Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 12, pp.43287-43294, December, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

EMPLOYING MINWER WIND CATCHER HEAT EXCHANGER AS A PASSIVE EVAPORATIVE COOLING SYSTEM AT HOUSE

*Jamal Abed Al Wahid Jassim Al Sudany

Department of Architectural Decoration, Middle Technical University, Baghdad, Iraq

ARTICLE INFO

Article History:
Received 03rd September, 2016
Received in revised form
15th October, 2016
Accepted 08th November, 2016
Published online 30th December, 2016

Key words:

Building environment,
Environmental design,
Sustainable architecture,
Ventilation,
Wind catchers.

ABSTRACT

The study aims to employ Minwer to the wind catcher heat exchange from the earth to the air WETHE to promote the hours thermal comfort, Because the heat exchanger systems are inadequate and need to run equipment, By integrating the Minwer with a passive evaporative cooling of the proposed system. Part of the wind catcher rises above the surface of the housing and a portion of the soil depth of 4.0 m Provider spraying water system to the lining of the wind catcher, Pottery tubes along the 80m wetted because of groundwater, And depending on the air pressure of the air column and it is moving exchange between the air and the walls of the Minwer and tubes within the concept of evaporative cooling, Experimental readings adopted and the development of a heat exchanger model based on computational fluid dynamics to predict system performance, These results show a decrease in air temperature in the summer season, the temperature dropped 19°C when she was abroad 46.7°C, and improve the relative humidity to 35%, The winter season has increased the temperature 6.1°C when she was abroad 11.3°C. Moreover, there is a difference in temperature within the tube path and also because of the difference in airspeed, It could be argued that the system can be applied in future residential complexes to reduce energy consumption and that alone is enough to achieve thermal comfort in summer and winter need assistance.

Citation: Jamal Abed Al Wahid Jassim Al Sudany, 2016. "Employing minwer wind catcher heat exchanger as a passive evaporative cooling system at house", *International Journal of Current Research,* 8, (12), 43287-43294.

INTRODUCTION

Use the wind catcher system of natural ventilation and passive cooling for long periods in the traditional architecture of the air entering through the slot from the face of the movement of wind and the differences in the negative pressure, wind between the outside and inside to cause increased air movement inside the building, However, the holder, wind has disappeared in modern architectural practice since they don't meet the necessities of thermal comfort for the person for the time being. The emergence of evaporative coolers, air conditioners operating pressure refrigerant vapor is what you pay for the hot air of external area and the cause of the votes, In addition to air bearing moisture when in use air coolers and evaporative be dry when the use of air conditioners, affecting increasing action in the air that cause drowsiness and depressions for users of synthetic devices (Alsahrawardy and Al-Jawadi, 2010) Meet a height in energy consuming. Together in the presence of an energy crisis in addition to rising prices. Making us contemplate finding a less expensive contemporary alternative depends on the Passive cooling explore the many alternative energy technologies such as heat exchanges ground with air (Afeef and Masa, 2014). ETHER system, it depends on the pumped air during tubes inhumed under the soil for summer cooling and vice in the winter. Attempts by researchers in the development of passive cooling and improve ability the natural ventilation and thermal comfort produced many of the research. (Goswami *et al*., 1993) developed system EPAHE using a plastic tube wavy with a fan to push air through the tube and the study show up difference clear in temperature air. (Da Silva, 2005) Noted that the passive evaporative cooling performance is affected by evaporation cooling effectiveness through the hours cooling. And ineffective in the summer, that need for mechanical aid efforts to improve thermal comfort. (Bahadori *et al*., 2008) Study experimental of air towers, used the blinds are sprayed with water and another tower outfitted with internal surface platforms evaporative cooling, it was found that temperature air internal the space less than a temperature from the traditional wind catcher and a wind wet tower was more effective during the high winds, while the other be more effectiveness in times of drop wind. (Kalantar, 2009) Flow of air during the wind turret style analysis includes evaporative cooling organize with the help of numerical simulation CFD. (Either Safari and Hosseinnia, 2009) Adopted analysis in light of computational fluid dynamics indicated that wet columns

Corresponding author: Jamal Abed Al Wahid Jassim Al Sudany,
Department of Architectural Decoration, Middle Technical University, Baghdad, Iraq.

