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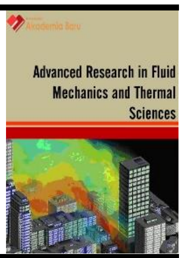

Design of Wind Catcher for Earth Air Heat Exchangers to Rationalize Energy Consumption

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ABSTRACT

Traditional architecture was responsive to climate and environmental considerations. One of the traditional architectural elements in hot dry climate was the Wind catcher that largely contributes thermal comfort inside buildings. However, Modern architectural design has moved away from this vocabulary. This research explores the air heat exchanger (WEAHE) that benefits from the earth soil temperature, as passive cooling system that improves the internal environment thermal comfort and reduces energy consumption in Iraq as an example for hot dry climate. The proposed system is based on increasing Wind catcher area, part of the structure of the Wind catcher is under the ground. To take the advantage of the lower soil temperatures and groundwater in summertime, to moisten the air moving areas through walls and tubes inside the soil. After that, Wind catcher was studied in a house Construction of the proposed model through the horizontal and vertical paths of air transmission to Earth and simulate using a computer a digital "simulation program (CFD)". Results showed through there were increased in airflow and a low temperature around 14 °C. The external temperature was 45.4 °C, relative humidity improved to 24%. The performance coefficient (COP) the "WEAHE system" is 3.34-5.42 with an increase in air velocity 1.5-3.5 m/s. New WEAHE design can be used as a self-cooling device that regulates internal air movement and achieves thermal comfort and sustainable exporter of renewable energy while decrease the need for mechanical means in hot dry climate such as Iraq.

Keywords:
Wind catcher; CFD; WEAHE system

1. Introduction

Traditional buildings were designed and built to provide thermal comfort in hot dry climate. One of the main building elements in it was the wind catcher. A traditional architectural element, that were used for passive cooling and achieving natural ventilation in buildings for long periods through fronting the prevalence wind and moved by building spaces cause of different in wind compression [1]. However, this architectural element had disappeared from modern housing after artificial ventilation Mechanical devices. That chance in the types of active cooling caused high consumption

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of fossil energy and the increased in prices and the apparent lack of energy. For this reason, one of the most urgent necessities of our time is to find alternatives that reduce fossil energy consumption or to improve the element used in the past to meet the thermal comfort conditions in order to provide a comfortable environment [3]. There were many recent studies that searched of reducing energy consumption for dwelling buildings in hot aired climate through passive design and renewable energy sources [4] explore the effect of wind catcher natural ventilations on reducing energy consumption. For instance, these studies showed the importance and value of wind catcher as a new alternative to the natural ventilation and cooling system [3]. The study indicates to design efforts a windshield inside intelligent buildings and use modern tools like light aluminum sheet metal and a thin flexible over the ceiling. The research by Mahmud Dehnavi *et al.,* [5] proposed a new design Wind catcher. The proposed industrial flexible towers were formed over buildings in the face of high wind movement. It was also able to rotate and position same in the direction of the wind speed limit. In areas where the low wind speed. On the other hand, Benhammou *et al.,* [6] provided a model for predicting air velocity within the pipe and the depth of the most suitable burial 2 m. The results showed that the wind tower dimensions (Cross-section high). It had no significant effect compared to the length and diameter of the pipe. Benhammou *et al.,* [7] proposed a one-dimensional model is progressing to study thermal performance of summer cooling of earth to air heat exchangers (EAHE). The results showed that the outside air temperature decreases with the length the tube but accretion with an accretion cross-section of the tube and air speed [8]. As well focuses on indoor air quality (IAQ) and thermal comfort aspects. Compared to different experimental methods and theoretically used by researchers in different case studies to assess indoor air quality and thermal comfort using CFD, and experimental techniques. The review also looked at the different types of cooling methods combined with Wind catchers such as evaporative cooling and heat exchangers from the ground to air (EAHE) and heat transfer devices (HTD). Montazeri and Montazeri [9] provided a detailed assessment of the impact of wind catch openings on ventilation performance. The evaluation is based on three indicators for the performance of ventilation. The results showed that the outlet holes too close to the positioned will not increase the resulting airflow. Together it leads to a significant reduction in indoor air quality. The use of two air inlets for the wind catcher leads to lower indoor air quality and efficient air change. In another place, Gao *et al.,* [10] reviewed the latest studies on terrestrial heat exchanger from several new perspectives and shows them potential to achieve energy-free buildings, which provide an outstanding solution to improve the quality and energy efficiency of buildings. Ahmad Zaki *et al.,* [11] analyzed the flow behavior within the conventional double-sided wind catcher to understand the best effect of airflow on internal ventilation behavior. It concluded that more representative pilot methodologies should be used when studying natural ventilation with wind catcher. These studies and other studies [12-14] had showed the mechanical techniques used to improve the studies of ventilation and cooling methods combined with evaporative cooling and heat exchangers from the ground to air (EAHE). However, the studies did not address the increasing wind catcher clip space and part of the wind catcher underground, incorporation of traditional design principles into the contemporaneous design is a defy for researchers. Which made us think of a contemporary application of traditional concepts and the lowest cost. Through the adoption of the lighthouse in the dwelling and employ it as a wind catcher part of it inside the soil with a network of pipes inside the soil. This means an increase in the volume of wind catcher and to achieve ground heat exchangers and air, through horizontal and vertical passages, which means moistening catcher walls of the vertical and horizontal across the groundwater of the earth, that can reduce air temperature. The process of moving being air smoothly from entering the lanes and wet tubing to achieve thermal comfort and the rationalization of energy consumption.

