An Innovative Approach to Solve Thermal Comfort Problem Related to 100m2 Houses in Erbil

Haval Sami Ali[1] & Hassan Majeed Hassoon Aldelfi[2]

[1]Architecture Department, Faculty of Engineering, Tishk International University, Erbil, Iraq
[2]Interior Design Department, Faculty of Engineering, Tishk International University, Erbil, Iraq
Correspondence: Haval Sami, Tishk International University, Erbil, Iraq.
Email: haval.sami@tiu.edu.iq

Doi: 10.23918/eajse.v7i1p38

Abstract: Due to the rapid growth of Erbil population and the resulting shortage of residential buildings, individuals actively utilized 5x20 m plots for two-bedroom residential houses. Consequently, poor, and unhealthy ventilation comes about. In this paper, the authors developed an old Barajeel (Wind Catchers) approach for natural ventilation. Two Barajeels (Wind Catchers) are designed and located at both extreme ends of the built unit. The two wind catchers are made as inlet and outlet for the air movement where the rate of air changes at its best. To validate the usage of the wind catchers a CFD Software was used to simulate the operation of the wind catchers for natural ventilations for average wind speed of 2 m/s. The results show a positive solution to solve the problem of the cramped such built units. It can be concluded that such solutions can be deployed by the local Kurdistan authorities.

Keywords: Wind Catcher, Natural Ventilation, Air Changes, Barajeel, Erbil Houses, Energy, Movements, Air flow, Simulation

1. Introduction

Globally, modern life is completely reliant on electrical energy; the most of them is produced from the combustion of non-renewable fossil fuels that cause to global warming. Population growth and increasing global economic is predicated on increasing energy use and thus increasing fossil fuels use in the absence of fully deployed and developed renewable alternatives (Azabany, Khan & Ahmed 2014). Moreover, the energy price has always tended to rise over the last decades due to market forces, making it a significant expense for many companies and individuals (Apergis & Payne 2010). In buildings, mechanical cooling systems are the main source of the emissions of carbon dioxide, which amplify global warming and have negative influences on environment, especially in hot climate. Due to the lack of energy supply, windcatchers can be used as a sustainable attempt for the purposes of cooling and ventilation (Saadatian, Haw, Sopian, & Sulaiman, 2012). Erbil is fast expanding Middle Eastern city, which has experienced sudden economic growth and population rise due to movements from rural areas and displaced people from the war-stricken zones in north and west of Iraq. Erbil is located at 36-degree latitude and 40-degree longitude; it has dry hot weather in summer and severe cold in winter (Ur et al., 2013). This weather conditions have resulted to endurable internal conditions of those environments. The environmental and green building concepts have not yet achieved a foothold in the country (Al-Nuaimy 2015).

Received: March 5, 2021
Accepted: June 2, 2021
Ali, H.S., & Aldelfi, H.M.S. (2021). An Innovative Approach to Solve Thermal Comfort Problem Related to 100m2 Houses in Erbil. Eurasian Journal of Science & Engineering, 7(1), 38-45.

Wind catchers are instruments of ventilation utilized for acquiring the characteristic of cooling. In buildings, they have been used for a long time in hot dry countries especially in the Middle East (Ali, Mohd Yatim, & Bahsan, 2020; Alwetaishi & Gadi, 2020). Many attempts have been tried in the old history in the region of south of Iran where wealthy families' houses were supplied with a simple architectural structure which allows a reasonable air changes that was called Barjeel (Montazari, 2011; Hosseini et al., 2016). In recent history many houses in the Gulf States used extensively such elements for natural ventilations where the humidity is in its extreme (Zarandi, 2009). The more the number of such Baraeel the more the wealthy is the family. In western Europe and America some sort of such a device have been adopted to ensure a high rates of air changes which are termed by wind catchers (Elmualim, 2009).

In addition, in modern buildings wind catcher is increasingly utilized as a natural ventilation system in to minimize non-renewable energy consumption and reduce the harmful emissions. The number of openings, height, cross section and place of the air passages are the main factors which affect the performance of ventilation of a wind catcher structure (Montazeri, 2011). In Erbil an already existing typical hundreds of 5x20 m unit house built with in Erbil. Those houses are equipped a low-income family such house is cramped and having unhealthy interior conditions, it is therefore suggested to have a natural ventilated device which is almost zero net energy lose and provide natural continuously fresh air input. The outcome of this proposed pilot solution is to introduce zero net energy fresh air supply into the cramped and unhealthy inside conditions (Iwan, 2014).

2. Research Approach

In this research paper the existing conditions of such residential houses have been considered with no alteration to the existing architectural structure. In accordance with the investigation of the prevailing wind direction for Erbil city, which is the southwest for most of the summer months June July and August, and the west direction for the other months of summer season May, September and October, while the overall year-round is in the northeast direction (Sabir, 2014) two types louvered of manually adjustable wind catchers were designed as per Figure 1.