rise 10m reduces the temperature up to 12 degrees Celsius and increased air relative humidity of 22%. (Bansal *et al*., 2012) An attempt to integrate the passive heating and cooling systems with evaporation cooler when you go out using computational fluid dynamics CFD the results showed a great ameliorate the benefit system EATHE While combined with the evaporative cooling in the hot dry climate. (Bisoniya *et al*., 2013) Earth–air heat exchanges are one applications, renewable vitality quickest developing in the world. It is basically a set of tubes of metal, Concrete or plastic material placed under the soil at the specific deepness to the air flowing through. (Dehghan *et al*., 2013) The concept of Wind catcher is concept is usually a long structure show that air flow style relied on the column of the air pressure and air speed, which are strongly influenced by wind catcher roof geometry and direction of wind flow. (Tudor and Badescu, 2013) Revealed that the temperate climate with a vast distinction between the temperature in summer and winter are suitable for heat exchanges earth tube. It has been used different shape of heat exchange in many fields. These studies and other studies within the heat exchanger system from the ground to air relied on energy in their work in pushing the air through the tubes of the spaces. And based on this study is to recruit Minwer wind catcher purpose of finding the importance of rising column air and realization heat exchange with walls Minwer who is part of the walls are lined brick clay proud provider of water spray and part of Minwer beneath the soil and tubes made of pottery inside the moistened soil due to groundwater and then into indoor. The research aims to design Minwer wind-catcher earth to air heat exchanger based at normal movement of air and investigation evaporative cooling and normal ventilation to decrease Nonrenewable vitality and lessening of ecologically destructive emanations utilization. Adopted search computer simulation using a numerical simulation program CFD. The suitability of any passive cooling system depends not only on internal conditions, but also on the type of building and local climate, This proposed system can benefit from it in the future residential complexes and ensure the achievement of natural lighting and regulate air movement within the pure natural spaces and to achieve thermal comfort for occupants. Fig.1. Show different openings of air moving Wind catcher models of traditional architecture.

Characteristics climate of the city of Baghdad

The city of Baghdad, Iraq, located on the longitude 44°40'E and latitude 33°30'N, elevation above sea level 34.1 m. Within the hot dry regions and contains two chapters two main cold winters and hot summer. Exposed Baghdad region of is exposed to much of solar radiation through the year and the drought resulting from high rates of evaporation of disparity the temperature amongst summer and winter, Vary the temperature between summer and winter, and between night and day and the lowest average value appear on the clock at six in the morning of 4°C, Temperature reaches 50°C in the month of August. Relative humidity between 21% and 72% in June, December, Local prevailing winds generally laden with dust on most days, We can say that the period of moderate and warm up to eight months and the remaining four months represented the cold season. Which gives a clear idea about the length of the hot season in the city of Baghdad, Necessary and the need for air conditioning is on an ongoing basis, As the winter season, the heating is not this need, Which means that there is a real need for electrical energy and high energy prices. We made us think about finding alternative means of energy, reduce as much as possible from the exchange on polluting energy through the antenna to move natural groundwater exploitation and low soil temperature.

Describe Minwer wind catcher with passive cooling techniques

Incorporating negative techniques in the design of the building to reduce reliance on mechanical method for warming, cooling, ventilation and lighting systems and achieve a negative thermal and visual comfort by utilizing natural resources and achieve internal gains. These vary from climate to another with the aim of the architects warm climate would be building design to minimize solar gains and achieve natural ventilation. It can be exploited for passive cooled system to maintain the proper temperature in the indoor or ease the burden of air-conditioning device. Ancient buildings have shown ingenuity in how to use the techniques of the negative, and there is a lot of inclination towards these systems, economic and environmental reasons (Maerefat and Haghighi, 2010)

Figure 1. Wind-catcher in traditional architecture with different number of openings

The heating and cooling frameworks, passive, less energy utilization with proficient heating and cooling frameworks, compared to energy utilization, the idea of wind catcher structure rises from the roof of the building wind capture at higher speeds and less dust be addressed to the wind direction. Is based on the concept of the Earth cooled to transfer heat from the building to the ground, during the cooling season warming lowest temperature of the outside air, This conversion is finished either by direct contact with the building envelope or through the air injected underground into the building through the heat exchange earth-to-air. The fluctuate of earth's temperature decreases with depth and temperature, depth of 4 m is roughly equal to the average annual temperature, as shown in the Fig. 2. (D.G. Leo Samuel, S.M. Shiva, M.P. Maiya, 2013).

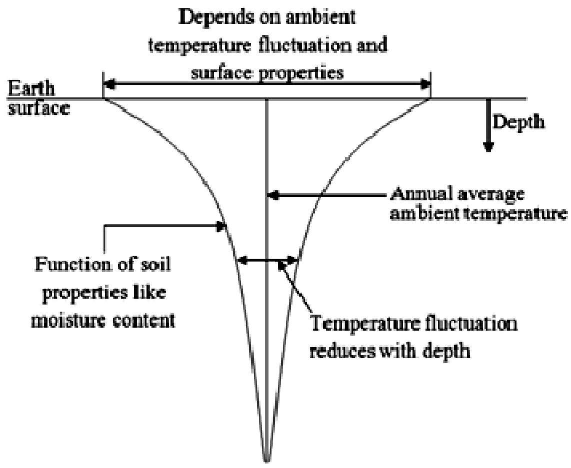

Figure 2. Different of Earth's temperature with different depth. (D.G. Leo Samuel, S.M. Shiva, M.P. Maiya 2013)