2. Methodology

The study model is located in Baghdad the capital of Iraq, the largest city in Iraq. It located on the longitude 44.25°E, and Latitude 33.19°N classified as a hot dry climate [15]. Desert or semi-desert characterized by the power of solar radiation and high induced drought evaporation average, Most of the year the clear sky, hours brightness in summer 11.4 hours/day, and winter 6.30 hours. The maximum temperature ranges 44°C in latest July, the "Relative humidity (RH)" between 25%-73% [16]. Warm and mild a period of eight months, and the cold period is four months. The study was conducted for three days in June and August 2018.

The research methodology based on study the effectiveness of natural ventilations for Wind catcher in dwelling buildings. Wind catcher system of natural ventilation adopted in many different climate areas. The move away from this element in modern designs caused lack in thermal comfort for the contemporary human requirements; this research proposed a development in design Wind catcher system, increasing the air movement and achieves the heat exchange of the land and air.

2.1 Description of the Wind Catcher Design

i. Increasing the Wind catcher space.
ii. The structure consists of two parts, one above the ground level and rise above the highest point of the house up to 2.1 m and facing the prevailing wind movement in the region, the other part underground to a depth of 2.0 m.
iii. Part of the Wind catcher continues inside the earth soil, At the base, a network of pipes inside the soil is connected to lengths of (40m) (44m) diameter 50 cm made of polyethylene or high-density ceramic material chemically treated to prevent the growth of bacteria, fungus and weatherproof to ensure heat exchange, Ending with vertical paths within the space of the dwelling.
iv. Wind catcher liner is built from high-profile, high-density brick (Degree of pride temperature (850-1400°C) It is recommended not to use low-porous brick with reddish color, because it is damaged and crumbly when used.
v. The presence of water spray system on the lining of the wind catcher, the upper part above the ground level is reinforced with 40 mm diameter plastic pipes contains openings of diameter 4 mm per 10 cm, the system provides a water tank to control the amount of downstream water.
vi. The height of the vertical tracks (1.7 m) from the ground level of housing, contain clip (metal wire), equipped with a fan to increase air traffic control opening and closing.
vii. The air moves from the top down to the Wind catcher cavity and wet lining with water droplets, the wet pipe network due to soil groundwater, Cool, cool air moves into the space of the dwelling.

