A NEW DESIGN OF ROOF SOLAR COLLECTOR MAXIMIZING NATURAL VENTILATION

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ABSTRACT :

The paper discusses the performance of a construction element : the Roof Solar Collector (RSC) with regard to the rate of induced natural ventilation which contribute to improve houses indoor thermal comfort. The RSC configuration was made by using modern materials : CPAC monier concrete tiles on the outer side and gypsum board on the inner one. The comparison of numerical results with available experimental data validated the developed model. The effect of RSC parameters, mainly, tilt angle and length was analyzed numerically. Finally, a new configuration of RSC was proposed.

KEY WORDS : Design, Roof Solar Collector, Simulation, Natural Ventilation.

1 Introduction

The need for indoor thermal comfort of building is greatest in tropical countries, where high annual temperature are predominant. Today's technology can be used to provide required thermal comfort, but the economical penalty is high. Thus, passive solar designs of building are being interested again today.

One interesting application of passive solar cooling [1-2], is to induce natural ventilation. Ventilation provides cooling by using moving air to carry away heat from building, making comfortable for the building occupants.

In this study the large area of roof is used to reduce the heat accumulation under the roof structure and to induce suitable natural ventilation [3-4]. However, as experiments cannot research all condition and need long time, analyze of the performance of the "Roof Solar Collector" is done numerically

2. Modelling of RSC

The roof solar collector is made by using CPAC monier roof tiles on the upper part and gypsum at the lower part, as shown in Fig. 1

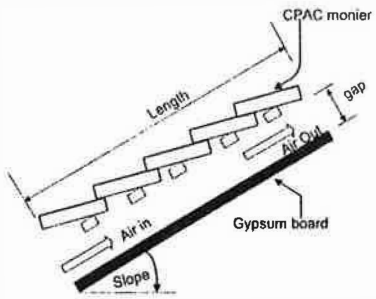

Fig. 1 Schematic representation of RSC

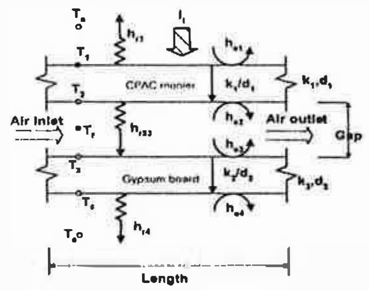

Fig. 2 Node and heat transfer exchangess through the RSC

Heat transfer is considered to be steady state and one dimensional and thermal capacity of material are neglected. The radiation exchange between CPAC monier and gypsum is accounted for, since the heat transfer fluid is regard as a non-radiation absorbing. The inlet air temperature is considered equal to ambient temperature. Considering Fig. 2, under the preceding assumptions, a nodal formulation of RSC system is provided by performing an energy balance on each node of the RSC.

- On monier-upper surface

$$(\alpha_m) I_t A = (h_1 + h_{r1}) A (T_1 - T_a) + (k_1 / d_1) A (T_1 - T_2) \quad (1)$$

- Monier-lower surface

$$(k_1 / d_1) A (T_1 - T_2) = h_{c2} A (T_2 - T_a) + h_{r23} A (T_2 - T_3) \quad (2)$$

- Upper surface of gypsum board

$$h_{r23} A (T_2 - T_3) = h_{c3} A (T_3 - T_f) + (k_2 / d_2) A (T_3 - T_4) \quad (3)$$

- Lower surface of gypsum

$$(k_2 / d_2) A (T_3 - T_4) = (h_{r4} + h_{c4}) A (T_4 - T_a) \quad (4)$$

- section of moving air

$$m C_p (T_o - T_i) = h_{c2} A (T_2 - T_f) + h_{c3} A (T_3 - T_f) \quad (5)$$

- Solar chimney equation [5]

$$Q = C_d A_o \{ g H \sin\theta (T_o - T_i) / T_i \}^{0.5} \quad (6)$$

The different heat transfer coefficients are discussed in detail in reference [6]. The ambient conditions (solar radiation, ambient temperature, wind velocity) used are those based on data of Bangkok [7-9]. The above set of nonlinear algebraic equations are solved using Newton-Raphson method [10].

3 Numerical Results

3.1 Validation of numerical model

The figure 3 shows that the calculated results of air RSC temperature followed well the ambient condition. It can be seen a few disagreement with the measured data. This is mainly due to the effect of rain heat loss and wind which weren't accounted in the model. However, regarding the weak temperature difference between the RSC air and the ambient air, and also with the quite weak wind speed (about 1.5 m/s for Bangkok), the developed numerical model can be considered as a good approximation, for estimating the long- term performance of RSC.