Wind-catcher traditional tower rises above the building provider before the prevalent wind outlet. As cold air captures and moving to internal area in the building, and there is an area of the enlightened and acceptable and rises from the level of building a suitable height can be used for air transport, relies design idea:

- Minwer designed spaces within the housing interior to deport 0.90 * 0.90 m rises from the housing aperture 3.0m ends to the north-west, where the prevailing winds in the study area.
- Walls contain spaces for lighting, sealed.
- Horizontal tracks in the form of underground tube deep 4m length 80m in diameter and 35 cm and a thickness of 2,50 cm tube manufacturing of ceramic material or of high-density polyethylene bears high pressures chemically treated to prevent the proliferation of microbes to ensure the quality of heat exchange.
- Vertical single track 0.35*0.35 m to expel the air to move into the closed slot space at a height of 1.60 m equipped with controls conquest and closing.
- The existence of a hole in the roof of the closed space 35 cm continue on to the roof of the building raises 1.5 m diameter on the level ground surface.
- The existence of pulling air into the air exit port contributes to increased hot air pull.
- Develop a drawer in the air Minwer ground level housing to boost air circulation when intervals stillness air.

The study assumed that symmetric soil properties and low soil temperature 12-16°C relies on upon the soil kind and deepness. The heat exchange between the air and the walls of Minwer who is part moisturizer cold and wet tubes, cold, moist, Air moves in accordance with the precept of air compression between the air intake opening of skylight and air exit opening column difference. Cold fresh air appropriate quantity and moisture-laden and comparatively do not contain dust in comparison with the conventional wind catcher. Rendering us think of the significance of adopting normal ventilation, and air, wind-catcher development model space section raising the level of the heat exchanger of earth into the air.

Research Methodology

To achieve the goal of research in the performance of the heat exchanger through the effective employment of the Minwer wind catcher conditioning and the role of natural air movement in the performance of the heat exchanger from the earth to the air, adopted by the research, The study was conducted in the months of July and August in the summer season 2015, and in January and February during the winter season 2015 for three consecutive days within the terms of the climate of the city of Baghdad, which lies within the tropics dry warm, The study was conducted in two phases:

- Experimental measurements of the model study, which represents a single housing contain Munawar employed wind catcher air using a device testo testo 417 Set-2 Anemometer.
- Default model building and simulation within a computational fluid dynamics program CFD.

The study model

Since the aim of the study to employ Minwer wind catcher conditioning and access to renewable energy for the home efficiently with maximum use, Housing model which is used for the study of a housing unit for single-family on two floors in the city of Baghdad, ground area 240 m^2, construction area of each floor 168 m^2 as appears in Fig.4. Existence Minwer dimensions of 0.90*0.90 m were designed wind catcher related to the number of spaces to deport them to sit internal space of 6.90 m length 5.00 m width 3.15 m height of the space, Extends above the surface of the housing four meter port containing air to enter the prompt to the north-west, and the other part of the Minwer implemented into the soil to a depth of 4m. The walls of the house built of light concrete thickness of 25cm billets from abroad Alcino stone, inside the white plaster. The windows are made of polyvinyl chloride PVC double glazed, Roof Concrete, There are front and rear garden of the house, a hole in the roof space extends to the surface warm air, Fig.3.

Description thermal exchange

Heat exchange between the air influential from the slot with lining Minwer the earth deeply 4.0 m (wet) water spray the first phase of air cooling. The next phase of air passing during the porcelain tube of deep 35cm with 2cm thick that are moistened because of groundwater, soil and low temperature piping. Heat is exchanged between the process of wetting the walls of these tubes and the air. The system includes tubes 80m long. Developed deeply of 4m beneath the earth's surface, they slop to a little Minwer rule to avoid water stay within tubes.