Figure 1: Design of Wind Catcher: Sketch Up

The two Barajeels (Wind Catchers) were located at the two extreme ends of the unit (Figure 2) such as a natural air flow movement from top to the bottom interior of the unit and leaving at the other end by the second wind catcher. In order to validate such research, a well-known ready for use program (Autodesk CFD) has been deployed for simulating an incoming wind speed of 0.5 m/s, 1.4 m/s and 2.0 m/s.; these values are typical for wind speed in the SW directions (Sabir, 2014). It is hoped that the conclusive results of this paper will be used as a guideline by Erbil and Kurdistan developers, planners and local municipalities for promoting an alternative energy usage for natural cooling and ventilation of the thousands of such unit houses.

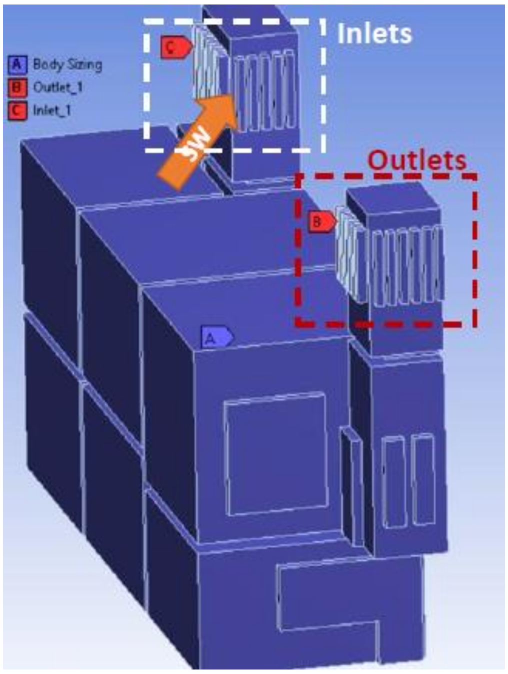

Figure 2: The model of Windcacthe

3. Model Simulation

The model of typical of 5x20 m houses (Figure 3) are already built for the low-income families in different areas of Erbil city. Two types of wind catchers positioned at the extreme ends of each unit and adjusted twice yearly for the SW and W directions whenever applicable. The authors intended to validate empirically the flow of incoming wind to produce natural zero energy air changes within the built unit. CFD Autodesk model has been deployed for simulation for different incoming wind speeds of 0.5 m/s, 1.4 m/s and 2.0 m/s. where the average wind speed for the peak summer period is around 2 m/s. The model is run in layers in the X, Y and XZ directions as per attached images and video presentation. It can be seen in the appendix A.

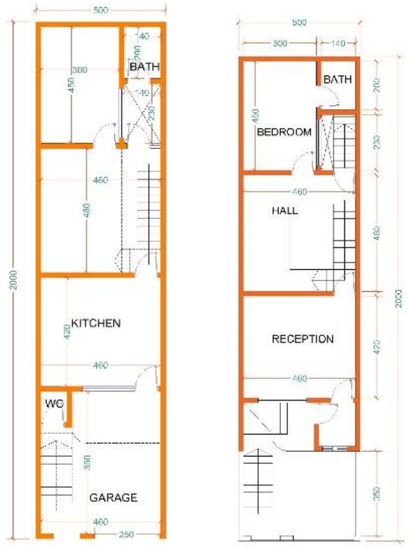

Figure 3: The plan views of the ground floor and first floor of the built unit

4. Results and Discussion

In referring to (Figure 4) it is clearly shown that the flux of wind and air changes at height 1.2 m above ground floor within the built unit is progressively improving with the increase of input wind speed of 2 m/s

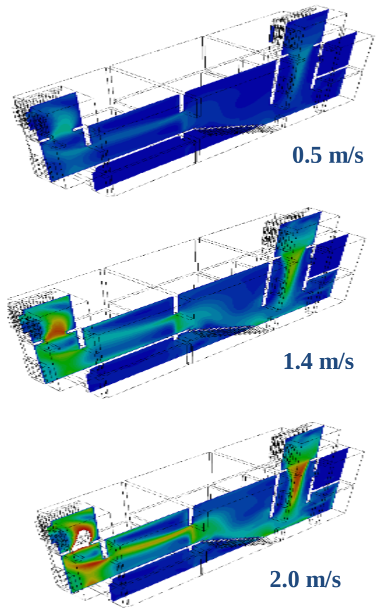

Figure 4: shows the Z Axis view simulation of different wind speed 0.5m/s, 1.4m/s and 2m/s for unit

The performance of air changes of the unit at the first floor proved to be more effective than the performance at ground floor at the 1.2 m above floor level; this is because of the restriction of some of the existing walls at the ground floor which restrict the air movement to its outlet as per Figure 5 which shows the air movement at ground and first floor at height 1.2 m above floor level.