The tested experiments were done in two stages.

i. Stage I: Measurement a field of the study model in the city of Baghdad, House contains (Munawar) open spaces that worked as a Wind catcher, used (Data-logger temperature).
ii. Stage II: Building a typical represents a default development model of the first phase by continuing Wind catcher inside the ground with a network of pipes inside the soil, simulate using a computer a digital "simulation program. (CFD)".

2.2 Tested Model

The tested model of a two-story house represents a 250m^2 house area, the elevation was eastern. The courtyard area (22m^2), walls built of Lightweight Concrete for 25 cm thickness (insulation of regular building materials twice), wind catcher space 2.2m^2. The wind direction was north-west. Rising from the ground level of 1.50 m to the west and north of the wall. The height of the eastern and southern wall 3.00 m, the basic model of Wind catcher was developed by adding a vertical tunnel under the ground (2.2m). The air puller was placed at the ground level increased air movement during air dormancy periods. The diameter of the horizontal tubes is 50 cm, the air column height is 13.90 m is shown in Figure 1 and listed in Table 1.

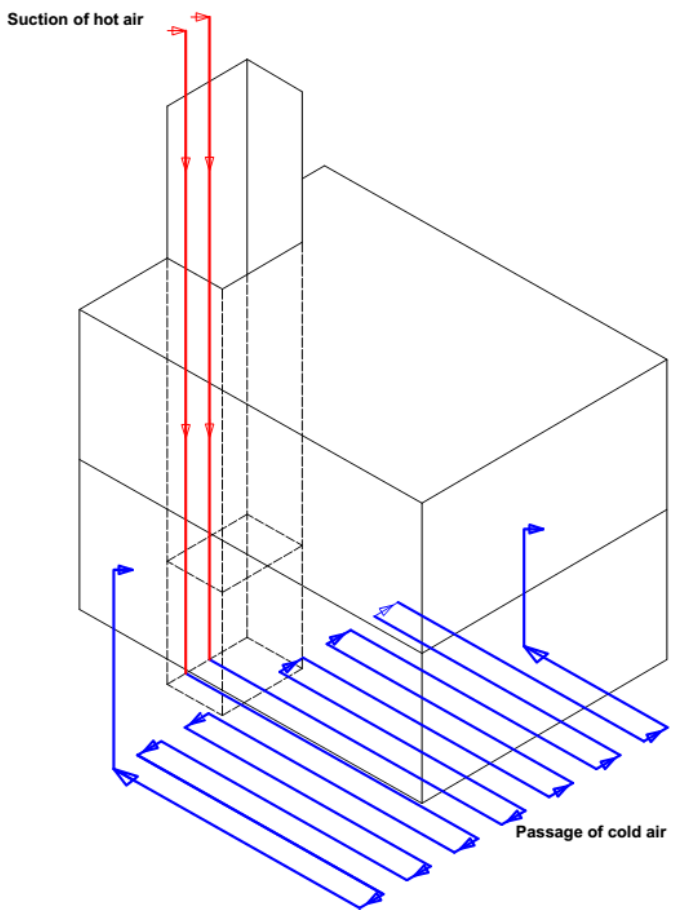

Fig. 1. Movement of the air from the entrance to the wind catch and move through the passages into the soil

Table 1
Physical and thermal parameters used in simulation

Materials	Density (Kg/m^3)	Specific Heat Capacity (J/Kg.K)	Thermal Conductivity (W/mK)
Air	1.225	1006	0.0242
Soil	2050	1840	0.52
Pottery therapist	1600	1436	0.405

2.3 Performance Analysis CFD and Experimental Verification

Several programs had been adopted to simulate heat transfer and airflow for more accurate results and clear understanding during 3D models. One of them is the Computer Fluid Dynamics (CFD). It had been effectively applied by many researchers to determine the advantages of natural ventilation [17-20].

