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Investigation of Phase Change Materials in Passive Cooling to Improve Natural Ventilation and Thermal Comfort

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Abstract

The cooling energy has covered most portion of building energy consumption in hot and arid climates. Accordingly, supplying the required energy for cooling systems, as well as passive solutions to reduce air temperature, is so noticeable. As an effective factor, Phase change materials through changing phases save energy and help to improve natural ventilation and thermal comfort. Base on the chemical structure and melting point these materials have various types. In this way, optimal PCMs selection based on their application and melting point is very important so as to improve natural ventilation and cooling energy in buildings. The current study investigates the properties and behavior of phase change materials for their implementation in building passive cooling systems as well as natural ventilation by reviewing and analyzing valid research and documents in the hot and dry climate of Yazd city. Finally, due to PCMs type, their application, and climate condition optimal PCM has been obtained in order to provide thermal comfort, energy consumption reduction, and natural ventilation. As a result, PCM with a melting point of 28 ° C can put the indoor temperature in the thermal comfort zone; moreover, that improves natural ventilation.

Keywords: natural ventilation, phase change materials (PCM), energy storage, passive cooling, thermal comfort.

1. INTRODUCTION

As the International Energy Agency has mentioned, over the past 20 years, initial energy productions and CO2 emissions have increased up to 49% and 43% respectively [1]. Since providing the required energy for users is an important matter, increasing papulation, higher up the number of residential buildings and energy demands are some factors playing in turn an important role in evaluation of the importance of this issue. In this regard, thermal energy storage, as a solution, can fill the gap between energy consumption and its supply in the building cooling systems [2]. A thermal energy storage system can save latent temperature, tangible temperature or chemical reactions. Phase change materials by making use of some methods such as latent heat can play an effective role in storing energy, increasing the efficiency of such these systems and improving natural ventilation. Based on phase change, thermal properties, and melting point, PCMs can in turn lead the ambient air to an improved one [3]. Therefore, employing optimal PCM considering the applications and region climate zone can achieve the research objectives. In natural ventilation scope, it can be mentioned the studies of Liu et al through CFD simulation, CFD has been done Considering to conserve energy, reduce emissions, improve the thermal comfort zone, and optimize the building natural ventilation [4]. Lizana et al. In a study investigated building passive cooling using phase change materials and Transis software to reduce the building cooling energy [5]. Besides, Sun et al. Concluded that phase change materials can lead energy consumption to 67% reduction [6]. Eventually, the literature review shows that no comprehensive research has so far been done on phase change materials as a passive solution to increase the natural ventilation performance in buildings. Moreover, the research innovation is to investigate the phase change materials in building cooling systems, increase natural ventilation and select optimal PCM with a suitable melting point.

2. MATERIAL AND METHOD

This research is going to introduce various methods of passive cooling, different types of phase change materials, PCMs performance and finally to suggest the PCM with a suitable melting point for the climate of Yazd city in Iran through a descriptive-analysis approach. It is just worth mentioning that this article provides some good comprehensive information about the subject by analyzing the climatic data of Yazd city, the characteristics and performance of PCMs with various melting points. Meanwhile, the city of Yazd as the most well-known hot and dry climate of Iran that has a long history of the use of windcatchers and natural ventilation, as a passive solution, has been considered.

3. Results and Discussion

3.1. Selection of phase change materials for different applications

Figure 1 shows a wide range of melting points and latent heat for PCMs. As it is obvious, phase change materials are able to have heat storage ability, including cold storage with melting point (-21-90) ° C, mean thermal comfort zone (34_18) ° C, sanitary hot water storage range (64_30) ° C, heating system storage (150_54) ° C and industrial and commercial range (-108_34) °C. Therefore, according to application type for the such these materials, PCM with the appropriate melting point can be selected. Besides, a suitable PCM with a melting point (34_18) can be considered in order to cooling and thermal comfort demands [7].

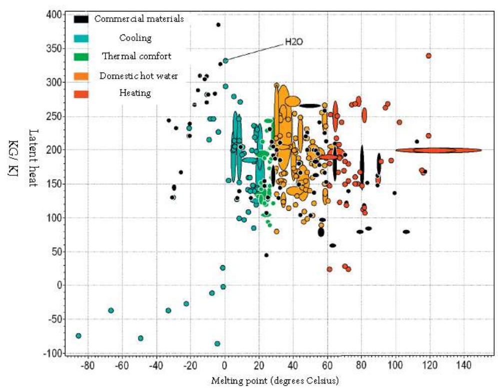

Figure 1. Relationship between melting point and latent heat for phase change materials in different applications [7].

3.2. Selection of PCM with suitable melting point for natural ventilation in hot and dry climate of Yazd

Through PCMs applications in providing thermal comfort conditions, made possible to use PCMs having a melting points in accordance with the temperature of climate zone, which are in the range of 18 to 34 °C. The range of average daily temperature in Yazd is 18 to 43 °C; the average of day temperature for the hottest month of the year in this climate is also 43 °C. Moreover, according to the Iran's national regulations, the thermal comfort zone for Yazd is 21 to 28 °C. Therefore, according to thermal comfort zone and the average temperature, in Yazd, PCMs with melting points of 20 to 30 ° C are used to improve passive cooling systems efficiency [8]. Since maximum temperature in range of thermal comfort zone in the hottest month of the year for Yazd, is 28 °C, the use of PCM 28°C can set the ambient temperature in thermal comfort zone. Implementation and maintenance costs are also significantly reduced using PCMs in passive cooling systems. The use of PCMs in active cooling systems of buildings can consume less electricity up to 9% [9]. As shown in Figure 2, PCM with a melting point of 28 ° C based on examining its behavior and enthalpy curve would be an optimal option improving thermal comfort and natural ventilation conditions. It through phase change stores excess heat in temperatures above 28 ° C and returns that heat to the atmosphere when the temperature goes down below 21 ° C.

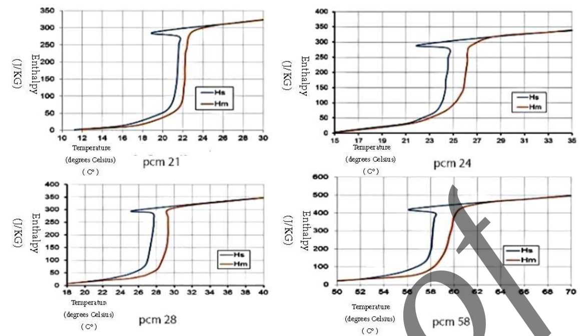

Figure 2. Enthalpy diagram for PCMs with melting point; 21, 24, 28 and 58 ° C (Author)

4. Conclusion

This study, according to the indoor temperature range, thermal comfort, and climatic conditions of Yazd city in Iran, helps to select the appropriate PCM in order to using in passive cooling systems, reducing energy consumption, and improving the natural ventilation. Eventually, this work finds out how to use the appropriate PCM according to its application and the region climate conditions, what kind of PCMs are used in different applications including Cooling, passive systems, hot water, commercial, and thermal comfort. In this regard, for the hot and dry climate of Yazd, considering the comfort temperature of 21 to 28 °C and the average temperature of 5 to 32 °C, PCM 28 °C is suitable for improving building passive cooling, natural ventilation and indoor thermal comfort conditions.

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