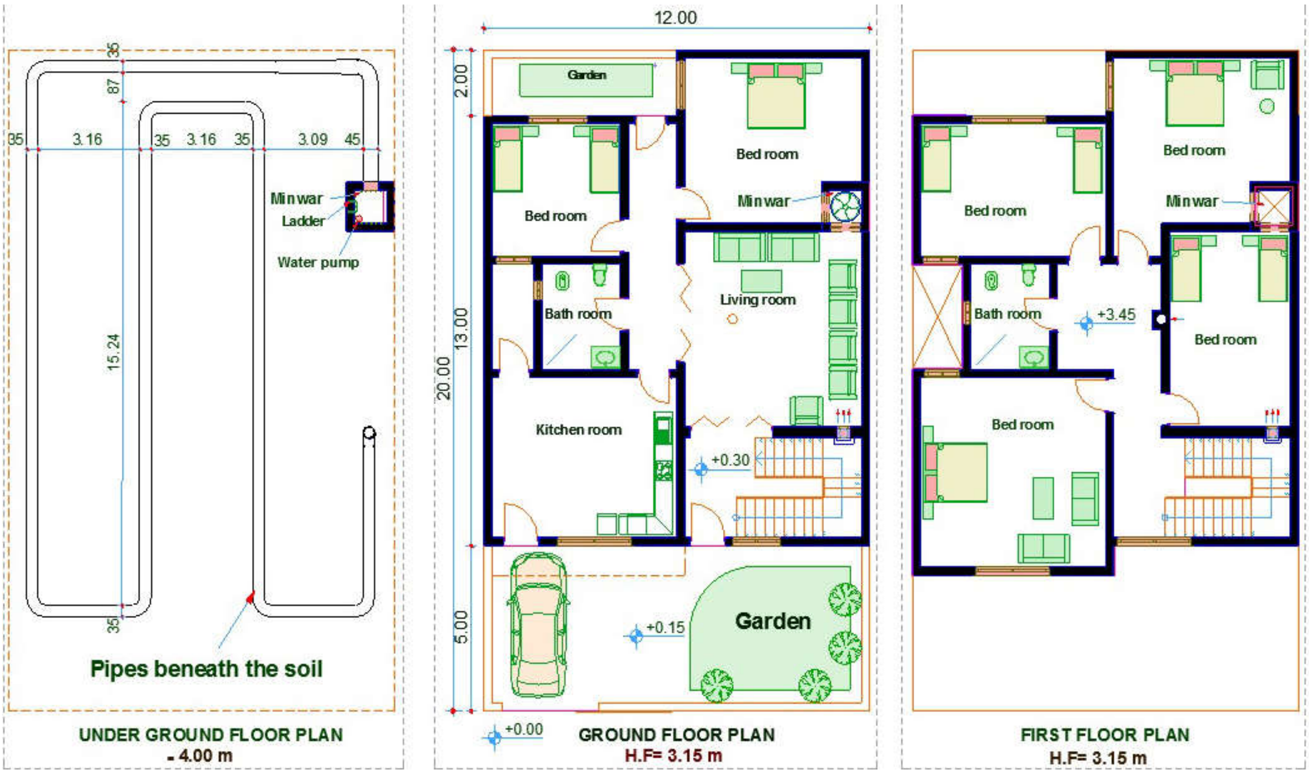

Figure 3. Suggested prototype model planned for the single-family homes a separate

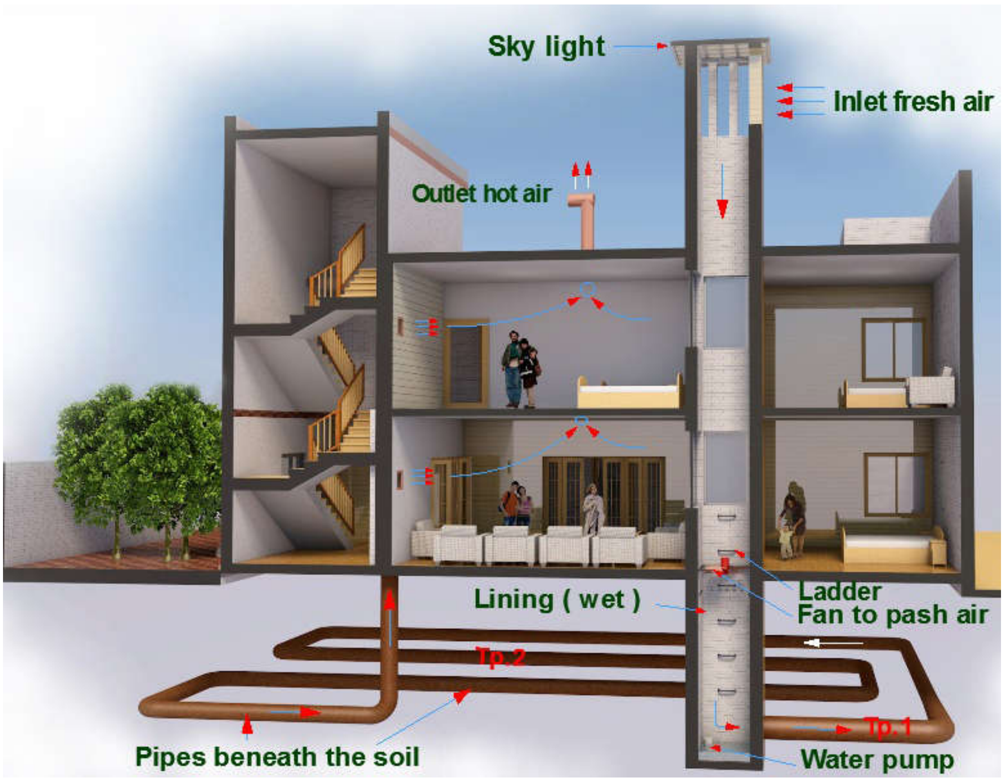

Figure 4. The perspectives of the model proposed for the house show movement natural air heat exchange

