Exploring Energy Conservation in Office Buildings with Thermal Comfort Criterion towards Sustainable New Developments in Warm and Humid Climate

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Abstract

India is experiencing rapid urbanization and there is tremendous growth in the building construction sector since the last decade. India has proposed 100 smart cities and the offices/commercial built space is expected to increase fourfold between 2015 and 2030. Building sector consumes 40% of the world’s energy and is the single leading contributor to anthropogenic climate change. The office buildings in the warm and humid region in India are mostly installed with air-conditioning to maintain indoor thermal comfort. This system consumes the most energy of all building services representing 55% of the total energy consumption in office buildings and has the largest potential in energy savings. As a case study, a six storey office building in Manipal in Coastal Karnataka, India is documented and simulated for indoor thermal comfort analysis. Various building envelope design strategies are examined in order to improve indoor temperatures and conserve energy towards sustainable new developments in warm and humid climate.

Keywords: Building Envelope; Warm and Humid Climate; Building Energy Simulation; Thermal Comfort; Natural Ventilation

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1. Introduction

In recent years, facing the risk of climate change and depletion of fossil fuels, reduction in energy consumption is an environmental sustainability goal for many countries, including India. With a population of 1.1 billion people and one of the fastest-growing economies in the world, India is experiencing a rising demand for energy. According to International Energy Agency, India’s CO$_2$ emissions are expected to nearly triple between 2015 and 2030 [1].

One driver for this increase in energy use and carbon generation is the growth in building stock expected over the coming decades. Based on forecasts of building construction, it is estimated that about 70% of the commercial floor space that will exist in India in 2030 is yet to be built [2]. According to India’s Central Electricity Authority the current energy installed capacity in the country is 160,000 MW and the projected energy load for 2030 is 800,000MW. India’s demand for commercial energy is surging and there is an urgent need by the building sector to adopt non-energy intensive systems with a low carbon footprint. Challenge before India is to plan and implement energy efficiency measures during the early stages of growth in the building sector, so research to reduce energy consumption in the building sector through passive design strategies without compromising human comfort is essential. There is tremendous amount of construction activity in the warm and humid region of coastal Karnataka and most of the office buildings are designed for space cooling using air conditioning systems. The Heating, Ventilation and Air-conditioning (HVAC) systems in office buildings contribute substantially to the energy consumption and there is now a pressing need to address cooling needs. The National Building Code of India (NBC) specifies two narrow ranges of indoor comfort temperatures (23-26°C) irrespective of the type of building or its climatic location [3]. NBC follow the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standard-55 and designers overdesign HVAC as per Predicted Mean Vote (PMV) comfort model resulting in unnecessary wastage of energy. The recent trend in India is to design air-conditioned office buildings that often operate at 22.5 ± 1°C all year round to meet the stringent comfort specifications articulated in documents such as the International Standardization Organization’s comfort standard (ISO, 2005). Air-conditioning systems consumes the most energy of all building services, which comprises 55% of the total energy consumption in commercial buildings and has the largest potential in energy savings [2]. Recent studies have found that the comfort temperatures to the tune of 31.45°C with or without the use of fan were achieved in indoor environments, as against the stipulated standard comfort zone of (23-26°C) [4]. Providing a comfortable environment for occupants in office buildings should be a high priority without which the building will have decreased worker productivity. Thermal comfort is an effective criterion to integrate the various impacts of facade components on indoor thermal environment. An important factor that affects thermal comfort in buildings is the thermal performance of the building envelope and for this reason building design in warm humid climates needs to get more attention to building orientations, shading devices, material selections and window design [5, 6].

With the increase of air velocity the indoor temperature of thermal comfort can be increased [7, 8]. As the benefits of natural ventilation, including reducing operation costs, improving indoor air quality and providing satisfactory thermal comfort in certain climates are recognized, passive cooling of offices using natural ventilation has become an attractive option to design low energy buildings which are environmentally sustainable. There are many research studies related to the energy consumption due to the impacts of building facade components in sealed air conditioned buildings and mechanically ventilated buildings [9, 10]. Research related to building envelope designs towards energy savings and thermal comfort is deficient especially for office buildings in warm and humid climate. The research objectives are to use simulation tools to analyze the role of building envelope design and natural ventilation in achieving adaptive thermal comfort in office buildings in warm and humid climate.

2. Methodology

Several office buildings in the warm and humid region along the west coast of India were surveyed in 2012-13 to understand the generic architectural design principles, current construction practices adopted and energy consumption scenarios. The study reveals that the most of the office buildings surveyed were designed without any climatic considerations and mainly used reinforced cement concrete for roof slabs and concrete block for masonry walls with cement plastering. The indoor temperatures remains very high during the day because of heat gain through the building envelope and most of the office buildings use air conditioning systems due to occupant thermal discomfort. To
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