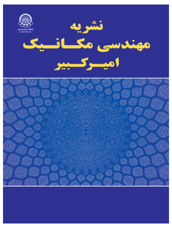

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Thermal Comfort Evaluation for Naturally Ventilated Building Applying an Adaptive Model in Different Cities of Iran

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ABSTRACT: In the present article, the performance of natural cross ventilation in providing thermal comfort in a building across six cities of Iran with different climates has been investigated using EnergyPlus software. To evaluate the thermal comfort of the building, the adaptive thermal comfort model of ASHRAE Standard 55 has been applied. This model is proposed to evaluate thermal comfort in naturally ventilated buildings without any mechanical ventilation equipment. However, the airflow network model has been considered to simulate natural ventilation through openings. The simulation time for all six cities is considered from 21 March to 22 September. The results show that the achievement of thermal comfort in the building depends mainly on climate. The best and the worst performance has been observed for Tabriz with its cold climate and Bandar Abbas with its hot and humid climate, respectively. Thermal comfort has been provided more than 69% of the time by applying natural cross ventilation in Tabriz for building without insulation. While this value for Bandar Abbas is estimated at about 12%. Also, results show that the use of insulation with a thickness of 5 cm in the external constructions of the building makes an increase of about 8-12% in the hours of thermal comfort for all cities compared to the building without insulation.

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1- Introduction

Ventilation of the internal spaces may be categorized into three kinds: mechanical ventilation, natural ventilation, or a combination of these two methods. In mechanical ventilation systems, electrical energy is needed to ventilate, cool, and refresh the indoor air. However, in natural ventilation fresh air from the outside enters the interior spaces through openings such as doors and windows, and in addition to establishing thermal comfort in space, it also removes pollution from the air in the room. Natural ventilation is considered a passive ventilation system as well as a proper alternative to mechanical air conditioning systems [1].

Among the various methods of assessing natural ventilation, the analytical models due to simplicity are implemented in building simulations software e.g., EnergyPlus [2]. In most research, to investigate thermal comfort in naturally ventilated buildings, the Fanger model [3] has been applied to check the thermal sensations of occupants. Field studies in warm climates in buildings without air-conditioning systems have shown that the Fanger model [3] predicts a warmer thermal sensation than the occupants actually feel. For this reason, Dear and Brager [4] presented an adaptive thermal comfort model at the request of ASHRAE [5] for naturally ventilated buildings.

Most of the research carried out in the field of natural ventilation in Iranian cities has been done by considering single-zone buildings. While almost all buildings in Iran have more than one zone, so the study of natural ventilation in multi-zone buildings is crucial. Therefore, in the present study, the ability of natural ventilation in establishing thermal comfort in a multi-zone building (with a living room, a kitchen, and two bedrooms) during the cooling period for six cities in Iran has been investigated using EnergyPlus software [2]. Also, the adaptive thermal comfort model of ASHRAE [5] has been used to analyze thermal comfort in the naturally ventilated reference building.

2- Methodology

2- 1- Reference building

To assess the natural ventilation, a multi-zone building consisting of a living room, a kitchen, two bedrooms, and a staircase is considered. Also, the orientation of the building is north-south. The schematic of the reference building is shown in Fig. 1. Due to the presence of windows on both sides of the building and shared doors between the spaces of the building, Natural ventilation is considered to be a type of cross natural ventilation. The materials considered for the building are common materials used in Iranian buildings. All occupants in the building consist of two people in the living room and one person in each bedroom.

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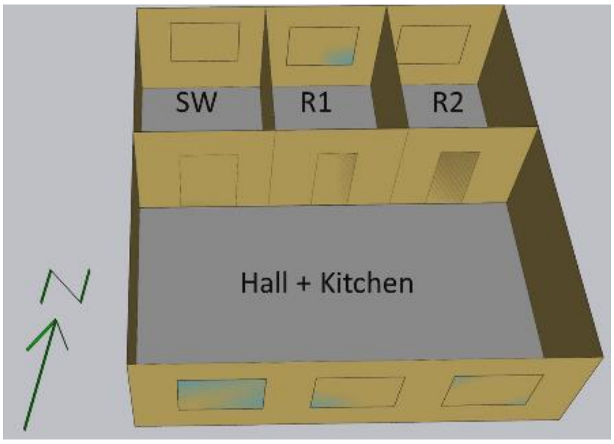

Fig. 1. Schematic of sample building

2- 2- Using the airflow network model

In this research, the Airflow Network model is used to calculate the natural ventilation flow rate. The airflow network model of EnergyPlus software has been validated using measured data at Oak Ridge National Laboratory (ORNL) and the Florida Solar Energy Center (FSEC) [6].

2- 3- Adaptive thermal comfort model

In the present study, the Adaptive thermal comfort model [4] of the ASHRAE [5] model is used to investigate the thermal comfort of occupants. In the Adaptive thermal comfort model, the thermal comfort conditions of the indoor environment vary according to the outdoor environment conditions. According to ASHRAE/ANSI 55 [5], the acceptable indoor temperature should be selected based on the satisfaction of 80% of the residents, which is expressed by Eq. (1):

$$T_{comf} = 0.31 T_{a,out} + 17.8 \mp 3.5 \qquad (1)$$

Where $T_{a,out}$ and T_{comf} are the average outside temperature in a period of one month and the optimal indoor temperature, respectively.

