Effect on Comfort using Evaporative Cooling assisted Building Ventilation with Rooftop Ventilators

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***Abstract*--The natural ventilation concept is not novel, it is in practice since fire places were brought into the dwelling resulting in a need for an opening in the roof to let out smoke. Today new as well as refurbished buildings are being designed using natural ventilation. Natural ventilation relies on the wind and thermal buoyancy as driving force. The utilization of the natural driving forces has provided the desired thermal comfort and air quality through air change. The paper presents the design, installation and analysis of rooftop ventilators in a classroom of an educational institute in Dhule (74 º 45" N 20 º 50" E, 259 m above MSL) about 150 km. NE of Nashik located in Maharashtra state of India, which is in a hot and arid climatic zone. The performance was evaluated in respect of temperature for three cases viz. When the rooftop ventilators are not working, rooftop ventilators are working and rooftop ventilators are working with windows openings covered with wetted wood wool pads used for evaporative cooling. It is observed that during working condition of rooftop ventilators, temperature drop was 1.1^{0}C over non working condition of rooftop ventilators. In accordance with wetted evaporative wood wool pads, a temperature drop of 6.1^{0}C was recorded. % RH ramping from 50 to 60%. Positive air change makes sustainable environment in hot and humid condition in the month of monsoon i.e. June to October which is hot and humid. Positive air change maintains %RH in the range of 60 to 65%. During load shading period i.e. grid power is not available, present system is the best alternative in the hot and dry climatic condition.**

Keywords : RVEC, Rooftop Ventilators, Evaporative Cooling and Dry Bulb Temperature (DBT)

Nomenclature:-

RVEC: Rooftop Ventilator Evaporative Cooling
ACR : Air Change Rate
MSL : Mean Sea Level m
DBT : Dry Bulb Temperature ^{0}C
WBT : Wet Bulb Temperature ^{0}C
RH: Relative Humidity %

I. INTRODUCTION:

The basic purpose of the ventilation system in many applications is not just to control the indoor air quality during the summer but to achieve the thermal comfort through natural ventilation. In many hot and humid zones, the engineers and scientists are trying to find the ways for achieving the thermal comfort and controlling the air quality using natural ventilation. Proper and good ventilation in the building can assist in minimizing the condensation, excessive humidity, overheating and formation of odors, smokes and pollutants. An environmental friendly and economical way to achieve good ventilation is the use of rooftop ventilators. The rooftop ventilators are cheap to manufacture, install and maintain, hence they are available in various types in the market.

A rooftop ventilator is a wind driven air extractor. Its concept was originally patented as early as in 1929 by Meadows, who described it as a rotary ventilator, and first commercialized extensively by Edmonds of Australia in 1931 [1]. It consists of a base and a top in the form of a rotor. The rotation produces a negative pressure inside and the air is sucked from the inside base duct. The turbine ventilator includes a number of vertical (either straight or curved) blades in a cylindrical or spherical fashion. They are available in different sizes that may range from throat diameter12″ to 36″. The selection depends on climatic conditions, wind velocities, blade size, shape of blade, blade angle, inclination angle of roof etc.

Very little attention has been focused on wind driven ventilator from the past to the present time. The ventilator consist of two parts or two bodies, one being the top portion of the ventilator or the rotating head with a number of blades behaving like a rotating cylinder while the second being the lower portion of the ventilator behaving like a stationary cylinder.

A review and update on rooftop ventilator [1] recommended criteria that should be considered in designing future turbine ventilator, which is not only to ventilate well in high-wind speed region, but also could be an effective multifunction device even in low wind velocity region.

A numerical analysis of the difference in comfort level inside a room of a residential building when a rooftop ventilator is installed has been presented [2]. This analysis simulates various comfort factors which includes the indoor air movement, room temperature, Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD).

A comparative study on ventilation performance of a curved-blade turbine ventilator, a straight column covered with a flat hat, and a device of their combination [3] of the same material has been made. The results show that when buoyancy effects were dominant, i.e. internal heat source under low wind speed, the column performed best, followed by the combined device and lastly the rooftop ventilator. When wind effects were dominant, the combined device worked best, followed by the turbine, which was close to the column.

Shao Ting J Lein, Noor A Ahmed in the effect of an inclined roof on the airflow associated with a wind driven turbine ventilator [4], rotating wind driven turbine ventilator has been used as cost-effective environmental friendly natural ventilation device. An important conclusion has been drawn from this investigation that the presence of the inclined roof may extend the safety margin in the operation of a turbine ventilator at high wind speed by reducing the magnitude of the total force that acts on the ventilator.

A simple model [5] has been made to estimate the minimum driving force of the wind power that needs to overcome the inertia of the turbine ventilator mechanism and the electromechanical energy conversion of electro-active materials.

Simulation of air flow using CFD technique and aerodynamic forces acting on rooftop ventilator was done for increasing the efficiency at reduced cost of rooftop ventilator [6].