Table 1. Thermal physicist specifications used in the simulation

Material	Density (kg/m^{-3})	Specific heat Capacity (J/kg^{-1} K^{-1})	Thermal conductivity (Wm^{-1}K^{-1})
Air	1.225	1006	0.0242
Soil (So1)	2050	1840	0.52
Soil (So2)	2050	1840	2.0
Soil (So3)	2050	1840	2.0
Pottery therapist	1600	1436	0.405
PVC	1380	900	1.16

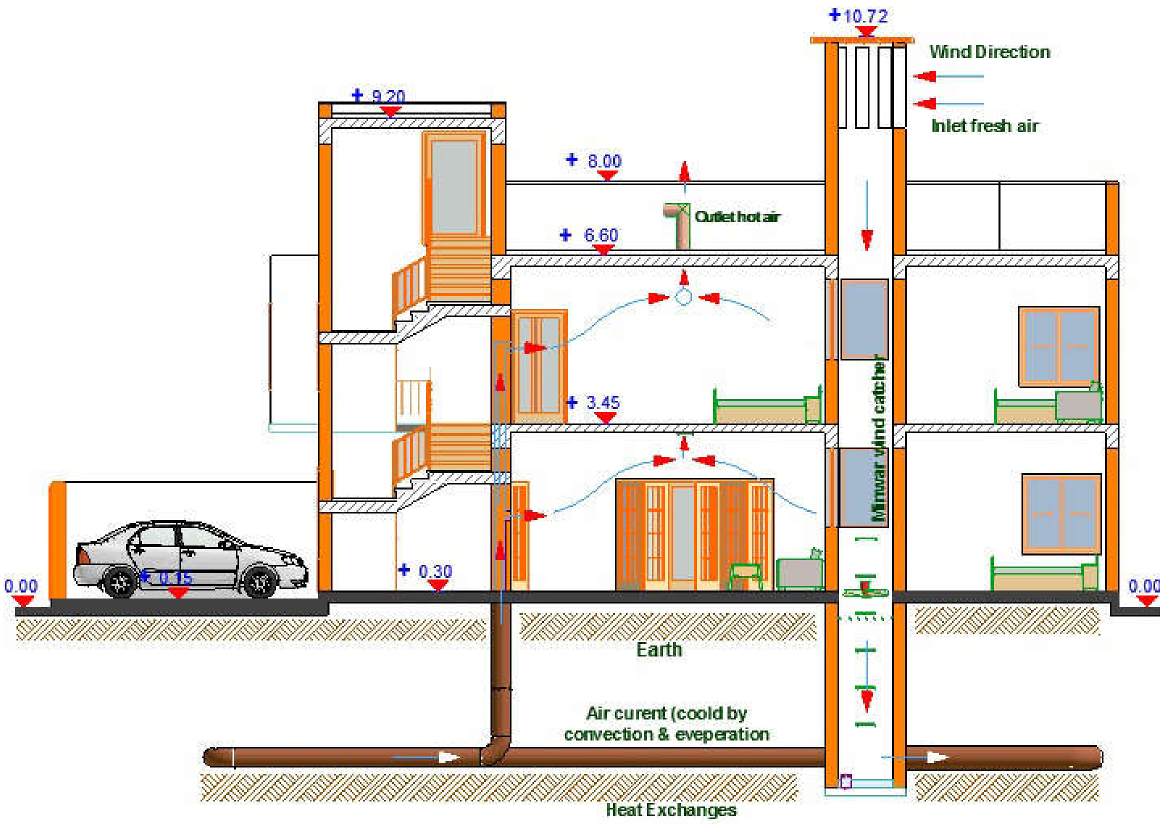

Figure 5. The cross-section of the proposed model home that contains Minwer

Table 2. Comparison of temperature the experimenter through the winter and summer 2015

Month	Air temperature of the day14		Air temperature of the day15		Air temperature of the day16	
	External temperature	Internal temperature	External temperature	Internal temperature	External temperature	Internal temperature
July	46.7	26.6	46.8	27.1	46.5	26.5
August	47.7	27.3	47.8	27.5	48.1	27.6
January	11.3	17.2	11.7	17.5	11.8	17.9
February	10.2	16.2	10.4	16.6	10.9	16.9

Table 3. Temperature and relative humidity with a different air speed, experimental readings and simulation for the summer and winter of 14-2015

