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A review of sustainable cooling technologies in buildings

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ABSTRACT

Heating, ventilating and air-conditioning (HVAC) systems play a vital part in ensuring the required comfort levels of residents inside building environments. However, most modern cooling equipments consume high levels of electrical power, thus create high energy consumption rates in buildings. The purpose of this review is to evaluate the common practice of implementing passive and active cooling technologies in buildings. Basic description along with the features and limitations of the techniques are outlined. Comparisons made on the electricity consumption and the capital expenditure has also been proposed. Alternatives such as utilizing heat-pipe heat exchangers for energy recovery have been described. The review highlights that wind towers are prospective alternatives to meet the demand of urban electricity utility along with its contribution to green building.

Contents

1. Introduction

Buildings utilize energy in two primary methodologies, first, to keep the interior as contented as achievable through optimizing heating, ventilation and air-conditioning (HVAC) and secondly, to generate power to run the required domestic applications, all of which leading to an increase in resultant global CO_2 emissions. Buildings are accountable for almost 40% of the global energy consumption and are responsible for almost 40–50% of the world's green house gas emissions [1,2].

In areas of hot climatic conditions and high-humidity, ventilation is predominantly significant in reducing the discomfort levels

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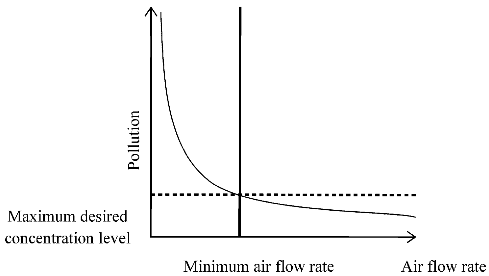

Fig. 1. Natural ventilation for indoor air quality [4].

from moist human skin due to an increase in air velocity over the body [3]. Buildings consume a major load of the utilization of energy; therefore there is a constant feasibility scope for a reduction in the energy consumption using various active and passive cooling techniques to be identified.

Suitable planning of energy-cognizant buildings requires a balance between the thermal performance of the building and the appropriate selection of techniques for heating and cooling. It also necessitates thermal comfort which comes from an adequate quality of the indoor climate. Utilizing natural ventilation for maintaining satisfactory air quality in the interior is dependent on the supply of fresh air. The quantity of ventilation needed to ensure an adequate air quality indoors depends on the amount of the pollutant in a space. It is known that the pollution level decreases exponentially with the airflow rate. Hence, the ideal airflow rate can be calculated by knowing the pollution intensity of the system [4]. Fig. 1 displays the exponential rate of pollution with increasing flow rate.

2. Cooling strategies for air conditioning in buildings

Building cooling technologies comprise of two logical strategies, namely passive and active. Passive cooling involves the cooling of a building feature without the utilization of mechanical apparatus that consume power. The urban microclimate is a major factor in the operational performance of passive cooling technologies in commercial buildings.

One major aspect of integrating passive cooling in buildings is reducing cooling loads or minimizing heat gains. Majority of cooling load in a building comprises of lighting and solar gains. Therefore, a reduction in solar heat gains using simple techniques such as correct insulation and overhangs can substantially increase the energy efficiency of the building and reduce the cooling load [5].

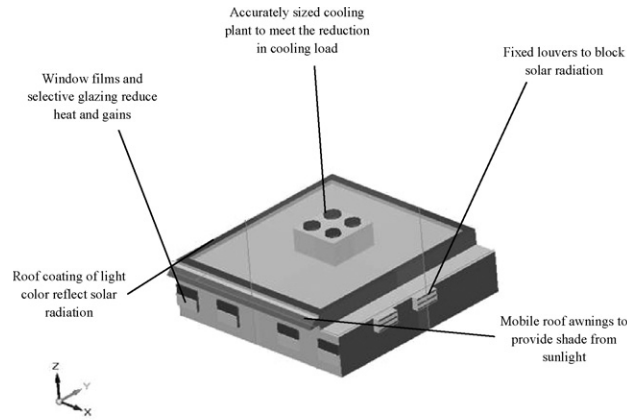

Fig. 3. General techniques to reduce cooling load in a commercial building.

Becker and Paciuk [6] studied various ventilation and pre-cooling strategies and its overall effect on the energy utilization and thermal performance to reduce the energy demands in buildings. The research incorporated simulations on assorted features of the building envelope for varying internal heat loads. The results showed that concentrated night pre-cooling is extremely efficient cooling technique for buildings with high internal heat loads since it reduced the internal mass temperature below the air temperature, consequently decreasing the peak power requirements.

Buoyancy and wind are the foremost driving forces for the working of all natural ventilation techniques and strategies, which include namely wind-variation induced single-sided ventilation, wind-pressure driven cross ventilation and buoyancy pressure-driven stack ventilation. Fig. 2 displays the respective natural ventilation strategies commonly used to reduce solar gains in commercial residences.

On the contrary, if a building cannot be cooled using passive means, the active cooling strategies need consideration. In today's market, major cooling systems are electrically driven compression chillers which have an average coefficient of performance of the installed systems in the range of 3.0–5.0 [8].

Fig. 3 displays some of the common techniques to reduce heat loads. From a general perspective, in warm climates, cooling during the day causes peak energy demands, which results in high expenses of generating the required electricity. In comparison with other time periods, electricity consumption during the night is significantly lower due to the cooler temperatures outside. Various strategies in buildings are already being practiced which exploit

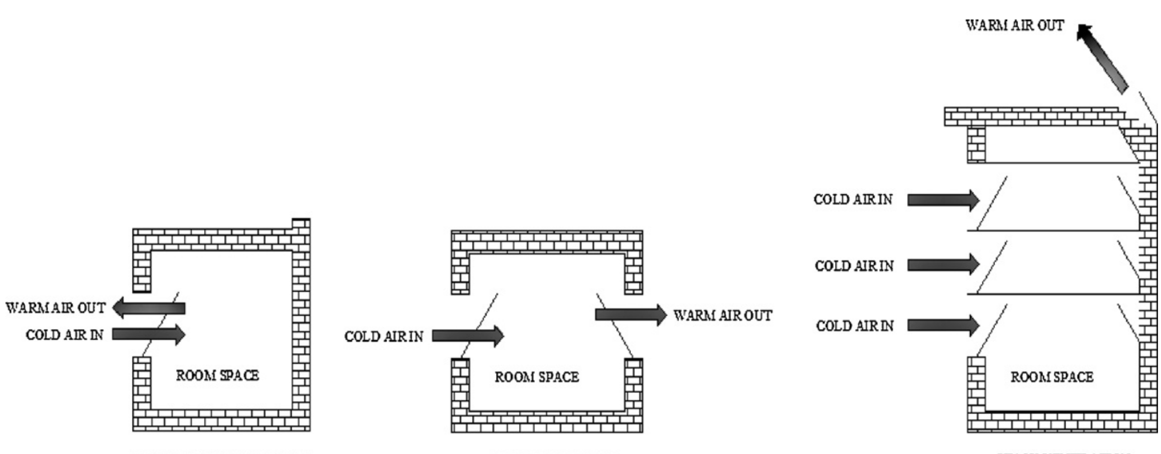

Fig. 2. Natural ventilation common concepts [7].