THE VENTILATION PERFORMANCE OF A SOLAR-POWERED ATTIC FAN IN MALAYSIAN CLIMATE

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Abstract

A study was conducted to investigate the effectiveness of a ventilation system, in providing thermal comfort to the interior space of a building in hot and humid climates. The system consists of a solar powered attic fan with lightweight fan blades powered by photovoltaic (PV) panels. The system is widely used in temperate climate countries to improve interior environments during daytime in the summer, since it is purely solar radiation dependent. The ventilator functions as a heat extractor, extracting out warm air and moisture trapped between the ceiling and roof, thus reducing the heat radiating effect on the living spaces. As a result, the temperature in the occupied space is reduced. The hot air trapped in attic during the daytime becomes a major source of heat. In this study, the temperature, air movement, and humidity inside a room and the attic in which the ventilation system has been installed, were monitored continuously over a certain period of time. Comparisons on the measured values were then made for cases with and without the ventilation system, thus giving an analysis of the overall performance and effectiveness of the system for humid climates. The results of this study could be used for further improvisation of the systems to accommodate the requirements of hot and humid climates.

Keywords : Natural ventilation, PV panels, Air movement, Thermal comfort.

1. Introduction

Air trapped in between the ceiling and roof is a major problem for hot climates. The hot air trapped during the daytime becomes a major source of heat (Abdul Rahman, S. et al., 2004). Insufficient ventilation and attic air exchange are claimed to be among the main causes that contribute to these phenomena. The hot air eventually transfers into the living spaces, sending both utility bills and temperatures soaring. For hot and humid climates, achieving thermal comfort without the use of active energy consuming measures is a great challenge. Studies have indicated that there is a need for both ventilation and dehumidification for regions of these climatic conditions (Abdul Rahman, S. et al., 2004, Zain_Ahmed, A. and Abdul Rahman, S., 2000). Humidity levels play a significant role in the evaporative capacity of the air. When the humidity is high, the high vapor pressure will prevent evaporation thus restricting the cooling effect unless higher air velocities are introduced (Abdul Rahman, S., 1999).

A solar-powered attic fan (Fig.2) is a passive ventilation system mainly designed for the purpose of extracting out the hot air trapped inside the attic of a building while simultaneously drawing in air from outside through the openings at the lower intake vents of roofs (Fig.1). The system consists of lightweight fan blades powered by PV panels. The system was developed for temperate climate countries where the outdoor and indoor temperature difference is substantial but was never tested in hot humid climatic conditions. The attic fan runs best when the solar panel is in direct sunlight. Being dependent on solar panels, it only operates during daytime. However, if it works, the system can provide potential energy and cost savings. Theoretically, by extracting the heat and moisture out of attic spaces, the system consequently reduce the heat radiating effect on living spaces while fighting against mold and control humidity levels like shown in Fig.1.

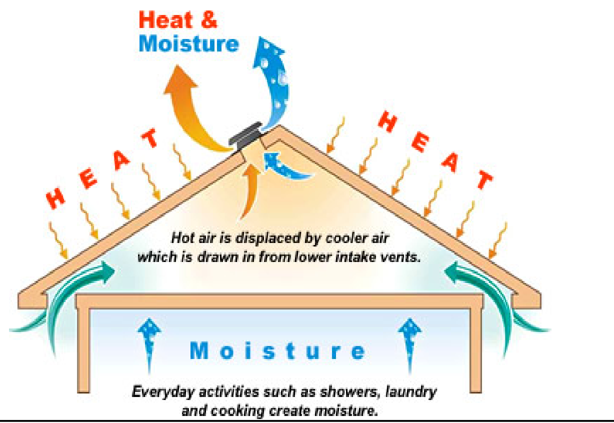

Fig.1 A Solar Powered Attic Fan on operation.
(http://www.solatubeskylight.com/solarstar.html)

Fig.2 Solar-Powered Attic Fan
(http://www.solatubeskylight.com/solarstar.html)

The objective of this paper is to report on the effectiveness of the system in improving the interior conditions of building spaces in hot humid climates by ventilating the attic spaces of the building. The results of this study can be used for further improvisation of systems of similar functions that is currently being developed.

2. Methodology

The solar-powered attic fan was installed in a test room of floor size 4.5 m x 4.5 m and height 3.05 m. The room, which was painted white has one door and two windows on adjacent walls with opening area equivalent to 10% of the floor area as required by the Malaysian Uniform Buildings By Law. The test room has a steel roof with asbestos ceiling. The door was closed during the whole duration of the experiment. The attic fan was located at approximately the center of the room, facing West.