			The speed of airflow 1.5 m/s			The speed of airflow 3 m/s			The speed of airflow 5 m/s		
	Month	Location	Expe. Temp.	Sim. Temp	RH	Expe. Temp	Sim. Temp	RH	Expe. Temp	Sim. Temp.	RH
Summer	July	T exte	46.7	46.7	26%	46.7	46.7	26%	46.7	46.7	26%
		T p1	36.9	37.4	29%	36.2	37.5	30%	36.1	37.2	29%
		T p2	31.2	32.3	32%	30.9	31.1	33%	30.7	31.4	32%
		T inte	26.6	27.3	35%	26.1	27.1	34%	26.0	28.1	34%
	August	T exte	47.7	47.7	26%	47.7	47.7	26%	47.7	47.7	26%
		T p1	37.3	37.9	28%	36.5	37.1	28%	37.0	37.8	28%
		T p2	31.4	32.1	31%	30.2	30.9	30%	29.1	29.9	31%
		T inte	27.3	28.4	34%	26.8	27.5	32%	26.2	27.1	33%
Winter	January	T exte	11.3	11.3	60%	11.3	11.3	60%	11.3	11.3	60%
		T p1	13.4	14.9	62%	14.9	14.6	61%	15.2	14.9	61%
		T p2	15.1	15.9	63%	15.7	16.4	62%	16.1	16.6	62%
		T inte	17.2	17.4	65%	17.5	17.6	63%	17.8	17.4	63%
	February	T exte	10.2	10.2	62%	10.2	10.2	62%	10.2	10.2	62%
		T p1	13.9	14.5	64%	14.9	14.6	65%	15.3	14.8	65%
		T p2	15.3	15.8	65%	15.7	16.3	66%	16.5	16.9	66%
		T inte	16.2	16.6	66%	16.7	17.1	67%	17.1	17.8	67%

The system has provided by a fan developed on the ground floor to push air in the absence of wind. That's the pressure difference between the inlet and outlet to get out because of the difference of air column. Anemometer testo testo 417 Set-2 0.3 up to 20 m/s, measure the wind speed and temperature Table 1. Fig.4, Fig.5.

Hourly analysis

Providing thermal comfort conditions integrated evaporative cooling system adopted MATHE, Carried out using the Minwer wind-catcher wind for housing the city of Baghdad. An evaporative cooling system proposed complete definition the appropriateness of satisfaction heat. It is validating conduct experimental accounts CFD design MEAHE separately to test 14-15-16 days of July and August 2015 summer months of January and February the winter 2015 three hours 12 am to 3 pm daily. Transfer down-draft flow 1.5-3.0-5.0 m/s speed records, coefficient of performance calculation COP of the earth tube during the entire testing period. And it is considered one of the measures the efficiency of the heat exchanger. The calculation was based on the initial temperature inside the buildings and soil temperature at the outlet tube within the first fifteen minutes. Values ranged COP between 3.24-5.59. With reason the equations which suggest that (ASHRAE, 1980) calculation of the overall cooling airflow for hours with reason the equations set out:

$$Qout = m\ Cp\ (Toutlet - Tenter) \quad (1)$$

m= mass flow rate (kg s^{-1})

$$Qc = m\ Cp\ (Tenter - Toutlet) \quad (2)$$

$$m = V / v \quad (3)$$

V = volumetric flow rate ($m^3\ s^{-1}$)

v = air specific volume ($m^3\ kg^{-1}$)

$$V = Vel\ (\pi d2/ 4) * 10^{-4} \quad (4)$$

Vel = air velocity (ms^{-1})

d = pipe diameter (cm)

Description of the CFD model for energy simulation

Computational Fluid Dynamics CFD provides a careful analysis of heat transfer and liquid flow, Provide practical solutions to the complex differential equations, to detect numeral solutions on pressure allocation, air flow and temperature, slope the temperature, in this study was the use of CFD software fluent version 6.3, to resolve the field of heat transmitted degrees about the horizontal tubes buried WEAHE, The tube wall was designed to be more intense, Suppose the air is incompressible and homogeneous earth physical properties and constant. As has been the assumption that the heat conduction of the Soil steady, The study also used three kinds of soils are the S1, S2 and S3. Table 1, Thermal properties of the soil S1, S2, S3 heat capacity, density and thermal conductivity, were then used to validate the contrast model.

RESULTS AND DISCUSSION

System of the soil temperature

The soil temperature system depends on level of groundwater and the analogy of the soil physical characteristics It was found that temperature system stable depth of between 3 to 4 m. Monthly rate the degree of soil temperatures in the study area at a depth of 3.0 m between 22.30 to 24.20°C and depth 4 m between 21.90 to 23.10°C during the probationary period Sharan and Jadhav. You can use these depths in the summer as a source for cooling.

Readings of experimental outdoors and inside presence Minwer wind catcher

Table 2 Appears temperature in outdoor and temperatures inside during the probationary period in the winter 2015 for the months January and February and the summer 2015 July, August months During the three-day 14-15-16 From 12 am to 3 pm of every month in a row. And it gave an average daily volatility of hours of testing, The results indicated that the temperature in the indoor showed the highest fluctuation during the month of August compared with July, But much smaller than the ocean. That there is a decrease in the average temperature in indoor and outdoor during the probationary period, Temperature difference 21°C and 8°C in summer and winter. This means that the system managed to improve relative humidity and to reduce the ambient air temperature. Which indicates that the system was exchanging heat between the walls and the tube and soil quite effectively during the operating period, Fig. 3, shows the temperature difference in the length of the tube.

