Abstract

This thesis presents thermal retrofitting strategies for different climatic zones in India, focusing on building energy savings while enhancing thermal comfort and indoor air quality. Developing new buildings or renovating existing ones is a critical challenge for the coming decades, as it involves building heat-resilient buildings and combating building energy inefficiencies. Maintaining a comfortable indoor environment with an inefficient building envelope has substantial implications for its occupants, particularly those with limited financial resources. In regions where extreme conditions are periodic, and building owners cannot afford air conditioning systems, passive retrofitting or the use of passive methods in new buildings should be considered to regulate indoor air temperature.

In the first phase of the thesis, a numerical model is developed using the DesignBuilder simulation tool to investigate the heat transfer barrier, comprising phase change material (PCM), insulation, reflective paint, and a shading system, with both individual and synergistic implementations in composite climatic conditions. The holistic analysis of multi-retrofit solutions, appropriately incorporated into the building envelope for different regions within the same climatic zones, is performed discreetly. Out of the different insulators, shading systems, PCMs, and reflective paint investigated in the present study, the combination of reflective paint and insulation provides the best thermal performance. Furthermore, the non-sorting genetic algorithm (NSGA)-II is applied in a practical context to optimally construct a multi-retrofit envelope using thermal insulator, glazing system, orientation, and window-to-wall ratios of a building across various climatic conditions in India. The existing design parameters of the building can be significantly optimized to assess its sustainability quotient. By modifying the building envelope's characteristics with reflective paint, insulation, and other passive strategies, total HVAC loads are reduced by 6–32 %, and the reflective coating offers lower thermal mass or resistance for similar energy

performance.

Further research aimed to design and demonstrate material-based passive strategies that enhance occupants' thermal comfort in India's composite climate. Insulation, phase change material, and reflective paint strategies are tested with a test room model to enhance thermal efficiency. The thermal performance of the PCM room fluctuates considerably depending on external climate conditions. However, the performance of the reflective paint room is observed to be closely aligned and stable with the intensity of outdoor solar radiation. The reflective paint room offers a more productive and enhanced thermal environment at night, rendering it more effective for enhancing nighttime comfort in free-floating buildings than alternative roofing solutions. The research also validates the numerical model through experimental monitoring of the ceiling surface and indoor air temperature in four small-scale test rooms. A comprehensive comparative analysis has been conducted using temperature, energy, economic, life cycle assessment (LCA), and environmental-based indices to highlight the advantages of incorporating different passive strategies. The energy analysis based on the studied passive strategies yields substantial annual energy savings of 8 kWh/m^2 to 37.7 kWh/m^2, which can result in a carbon emission reduction of 2.5 to 8 kg CO_2eq/year/m^2. The cost-benefit analysis uncovers the minimal payback period of 0.9 to 4.4 years, except for PCM, and the minimal return period is highly dependent on building utilization time.

Furthermore, the thesis endeavored to accentuate a resource and energy-conservative indoor space wherein occupants' comfort could be effectively maintained in terms of thermal and air quality. The aim of the research is to enhance indoor air quality and control energy consumption by assessing mandatory ventilation requirements for different occupancy scenarios and outdoor CO_2 concentration. Implementing tailored ventilation strategies based on specific building scenarios can result in energy savings of up to 50 % in the building. Post-night occupancy, leveraging ambient CO_2 levels can also save further energy.