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Field investigation on indoor thermal environment of a high-rise condominium in hot-humid climate of Bangkok, Thailand

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Abstract

The highest possession of condominium supply among Bangkok's real estate market tends toward dramatic increase in energy consumption of the building sector. Condominium's entrepreneurs have less concerns on green building evaluation due to the barrier of complication in criteria and the investment in energy efficient technology is generally higher per square meter. From the pilot study on indoor thermal environment of a high-rise condominium in the hot-humid climate of Bangkok, Thailand, during May 9th to June 8th, 2015, the highest demanded one bedroom unit was selected. The room conditions during the field measurement were chosen based on the occupancy characteristics towards the use of natural ventilation (NA) and air conditioning system (AC). The results show that by applying natural ventilation during the day while using an air-conditioning system at night is an effective approach for reducing the room's environmental temperature (EnvT). During the daytime with natural ventilation, heat gain and heat loss occur rapidly because the difference between the indoor and the outdoor air temperature is marginal. Dragging EnvT into the comfort zone is possible with an indoor air velocity of 1.5 m/s. In addition, low outdoor air temperature is preferable for natural ventilation since the thermal energy absorbed by internal surfaces increases the cooling load. In a hot-humid climatic region, relative humidity is very high at night. The addition of using air conditioning system at night is likely to provide a comfortable thermal environment.

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Keywords: Thermal environment; field measurement; high-rise condominium; thermal comfort; cooling load; Thailand

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1. Introduction

Bangkok, the capital of Thailand, is located between 13º45' North Latitude and 100º35' East Longitude. As in a typical hot-humid climatic region, the air temperature and relative humidity (RH) are high for most of the year. The average mean dry bulb temperature ranges from 28.46 ºC to 30.23 ºC and RH is between 70% and 76%. The wind speed is low with its annual average at 1.0 m/s [1]. Since these weather conditions are mostly outside thermal comfort zone, people usually enhance their comfort by using air conditioning (AC) systems, especially during the hottest months around April and May. The peak demand for electricity had recently beaten the record at 29,403 MW as of April 28, 2016 [2].

The total electricity consumption of the country has been on the rising trend. The industrial sector holds 44% of the total consumption followed by the residential, commercial, small general services, and other sectors (e.g. the non-profit sector and agriculture pumping) account for a share of 23%, 19%, 11%, and 3%, respectively [3]. Meanwhile, the residential sector also holds the largest share of 89% of electricity consumers in Thailand. The expansion of real estate market has led to the increasing in electricity consumption by one-third of the total consumption. Condominiums in Bangkok account for the largest share of 63% of the new supply offered for sales [4], which caused the dramatic increase in energy consumption from using air conditioning systems during the occupancy period.

Since the indoor thermal comfort significantly affects the energy usage, thermal environment related to thermal comfort should be determined. In this study, environmental factors in a typical unit of high-rise residential building in Bangkok were investigated through field measurement. The use of an air-conditioning system and windows towards the occupancy characteristic were set during the investigation. The comparative results between thermal comfort and cooling load are also discussed. The significance of the results reported here is limited as the results are based on a specific building configuration and thus, it is difficult to generalise the conclusions.

2. Methodology

The location of a selected condominium is in a very high-density residential area of Thonburi, the outer area of Bangkok, and close to the mass transit line. With the price of 93,000 Baht/m^2, it is in the economy to upper-class segment (50,000-99,999 Baht/m^2), which has the highest shares in condominium market [4]. The field investigations were performed in 33 m^2 of one bedroom unit on the 19th floor (27 floors in total) as shown in Fig. 1. It is a corner room facing south west. The living room has two external walls with 50% of opening facing south (1.6 m^2 operable area) and 20% facing west, which receives high radiative heat gain. One semi-external wall faces north and connects to the public corridor. About 40% of the internal wall that separates the living room and the bedroom is a 6 mm single glassing fixed window. The bedroom has one external wall with 60% of opening facing south (1.1 m^2 operable area).

Monitoring equipment (Table 1) was installed accordingly to the ASHRAE standard 55 [5], see Fig. 2. For the indoor investigation, an air temperature sensor was set up at 1.1 m above the floor. Humidity, wind speed, and globe temperature sensors were set up at 0.6 m above the floor. Moreover, the surface temperature was also measured by temperature sensors attached on indoor wall surfaces, both in the living room and the bedroom. For the outdoor investigation, HOBO outdoor weather station was set up on the balcony to collect micro-climate data. The investigations were conducted from May to June 2015 as it was the hottest period of the year based on the maximum energy consumption resulted from high level of air conditioning usage.

During the 24 hours investigation, the occupancy characteristic was set under 4 cases as follows:

- Case 1: 24 hours without ventilation, all windows were closed (from May 9 to May 13).
- Case 2: 24 hours with natural ventilation, all windows were opened (from May 29 to June 2).
- Case 3: Daytime (6:00 am to 6:00 pm) without ventilation (all windows were closed) and nighttime (6:00 pm to 6:00 am) with an air conditioning system turned on (from June 3 to June 7).
- Case 4: Daytime with natural ventilation (all windows were opened) and nighttime with an air conditioning system turned on (from May 24 to May 28).