Readings computer simulations and experimental heat exchange

The average outside temperature and the average temperature of the internal space temperature shown in Table 3 within three days of the test period 14-15-16 of the months of July and August the summer of 2015 Depending on the winter months of January and February 2015 for a period of three hours, 12 am till 3 pm during those days respectively, Using computer simulations by computational fluid dynamics program CFD and compared with experimental readings. The results indicated differences in external temperatures and internal temperatures, and that there is a decline in July 20-21°C while the external temperature was 46.7°C and 47.7°C within the wind 1.5m/s speed. The rise in internal temperature for the month of January 5.9°C while the temperature outside 11.3°C and 10.2°C for month of February and the improvement in the relative humidity of 26% - 35% in summer and 60% - 65%. Table 3 medium experimental readings and computer simulations of temperatures at external temperatures at the start of the tube line is buried and the middle route of the tube line with varying wind velocity 1.5 - 3.0 - 5.0m/s through months of studying. The system pointed MEAHE There is a difference in temperature depending on the speed of the air, was recorded in the summer for the month of July 26.6°C in the month of August 27.3°C, when the airspeed. 1.5 m/s, and the temperature dropped and ranged from 26.0°C to 26.2°C when the air speed of 5 m/s and an increase in the temperature difference in the summer, and this helps to approach the thermal comfort the area. Either during the winter, there will an increase in temperature 5.9°C for the month of January. Either month of February increased 5.0°C. The values obtained during the day in the summer were within the limits of thermal comfort, In the winter, the difference will be tight and that gives an indication of limits thermal comfort, and can say that the system approached achieve thermal comfort in the summer and he alone is enough to bring the convenience of the occupants without the need for aid from the artificial energy, either in the winter season, which is a short period and it needs a simple aid to achieve thermal comfort. You can easily apply this system in hot climates Table 3, Fig. 6.

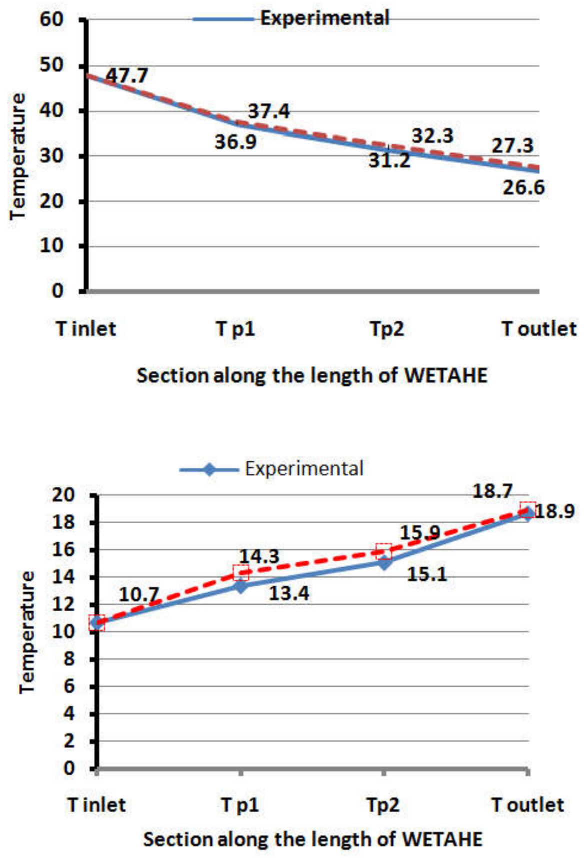

Figure 6. Comparison of the temperatures during the natural movement of air in the tubes, air speed of 1.5 m/s during the winter and summer 2015

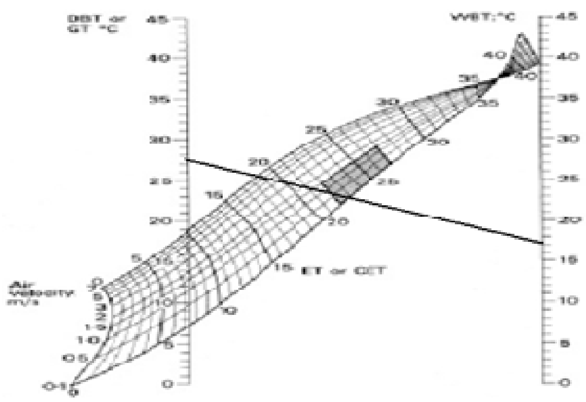

Figure 7. Nomogram effective degree heat for people wearing normal clothes

Correlation amongst thermal comfort limits and results

The definition of effective temperature of the main factors for thermal comfort, relative humidity, air velocity, air temperature, clothing, The diagram is a simple equation and you do not have restrictions (O. H. K, T. G. INGERSOLL, A. MAYHEW, & S. V. SZOKOLAY: 1974). In summer, August 16/08/2015. The air temperature inside the living space of 27.3°C. The average relative humidity of 34%. The air temperature situates for wet knob thermometer the17.7, The movement of air within the space 1.5 m/s. Therefore, the person who wears casual clothes (1Clo.). It will be up to 21.4 degrees Celsius, these can be considered within the criterion thermal comfort as indicated in Fig.7.