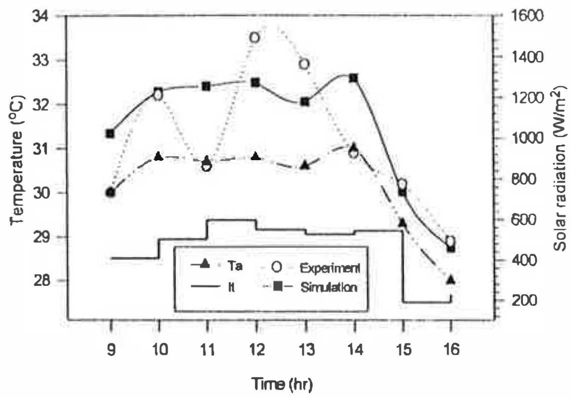

Figure 3 Hourly variation of RSC air temperature and ambient conditions (length 2 m)

3.2 Effect of RSC' parameters

The results are presented parametrically by selecting a base case and varying one parameter at a time whereas the other RSC's parameters are kept constants. In this study, the air inlet and outlet surface areas were considered equal, and the width and gap of RSC were fixed at 100 cm and 14 cm, respectively.

Figure 4 shows that the induced air flowrate is a function of slope and the intensity of solar radiation. Up to 30°, the induced air flowrate increased rapidly with increasing the tilt angle. However the vertical height still small to induced higher air flowrate although the energy absorbed by tiles is higher. For $\theta > 60°$, the increased of air flowrate was quiet insignificant. Consequently, for the further design of RSC's systems, the appropriate rang of tilt angle should be considered between 20° to 60°.

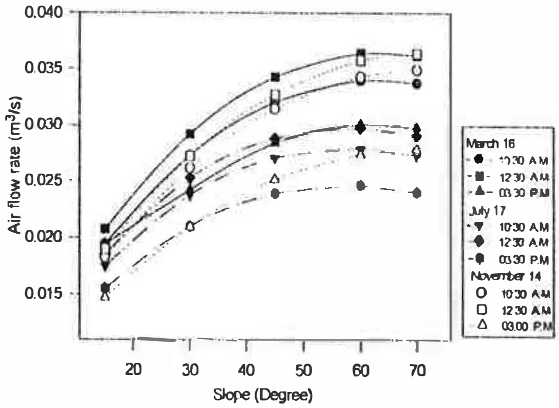

Figure 4 Variations of the air flow rate Vs. slope of RSC for different months at different times (Gap: 0.14 m; Length: 2 m).

Figure 6 shows that for all slopes, increasing the length of RSC increased the air flowrate which is a consequence of the increased vertical height of ventilation path.

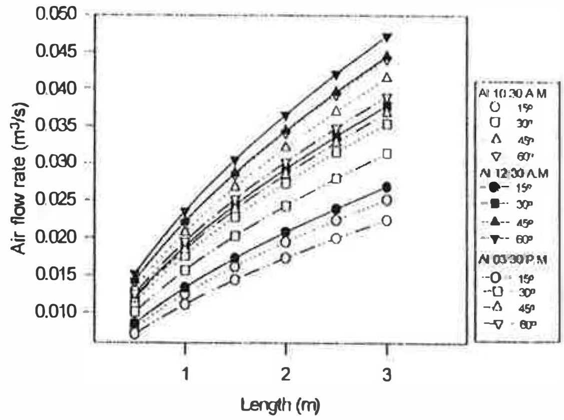

Figure 5 Variations of air flowrate with length of RSC at three different times for different slopes (March 17, Gap: 0.14 m).

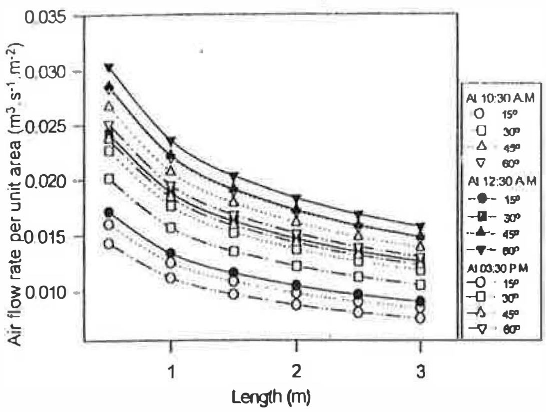

Figure 6 Variation of air flowrate per unit area of RSC Vs. length at different times for different Slopes (March 17, Gap: 0.14 m).

However, as shown in figure 6, the air flow rate per unit area decreased with increasing length of RSC. Thus, the amount of air flowrate induced by one longer RSC would be lower than that induce by two units of RSC with a total length equal to that of the longer unit. Therefore, to maximize the air ventilation by RSC's system, the length of RSC should be shorter on the order of 100 to 200 cm. This length could be selected by architects depending on available surfac area of roof

Based on preceding results, the RSC's concept can be used to induce a natural air circulation within the roof structure, which consequently will reduce the heat accumulation under the roof. Fig. 7 presents a first approach for the new design of roof of new houses.

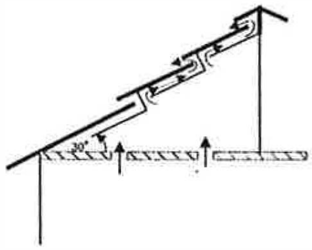

Fig 7 Schematic view of proposed new design of RSC's system

4 Conclusion

Roof Solar Collector can provide a significant part of ventilation air flowrate of houses. The proposed configuration of RSC system has to be verified with a full scale testing. With only RSC system, there is a little potential in inducing sufficient natural ventilation to satisfy resident's comfort.

However, if it is coupled with other passive cooling devices such as Trombe wall and/or small mechanical system, the cooling efficiency will be improved considerably.

5. References

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