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The effects of urban block forms on the patterns of wind and natural ventilation

Mohammad Mehdi Azizi[a]*, Komar Javanmardi[b]

[a] *School of Urban Planning, College of Fine Arts, University of Tehran, Iran*
[b] *College of Fine Arts, University of Tehran, Iran*

Abstract

An energy-efficient design can be achieved mainly through accurate design of built –environment forms. This paper aims to investigate the effects of urban block forms on natural ventilation patterns in the Sanayee neighborhood in Tehran, thereby potentially having air pollution, using computational fluid dynamics (CFD) analysis. The wind pressure and speed indicators were measured by ANSYS Fluent software, using standard k-ε model. The results showed that two factors with the most effect on wind pressure difference were urban block height and widths of adjunct roads. As a result, natural ventilation and consequently energy consumption were affected.

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Keywords: Urban structure; urban block; Energy; natural ventilation; CFD; Tehran

1. Introduction

Interaction between energy systems and urban structure happen in all spatial scales, from regional and urban neighborhoods, to buildings [15]. Up to now, sustainable urban structures have had a key role in the reduction of energy consumption. Energy efficiency can be achieved through accurate design of built structures, use of facilities operating with re-usable energy (wind, solar, etc.) as well as passive solutions.

Urban planning process seeks urban structures that improve natural ventilation. As indicated in several scientific works, inaccurate urban expansion has caused changes in climate parameters, including temperature comfort [2, 14].

* Corresponding author. Tel.: 021-66402444; fax: 021-66461504.
E-mail address: mmazizi@ut.ac.ir

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Putting into operation of inactive guidelines can result in efficient energy consumption, such as using day-light and natural conditions. Natural ventilation takes place when there is a difference in natural air pressure around the buildings because of wind or viscosity. Natural ventilation depend on three climate phenomena, namely wind speed, wind direction, and temperature difference [12]. In Iranian traditional architecture, natural ventilation through wind energy has been an important issue in building designs, although it has been mainly neglected today, because of higher construction densities [10].

Urban forms are the result of interaction between buildings` height, their distances, and floor space. These can cause the amount of influence of wind flow inside the urban textures, affecting the use of this flow for inactive coldness [3]. Nevertheless, in order to use wind flow for inactive building coldness, it is necessary to understand this physical phenomenon as well as factors affecting the process of natural ventilation. Recently, creating compatibility between vertical developments, the amount of high floor space, and protecting the level of natural ventilation in urban areas has been studied. This can create a macro climate that has not been in natural conditions. Analyzing the aspects of natural ventilation through modeling, can facilitate architectural and urban planning processes. Air tunnel tests, software and mathematical models are important instruments in the analysis of urban changes. These can provide more accuracy in the measurement of wind flow in internal and external environments, as seen in the studies of Prata-Shimomura, et al. [17].

Wind orientation and velocity have influence on passive cooling of outdoor and indoor spaces; preservation of cool airflow currents leads to reduction of energy consumption [7]. Effects of urban areas on airflow characteristics, e.g. velocity and airflow orientation, has well been analyzed and modeled by wind tunnel tests [4, 5]. By analogy, the effects of density of different planned area, and the ration between building height and airflow orientation, in common rectangular pattern, upon pressure coefficient surrounding individual building have been modeled and trialed carefully [6].

In the context of assessment of natural ventilation in urban areas, a large number of investigations have been conducted in recent years, and CFD method has been introduced as an appropriate approach, there are many studies on the relationship between urban forms and their effects on wind behavior [1, 13] and ventilation in the urban built environments [16]. The method has a high consistency with experimental outputs which, in turn is the indication of its high ability and precision. Asfour has analyzed wind environment surrounding housing blocks in assumed sites in Gaza. The aim of this effort is to predict wind environment in different grouping patterns of housing blocks, and consequently potential of natural ventilation through CFD method in this case. In the research, the best configuration in exposure to air has been known as a central space articulated by buildings and oriented towards the prevailing wind [1].

In addition, in the field of urban morphology, and its effect upon airflow movement pattern, wind blowing, and also air pollution, particularly at the pedestrian level, there have been a great deal of researches carried out[9, 17]. Ng et al. has examined, in a high-density part of Hong Kong, the effects of urban morphology upon local wind pattern and air pollution in pedestrian. Research team has analyzed one specific urban area, its future development, and also their impact on wind pattern quality and that of air [13].

In the current research, experiences of pertinent researches have been used in order to appropriately model case of study. The modeled boundary is an objective urban area, in which average wind pressure and wind velocity pattern has been measured respectively upon all the block facades and existing roads. Eventually, with respect to geometry and dimension of urban blocks, various angles, and also width of roads, a suitable understanding of wind behavior change has been achieved.

In this research, Sanayee neighborhood in Tehran has been selected as a case study. This neighborhood is located in the central area of Tehran, district 6, which is one of the most important districts of the city. Several factors can be noted for the selected neighborhood in this district to be studied for the aims of this research. First, district 6 in Tehran is one of the most congested areas with relatively heavy traffic, resulting in higher air pollution. Second, the temperature in summer time is higher, compared to many other districts located in northern parts of the city. Third, the neighborhood has diverse block directions, leading to problems of natural ventilation, consequently, the issue of heat islands can be analyzed in this neighborhood.