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DESIGNING OF A THAI BIO-CLIMATIC ROOF

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ABSTRACT

This paper presents an innovative roof design. The roof is designed in response to the Tropical climate of Thailand with respect to human thermal comfort. It is composed of a combination of CPAC Monier concrete and transparent tiles on the outer side, air gap and another combination of gypsum with aluminum foil board and translucent sheets on the house side. It has two functions in operation: In daytime the roof acts as a solar chimney and induces natural ventilation. The transparent tile provides not only sufficient daylight for housing but also help in increasing the ventilation rate. In nighttime, the Thai bio-climatic roof plays the role of a roof radiator to dissipate the heat accumulated during daytime by long-wave radiation to the sky dome. The roof surface temperature decreases below ambient in several degree celcius. The cool air located between the two sides of roof flows downward providing nocturnal cooling.

KEYWORDS

Bio-climatic; daylight; natural ventilation; nocturnal cooling; energy conservation.

INTRODUCTION

Since the energy crisis in 1970s, the energy conservation is receiving serious consideration not only in industrial sector but also at residential scale. Building design with climate has become the important tool for both energy and environment conscious (Zuhairy *et al.*, 1993). It is now generally accepted that the use of daylight and use of solar energy to enhance natural ventilation is one of the solutions for energy conservation (Gallo *et al.*, 1998). On average, exterior illuminance is considerably high in the Tropical hot and humid climate of Thailand. Thus, the mean to obtain human thermal comfort is to induce natural ventilation during daytime by solar chimney (Khedari *et al.*, 1997) and night radiation cooling during nighttime (Khedari *et al.*, 2000). Although lighting technology was rapidly developed and the utilization of high efficacy fluorescent lamps (Ryan 1990) was implemented in Thailand, the natural light from the luminous sky over this region has not been considered mainly because of constraint of overheating. The objective of this paper is, therefore, to design a roof which can provide sufficient natural light while avoiding overheating. Consequently, this innovative roof design, called a Thai bio-climatic roof, can provide sufficient daylight, induce high ventilation rate and decrease both the overheating due to the natural light and the heat transmitted into houses through roof structure. That means an efficient device for energy conservation in buildings.

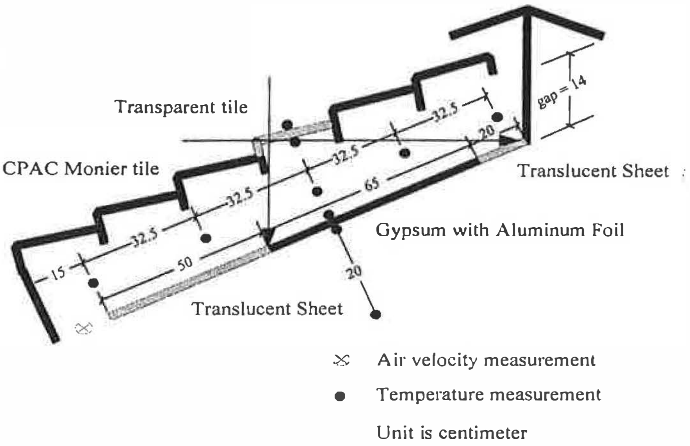

Fig. 1. Configuration of the Thai bio-climatic roof (BCR) and the positions of measurement.

EXPERIMENTAL SETUP AND RESULTS

A Thai bio-climatic roof (BCR) is composed mainly of two parts as shown in Fig. 1. The upper part is a combination of CPAC Monier concrete tiles and transparent tiles and the lower one is a combination of gypsum with aluminum foil board and translucent sheets. Dimensions were calculated in order to avoid direct translucent exposition to sun rays. The performance of BCR was compared to a roof solar collector (RSC) experimentally. Both units of 1.5 m^2 surface area each were integrated into the roof of the school single-room solar house of 25 m^3 approximately. Plywood boards were used to separate the interior space under the two units (BCR and RSC). Type K thermocouple wires were used to record temperature at various points of both roofs. The inlet air velocity was measured by a hot wire anemometer. The illuminance on work plane was measured by using a lux meter two times: when the outdoor illuminance delivered through the openings (door and window) was allowed /not allowed respectively. The different positions of measurement are illustrated in Fig. 1. Global radiation and ambient air temperature were also recorded. Data were recorded every 30 minutes during 24 hours. The sky condition during nighttime was observed and approximately quoted. The experiments were carried out in winter season (23 December 1999).

Fig. 2. shows that the average air gap temperature of BCR is much higher than that of RSC. This is, obviously, due to the transparent tiles which admit not only daylight but also heat. However, the room temperature (measured at 1.50 m above floor) did not increase following the air gap temperature that is extremely important as no overheating was observed due to daylight. The experimental results showed that the room temperature under BCR is lower than room temperature under RSC. We remind that the two room sections below BCR and RSC were separated by plywood boards. During daytime, the room temperature of BCR section is slightly higher than ambient air between noon until 6 p.m. whereas the room temperature of RSC is higher than ambient air by about 2 C. This demonstrates that the utilization of daylight is possible without any overheating.