The experimental work was divided into two major parts; measurements in the attic and in the occupied space of the test room for cases with and without the system. However measurements in the occupied spaces included two additional cases of with and without opening. In order to take measurements without the system, the solar panels were temporarily covered with a piece of black plastic disk to block the light from striking it. For cases of without openings, the windows were shut and covered. Since all the experimental works were carried out in the same test room, taking temperature or humidity for different cases simultaneously was not possible. However, the temperature and humidity were always measured simultaneously for every case.

Measurements were taken using Lastem Sensors connected to a data logger which is able to record data automatically over a period of time. The data was then transferred to a computer using a software called Dewesoft. All calculation was done using Microsoft Excell Software. The outdoor climatic parameters were measured and recorded continuously using Symphonie data logger. The sensors for measuring the outdoor data were placed at a height of one meter above the rooftop whereas for the indoor, all sensors were placed at work level, that is 0.75 m above the floor. Interior measurements were taken every minute, while outdoor measurement every 10 minutes for the period between 8:00 am and 6:00 pm. For each case the experiment was repeated twice.

3. Results and Discussions

3.1 Attic Measurements

Tables 1 and 2 show the results for airspeed, humidity, and temperature outdoors and inside the attic for cases without and with the system installed respectively.

Table 1: Outdoor and Indoor Measurement For The Attic Without The System

Time	Attic Humidity (%RH)	Outdoor Humidity (%RH)	Diff in Humidity (%RH)	Attic Temp (DegC)	Outdoor Temp. (DegC)	Temp. Diff. $T_{Outdoor}$ - T_{Attic} (DegC)
8:00:00a.m.	72.648	69.5	-3.148	26.25	25.8	-0.45
10:00:00a.m.	74.671	60.7	-13.971	27.72	29.3	1.58
12:00:00noon	62.274	58.7	-3.574	30.71	33.3	2.59
2:00:00p.m.	60.550	60.0	-0.550	32.62	31.8	-0.82
4:00:00p.m.	60.930	60.5	-0.430	31.73	29.0	-2.73
6:00:00p.m.	66.800	62.4	-4.400	29.65	26.6	-3.05

Table 2: Outdoor and Indoor Measurement For The Attic With The System Installed

Time	Attic Humidity (%RH)	Outdoor Humidity (%RH)	Diff in Humidity (%RH)	Attic Temp (DegC)	Outdoor Temp. (DegC)	Temp. Diff. $T_{Outdoor}$ - T_{Attic} (DegC)
8:00:00a.m.	70.631	58.8	-11.831	31.61	31.61	0.00
10:00:00a.m.	63.417	62.7	-0.717	28.75	32.71	3.96
12:00:00noon	51.418	55.9	4.482	32.93	34.37	1.44
2:00:00p.m.	46.189	57.8	11.611	34.42	34.51	0.09
4:00:00p.m.	46.184	58.8	12.616	32.89	32.58	-0.31
6:00:00p.m.	49.465	61.5	12.035	31.43	32.00	0.57

The results show that there appears to be relative reductions in attic temperature and humidity when the solar attic fan was used as shown in Tables 1 and 2. This is portrayed graphically in Fig.3, Fig.4, Fig.6 and Fig.7. Reduction of attic temperature and humidity is a clear indication that ventilation in the attic has improved. In the morning, the temperature difference was not very significant. However, it appears to increase as the day progresses especially after 12:00 o'clock in the afternoon. This is expected as the PV panels of the system faces West, thus increasing the efficiency of the fans during and consequently the ventilation performance of the system towards the later part of the afternoon. This would be a great advantage as attic temperatures get higher as the day progresses due to the heat being trapped in the attic as the roof is increasingly being exposed to the hot sun.

