

Abstract

The advent of the 21st century has witnessed an increase in urbanization, resulting in a rise in the number of residential and commercial buildings and, hence, the energy consumed by them. The United Nations Environment Programme (UNEP) expects the number of buildings to double by 2050. The increased demand is met directly or indirectly by fossil fuel-based systems, which are increasing the local temperatures and adversely affecting the planet Earth. The UNEP expects an increase in the cooling demand and an increase in energy consumption by two times.

The deteriorating indoor air quality and recurring instances of airborne diseases such as COVID-19 have mandated the incorporation of fresh air into closed spaces to dilute indoor air and, hence, reduce contamination levels. Further, exposure to natural daylight is observed to have a positive psychological effect and improve the productivity of occupants in a building. The incorporation of natural daylight also reduces the need for artificial light, subsequently reducing the energy consumption of a building. However, for tropical countries, the summers are hot, and such incorporation of fresh air and daylight can increase the cooling load considerably, subsequently increasing the energy demand of a building.

The present thesis analyzes the effect of precooling of fresh air on the cooling load and, hence, the energy savings achieved by the modified heating, ventilation, and air conditioning (HVAC) system. The thesis commences from an analytical study for designing a phase change material (PCM) incorporated pin fin heat exchanger to offset the peak load for different climatic zones. The PCM-incorporated system was able to offset the peak cooling load and hence provided a maximum energy saving of 4.7 % for Delhi, 2 % for Kolkata, and 2.75 % for Jaisalmer. The analytical study is followed by using multi-attribute decision-making methods for the selection of an appropriate PCM for building applications. The selected PCM is considered for a numerical study, which incorporates PCM into the annulus of a concentric tube PCM heat exchanger used for cooling the fresh air.

The cooled fresh air is incorporated into the HVAC system, and its effect on energy savings is analyzed. The study also examines the effect of carrying the energy storage capacity of heat exchangers by varying the PCM thickness in the annulus, along with increasing the heat transfer by extruding longitudinal fins in the air. It was observed that the combination providing temperature drop for a longer period provided higher energy savings as compared to traditional HVAC systems. When the HVAC system is retrofitted with a heat exchanger with a PCM thickness of 20 mm, the 12-finned version yields the highest energy savings at 3.22 %. For a PCM thickness of 50 mm, the 24-finned variant offers peak savings of 5.22 %. As the PCM thickness increases to 75 mm and 100 mm, the energy savings rise to 6.64 % and 9.06 %, respectively, when using the 48-finned heat exchanger.

Further, an existing building is analyzed for different cooling loads, and a nano-enhanced PCM-incorporated concentric tube heat exchanger is utilized for cooling the fresh air. It was observed

that in the summers, on average, the ventilation comprises 31% of the total load for three air changes per hour. The optimum configuration on the basis of pumping power and ventilation load reduction of the HVAC system is with 24 fins. Further addition of 1% of CuO to octadecane enhances the energy savings to 7.81% for 8 hours and can reach a maximum of 10%. While the LHSS melts completely in 8 hours of duration, the solidification from exhaust air solidifies it in 4 hours of operation.

An experimental study was conducted to increase the thermal mass of glazing to minimize solar heat gain while allowing daylight into the enclosed spaces. Octadecane is incorporated into the glazing for its melting temperature in close vicinity to the human thermal comfort range. Further, the angle of inclination was varied as 0 and 45 degrees to analyze the effect of inclination on the temperature of enclosed air and illuminance level in the enclosed space. The incorporation of PCM led to air temperature reduction by 6°C, and the illuminance was reduced by 1490 lux and 498 lux as compared to glazing without PCM when the glazing is kept at an inclination of 0° and 45° facing south, respectively. The thesis provides policymakers with energy-efficient and sustainable solutions for designing HVAC systems and glazings, which can reduce energy demand and help combat climate change.

Keyword - Air-phase change material heat exchanger, Heating, Ventilation and air conditioning (HVAC), Energy savings, Retrofitting techniques