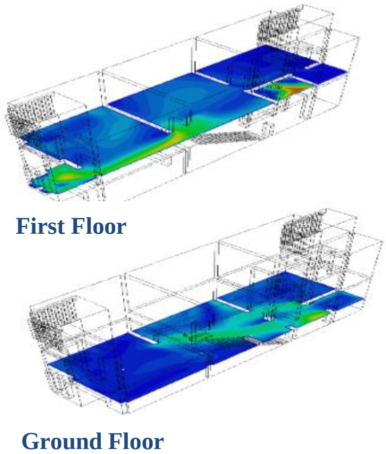

Figure 5: Air movement in the ground and first floor plan

5. Graphical and Numerical Analysis

5.1 Speed 0.5 m/s

The design of the inlet wind catcher contributes to creating a high-pressure inlet. It is a positive element because, the indoor air velocity reached on the roof level is around 1.8 - 2.0 m/s, which is almost 4 times the inlet pressure. However, the presence of multi-openings with considerable areas (e.g.: 4 doors, 2 big and 2 medium indoor windows) generated a disadvantage because it decreased the wind pressure and deplete the airflow power. In all indoor areas, the air movement was minimizing with an average of 0.2 to 0.4 m/s approximately. It is clearly evidenced by the images 5 and 5. Moreover, the best performance of the air movement was noted on the stairs area and the front wind catcher with areas that reached air velocities between 1.2 and 2.20 m/s. It was because it is the predicted air path for exhausting the indoor pressure.

According to the data obtained from the CFD program, the average of interior air velocity was 0.25 m/s in the whole net. It means that there are zones without air movement considering that in the wind catchers the air velocity average is around 2 m/s. These areas are principally the back rooms and baths as is shown in the Fig. 6. The total volume integral in relation to the velocity was about 110.43 (m/s) (m3), which represents the volume of air moved by this wind calculation. On the other hand, the maximum rate of uniformity index was about 0.684, which means that only the 68 % of the indoor air is being affected by the pressure or had been moved by the introduced air. This parameter is directly related to the area and the position of the wind flow inlets and outlets.

5.2 Speed 1.4 m/s

As similar of the first running, the pressure on the inlet wind catcher is considerably high in comparison to the initial air velocity. However, in this case, the indoor air velocity reached on the roof level is around 3.2 to 3.6 m/s, which is more than 2 times the inlet pressure. Consequently, the multi-openings decreased the wind pressure and deplete the airflow power. However, in this case, the effect is substantially smaller than the first running. In general, the air movement and velocity had a positive impact with the increasing of the inlet pressure. It is clearly evidenced by the images 4 and 5. Finally, the air movement has been improved in almost all of the spaces except for the kitchen and first floor back bath. This is principally because these zones have not ventilation areas which are able to create cross ventilation.

According to the data obtained from the CFD program, the average of interior air velocity was 0.69 m/s in the whole net. It means that the indoor air velocity increase but there still are zones without air movement. The total volume integral in relation to the velocity was about 306.2 (m/s) (m3), which is almost 3 times than the first calculation. On the other hand, the maximum rate of uniformity index was about 0.689, which means that only the 68.9 % of the indoor air is being affected by the pressure or had been moved by the introduced air. This parameter is directly related to the area and the position of the wind flow inlets and outlets.

5.3 Speed 2.0 m/s

The general movement of the air evidenced on the previous calculation is replicated by this case, but with more air flow and velocity in all zones of the house. However, the kitchen and back bath still have not proper air circulation. The positive circumstance is that the other spaces of the house as reception, halls and bedrooms had presented air velocity over 2m/s in some areas, which not only contributes to the air circulation but also could improve the indoor thermal comfort at the high temperatures. Nevertheless, this high speed in some places could be detrimental to the indoor comfort also. It is because, in the case of the stairs, adjacent corridor and exhaust wind catcher which has the reception entrance, may perhaps present problems for the users considering if they have light things which could fly away as papers, small objects or clothes. For that reason, these areas should be slightly modified for improving the air flow or labeled only for specific activities.

According to the data obtained from the CFD program, the average of interior air velocity was 1.04 m/s in the whole net. In similar way, the dead zones affect to the average velocity of indoor air. The total volume integral in relation to the velocity was about 460.46 (m/s) (m3), which is more than 4 times than the calculation with a wind speed of 0.5 m/s. On the other hand, the maximum rate of uniformity index was about 0.699, which means that only the 69.9 % of the indoor air is being affected by the pressure or had been moved by the introduced air. As is shown in by the 3 data, this parameter will be improved only if the area of inlets and outlets or wind catcher design is changed.

