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The Relationship Between the Placement of Building Blocks and Wind Flow at the Pedestrian Level

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Abstract
Assessing human comfort outdoors is one of the key criteria in the design of building. One of the effective factors in creating comfort conditions is wind flow. The purpose of this study is to investigate the effect of urban blocks on wind flow for creating the comfortable condition. The ratio of buildings height to distance (H/W) and the orientation of buildings as the most important factors affecting wind flow were examined. The ratios of 0.5, 1, 1.5, and 2 were selected and orientations of 135° to 200° were examined. A residential complex in Tabriz was selected as a case study and weather information of the last 19 years (2002-2021) of Tabriz was extracted from the Meteorological Organization. Months of the year that were unfavorable in terms of comfort conditions were identified by using the Penwarden standard. Accordingly, January 6, 2021, was selected as one of the coldest days of the year, and to simulate different scenarios, Envi-met (4.4.5) software was used. The results show that the H/W ratios of 0.5 to 1 and the orientations of 200° to 185° and 135° are the most appropriate. In this research two important factors, H/W and their orientation were studied in a linear form. One of the limitations of the research is that only the comfort conditions in the outdoor environment of the buildings have been studied. Therefore, in future research, the arrangement of urban blocks to consume less energy inside buildings can be examined.

Keywords: Outdoor thermal comfort, wind speed, building orientation, H/W ratio

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Introduction

Among the various factors of environmental comfort in outdoor space, wind flow has a great impact on the quality of urban spaces. In the 1970s, Lawson et al. reported the death of two elderly women due to sudden, strong winds around buildings. Wise et al. have conducted studies on shops that do not have customers due to wind conditions in the area. Various researches have been done on the shape and form of blocks, their ratio of height to their distance (H/W), orientations, and the effect of these factors on wind speed. However, most of this research has been done in areas with warm climates and cannot be generalized to other regions with different climates, and in most studies, the summer season has been analyzed and studied. A limited number of studies have examined the cold days of the year and cold climate. This research, in line with the research done in this field and with a more comprehensive look at the relationship between H/W ratio and also examining the orientation of buildings with more accurate angles, in the form of linear buildings, examines outdoor thermal comfort. This research has been done around one of the residential blocks in Tabriz, Iran with a dry climate and relatively hot summers and cold winters.

Materials and Methods

The study site is located in a residential area of Tabriz city. Tabriz (38.12°N, 46.24°E) is a metropolis in the Azerbaijan region of Iran and is the capital of East Azerbaijan Province. Tabriz has a population of over 1.7 million (2016). Its climate is dry steppe and enjoys a mild and fine climate in spring, a dry and semi-hot in summer, a humid and rainy in autumn, and snowy cold in winter. The prevailing wind is from east to west. The average annual temperature is 12.6°C (54.7 °F). It's elevation ranges between 1,350 and 1,600 meters (4,430 and 5,250 ft) above sea level.

One of the pioneers who prepared a graph to predict pedestrians' outdoor comfort zone is Penwarden. In 1975, he introduced his graph according to his comprehensive field studies in the UK. This graph that had been used for several years shows the needed periods for sunshine, shade, and wind according to the metabolic rate of the pedestrian with suitable seasonal clothes. For this reason, in this study, the Penwarden index was used to identify months of the year when conditions are unfavorable for pedestrians. Thus, January was identified as the worst month of the year in terms of thermal comfort. Also, February and December do not have favorable conditions. As a result, January 6, 2021, was selected as one of the coldest days of the year, and the effect of building blocks on wind flow in winter was investigated (Fig1).

