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# ANALYSIS OF A PASSIVE COOLED BUILDING FOR THE SEMIARID CLIMATE

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## 1. Introduction

Recently, Srivastava et al (1) have reported the design and thermal performance of a hostel building using passive cooling approaches for a Jodhpur climate in India. The proposed hostel was of 14 single-room apartments with a toilet and kichenette and with two lobby rooms with a provision of a tower on the roof of the lobby. Cool air can enter into various rooms through the lobby.

The following cooling approaches have been built into the design of a hostel suitable for semiarid climatic conditions (Jodhpur, India):

- o a tower has been erected over the lobby;
- o a courtyard for free air movement is provided;
- o rooms have been built partially sunk;
- o a fan with water evaporative pads has been provided in room;
- o evaporative cooling system over the roof has been used;
- o white painting has been used on the roof.

In order to analyse the performance of the proposed design, they have developed a periodic analysis of the system based on Fourier series (in time) expansions of solar insolation and ambient air temperature. They have only considered a unit of seven rooms, one lobby and a courtyard for the analysis, with the following assumptions:

- the walls are single-layered structures made of stone;
- heat flow has been averaged over the time period for partitioned walls;
- there is continuous operation of a fan with an evaporating pad;
- average flow velocity of air through tower has been taken into account;



- cool air coming through the tower has been distributed equally in all rooms;
- heat loss through the sunk portion of the walls and the floor has been taken into account by solving the one-dimensional heat conduction equation;
- heat capacities of the partition walls are equally divided and have been taken into account in the isothermal mass of the respective rooms.

On the basis of their numerical calculations, they have produced the following results:

- partially sunk rooms give a better cooling effect than others;
- evaporative cooling over the roof and cooling fan alone gives better thermal load levelling than any other combinations of cooling systems;
- tower and exhaust chimneys give a better cooling effect in night than untreated rooms;
- changing the flow rate of the cooling fan has an insignificant effect on its performance.

Jodhpur is a representative of the semiarid climate in India where, in summer, the maximum ambient air temperature is 40°C, relative humidity is 28% and substantial wind in the south-east direction is present. Under this type of climatic conditions, the use of a tower and exhaust fan during the day is not useful. Hence, one should open the tower with evaporating pads during the night-time, when ambient air temperature becomes very low, as suggested by Srivastava et al. (1). This effect has not been considered explicitly in the analysis by Srivastava et al. (1). They have considered an average value of wind velocity throughout the day due to which its effect is adverse during the day (curve 3 of their Fig. 3). Also, the use of a desert cooler throughout the day is not advisable because the hostels are generally not used during the day-time, hence, it is necessary to see the effect of intermittent use of the desert cooler on its performance, which has also not been considered by Srivastava et al. (1) in their analysis.

In this communication, a comprehensive analysis of the proposed design by incorporating the effect of intermittent use of tower opening and desert cooler has been presented. Some modification in the design has also been made. It was observed that the fluctuation in room temperatures observed previously is reduced significantly, which is important from the thermal comfort point of view in designing any solar house.

The modifications proposed in the design of hostels are as follows:

- All walls exposed to the atmosphere should be white

After knowing $[T_{jn}]$, the room air temperature $T_{jR}$ can be calculated from equation (12).

## 3. Results and Discussion

Equation (14) has been computerised for determining the room air temperature for the same sets of parameters as used by Srivastava et al.(1) except a change in the value of isothermal mass and intermittent use of tower, desert cooler and intermittent value of some heat transfer coefficients, as mentioned in the Introduction and Analysis.

Figure 2 shows the variation of the room air temperature of room 1. Curve 1 represents the room air temperature without any treatment, for comparison purposes. The variation of the room air temperature with use of the tower and exhaust chimney during the night is shown by curve 2. It is clear from the curve that use of the tower gives more comfortable temperature along with load levelling, in comparison with the analysis of Srivastava et al.(1) (dashed line) because they have not considered this effect explicitly. Also, the variation in temperature due to the tower and desert cooler are exactly the same, and approach the same behaviour as obtained by the evaporative cooling system. Since water is an acute problem in desert areas, one should always prefer to use a tower or desert cooler during off-sunshine hours, when the ambient air temperature becomes very low.

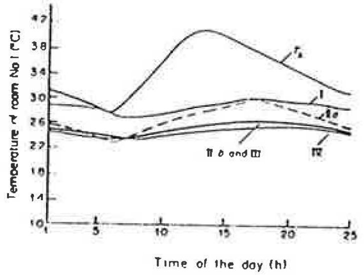


Fig. 2. Variation of the room air temperature of room 1 with time. (I) Without any treatment; (II) tower and exhaust chimneys open at night: (a) Srivastava et al. [1], (b) present model; (III) desert cooler fan working at $m_c$ = 0.5 kg/s, $T_o$ = 20°C along tower and exhaust chimneys only in night; (IV) evaporation cooling [1].

Further, on the basis of the numerical calculations, in addition to the above results, the other conclusions can be summarized in the following form:



- Opening of windows during night-time, along with a water pad, also gives a more comfortable temperature range (1-1.5°C below curve 1), due to the fact that cross-ventilation occurs between the window and exhaust chimney.
- Opening of windows has an insignificant effect during operation of the tower or desert cooler during the night, but gives an adverse effect.
- The operation of the tower and desert cooler gives a significant effect in the first-floor rooms, in comparison to the ground-floor rooms.
- The decrease in isothermal mass, i.e. replacement of partition wall by wood, tends to give more fluctuation in room temperature.
- The combined effect of the tower and desert cooler during night hours gives better performance than the evaporative cooling system (average No.1 room air temperature is about 23°C).
- The use of the tower and desert cooler, working at 20°C during night hours, along with the evaporative cooling system over the roof, gives the best results among the rest of the combinations of various cooling approaches (average No.1 room air temperature is about 21-22°C).

## 4. References

(1) Srivastava A., Nayak, J.K., Tiwari, G.N. and Sodha, M.S., Energy Building, 6, 3 1984.

(2) Tiwari, G.N., Garg, H.P., Singh, U. and Madhuri, Energy Convers. Mgmt. 24, 223, 1984.

(3) Shauiv, E. and Shauiv, G. Architectural Sciences and Design Methods, working paper ASDM-8, 1979.

(4) Tiwari, G.N., Int. J. Solar Energy 3, 19, 1984.

(5) Tiwari, G.N., Energy Conversion and Management, 26, 375, 1986.

## 5. Nomenclature

A = Area ($m^2$)
C = Specific heat (J/kg°C)
h = Heat transfer Coefficient(W/$m^2$°C)
M = Heat capacity (J/°C)
$\dot{m}$ = Mass flow rate (kg/s)
$\dot{Q}$ = Rate of heat transfer (W/$m^2$)
T = Temperature (°C)
$\alpha,\tau$ = Absorptivity and transmittivity

**Superscripts**

C,Ch = Cooler and Tower
D,IS = Door and Isothermal
j-k = jth to kth
F,R,W = Floor,roof and wall
WI = Window