To validate CFD-style WEAHE Conducting separate test accounts for the daily test on June 15-16, for summer of 2018, and reinstall it for July and August, both in experiments and simulations. The air flow was calculated at (1.5, 2.5, and 3.5 m/s) by the following equation.

$$Qc = 3600\ \dot{m}\ Cd\ cp(T_{inlet} - T_{outlet}) \tag{1}$$

where,
$\dot{m}$ = Air mass flow rate through the tubes
Cp = specific heat capacity at a steady pressure (KJ/ Kg °C)
Cd = coefficient of discharge of the tubes = 0.6
T_{outlet} = outlet temperature (°C)
T_{inlet}= inlet temperature (°C)

"Coefficient of performance of the system (COP)" can be determined by the following equation

$$COP = \frac{\dot{m}C_d\ cp(T_{inlet} - T_{outlet})}{Q_i} \tag{2}$$

The volumetric rate is calculated from

$$v = vel\left(\frac{\pi d2}{4}\right) * 10^{-4} \tag{3}$$

where,
Vel = Air velocity (ms^{-1})
d = pipe diameter (cm)

3. Results

3.1 Soil Temperature Style

The study region soil temperature relies on the soil type and groundwater level. A constant system of temperature ranging from 25.30 °C to 28.20 °C, was found at a depth of 2.5-3.0 m as shown in Figure 2 [21-23]. Deep soil can be used as cooling source in summer for hot climate zone.

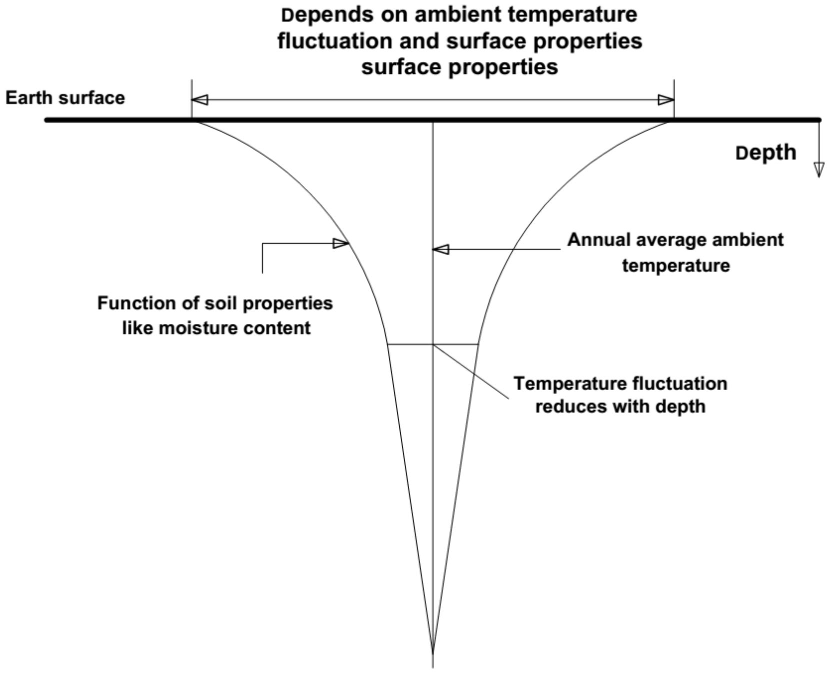

Fig. 2. Earth temperature varies with depth [21]

3.2 Different Temperature in Indoor and Outdoor Building
3.2.1 Field measurements for the first phase of improved wind catcher

Field measurements were conducted, before examining the design WEAHE model. Table 2 shows outdoor temperatures and internal temperatures in the bedroom and living room during the testing period in the summer months of August, July, and September, within three days of each month 16-17-18. From 12:00 to 15:00, consecutive take the readings rate to test hours. The results showed that internal temperature is highly volatile during July compared to months, despite difference between external temperatures and degrees inside the inner space. The bedroom recorded a difference of 10.1 to 10.6 °C, which is lower compared to the living room.

