiple positions in a classroom, we come to know that there is a significant variation between natural and artificial ventilation. It is clearly explained in Figure 7. By analysing the result, we found that when compared to artificial ventilation, the natural air flow rate is satisfying the people at a high price. As the building is located at a certain height above the average road level, we found there is sufficient ventilation available naturally for the people.

Questionnaire Survey

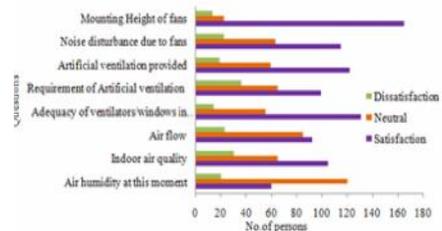


Figure 8 Satisfaction, Neutral and Dissatisfaction of 200 persons (Summer)

Table 1 Satisfaction, Neutral and Dissatisfaction of 200 persons (Summer)

Factors Questions	Satisfaction		Neutral		Dissatisfaction	
	Persons	%	Persons	%	Persons	%
Air humidity at this moment	60	30	120	60	20	10
Indoor air quality	105	52.5	65	32.5	30	15
Airflow	92	46	85	42.5	23	11.5
Adequacy of ventilators/windows in building for air flow	131	65.5	55	27.5	14	7
The requirement of artificial ventilation	99	49.5	65	32.5	36	18
Artificial ventilation provided	122	61	59	29.5	19	9.5
Noise disturbance due to fans	115	57.5	63	31.5	22	11
Mounting height of fans	165	82.5	22	11	13	6.5
	Avg	55.56	Avg	33.37	Avg	11.06

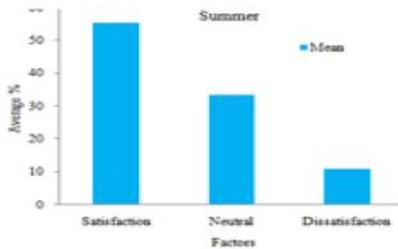


Figure 9 Variation of Average Percentage with Factors (Summer)

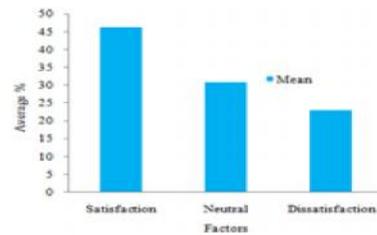


Figure 11 Variation of Average Percentage with Factors (Winter)

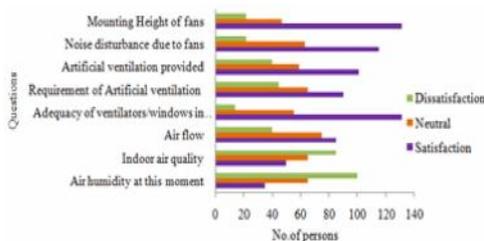


Figure 10 Satisfaction, Neutral and Dissatisfaction of 200 persons (Winter)

Table 2 Satisfaction, Neutral and Dissatisfaction of 200 persons (Winter)

Factors Questions	Satisfaction		Neutral		Dissatisfaction	
	Persons	%	Persons	%	Persons	%
Air humidity at this moment	35	17.5	65	32.5	100	50
Indoor air quality	50	25	65	32.5	85	42.5
Airflow	85	42.5	75	37.5	40	20
Adequacy of ventilators / windows in building for air flow	131	65.5	55	27.5	14	7
The requirement of artificial ventilation	90	45	65	32.5	45	22.5
Artificial ventilation provided	101	50.5	59	29.5	40	20
Noise disturbance due to fans	115	57.5	63	31.5	22	11

Mounting height of fans	131	65.5	47	23.5	22	11
	Avg	46.12	Avg	30.87	Avg	23

Figures 8 and 9 give the satisfaction level of people and their average value in summer. Number 10 and 11 provide the satisfaction level of people and their average value in winter. Table 1 and 2 provide satisfaction with, neutral and dissatisfaction of 200 persons in summer and winter. During summer and winter, students are highly satisfied with natural ventilation.

Conclusion

All the factors related to natural ventilation were analysed, and it is found that maximum amount of natural ventilation is utilised by the people and it highly satisfies the people in summer, but it is moderately meeting the people in winter. From the above discussions, we suggest some of the energy saving opportunities such as gain top management commitment, conduct energy audit and establish energy goals and objectives, develop education plan, maintain good relationships with other department, advise on energy matters, automatic control, use sophisticated technical innovation and promote awareness and communicate to employee to gain people involvement in the energy management project.

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