How cool roofs interact with PCMs: investigating thermal-energy behavior of a cool roof membrane with paraffin based PCM inclusion

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1 EXTENDED SUMMARY

The effect of Phase Change Materials (PCMs) to optimize indoor thermal comfort conditions and reduce cooling energy requirement when included in envelope components and materials is demonstrated by an extensive scientific literature (Zhou et al., 2012. Orò et al., 2012). In this view, this research consists of the development and prototyping of an innovative passive cooling polyurethane based membrane with PCMs inclusion for roofing applications (Pisello et al., 2015). The nanoscale morphological characteristics of the composite membrane are assessed and compared to the classic one without PCM inclusions. Then, thermal-optical properties are determined through laboratory analyses. Additionally, calorimetry tests are performed to study the role of different concentration and phase change temperature of PCMs in terms of thermal storage/release potential. In particular, PCMs with transition temperatures at 25°C and 55°C are considered. Finally, the thermal-energy analysis of such composite membrane is performed by means of calibrated dynamic simulation of a prototype building located in central Italy (Figure 1). In particular, the effect of PCMs with varying phase change temperature is assessed in different climate conditions both in winter and summer conditions. To this aim, the roof configurations are simulated and compared with and without the integration of PCMs with different transition point i.e. 25°C, 35°C, 45°C, and 55°C, in Mediterranean climate, i.e. Rome, and in Hot desert climate, i.e. Abu Dhabi. Additionally, the inclusion of PCMs into non-cool bitumen based membrane is evaluated with the purpose to optimize the choice of the proper PCMs by taking into account the passive cooling capability of the inclusion medium.

2 DISCUSSION

The prototyping procedure showed that non-capsulated paraffin-based PCMs are able to be stored in the existing cool roofing membrane and to be distributed into the medium with no technical and operative problems. The results of heat transfer calculation showed that configurations with cool polyurethane-based membrane as roof coating always present lower external surface temperatures and heat gains through the roof, in both summer and winter and for both climate conditions, i.e. Mediterranean (Rome) and Hot desert (Abu Dhabi), due to the higher solar reflectance capability. In summer, the integration of the proper PCM in the cool membrane for Rome and Abu Dhabi, provides further cooling effect. PCMs changing phase at higher temperature (from 35°C to 45°C) better optimize the performance of the non-cool black membrane in terms of external surface temperature and heat gains reduction both in Rome and Abu Dhabi.

Figure 1: Continuously monitored buildings representing the field case study of the research.

Therefore, in order to obtain effective thermal benefits, PCMs should be selected not only with varying indoor and outdoor boundary conditions, but also with varying materials properties, in particular its passive cooling capability, e.g. solar reflectance and thermal emittance.

The dynamic thermal-energy simulation showed key energy saving produced by PCMs inclusion in summer conditions in Mediterranean climate and in winter conditions in hot desert climate. In particular, the integration of PCMs in the water-proof membrane was able to decrease the energy demand for cooling up to 22% and 12% with respect to the simple cool membrane and of 23% and 11% with respect to the non-cool membrane in the hottest months in Rome and the coolest months in Abu Dhabi, respectively. However, during winter in Rome PCMs showed to be not activated.

In this panorama, this work combined numerical and experimental campaigns to show that PCMs can be effectively included in waterproof polyurethane based roofing membranes and that the integration of passive cooling system such as cool roofs and thermal storage systems such as phase change materials is operatively possible and effective, showing promising opportunities for energy saving in buildings in hot weather conditions. The thermal-energy analysis also pointed out that the proper choice of PCM melting temperature should be carried out not only by taking into account a complex integration of boundaries such as indoor and outdoor environmental conditions, but also considering the optic-energy characteristics of the media, such as solar reflectance capability, largely affecting their thermal behavior under the sun.

3 REFERENCES

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