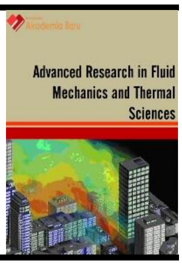
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Air-Conditioning of Buildings by Using Ground and water Effects to Drop Down the Inlet Air Temperature

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ARTICLE INFO

Article history:
Received 31 August 2018
Received in revised form 25 October 2018
Accepted 8 December 2018
Available online 12 February 2019

ABSTRACT

This paper presents an experimental and theoretical study of using the ground and water geothermal affects to the cool the buildings. This done by helical heat exchanger submerged under the well water. Where the tests were conducted in the city of Tikrit / Iraq in hot and dry climate for the period from May to June. The results showed that the use of the water heat exchanger reduces the temperature of the air inside the test room 10 - 15 °C less than the ambient temperature. In addition, the results showed an improvement in relative humidity of 15-20% and a decrease in cooling loads by 50%. The temperature of the well water has great effects on the temperature of the supply air from the heat exchanger. Also, the temperature at the depth of 3 m under the ground will be constant and reached to 21 - 22 °C. The solar radiation has more effect on the ground's temperature at depth 0.25 m. Results showed a significant agreement between theoretical and experimental results.

Keywords:
Cooling buildings, heat exchange, Air conditioning, geothermal

1. Introduction

Among the most important problems faced by the world is the energy crisis and high fuel price. Therefore, most researchers tended to find alternatives by taking advantage of renewable energies to reduce pollutants, energy consumption and costs. In most of the buildings, the internal conditions are uncomfortable because of extreme outdoor weather and the incorrect locations of windows and doors in the appropriate places for natural ventilation [1].

The ancient buildings were built close to each other and the light colors for the roof and walls were used. It contains at least two openings in each room in the direction of the wind and the other in the opposite direction to generate wind circulation. The buildings are also built in the east and west direction and the windows are placed in the south of the buildings. These technologies are able to reduce the energy and costs of cooling and achieve a comfortable interior condition [2].

The use of vegetation is a good option for residential buildings because it can save energy by reducing the working hours of the air conditioning system [3,4]. It is possible to save energy by 23.96% in the hottest month of July when planting trees in the south and west facade of a typical

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residential house [5]. Also, the uses of these techniques can reduce temperatures by 5°C in July while energy demand for air conditioning is reduced to 20% [6].

There is a possibility of reducing the required cooling capacity up to 37% by using the shaded glass of the buildings facades in the hot dry climate [7]. Passive cooling techniques are economically feasible, as it can decrease the annual energy consumption by 23.6% [8]. While, reduce cooling load by 9% using natural ventilation, double glass and green roof as roof insulation [9]. The daily temperature fluctuations of the ground's surface decrease with increase the depth and these fluctuation disappear at a depth more than 0.25 m [10].

When the ground heat exchanger without the air conditioning systems is used, the temperature inside the house was 27°C [11,12]. The temperature difference between the outside and inside condition is 10°C [13]. Where, the energy efficiency around 14-28%, which represents 38% of the cooling loads [14]. The insulation residential buildings reduce energy consumption by around 80%, with the possibility of the low temperature inside the room to 31°C [15]. At the flow air velocities 2–5 m/s the temperature of the heat exchanger was 8.0 –12.7°C [16].

This study aims to decrease air temperature, improve relative humidity and reduce the cooling load for the conditioner space in the weather conditions of Iraq, also to find the appropriate depth of the tubular heat exchanger underground or immersed in the well water.

2. Experimental Study

The experiment was conducted in summer season (May and June months) with different parameters. The temperatures of ambient air and test room were recorded by thermocouples. The temperature of air which enters and exits from the tubular heat exchanger was also recorded. The circulated flow rate of air was measured by using normal hot wire anemometer. The experiments were repeated three times to make sure of the accuracy of measurement and reading.

2.1 Experimental Set-Up

The study was carried out on a test room (210 x 100 x 110 cm) made of a compressed wood material, which has an adjustable slots to control the amount of inlet and outlet air. The test room connected with the tubes of the tubular heat exchanger. The tubes made of plastic material available in local markets with dimensions (length of 9 m and 5 cm diameter) as shown in Figure 1.

Fig. 1. Heat exchanger tubes (plastic)

The tests were conducted during May and June months in the research area of Tikrit / Iraq and recorded readings per hour. The sensors used to measure the temperature inside the water basin and test room. The relative humidity sensor fixed inside and outside the test room as shown in Figure 2.

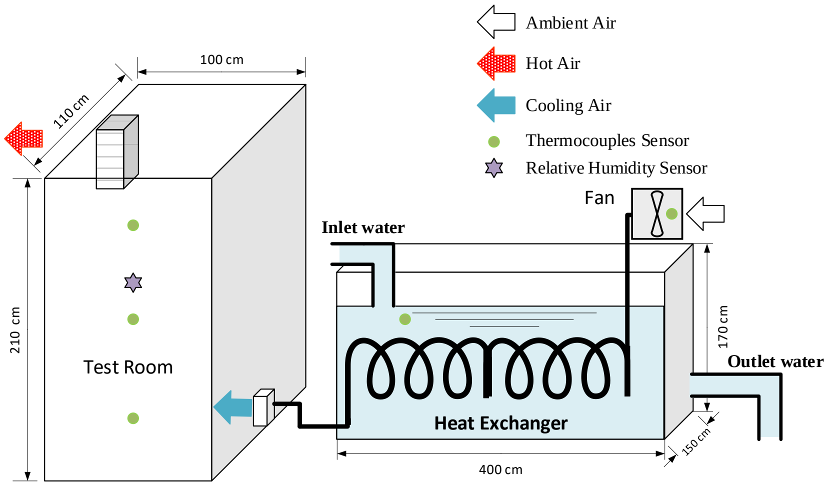


Fig. 2. A tubular heat exchanger using a thermocouple and humidity sensors.