The potential and effectiveness of the hybrid turbine ventilator (HTV) application in actual building has been studied under Malaysian weather condition[7]

In performance testing and comparison of rooftop ventilators, measurement of flow rates of four commercial rooftop ventilators on a specially designed experimental system was done. The ventilation flow rates and rotational speeds were taken at different wind speeds and compared with simple open column and two standard vent hats[8].

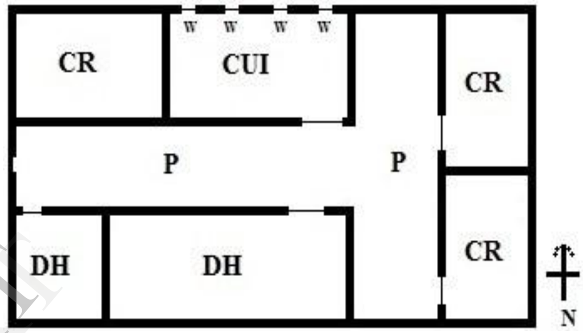
II. METHODOLOGY AND EXPERIMENTATION:

The educational institute having roof top of metal sheet gains solar heat in a considerable manner. It also picks heat from all sources like students, electrical appliances due to which the temperature of the air increases. In addition to this heat gain, the important factor is humidity which increases due to high occupancy of students. This hot and humid air rises and accumulates at the top space inside the inclined roof top.

The best option as per ventilation norms is to vent this hot and humid air and maintain the air change rate. For classrooms prescribed air change rates (ACR) are 10 to 15 [9]. By taking 10 ACR number of wind ventilators calculated for the entire educational building were 64. The 16 turbo ventilators are already installed on the rooftop.

It was suggested that previous installed 16 wind ventilators are to be shifted to top of the ridge and new 48 wind ventilators are to be installed at the top of the inclined roof. All 64 wind ventilators should be uniformly distributed throughout the top of the roof and nearer to ridge. Openings and leaks were closed for better performance of ventilators.

The educational institute's classroom (NE, 3rd floor, 10.2m from ground) having asbestos false ceiling was taken for experimentation. Earlier the classroom asbestos ceiling was not closed. The opening area for the same was calculated considering the flow rate of air from the room, average air velocity and hence the opening area was calculated. The classroom contains two rooftop ventilators. One asbestos plate size was 610 x 610 mm and room has total 16 openings created for air circulation.



CUI-Classroom Under Investigation, W-Window, D-Door, P-Passage, CR-Class Room, DH-Drawing Hall

Fig. 1 Plan of educational building

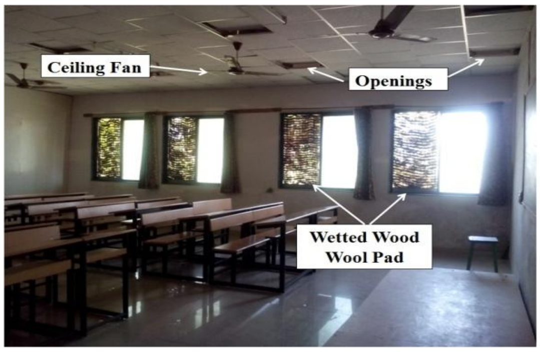


Fig. 2 Classroom under investigation

The experimentation room provides evaporative cooling system at windows (size 0.7m x 1.5m). The wood wool pads are installed in the half portion of windows while remaining half is covered with glass as shown in Figure 2. Water dripping arrangement as in Figure 3 was provided over these pads. Small size water nozzles are adjusting the flow of water over pads which decreases the inside room temperature. Due to dripping, rate of evaporation is not as high as in pumped circulation of water.

Fig.3 Water dripping arrangement

Temperature measuring stand has a total height 3m and 2.5 m long strips horizontally attached at 0.5m distance each from base of the stand. Measurement of actual temperature in the said space is taken using a data logger at a different location with the use of RTD type thermocouple. Temperature measurement was done as follows:

The following three cases are studied :
Case I (RVEC – Rooftop ventilators not working) : In this case rooftop ventilators are not working and the windows are not covered with wood wool pads.

Case II (RVEC – Rooftop ventilators in working): In this case rooftop ventilators are in working state, but no windows are covered with wood wool pads.

Case III (RVEC – Rooftop ventilators in working with evaporative cooling): In this case rooftop ventilators are working and windows are covered with wetted wood wool pads.

III. RESULTS AND DISCUSSION:

Figure 4 shows Height from floor verses Temperature plot when the rooftop ventilators are not working and windows are not covered with evaporative pads. Considering an average height of students, seating in the classroom to be 1.29 m from the floor and around 2 pm, the temperature was found to be 37^0 C.