6. Comments & Recommendations

In general, it is clearly seen that the wind catchers are working well but no more than at 60% of its capacity. It is because the indoor design of these elements does not contribute to distribute the wind flow properly. Moreover, the lack of a direct air inlet/outlet on the kitchen reduces the possibility to have a proper ventilation of this area. Its circumstance reduces the general performance of the indoor air movement showed on the uniformity index and indoor air velocity values. On the other hand, there is a highly probability that there will be a problem at the exhaust wind catcher. It is because the air outlets are located at Southwest direction as similar as the main direction of the air. Also, there was evidence on the images number 1 in all cases that the air flow had a trend to out for the back part of the front wind catcher.

It can be recommended that it is essential to redesign the interior of the wind catchers with the aim to reduce the losing by the indoor areas. Probably one of the best decisions could be to assign only a specific area of the windows and doors for ventilation purpose, considering the volume of served spaces. Furthermore, another good solution could be the use of the wind catcher as inlet and outlet of air. It could be done just dividing it in two ducts strategically located for serving contrary areas for increasing the cross ventilation. Finally, it is strongly recommended to change the position of the air outlets to the back area of the front wind catcher in order to avoid the possible wind clutter. At least it is needed to create vertical elements with an angle of 90 degrees in relation to the Southwest with the aim to redirect the air flow outlet.

7. Conclusions

Based on the result of calculation and simulations, the following can be concluded:

1. Simulations for wind speed of 2 m/s leads to 45 air changes per hour which is typical for evaporative cooling purposes.
2. Simulations using the CFD Autodesk Software program provide a positive empirical air flow for ventilations purposes for the 20x5 m-built unit.
3. An adjustable directional wind catcher (barajeel) units can be installed to solve the cramped built units for solving natural ventilation at zero net energy.
4. Such proposed solutions can be adopted successfully by the local Kurdistan authorities for the low income-built houses.

References

Ali, N., Mohd Yatim, M., & Bahsan, R. (2020). CFD analysis on velocity and temperature distribution of airflow inside model building with windcatcher. *IOP Conference Series: Materials Science and Engineering*, 834, 012036.

Al-Nuaimy, A. (2015). Official holiday in Iraq due to high temperatures. Al-Arabi Al-Jadeed [online]. Retrieved on 17 August 2020 from http://www.alaraby.co.uk/society

Alwetaishi, M., & Gadi, M. (2020). New and Innovative Wind Catcher Designs to Improve Indoor Air Quality in Buildings. *Energy and Built Environment*,

Apergis, N. & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, 38(1), 656-660.

Autodesk (2017). Autodesk, CFD. Retrieved from https://www.autodesk.com/products/cfd/overview.

Azabany, A., Khan, K. & Ahmed, W. (2014). Solar photovoltaic generation potential and plant capacity in Northern Iraq. *Asian Journal of Science and Technology*, 5(7), 423-426.

Elmualim, A.A. (2009). Utility of Wind Catchers for Nocturnal Ventilation. *International Journal of Ventilation*, 85-92.

Hosseini, S., Shokry, E., Ahmadian Hosseini, A., Ahmadi, G., Calautit, J. (2016). Evaluation of airflow and thermal comfort in buildings ventilated with wind catchers: Simulation of conditions in Yazd City, Iran. *Energy for Sustainable Development*, 35, 7-24.

Iwan, A. (2014). Energy efficient buildings in a hot and dry climate: *Improvement of traditional houses in Kurdistan region*.

Montazari, H. (2011). Experimental and numerical study on natural ventilation performance of various multi-opening wind catcher. *Building and Environment*, 370-378.

Montazeri, H. (2011). Experimental and numerical study on natural ventilation performance of various multi-opening wind catchers. *Building and Environment*, 46(2), 370-378.

Saadatian, O., Haw, L., Sopian, K., & Sulaiman, M. (2012). Review of windcatcher technologies. *Renewable and Sustainable Energy Reviews*, 16(3), 1477-1495.

Sabir, T. (2014). Average climate Data of Erbil City for 2014. Erbil Metrology Directorate General, Erbil.

Ur, J., de Jong, L., Giraud, J., Osborne, J., & MacGinnis, J. (2013). Ancient Cities and Landscapes in the Kurdistan Region of Iraq: *The Erbil Plain Archaeological Survey 2012 Season. Iraq*, 75, 89-117.

Zarandi, M.M. (2009). Analysis on Iranian wind catcher and its effect on natural ventilation as a solution towards sustainable architecture (Case Study: Yazd). *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 668-673, 2009.