The results also showed that with the system installed, the attic temperature never went higher than the outdoors. Without the system, the attic temperature was found to be after 2:00 pm (Fig.3 and Fig.4)

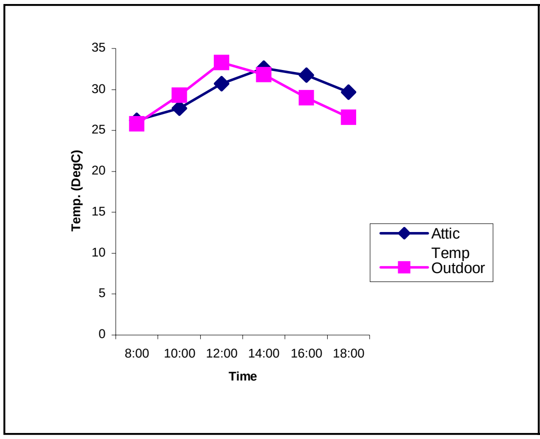

Fig.3 Graph of Temperature Vs. Time For the Attic Without the System

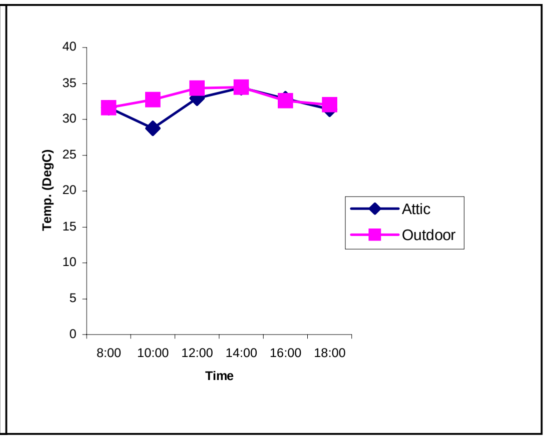

Fig.4 Graph of Temperature Vs. Time For the Attic With the System Installed

Since the measurements were taken on different days, it is also meaningful to observe the temperature differences rather than the true temperature. Fig.5 shows that the temperature differences is positive for all cases except one, when the system was installed, indicating that the attic temperature was lower than the outdoor temperature for most of the time.

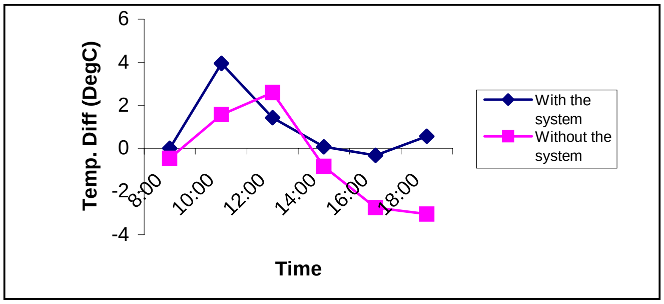

Fig.6 and Fig.7 show a significant decrease in humidity inside the attic compared to humidity outside when the attic fan was used. This is a very positive effect of the system as moisture in the attic can promote mold, fungal decay and plywood delamination.

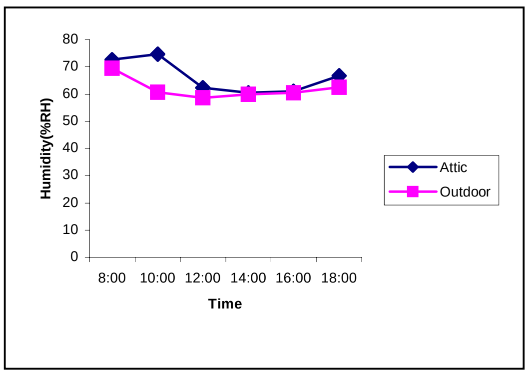

Fig.6 Graph of Humidity Vs. Time in the Attic (Without The System)

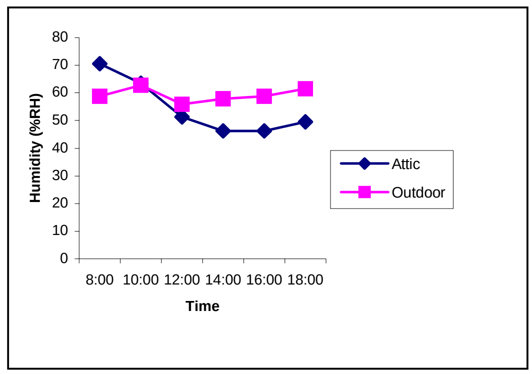

Fig.7 Graph of Humidity Vs. Time in the Attic (With The System)

Although results have shown significant changes in temperature and humidity, the airspeed in the attic was found to be very minimal. Table 3 below shows the average solar radiation and the average relative airspeed in the attic with and without the system taken from 12:00 o'clock in the afternoon until 6:00 p.m. With solar radiation as low as 4.97 W/m^2, there appears to be no significant difference in the performance of the attic fan when compared to when the solar radiation was 18.87 W/m^2, indicating that the PV panels have a high efficiency.

