CHAPTER 4

PERFORMANCE OF ROOF STRUCTURES IN SUMMER

4.1 PROBLEM INVESTIGATED

The heat transfer across the roof structures during July (one of the hot summer months) is investigated. As discussed in Chapter-3, the problem is modeled and analysed. The boundary conditions are applied appropriately. Figure 4.1 shows the atmospheric temperature variation applied over 24 h of the day and Figure 4.2 shows the solar radiation applied. The program is actually started on March 1\textsuperscript{st} with the boundary conditions during March month. On 1\textsuperscript{st} April, the condition at mid night of 31\textsuperscript{st} March is taken as the initial condition. Similarly for each day, the solution is advanced up to 28\textsuperscript{th} February of the next year. The Figures 4.1 and 4.2 show the atmospheric temperature and the solar radiation data used during July. The results shown are the results obtained on 15\textsuperscript{th} July.

Figure 4.1  Variation of atmospheric temperature over 24 hours of the day on 15th July
Figure 4.2 Variation of solar radiation on the roof surface over 24 hours of the day on 15th July

4.2 TEMPERATURE DISTRIBUTION ACROSS THE ROOF STRUCTURE

The variation of temperature across the roof structures on 15th July is shown in Figure 4.3(a), 4.3(b) and 4.3(c). The top surface of the roof is taken as $x=0$ and the bottom surface is taken as $x_m$ and the distance is normalized as $X^*=x/ x_m$.

Figure 4.3 (a) Temperature distributions across the RCC roof structure on 15th July
Figure 4.3 (b) Temperature distributions across the WC roof structure on 15\textsuperscript{th} July

Figure 4.3 (c) Temperature distributions across the PCM roof structure on 15\textsuperscript{th} July
Due to low thermal inertia, RCC roof shows faster response to the variation in the external weather conditions as shown in Figure 4.3 (a). From 20 h to 8 h, heat is lost from the roof to the external atmosphere. Thus, the roof temperature drops continuously at a given location. Due to increase in atmospheric air temperature and incident solar radiation, the roof temperature continuously raises from 8 h to 14 h. From 14 h to 20 h, the temperature of roof near top decreases. However, at the bottom portion of the roof the temperature raises as the heat stored at the middle moves in both the directions. In general, the roof top surface temperature varies from 27 ºC to 43 ºC and at the roof bottom varies in the range between 26.5 ºC – 34 ºC over the day during July.

In case of WC roof, due to more thermal resistance offered by the weathering coarse portion, the variation in external climate is damped in the WC portion and lesser fluctuations are observed in the RCC portion of the roof as shown in Figure 4.3 (b). The roof top surface varies in the range from 26 ºC to 49 ºC and the bottom surface temperature varies in the range between 26 ºC and 28 ºC. In case of PCM laid roof, almost all the external variations are observed by melting and solidification of PCM and least fluctuations are noticed in the RCC portion of roof as shown in Figure 4.3 (c). From 8 h to 20 h, all the heat entering through the roof top is absorbed by PCM by melting. From 20 h to 8 h, the stored heat is rejected to outside and the melted PCM solidifies during the period. Roof top surface temperature varies from 27 ºC to 49 ºC. The roof bottom surface temperature remains very close to the room inside temperature (25 ºC).

The melting and solidification of PCM over the day is shown in Figure 4.4. The melt fraction of 1.0 represents fully melted and 0.0 represents 100 % solid. At 6 h, a thin layer of PCM at the roof top side and about 80 % of PCM at the bottom side are in solid phase and in between is in liquid
phase. Due to heat entering into the roof top, the thin solid PCM at roof top side starts melting from 8 h and it is fully melted around 12 h. Melting of solid PCM at the bottom portion happens from 12 h up to 18 h. From 18 h, outside temperature is lower than the roof top temperature. Therefore, heat is rejected from the roof to the outside air. Thus, the liquid PCM at the top layer starts solidifying from 18 h and proceeds up to 6 h in the next day morning. As more heat entered into the roof than that is rejected, the total area of melted zone has increased slightly at the beginning of the next day. Similar melting – solidification cycle is repeated on all the days.

![Diagram](image)

**Figure 4.4** Melt fractions during various hours on 15\textsuperscript{th} of July

### 4.3 ROOF TEMPERATURE VARIATION OVER THE DAY AT SPECIFIC LOCATIONS

The roof temperature variations over the day on 15th July at specific locations are shown from Figure 4.5 to Figure 4.7.
Figure 4.5 Temperature variations over the day for RCC roof (15, July)

Figure 4.6 Temperature variations over the day for WC roof (15, July)
When the thermal inertia is more, the roof responds faster with the variation. Accordingly, the roof top surface temperatures are lower and the roof bottom surface temperatures are higher with RCC roof, when compared to other two roofs. The top surface temperature variation of WC and PCM roofs is almost same. As thermal inertia is more with the WC roof, the bottom surface temperatures obtained with WC roof are lower and with a time lag of about 11-12 hours. As the most of the heat flowing in to the roof top during sunny hours is stored in the PCM by melting and the same is rejected during night hours, the roof bottom surface temperatures obtained with PCM roof is almost constant over the year and is the lowest when compared to the other two roofs.

The roof bottom surface temperature shown in Figure 4.8 directly decides the heat entering the room. The roof bottom surface temperature is the lowest with PCM, about 2-3 °C higher with WC roof and about 3-10 °C higher with RCC roof. The PCM roof offers almost uniform temperature at roof bottom over the day. Mild fluctuations are observed with WC roof and large fluctuation with RCC roof.
4.4 HEAT FLOW INTO THE ROOM ACROSS THE ROOF

The total quantity of heat entering the room over a day through the roof can be calculated by summing up the heat flowing through each hour over 24 hours of the day. The heat flow per unit area over a day is calculated for all 31 days. Such values, averaged for a day in July month, are shown in Figure 4.9.

The quantity of heat entering the room is directly proportional to the difference between the roof bottom surface temperature and the room air temperature. Lesser the difference, lower is the heat entering into the room, which is preferable. The differences are the largest with RCC roof, moderate with WC roof and the least with PCM roof. In case of PCM roof, as all external variations are absorbed by melting and solidification of PCM, the RCC-PCM interface temperature remains constant over the day.
On 15th July, the heat entering the room during 24 hours is 2.535, 1.137 and 0.2623 MJ/m$^2$-day with RCC, WC and PCM roofs respectively. The heat entering through the PCM roof is 89.65 % lower, when compared to bare RCC roof and 76.92 % lower when compared to the conventional weathering coarse laid roof (marked as WC).