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Investigating the potential use of natural ventilation in new building designs in Turkey

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Abstract

The most economic air conditioning of living and working places can be achieved by natural ventilation if sufficient. This provides not only the circulation of clear air, but also the decrease of indoor temperature, especially, during hot summer days, provided that the temperature of clear air is lower than that of indoor. From the geometric optimization point of view, both size and position of windows in buildings are important parameters to obtain a uniform indoor air velocity distribution.

In this study, the potential use of natural ventilation as a passive cooling system in new building designs in Kayseri, a midsize city in Turkey located at 38.44°N and 35.29°W, was investigated by computational fluid dynamics (CFD). Using the FLUENT 6.2 program, which employs finite element methods, indoor air velocity distributions with respect to changing wind direction and magnitude were obtained in living places of different dimensions. The simulation results suggest that natural ventilation can be used to provide a thermally comfortable indoor environment during the summer season in the study area. The study presents useful design guidelines for natural ventilation at both site planning and individual building levels.

Keywords: Natural ventilation; Thermal comfort; Air velocity distribution; AHSRAE standards; Computational fluid dynamics; FLUENT

1. Introduction

Natural ventilation can be utilized as an effective passive cooling system to significantly reduce energy used by air conditioning systems in buildings. In Turkey, inner room ventilation during summer days is generally carried out through door and window openings. The main purpose of natural ventilation is to obtain as much as fresh and clear air, which eventually brings the room temperature down for thermal comfort and transfers the body heat through forced convection exceeding the natural convection boundaries.

Passive cooling design elements are mostly neglected in modern city planning and building designs. In general, local seasonal wind patterns are not taken into consideration at planning and design of living environments. Although doors and windows can easily provide natural ventilation for thermal comfort, but they usually are not considered in this context by designers. It is also important to note that high air velocity and irregular airflow distribution within living spaces may not serve a comfortable living condition. Actually, for a thermally comfortable environment, indoor air velocity should be about 0.4 m/s with the upper limit of 1 m/s at which the airflow starts to pick up light objects [1].

According to the ASHRAE standards the upper limit of comfortable temperature in living environments is 26 °C [1]. Depending on individual metabolic activity, the human body generates heat energy between 100 and 1000 W. The thermal comfort is, in fact, resulted from the transfer of the generated heat out of the body. In addition to air temperature, strong air movement can increase the rate of convective and evaporative heat loss from the human skin to the environment. Therefore, one feels cooler with a higher air velocity [2]. The so-called equivalent temperature reduction (ETR) defined by Lechner [3] represents the temperature increase necessary to maintain the same thermal sensation with a given air velocity. According to the author, for example, the ETR is 1.1, 1.9 and 3.3 °C at air velocities of 0.2, 0.4 and 1 m/s, respectively.

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Numerical methods were employed to analyze heat transfer and air flow through zones divided by plates [4]. An 'active temperature' was defined by experimental studies on human body depending on air temperature and relative humidity [5]. Transient water transfer out of human body was investigated in laboratory medium simulating natural conditions and water loss with time was determined at room conditions in equilibrium [6]. In the design of office buildings, computerized optimization models have been developed for different climatic regions to minimize the energy consumption [7]. The AHSRAE comfort standards for inadequately planned buildings in warm climatic regions were studied and the suitability of different building design strategies and the passive cooling systems in different climates were assessed [8]. The potential use of natural ventilation in new house designs in Thailand was explored and it was found that a thermally comfortable indoor environment can be achieved in houses in a Bangkok suburb during 20% of the year [9].

It is generally accepted that high natural ventilation is needed for warm air, while moderate ventilation is appropriate for comfortable air conditions. Since most modern building materials are made of high thermal mass including concrete and brick they store a large amount of heat during the day, and transfer it into the living space at night resulting in too hot microclimate conditions without the assistance of an air-conditioner.