Table 3: Airspeed in The Attic Compared to The Solar Radiation

Cases	Average Solar Radiation (W/m^2)	Average Airspeed in Attic (m/s)
Without Attic Fan	18.87	2.507×10^{-4}
With Attic Fan	4.97	2.42×10^{-4}

3.2 Occupied Space

Tables 3 and 4 show the results of measurement inside the occupied space. It can be seen that the system does give a significant impact on the indoor temperature and humidity. The decrease in the indoor air temperature can be clearly seen Fig. 8 to Fig.10.

Table 3: Outdoor and Indoor Measurement For The Occupied Space Without The System (Without Opening)

Time	Humidity (Occ space) (%RH)	Outdoor (%RH)	Diff in Humidity	Temp. (Occ space) (DegC)	Outdoor (DegC)	Diff in Temp (DegC)
8:00a.m.	70.99	61.8	9.19	27.85	27.6	-0.25
10:00a.m.	57.74	59.4	-1.66	27.76	31.3	3.54
12:00noon	46.36	58.3	-11.94	27.96	33.5	5.54
2:00p.m.	48.30	59.1	-10.80	28.08	30.8	2.72
4:00p.m.	58.03	59.0	-0.97	28.59	30.1	1.51
6:00p.m.	64.67	60.7	3.97	28.60	28.7	0.10

Table 4: Outdoor and Indoor Measurement For The Occupied Space With The System Installed (Without Opening)

Time	Humidity (Occ space) (%RH)	Outdoor (%RH)	Diff in Humidity	Temp (Occ space) (DegC)	Outdoor (DegC)	Diff in Temp (DegC)
8:00	51.32	61.9	10.58	26.82	26.9	0.08
10:00	44.79	60.6	15.81	26.86	30.4	3.54
12:00	41.45	59.3	17.85	27.1	31.4	4.30
2:00	47.52	59.5	11.98	27.6	30.5	2.90
4:00	49.52	58.9	9.38	28.29	31.7	3.41
6:00	48.94	61.5	12.56	28.36	26.6	-1.76

Fig.8 and Fig.9 are the results for the cases of no opening whereas in Fig.10 and Fig.11, windows were opened to provide openings on the adjacent walls. It can be observed from Fig.9 that using the solar attic fan without opening gave the best result in reducing the air temperature inside the occupied space relative to the outside conditions. It is interesting to note that despite the outdoor air temperature that fluctuated drastically due to the change of weather, the indoor temperature changed only gradually indicating that the building enclosure were able to provide relatively good protection against temperature fluctuations.

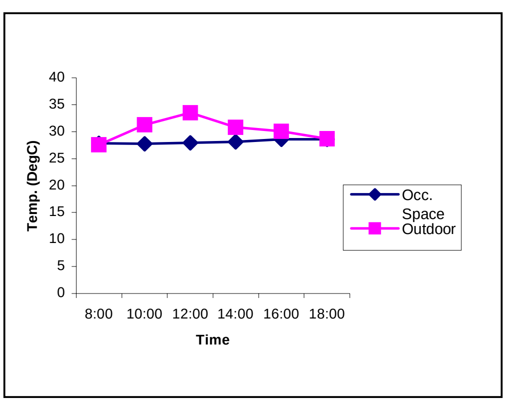

Fig.8 Graph of Temperature Vs. Time For the Occupied Space Without the System (Without Opening).

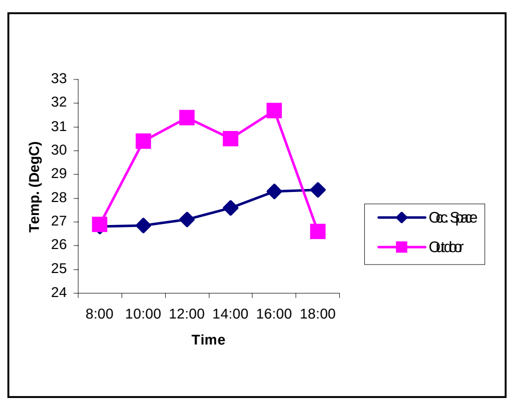

Fig.9 Graph of Temperature Vs. Time For the Occupied Space With the System (Without Opening).

As shown in Fig.9 and Fig.11, the temperature differences between the outdoor and the occupied space decreases when there is opening in the occupied space. This shows that the presence of openings presents an avenue for heat entry, thereby increasing the temperature of the interior space.