Table 2
Average external temperatures and temperatures in °C inside the house (in summer) within periods of study in the city of Baghdad, 2018

Month	Location	Medium air temperature for the day 16		Medium air temperature for the day 17		Medium air temperature for the day 18	
		Outside temperature	Internal temperature	Outside temperature	Internal temperature	Outside temperature	Internal temperature
July	Living R.	42.2	34.3	42.7	33.3	42.9	33.6
	Bed R.	42.2	32.0	42.7	32.8	42.9	32.0
August	Living R.	43.4	34.5	43.9	34.9	43.0	32.1
	Bed R.	43.4	31.9	43.9	32.6	43.0	32.6
September	Living R.	43.8	31.5	43.9	33.6	43.5	32.5
	Bed R.	43.8	33.2	43.9	32.4	43.5	32.3

3.2.2 Wind-catcher to heat exchanger from earth to air

Table 3 offers for degree of external air temperature and average temperature experimental and simulation for the living room, relative humidity through test interval to 16th month of July, August and September 2018, for three hours from 12:00 until 15:00 each day. The consequence indicate fluctuation in temperature during July, and that there is a clear difference between internal and external temperatures, lower in July of 27.3 to 27.8 °C. In August from 27.1 to 27.6 °C, and in September from 27.1 to 27.9 °C. When the external temperature ranges from 44.2 to 44.7 °C, "relative humidity" 18% to 23% at relative humidity abroad 16% to 18%. Material Construction of walls and pipelines helped to moisturize the air and reduce air temperature. Table 4 shows the experimental average temperature readings while simulations at room temperature. The test periods for the 17th of July, august and September 2018, for three hours from 12:00 to 15:15 each day. The system noted a significant difference during the month of June from 27.5 to 29.5 °C, and from 28.6 to 30.8 °C in August. When external temperature ranges between 42.6-45.9 °C. Increases the difference with the increasing airspeed. The "relative humidity" within the spaces recorded from 17% to 24%. Results show a difference in temperature within closed spaces. The living room is registered above the bedroom. The length of the pipe is reduced at the air temperature. At the same time the length of the pipe recorded a positive relevance. Relative humidity is inverse and the lowest in the living room.

Table 3
Comparison between simulation temperature, experimental degree and relative humidity of living room in summer 16/07/2018

Month	Location	Air speed 1.5 m/s			Air speed 2.5 m/s			Air speed 3.5 m/s		
		Exp. T.	Sim. T.	RH	Exp. T.	Sim. T.	RH	Exp. T.	Sim. T.	RH
July	T_{outlet}	44.2	44.2	18%	44.2	44.2	20%	44.2	44.2	18%
	T_{inlet}	29.8	28.6	24%	29.6	28.9	26%	30.1	30.6	17%
	$T_{courtyard}$	31.4	30.7	20%	31.9	30.1	19%	31.4	20.4	20%
August	T_{outlet}	44.3	44.3	16%	44.3	44.3	17%	44.3	44.3	16%
	T_{inlet}	29.7	28.6	23%	30.6	30.2	17%	30.7	30.8	27%
	$T_{courtyard}$	33.3	33.3	29%	33.6	31.3	20%	31.4	30.9	19%
September	T_{outlet}	44.7	44.7	17%	44.7	44.7	17%	44.7	44.7	16%
	T_{inlet}	29.7	29.7	24%	29.1	29.1	24%	30.1	30.4	27%
	$T_{courtyard}$	30.5	30.5	20%	30.8	30.8	19%	31.1	31.5	20%

Table 4
Comparison between simulation temperature and experimental degree and relative humidity of the bedroom in summer 16/07/2018