In this study, the applicability of natural ventilation as a passive cooling system was investigated in modern buildings in Kayseri, where a moderate climate prevails during the summer months of June, July and August with the air temperature ranging from 33 to 36 °C during the daytimes and the relative humidity ranging from 50 to 56%. More specifically, computer simulations of indoor air velocity distributions in living or working places of different dimensions were obtained to explore the potential use of natural ventilation and the possibility to reduce energy consumed by air-conditioners.

2. Definition of the problem

Building design with good natural ventilation in urban areas is challenging, because the surroundings have a significant impact on the wind pattern and indoor air velocity. In dense areas, where buildings often block each other from the wind, a hot microclimate is created during relatively warm periods of time.

Significant benefits from natural ventilation as a passive cooling system can be obtained provided that buildings are oriented towards prevailing wind directions in a staggered manner. As known that linear alignments of buildings result in a wind shadow leading to a low pressure area at the back of each building. In order to eliminate such problems and for an effective use of natural ventilation in buildings city planners and construction engineers should seriously take into consideration prevailing local wind directions.

In addition to the building orientation, the ratio of building dimensions (i.e., length and width) is an important factor in determining the amount of natural ventilation. Olgyay [10] suggests that the optimal ratio for a house in hot and humid climates is 1:1.7, with long sides facing north and south.

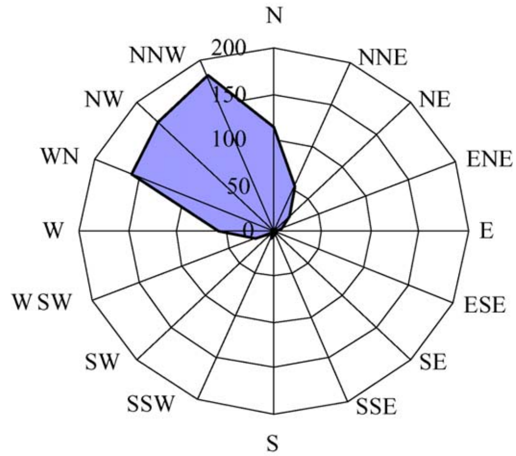

Fig. 1. The prevailing wind directions with the total number of hourly wind flows during summer between 10 and 18 h in Kayseri.

3. Model simulations

Unfortunately, as in many places in Turkey, most modern buildings in Kayseri have been designed without much attention to natural ventilation. In addition to misalignment of buildings with prevailing wind directions, wind blockage by upstream buildings seriously deteriorates air circulation in many neighborhoods. Therefore, air pollution, especially, during winter remains a real challenge to the local residents.

In the city, the prevailing wind during the summer months comes from three predominant directions, namely north-north-west (NNW), north-west (NW) and west-north (WN). Fig. 1 displays the prevailing wind directions and the number of hourly wind flows in June, July and August during the daytimes (i.e., from 10 to 18 h). The wind speed measured at 10 m height from the ground level generally varies nearly from 1.6 to 3.2 m/s in all directions during the daytimes [11].

Fig. 2 displays the variation of average wind speeds between 10 and 18 h in the prescribed months. The average daily wind speed values of the summer season were found 1.77 and 2.54 m/s for the entire day and the period between 10 and 18 h, respectively.

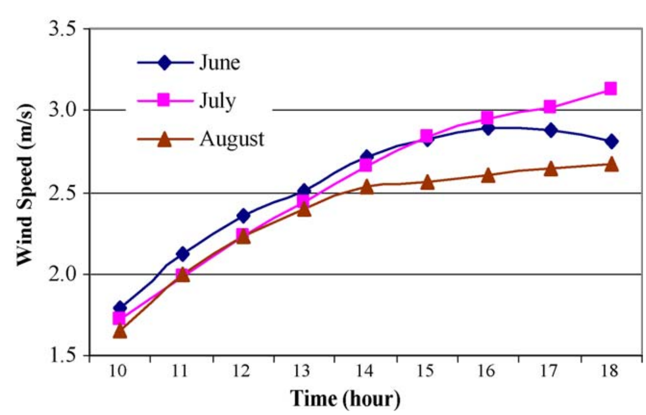

Fig. 2. The variation of average wind speeds of Kayseri during the summer months between 10 and 18 h.