The effect of wind towers on dwelling's aeraulic comfort. Case study: Dwelling of hot arid climate (Tougourt)

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Abstract:

Many researches erupt to deal between energy consumption, building geometry, passive strategies and indoor thermal comfort. In this regard, we attempt over this study to reveal the effect of wind towers and their geometrical parameters on dwelling's aeraulic comfort. Therefore, a computational fluid dynamic (CFD) simulation has been done through this research. The modelling simulation has been done by using Phoenix software. The investigation was conducted during summer time in hot arid climate (Touggort). The results of this study show that wind towers can mitigate indoor aeraulic thermal comfort. The output of this investigation also demonstrate that the geometrical parameters of wind towers have a crucial effect on air-cooling and aeraulic comfort.

Keywords : Wind towers , computational fluid dynamic (CFD), dwelling's aeraulic comfort, Phoenix software, hot arid climate (Touggort).

Introduction

Wind towers are passive cooling systems that can be used in the residential, commercial and administrative buildings and small covered arenas in hot and arid or hot and humid regions.(A.R. Dehghani-sanij et al 2015). Wind towers are considered as one of the oldest natural ventilation systems. Wind towers or wind catchers are focused on the early architecture of the Middle East, particularly Iran. They are towers that have openings at the top to "catch" the wind flow at high altitudes and permitting it to cross ventilate the room. The tower can have several duct sections (partitions) to let entry of fresh air and the exit of warm exhaust air. Wind catcher systems depend on two principles: wind speed and direction, and the stack effect due to differences in air densities. (Zaki, A et al 2019). According to Hughes et al (2012), the regional characteristics and thermal conditions influence widely the advantages and disadvantages of wind towers. Since, it is not an easy task to determine fixed parameters (such as shape, size and orientation) for wind catcher ventilation. Then, shapes and structures of wind catchers vary widely with the context of the climatic zones. Many studies (Perez-Lombard et al., 2008; Hughes et al., 2012; Bahadori, 1985; Badran, 2003; Gage and Graham, 2000; Hosseinnia et al., 2013; Nejat et al., 2016a; Nejat et al., 2016b; Calautit et al., 2015b; Elmualim, 2002; Haghighi et al., 2016; Hosseini et al., 2016; Zarandi, 2009; Dehghani-sanij et al., 2015; Montazeri et al., 2010; Mostafaeipour et al., 2014; Krishnan, 2016; Bahadori et al., 2008; Dehghan et al., 2013; Cruz-Salas et al., 2014; Khodakarami and M.R, 2015; Suleiman and Himmo, 2012; Ghadiri et al., 2013a; Cruz-Salas et al., 2018) reveal that the system ventilation efficiency can be enhanced by varying the catcher's duct geometry, the number of openings and size. According to (Zaki, A et al 2019), these parameters do not follow fixed rules, i.e. some profiles are appropriate for specific cases while completely inefficient for others. In this regard, we attempt over this investigation to determine the appropriate wind catcher's geometrical parameters, which lead to improve indoor thermal comfort and reduce energy consumption of residential dwelling in hot arid climate (Touggourt). To achieve this purpose Phoenix software has been used to make a computational fluid dynamic (CFD) simulation.

Methodology of research

Occupant thermal comfort is difficult to evaluate because it is as much physiological as it is psychological. 'Comfort' is an individual feeling or a state of mind - not a quantifiable metric.

This is where Computational Fluid Dynamics (CFD) comes to our aid. By utilizing CFD we can easily evaluate the temperature, velocity, comfort profiles for any given indoor model. CFD in thermal comfort analysis is one of the most useful methods of identifying thermal perceptions of occupants in a building space and of possible energy savings. CFD is a powerful tool to analyze thermal comfort and assess the dissatisfied percentage in buildings. (Praveen Kumar, 2019). One of the most used CFD software is PHOENICS.PHOENICS is a reliable, cost-effective CFD program with a proven record of accomplishment simulation scenarios involving fluid flow, heat or mass transfer, chemical reactions and combustion for a wide range of applications. In order to achieve CFD flowers simulation by using PHOENICS, four steps are mandatory (See figure1).

