

# **Investigation of Thermal Retrofitting Options for Improving Building Energy Performance**

## **ABSTRACT**

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This thesis illustrates the research endeavours devoted to building energy conservation through thermal retrofitting strategies in the hot climate of India. The overall research efforts in this thesis are broadly categorized into two aspects. The first aspect concerns the understanding and improvement of popular building thermal retrofits (phase change materials and thermal insulation) in the Indian climatic context. The other aspect is a venture towards the discovery of a new class of thermal retrofit which is reported for the first time for passive building cooling application.

The thermal performance of a phase change material (PCM) embedded roof is initially examined for different climatic conditions of India. The varying weather parameters (eg. incident solar radiation, ambient temperature swing, etc.) for different climates act as independent determinants of PCM incorporated roof's thermal performance. To identify a suitable PCM for a given climate, the effects of different weather parameters are consolidated into a single parameter viz. heat gain through a base roof without retrofit. The evaluation of several combinations of weather parameters and different PCMs demonstrated that the rate of heat gain through a building roof without any retrofit can act as a marker to dictate the relative suitability of one PCM with respect to another in a given climatic condition. This consolidated parameter is easy to evaluate and it helps bypass the tedious route of one-to-one mapping of each influencing weather parameter with PCM retrofitted building roof performance.

In addition to the weather effects, the size and location of thermal retrofit in the building envelope can also impact the overall thermal performance of a building. This aspect is dealt with at a deeper level by developing a genetic algorithm framework for continuous and simultaneous

variation of multiple envelope retrofits' sizes and locations. Diverse asymmetric results (in terms of optimum envelope configuration) are obtained for different retrofit material combinations and different orientations of buildings. The energy savings with an optimally configured retrofitted envelope could be as high as 33.5% in hot Indian climate.

The outbreak of COVID-19 during the tenure of this research instigated a worldwide crisis of healthcare wards to accommodate a vast infected population. India has been one of the highest affected countries where COVID-19 spread rapidly throughout the nation. Considering the state of emergency, a major part of this thesis is devoted to energy and space conservative healthcare ward design to accommodate patients with airborne infection. Thermal retrofitting measures are tested in the ward envelope so that indoor thermal comfort could be retained with a minimum active HVAC power supply. The changes in the airflow within the ward are examined for different cases of retrofitting. An optimal design is finally suggested which could address the shortage of healthcare facilities while maintaining a conservative approach for the limited space, energy, and other construction resources for a large-scale infrastructure upgrade.

Finally, the thesis reports for the first time a new category of PCM which operates in the liquid-vapour phase transition regime. The existing PCMs deployed throughout the world for passive building cooling applications majorly operate in the solid-liquid phase transition. Such solid-liquid PCMs (SLPCMs) have certain limitations arising from their inherent material characteristics. The novel liquid-vapour PCM (LVPCM) demonstrated competitive performance with its SLPCM predecessors while overcoming the major SLPCM limitation of night-time heating. Furthermore, LVPCM system could be fabricated with common low-cost and environment-friendly materials. This new technology is therefore anticipated to launch a new paradigm of passive building conditioning research.

The design strategies and outcomes covered in the thesis can contribute to the global energy sustainability campaign whereas the new class of PCM discovered in this research could be the harbinger of major reforms in thermal retrofitting practices for building cooling.