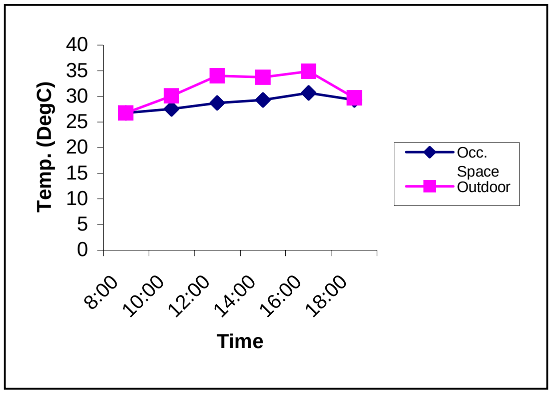

Fig.10 Graph of Temperature Vs. Time For the Occupied Space Without the System (With Opening)

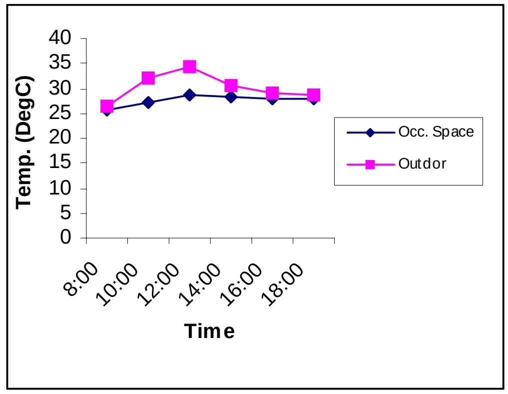

Fig.11 Graph of Temperature Vs. Time For the Occupied Space With the System (With Opening).

Fig.12 is the results for the case of the occupied space without the Attic Fan. As could be seen in Fig.13, the presence of the attic fan really reduced the humidity levels inside the occupied space. In order to achieve thermal comfort, reducing the humidity level is essential. Air temperature and humidity are two major factors that influence thermal comfort. The accepted humidity level for buildings occupants to stay thermally comfortable is 40 – 70%RH (**http://www.acc.co.nz**). However, in high temperature regions like Malaysia, a lower humidity is definitely more favorable as this would translate to withstanding higher temperatures.

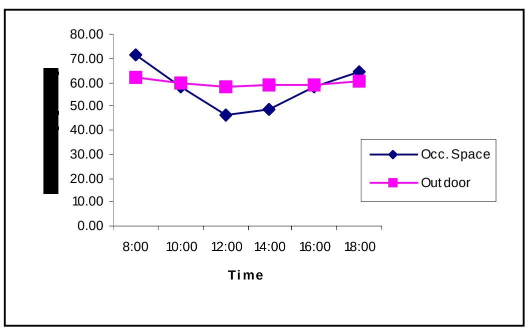

Fig.12 Graph of Humidity Vs. Time For The Occupied Space Without The Attic Fan

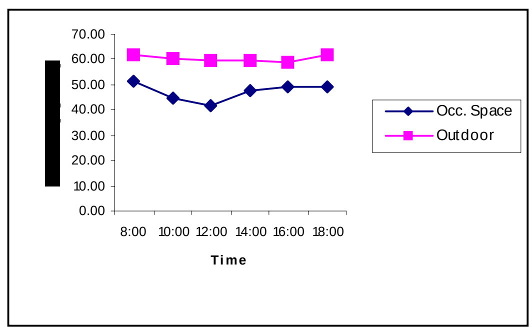

Fig.13 Graph of Humidity Vs. Time For The Occupied Space With The Attic Fan Installed

4. Conclusions

From this study, it can be concluded that introducing good ventilation in the attic could be one effective way of reducing air temperature and humidity in buildings. It was also shown that the presence of openings can cause a relatively significant increase in interior temperatures. In general, the use of solar-powered attic fan in Malaysian climate has shown positive effects towards achieving thermal comfort. The results show that the system does succeed in reducing the air temperature and humidity levels inside a building. When humidity level is low, human body could compromise a higher temperature to stay comfortable compared to a more humid environment. The application of this fan would be optimum if additional outlets were provided for in the ceiling for the warm air in the interior space to escape while creating air movement. The application of the system can be a good potential energy and money savings strategy in a long-term as it requires no maintenance and no cost of operation, besides being environmentally friendly. However, being solar radiation dependent, the function is limited during daytime only. In addition, the use of solar panels makes the system expensive and unaffordable to all levels of consumers although it is a worthy investment.

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