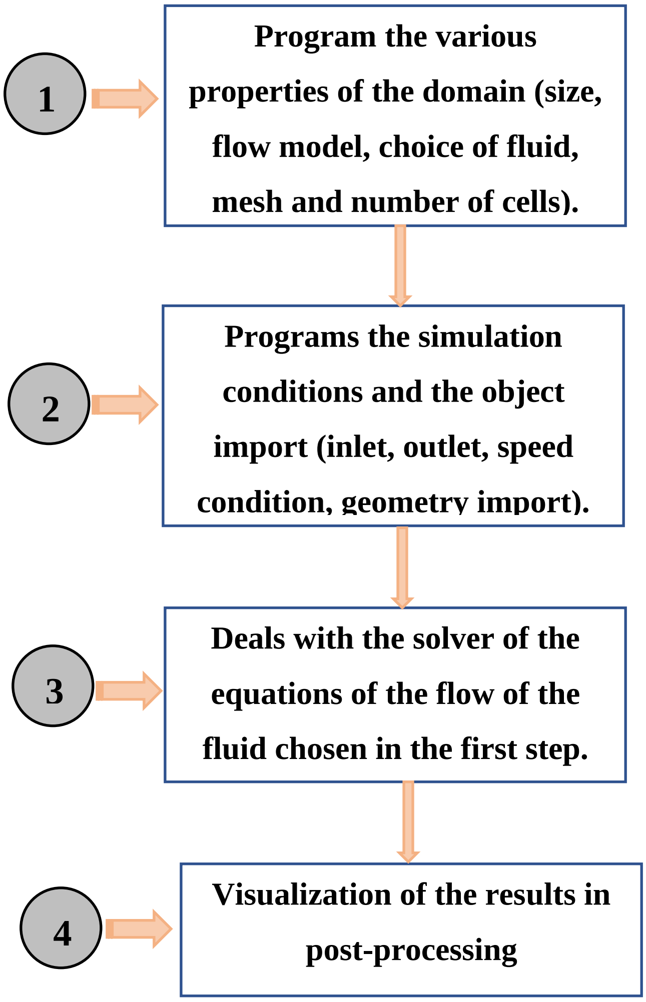

Figure1 : Steps of CFD simulation

Wind towers can be classified according to the function, the form, and the number of orifices. In this regard, to determine the appropriate wind tower's geometrical parameters in hot arid climate (Touggourt), two forms has been investigated (square, hexagonal). Afterward the number of orifices and orientation has been varied and evaluated.

Case study:

The investigation was conducted in Touggourt (Algeria) located at (33.06^0 North and 06.03^0 East). The altitude is about 72 m above sea level. This city is characterized by arid climate which is hot and dry in the summer with an average maximum temperature of $43,49^0$ C occurring during July month. In addition, the sun radiation intensities over this region are very high with clear skies and sunny periods occupying a large portion of the day. Winds are relatively frequent and their speed is high from April to July, which during this period causes sirocco and sand winds. The average wind speed is higher in May, lower in December. All these contribute to the climatic harshness of this city (Touggourt).

The study area is located in the northwest of Touggourt town near the railway; it has a square geometric form. Its surface is about 207,174 m^2. It is intended for individual dwellings (See figure2).