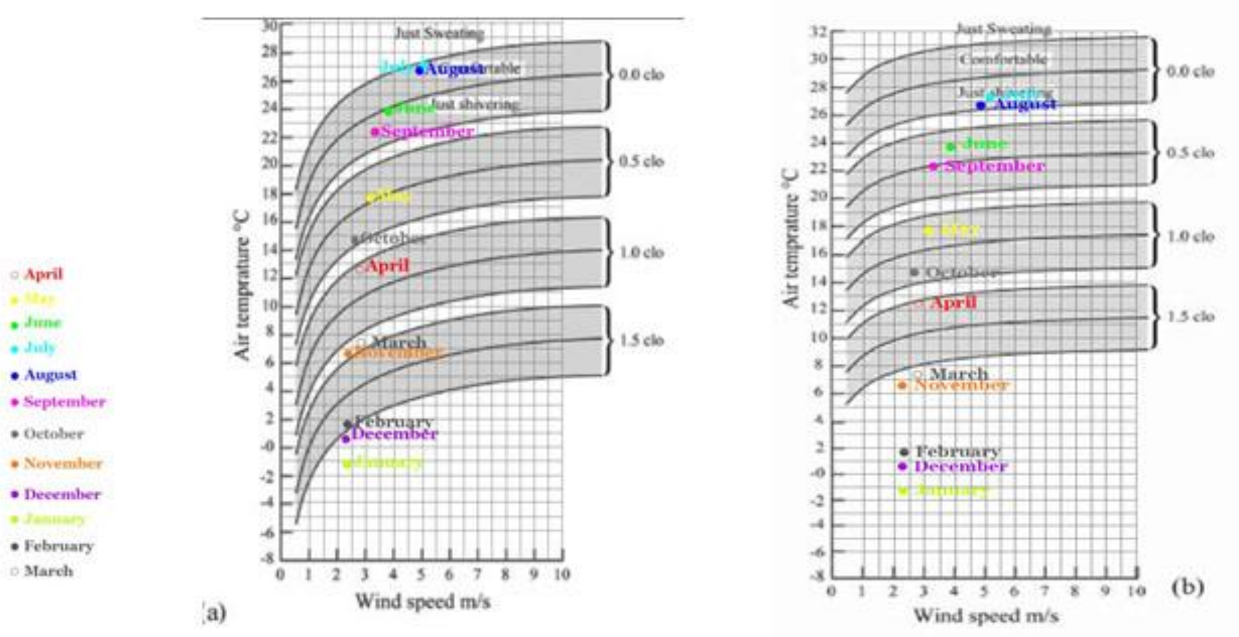

Figure 1: Status of different months of the year in Penward index, right: shadow, left: sunny

ENVI-met software (4.4.5) was used to simulate the surrounding environmental conditions. The information entered in the software can be seen in Table 1.

Table 1: Information and data entered in ENVI-met software

Information entered in ENVI-met	
Geographical Location	46.24°E, 38.12°N
Name of the area	Tabriz, East Azerbaijan Province, Iran
Date	2021.01.06
Model Dimensions	x-Grids=50, y-Grids=50, z-Grids=40
Size of grid cell in meter	dx=4,dy=4,dz=5
Simulation time	9 AM-8 PM, 11hours
Temperature	Min: -9°c, Max: 0.6°c
Wind speed	2.9m/s
Wind direction	70°(North-East)
Relative humidity	58%
Pavement material: Cement Concrete	Albedo: 0.4, Thermal capacity: 2.08 $[J\ m^{-3}\ K^{-1}] \times 10^6$, Thermal Conductivity: 1.63 $[W\ m^{-1}\ K^{-1}]$
Building envelope: Cement Walls	Thickness: 15cm, U-value: 2.54 $(W/\ m^2K)$

Discussion of Results:

The comparison between the H/W ratio and wind speed shows that with increasing height above ground level and this ratio, wind speed also increases.

The results show that in winter, with increasing the H/W ratio, the wind speed also increases. The average of wind speed at the ratios H/W=0.5 and H/W=1 is close to each other and increases when this ratio changes to H/W=1.5 and H/W=2. Therefore, H/W=0.5 to 1 ratio is suitable for design in this climate, and increasing this ratio can disrupt outdoor comfort conditions. This study agrees with researches that have examined this ratio in different climates in winter.

Also about the orientation of the blocks, Oke, Jin et al. concluded that in the linear pattern the angle between the wind direction and the axes of the blocks are inversely related to the wind speed. As the angle between the wind direction and the axes of blocks increases, the wind speed decreases. Studies in the subtropical climate of Tunisia's Mediterranean climate in summer, the Brazilian subtropical climate, the temperate climate of the Netherlands in summer, the very cold climate of China considered North-South (NS) orientation as the most appropriate one. Rizk-Hegazy et al. compare the four directions of 70,160,100,10 degrees from the north in the hot and dry climate of Saudi Arabia and consider 160 degrees clockwise from the north as the most suitable option. Also, studies conducted in the hot and dry climate of Algeria, hot and humid climate of Brazil are considered northeast-southwest(NE-SW), Northwest-Southeast (NW-SE) as the best orientation. This study, which examines eight angles, shows that the angles of 200° to 185° and 135° have a lower average wind speed, so it creates favorable conditions at the site, and angles of 175°, 165°, 155°, and 145° have higher average wind speeds and cause unfavorable conditions in the environment.

Conclusions:

The present study evaluates wind speed as the most important factor affecting thermal comfort conditions around residential blocks in a linear manner. Assuming that the height, distance, and orientation of the blocks are the factors that can affect wind speed. In this study, an arid climate with relatively hot summers and cold winters was selected as the study area. By using the Penwarden index, and comparing temperature and wind speed, the months of the year with the worst comfort conditions were identified. January was selected as the month that needs to be studied more closely to improve environmental conditions. Examining the number of changes that occur in the average wind speed in changing the H/W ratio, it can be concluded that with increasing H/W ratio, the average wind speed has an upward trend. And, ratios of H/W=0.5 to 1 can be considered the most appropriate ratio. Concerning the orientation of the buildings, it shows that the average wind speed was the lowest at an angle of 200°, and with the change of the direction of the buildings clockwise to the north, the average of this index increased and reached the highest value at an angle of 165° then it decreases. Therefore, angles of 200° to 185° and 135° are the most favorable, and angles of 175° to 145° are not suitable. In this research two important factors, H/W and their orientation were studied in a linear form. One of the limitations of the research is that only the comfort conditions in the outdoor environment of the buildings have been studied. Therefore, in future research, the arrangement of urban blocks to consume less energy inside buildings can be examined.