In nighttime, the temperature of the sky is lower than ambient air and the roof surface is cooled by long-wave radiation. The experimental results show that BCR dissipated the heat accumulated in CPAC tiles during daytime more rapidly than RSC. After sunset, the room temperature of BCR is lower than ambient air all the night by about 1 C in average while the room temperature of RSC becomes below than ambient air only after 4 a.m..

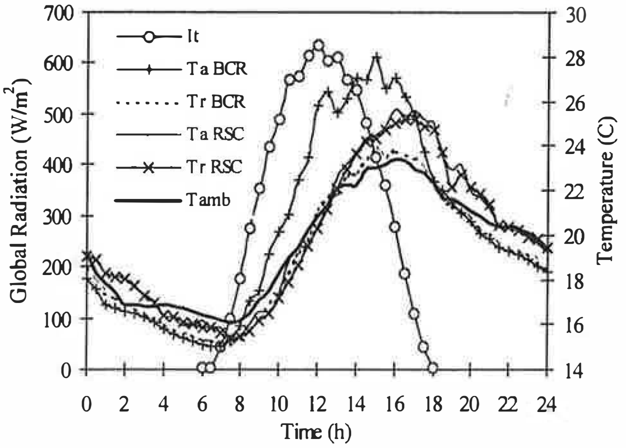

Fig. 2. Variations of global radiation, average air temperature and room temperature of both roofs.

Fig. 3. shows that the amount of room daylight depends directly on the global radiation intensity. Furthermore, it indicated that when the outdoor illuminance was not allowed through the room openings (door and window were masked), the amount of daylight delivery through the transparent tile and translucent sheet of BCR on the work plane is considerably high varying between 100-150 lm/m^2 during office hours (9:00-16:00). The amount of daylight delivery through the openings (door and window) is about 50 lm/m^2 approximately. Although the experiments were done during winter-the sun in the sky is low-however, we showed that this innovative roof design is very effective.

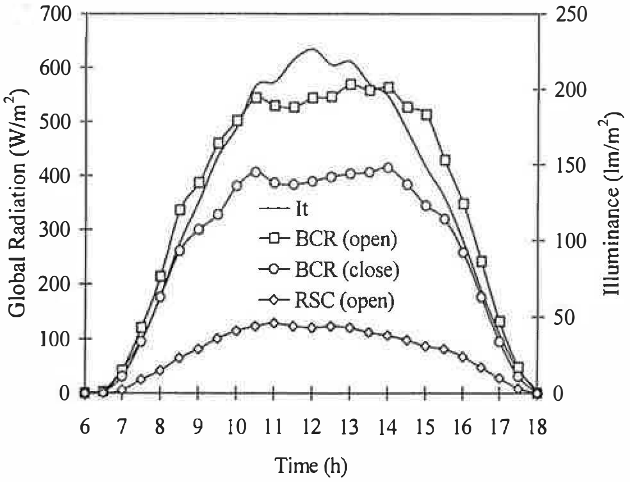

Fig. 3. Hourly variations of illuminance on work plane and solar radiation on horizontal plane.

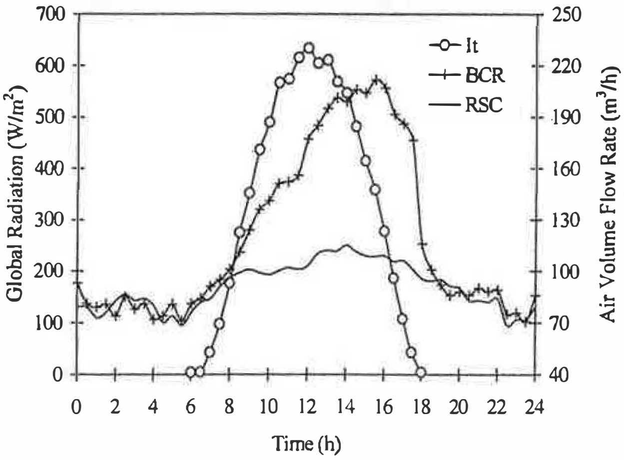

Fig. 4. Variations of air volume flow rate and solar radiation intensity.

From Fig. 4., it can be seen that the admission of daylight to room through the roof structure yields to a high ventilation rate. During daytime, the induced air flow rate of BCR is about twice than that of RSC. With only 1.5 m^2 of surface area, the resulting air change (ACH) was about 8 times, which is extremely important. During nighttime, the air volume flow rate of both roofs is nearly close.

CONCLUSION

The new bio-climatic roof design can not only help in increasing ventilation rate but also prevents overheating and provides sufficient lighting during daytime. During nighttime, it can dissipate the heat accumulated rapidly. With these features, the bio-climatic roof can lead to achieve complete residents' thermal comfort without any mechanical devices during a long period annually. Testing its performance during summer is scheduled and will be presented during the WREC meeting. This innovative concept could, of course, be applied to the other houses' component that is the wall.

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