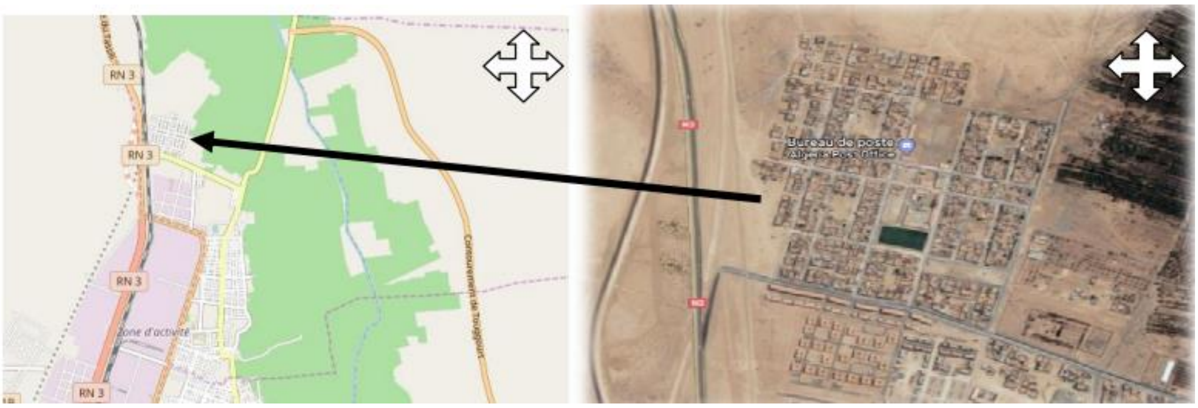

Figure 2 : Study area

The site is fairly exposed to the prevailing winds (north and north-west) and hot winds (south-east). However, it is protected from the summer breeze (north-east) by the oases which present significant obstacles (See figures 3,4,5,6).

Figure3: Southeast Wind direction (Windfinder.com)

Figure 4: Northeast Wind direction (Windfinder.com)

Figure 5: East wind direction (Windfinder.com)

Figure 6: North West wind direction (Windfinder.com)

Results:

The result of CFD simulation indicate that the wind tower has a significant effect on aeraulic comfort. Since the present figures (7,8) reveal that the presence of wind tower leads to increase the mean air speed from 1.9 m/s to 3.7 m/s. According to Beaufort scale, these values indicate that air condition is described calm in the first case, while it is described as light air in the second case. In order to determine the optimum geometrical parameters of wind tower according to Touggourt climate, a simulation of different profiles has been done. The form, number of orifices and orientation were varied according to the most used wind towers.

The effect of wind tower's form

Figures (8 and 9) reveal that the form of wind tower has an important effect on airflow. Since, airflow differs significantly in the tow case. Moreover, the square form can be considered as better than hexagonal form; this can be explained that the maximum and minimum wind speed is higher in the case of square form than the case of hexagonal form. In addition, the PMV in the dwelling of wind tower of square form is about 1.3, while the PMV[1] value in the dwelling of wind tower of hexagonal form is ranged on 1.46. PMV values indicate that user indoor thermal sensation in dwelling of square wind tower is better than that of dwelling of hexagonal wind tower. In order to optimize these results, the number of orifices in the wind tower of square form has been varied in the next step of this investigation.

[1] PMV values are calculated according to the formula of this application https://www.eat.lth.se/fileadmin/eat/Termisk_miljoe/PMV-PPD.html