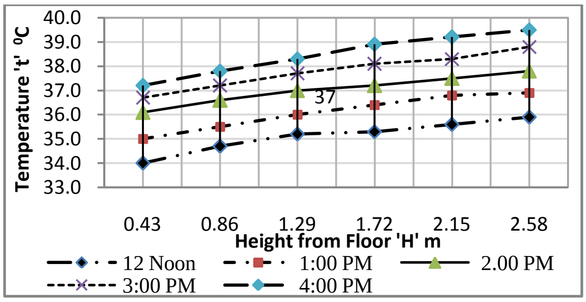


Fig. 4 Case I (RVEC – Rooftop ventilators not working)

Figure 5 shows plots when the Rooftop ventilators are working and windows are not covered with wood wool pads. At the same height from the floor and around 2 pm, the temperature recorded was 35.9^0C noting a drop of 1.1^0C when rooftop ventilators were working. But when the windows were covered with wood wool pads and rooftop ventilators in working mode, a significant drop of 5^0C was achieved compared to Case II as shown in Fig 6.

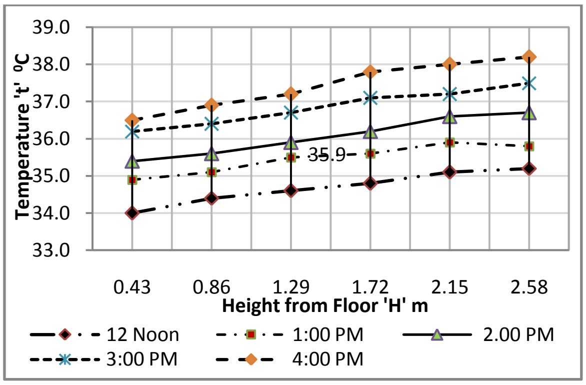


Fig. 5 Case 2 (RVEC – Rooftop ventilators in working)

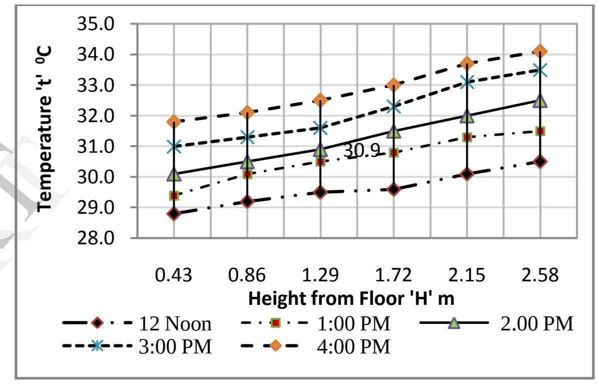


Fig. 6 Case 3 (RVEC – Rooftop ventilators in working with evaporative cooling)

Figure 7 shows a plot of Temperature against Time in all the three cases. It was observed that at any instant of time between 12 to 4 pm, temperature drop was recorded when the windows were covered with wood wool pads with rooftop ventilators in the working stage. A marginal drop was observed when rooftop ventilators are working and an appreciable drop was observed when rooftop ventilators with wetted wood wool pads.

The following correlation is obtained:

$$y = 0.066x^3 - 0.592x^2 + 2.240x + 27.8$$

with $R^2 = 0.997$ which indicates that the developed correlation is reliable and could be used effectively for predicting the average temperature. The correlation is only valid for installation height of 9.1m, hot and arid climate with ACR as 10, RVEC – Rooftop ventilators in working with evaporative cooling (Case III).

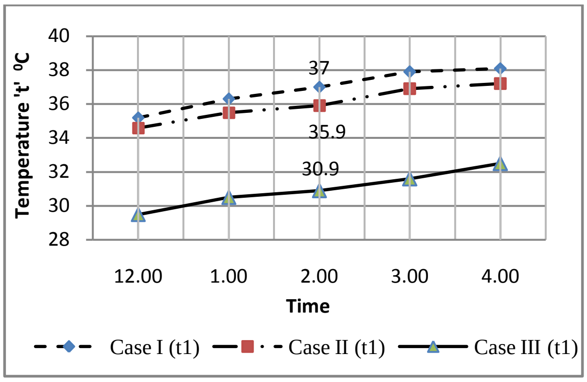


Fig. 7 Comparison of case studies

IV. CONCLUSION:

Comparison of three cases under investigation shows that rooftop ventilators working in accordance with wetted wood wool pad (Case III) perform better than rooftop ventilators in working condition (Case II). Obviously when rooftop ventilators are not working (Case I), it shows poor performance. Case II performs better in hot and humid climatic conditions like monsoon.

A drop of 1.1^{0}C was observed when rooftop ventilators are working and 6.1^{0}C when rooftop ventilators are working with wetted wood wool pads. This temperature drop was against non working of rooftop ventilators.

When national / state grid power is not available during load shading in the day time, Case III is an excellent option in hot and arid climatic condition. Since water dripping from overhead tank being used for wetting the wood wool pads, TOD (time of the day) tariff advantage can be used for water pumping.

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