Conclusion

Depending on the results received, it can be said that the employment of the Minwer wind-catcher heat exchange the earth to air. It gave great promise as a way for heating and cooling to saving fresh air, beside the existence of natural lighting. The increment wind catcher section, an area of led to an increment in the speed of the moving air and the quantity due to the column of air pressure difference. The heat exchange system proposed by the research MEAHE and take advantage of geothermal, which effectively be fixed and low, Lining Minwer built with bricks pottery (wet) because of underground water in the soil and the use of sprayed water to the walls of the tubes and the pottery system beneath the soil due to underground water contribute to a further evaporative cooling system and relative humidity to improve and reduce air temperature. The temperature has dropped in the summer up to 19.4°C, when the outside temperature 46.7°C, the increase in temperature in winter up to 6.1°C when the outside temperature 11.3°C. There is an opposite relation between relative humidity and temperature in space inside with a length of pipe is buried, A reverse relation between coefficient of performance COP and air velocity. At neutralization of thermal comfort among effectiveness and the temperatures it has been accomplished at at the border of the desired comfort when the air velocity is 1.5 m / s amount to 21.5°C. Existence the fan in Minwer contributed to the increase of air movement in case there is no wind, and could be seen as preliminary steps towards providing more comprehensive data for designs, air wind catcher of the house single and in residential complexes for Iraq's future.

Acknowledgment

I want to thank Dr. Miqdad Haidar AL-Jawadi, University of Technology, Department of Architecture, Baghdad, Iraq, supporting experimental settings and results. And its continued support in giving advice and guidance.

REFERENCES

Afeef, C. & Masa, N 2014. “A Proposed ‘Water Tube Heat Exchanger’ Space Cooling System Performance Analysis,” *Civil Engineering and Architecture*, 2 (4): 166-169.

Alsahrawardy, Ibtisam & Al-Jawadi, Miqdad 2010. "Healthy Architecture", Proceedings of the Third Architecture Conference, Department of Architecture, University of Technology, Baghdad, Iraq, November, 326–347.

Bahadori M, Mazidi M. 2008. “Dehghani. Experimental investigation of new designs of wind towers”. *Renew Energy*, 33: 2273–81.

Correia da Silva J.J. 2005. Passive downdraught evaporative cooling applied to an auditorium. In: Proceeding conference: passive and low energy cooling for the built environment, Santorini, Greece; 555–560.

Dehghan A.A., M.Kazemi Esfeh, M.Dehghan Manshadi 2013. "Natural ventilation characteristics of one-sided wind catchers: experimental and analytical evaluation", *Building and Environment*, Vol: 61, 366–377.

Goswami, D.Y. and K.M. Biseli 1993. ‘‘Use of Underground Air Pipes for Heating and Cooling Agricultural and Residential Buildings’’ Fact Sheet EES 78, a series of the Florida Energy Extension Service, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Kalantar V. 2009. ”Numerical simulation of cooling performance of wind tower (Baud-Geer) in hot and arid region”, *Renew Energy*, 34, 246–54.

Koenigsberger, O. H., T. G. Ingersoll, A. Mayhew, and S. V. Szokolay: 1974. Manual of Tropical Housing and Building. Longman, London. 320 pp.

Leo Samuel, D.G., S.M. Shiva Nagendra, M.P. Maiya, 2013. "Passive alternatives to mechanical air conditioning of building: A review", *Building and Environment*, Vol: 66, 54–64.

Maerefat M. and A.P. Haghighi, 2010. "Natural cooling of stand-alone houses using solar chimney and evaporative cooling cavity", *Renewable Energy*, Vol: 35, 2040–2052.

Saffari H, Hosseinnia S. 2009. “Two-phase Euler–Lagrange CFD simulation of evaporative cooling in a wind tower”. *Energy Build*; 41, 991–1000.

Trilok Singh Bisoniya, Anil Kumar, Prashant Baredar 2013. "Experimental and analytical studies of earth–air heat exchanger (EAHE) systems in India: A review", *Renewable and Sustainable Energy Reviews*, Vol: 19, 238–246.

Tudor, A. And V. Badescu 2013. The influence of several parameters on the performance of earth to air heat exchangers into southeastern European climates. U.P.B. Sci., Series D, vol. 75 Iss.3.

VikasBansal, Rohit Mishra, Ghanshyam Das Agarwal, Jyotirmay Mathur 2012. "Performance analysis of integrated earth–air-tunnel-evaporative cooling system in hot and dry climate", *Energy and Buildings*, Vol: 47, 525–532.

****