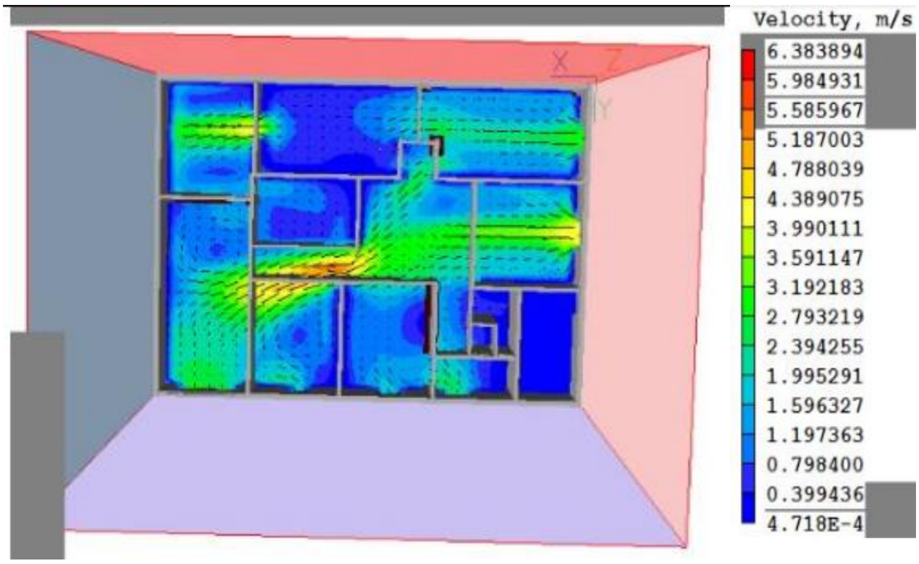

Figure 7: Airflow in dwelling without wind tower

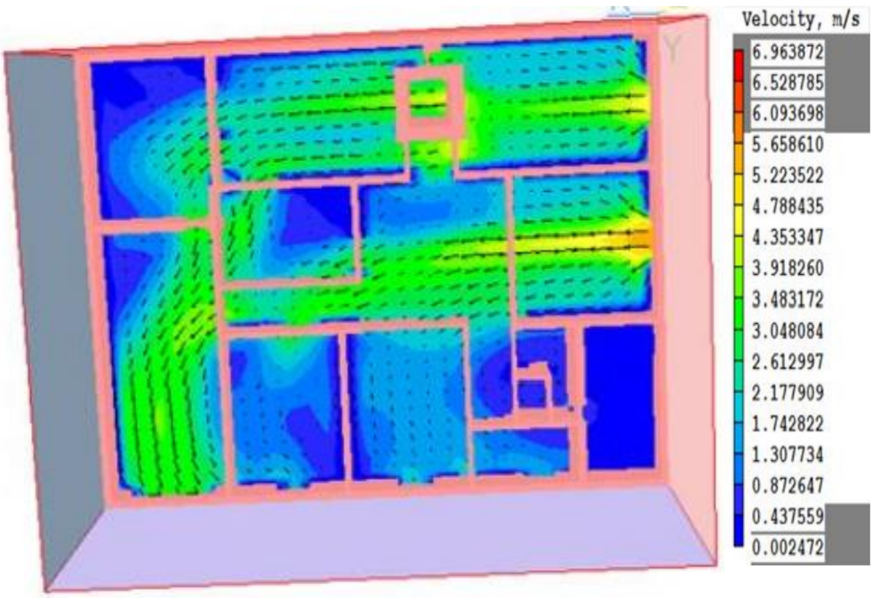

Figure 8: Airflow in dwelling with square wind tower of one orifice.

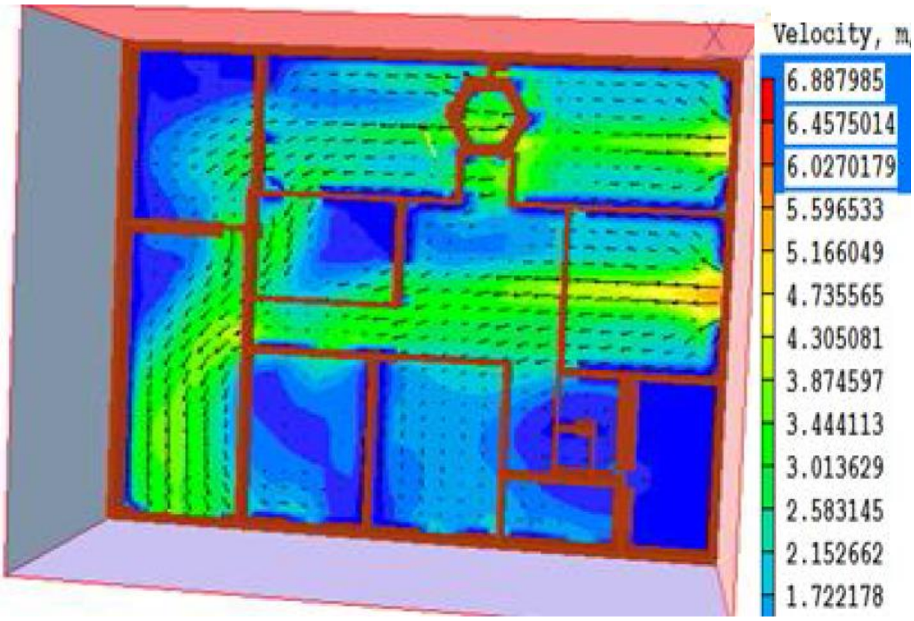

Figure 9: Airflow in dwelling with hexagonal wind tower of one orifice

The effect of wind tower orifices number on aeraulic thermal comfort:

Figures (8, 10, 11, and 12) show that airflow in the dwelling of wind tower square form of tow orifices is better than the others. Moreover, PMV value indicate this latter is the best. Since, the PMV value in the case of wind tower of square form of tow orifices is ranged on 0.98.

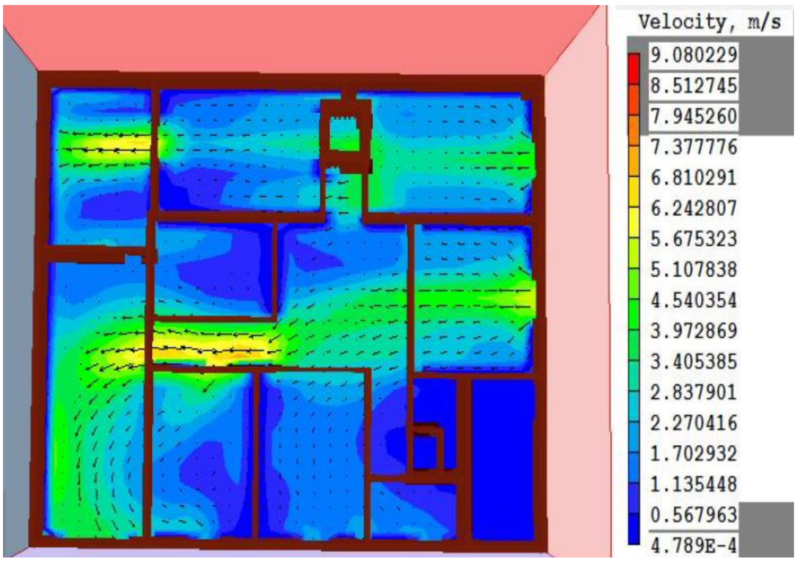

Figure 10: Airflow in dwelling with square wind tower of six orifices

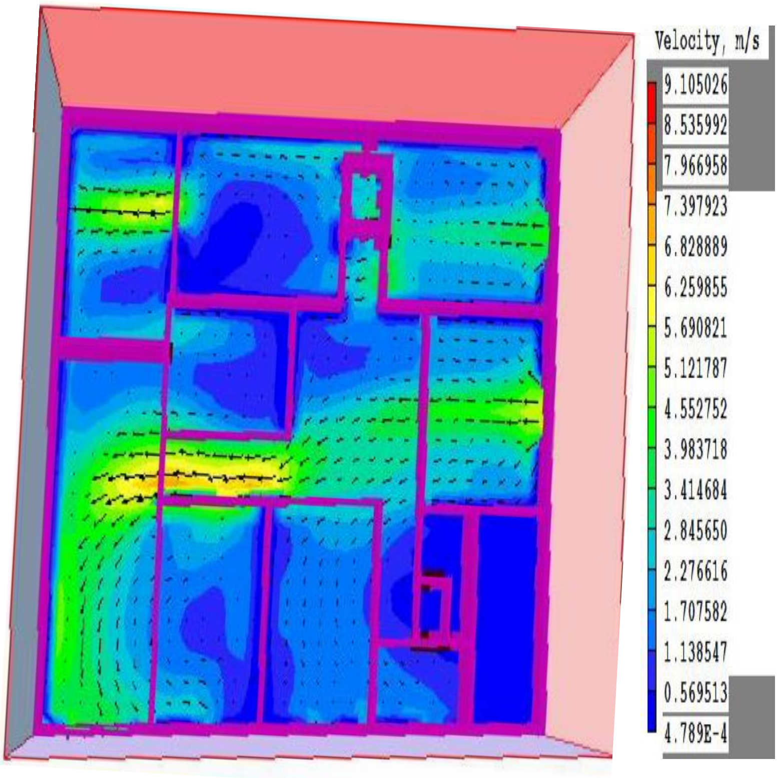

Figure 11: Airflow in dwelling with square wind tower
of two orifices

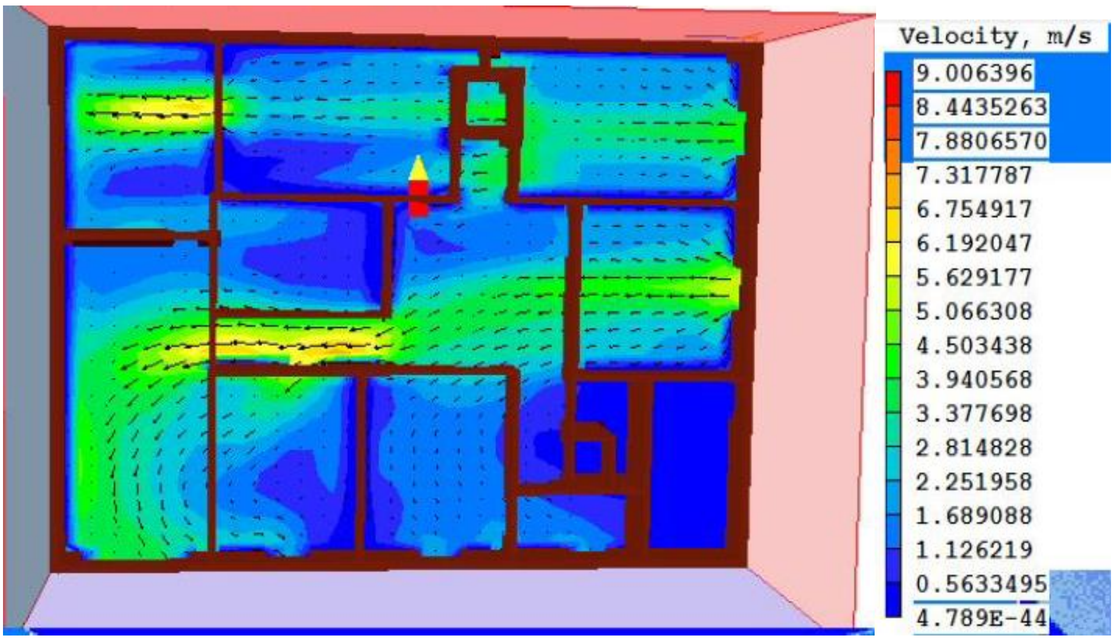

Figure 12: Airflow in dwelling with square wind tower of eight
orifices

The effect of wind tower direction on aeraulic thermal comfort

The results of CFD simulation and PMV calculation are summarized in the present table (Table1). As shown in table (1), the north south direction is considered as the best orientation of wind tower, because of the value of PMV, which is ranged on 1.03 in the north south axis, while it is about 0.92 in the East west axis.

Table 1: The effect of wind tower direction on aeraulic thermal comfort

		Orientation	Air speed	PMV	Beaufort force
Square plane	Tow orifices	North/South	12.98	1.03	4
		East/West	9.62	0.92	3

Conclusion

Traditional architecture in hot regions like Iran, Iraq, Egypt and other countries; constitutes a very rich heritage and can contribute to the enrichment of modern architecture. The wind tower is a traditional architectural element used to create natural ventilation and passive cooling in buildings. Through this study, the effect of wind tower and its geometrical parameters on aeraulic thermal comfort of residential dwelling in hot arid climate has been investigated. The results of CFD simulation and PMV calculation reveal that wind catchers of square form with tow orifices, which are oriented to the north south direction, can be considering as a good strategy to improve indoor aeraulic thermal comfort of residential dwelling in hot arid climate.

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