Month	Location	Air speed 1.5 m/s			Air speed 2.5 m/s			Air speed 3.5 m/s		
		Exp. T.	Sim. T.	RH	Exp. T.	Sim. T.	RH	Exp. T.	Sim. T.	RH
July	T_{outlet}	43.1	43.1	17%	43.1	43.1	19%	43.1	43.1	17%
	T_{inlet}	28.7	27.5	23%	28.5	27.8	25%	29.0	29.5	16%
	$T_{courtyard}$	30.3	29.6	20%	30.8	29.1	19%	30.3	29.2	20%
August	T_{outlet}	44.3	44.3	16%	44.3	44.3	17%	44.3	44.3	16%
	T_{inlet}	28.4	27.8	23%	29.2	29.1	17%	29.6	29.7	27%
	$T_{courtyard}$	32.2	32.1	29%	32.5	30.2	20%	30.4	29.9	19%
September	T_{outlet}	44.7	44.7	17%	44.7	44.7	17%	44.7	44.7	16%
	T_{inlet}	28.4	27.2	24%	28.1	27.4	24%	29.1	29.3	27%
	$T_{courtyard}$	30.1	29.8	20%	30.6	28.0	19%	30.9	30.3	20%

3.3 Comparison of Results and "Limits of Thermal Comfort"

In the summer of 2018, average air temperature is measured by dry air temperature inner the living room 28.3 °C. Relative humidity is about 23%. The temperature of the air temperature in the thermometer wet 17.2 °C [24]. Amended of airflow within the room was about 1.5 m/s. Thus, the temperature is palpable a person wearing natural clothing (1 Clo.) as accordingly in Figure 3, will be 22.2 °C, which lies within the determinants of thermal comfort [25].

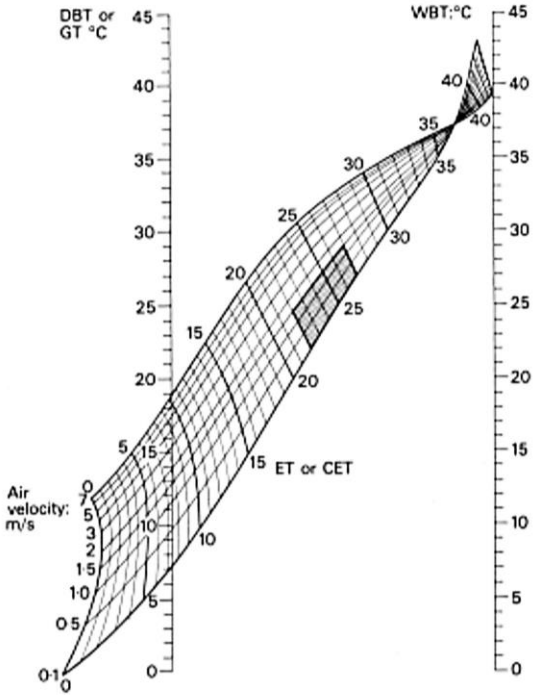

Fig. 3. The effective temperature of the "thermal comfort limits" for people in ordinary clothes, the relationship between air temperature and air speed and humidity

4. Conclusions

In the first stage increase, wind catcher space did not achieve thermal comfort at an acceptable level, cause high air temperature and solar radiation. In the second stage, the wind catcher system, earth-to-air heat exchanger contributed WEAHE reduce air temperature 13 °C which represents about 34% of the degree of external air temperature. That immediately related commensurate with the speed of the movement of air, the length of the path of underground pipes, and the adjustment in relative humidity, and emphasizes the importance of the use of pottery pipes in moisturizing. Air intake can be controlled in indoor, according to the season and increase antenna movement. Performance Factor (COP) System WEAHE difference 3.34-5.42 with increased airspeed 1.5 to 3.5 m/s, while thermal comfort equation among efficiency and temperature achieved at the required comfort limits, when an airspeed is 1.5 m / s up to 22 °C. This makes the new design method for self-cooling and a sustainable source of daylight and reduces power consumption in the drought, arid countries like Iraq.

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