3- Results and Discussions

To investigate the potential of natural ventilation in the reference building, six cities of Iran including Tehran, Tabriz, Yazd, Isfahan, Shiraz, and Bandar Abbas with different climates have been considered. To assess the cooling performance of the natural ventilation, the simulation period has been selected from March 21 to September 22. In Figs. 2 and 3, the temperature distribution of the living room, the outside temperature, and the upper and lower limits of the temperature for Bandar Abbas and Tabriz based on the 80% satisfaction of the occupant are shown. Figs. 2 and 3 are obtained for the building without insulation. However, indoor thermal comfort condition is established if the indoor temperature is between the continuous red line and the dashed red line.

Also, the effect of using insulation in the external walls and roof on the thermal comfort of residents has been investigated. In Fig. 4, the effect of using natural ventilation in establishing thermal comfort is shown by considering three different insulation thicknesses and also without insulation.

According to Fig. 4, thermal comfort conditions are established in more hours in insulated buildings.

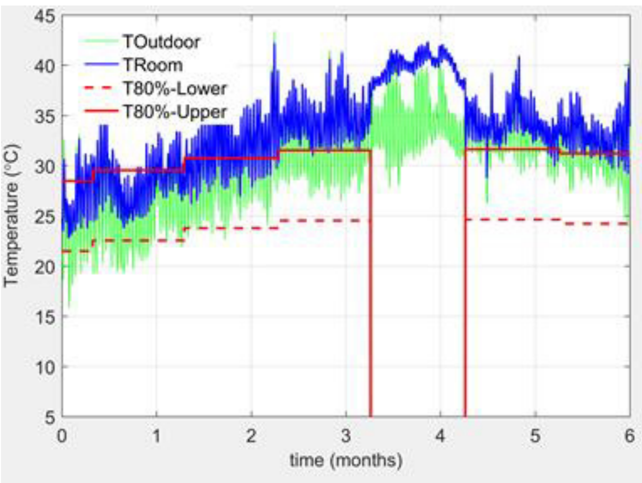

Fig. 2. Temperature variation of the living room and outdoor air in Bandar Abbas city

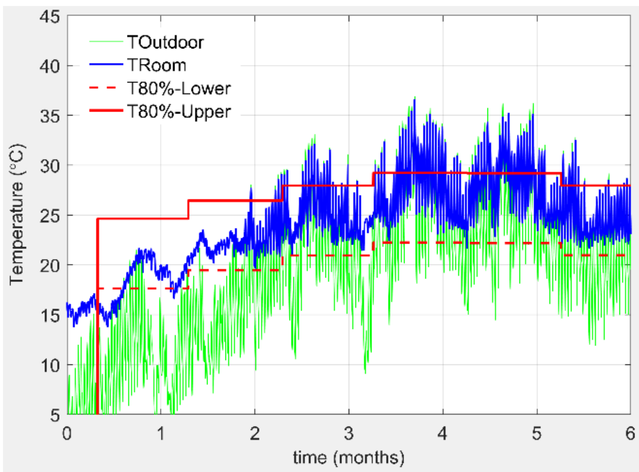

Fig. 3. Temperature variation of the living room and outdoor air in Tabriz city

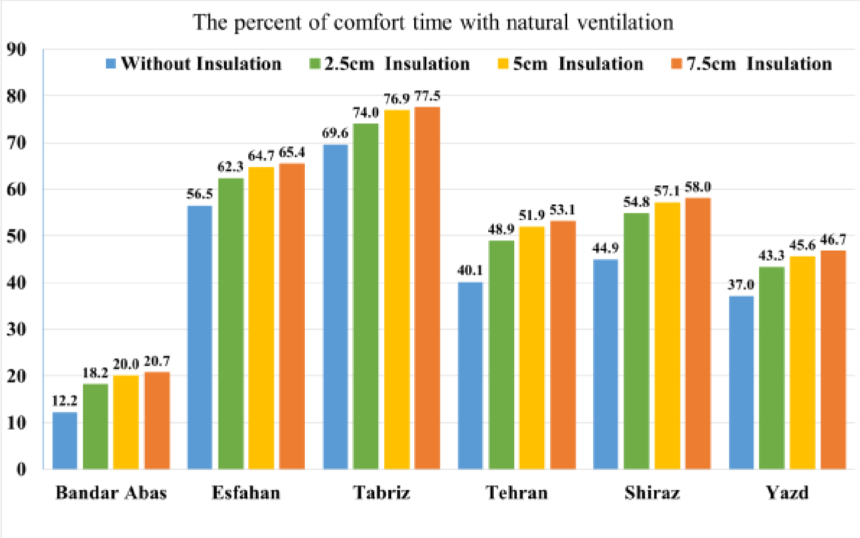

Fig. 4. The percent of comfort hours in spring and summer for insulated and non-insulated sample building

4- Conclusions

In the present study, thermal comfort in a multi-zone building has been investigated by applying cross natural ventilation across six cities in Iran. The simulations were carried out in the EnergyPlus software through the time period of March 21 to September 22. The results of the present study are as follows:

Tabriz with a cold and dry climate has shown the best performance. In this city, thermal comfort has been established in more than 69% of the hours for buildings without insulation.

The weakest performance has been observed in Bandar Abbas with a hot and humid climate. For this city, thermal comfort is established in about 12 percent of the considered times without insulation.

The percent of thermal comfort establishing hours for Tehran, Isfahan, Shiraz, and Yazd is about 40, 56, 45, and 37%, respectively.

The use of insulation with a thickness of 5 cm in the external walls and roof of the building increases the percentage of thermal comfort hours by 8-12% for all cities compared to buildings without insulation.

By increasing the insulation thickness from 2.5 cm to 5 cm, the percentage of comfort hours increases in the range of 2-4%.

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