2.2 Measure of Ground Temperature at Different Depth

Many experiments have been conducted for the purpose of knowing the relationship between atmospheric conditions and the ground temperature at different depths by examining the effect of solar radiation intensity. The study was carried out in Tikrit, Iraq, which features a hot, dry climate. Tests were carried out in May and June during daylight hours, temperature sensors were installed in the ground according to the depths (0.25, 0.5, 0.75, 1 and 3) m.

3. Theoretical and Physical Analysis

The process is executed by passing the air directly through the tubular heat exchanger which immersed under the water for cooling purpose. A fan is used as a blower of the air (circulating the air) through the tubular heat exchanger to reduce the air temperature by thermal exchange.

The following basis equations were used then solved them by MATLAB software for the purpose of the simulation and finding theoretical results [17-20].

$$Re = \frac{\rho V D}{\mu} \tag{1}$$

where the Reynolds number, Re, air density, ρ, velocity, V , diameter, D and dynamic viscosity, μ

The thermal entry length and Nusselt number correlations for turbulent flow are written as

$$Lt = 10\ D \tag{2}$$

where the thermal entry length, Lt

$$Nu = 0.023\ Re^{0.8}\ Pr^{0.4} \tag{3}$$

where the Nusselt number, Nu and Prandtl number, Pr

$$h = Nu\frac{k}{D} \tag{4}$$

where the heat transfer coefficient, h and thermal conductivity, k

$$Tout = Tw - (Tw - Ti)\ exp((-h\ \ As)/(\dot{m}\ Cp)) \tag{5}$$

where the outlet temperature of heat exchanger,$Tout$, water temperature, Tw, inlet temperature of heat exchanger, Ti, surface Area, As, mass flow rate, $m^{\bullet}$ and specific heat ,Cp

$$m^{\cdot} = \rho\ Ac\ V \quad , \quad Ac = (\pi\ D^2)/4 \quad , \quad As = \pi\ D\ La \tag{6}$$

where the cross sectional area, Ac and length of the exchanger, La

$$Q^{\cdot} = V\ Ac \tag{7}$$

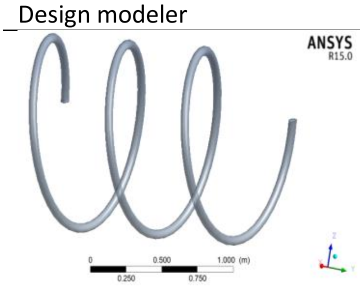
where the volumetric flow rate of air in the tube, $Q^{\cdot}$

The cooling effectiveness, Eff is calculated as follows

$$Eff = ((Tin - Tout)/(Tin - Tw)) \times 100 \tag{8}$$

Table 1 shows the simulation data required for ANSYS software for the purpose of finding the theoretical results.

Table 1
Simulation data required for ANSYS software

Design modeler	mesh	Input data	Boundary Condition
	Nodes :457758	Tin = 45°C Tw=26°C V=2 and 6 m/s La=9 m D=5 cm	Inlet :Velocity inlet with time varying profile file
	Elements:375418		Outlet :Pressure outlet with zero static pressure
	Smoothing: Medium Transition: Slow		Pipe :Stationary walls

4. Results and Discussion

Figure 3 shows the relationship between temperature (test room and ambient) over time using a tubular heat exchanger with a tube diameter (5 cm or 2 inches) at the air flow rate 28.3 m^3/hr. The temperature of the ambient air and the test room increases gradually due to the increase in the intensity of solar radiation to reach the highest values of 41°C and 32.6°C respectively, at the intensity of the solar radiation 736_w/m^2 at 1 pm, the average daily ambient air temperature and water temperature 37.8°C and 25.7°C Respectively. And the difference between ambient air temperature and the test room (Ta-Troom) 6.4°C. The maximum difference between the daily temperature of the heat exchanger and the ambient air was 14.2 at 1 pm. Total temperature difference between the ambient air and the outlet air from the heat exchanger equal to 11.2°C.

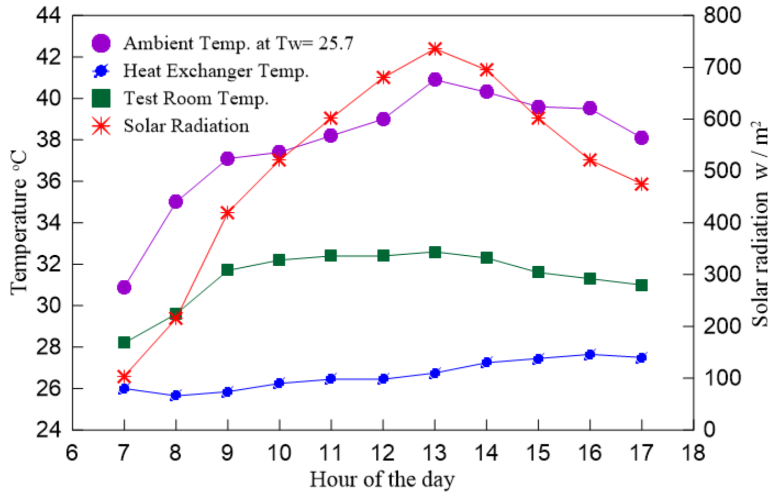


Fig. 3. The temperature and solar radiation variatiowith time at air flow rate. (Q̇ = 28.3 m^3 / hr)

Figure 4 shows the relationship between temperature (test room and ambient) during daylight hours using a water exchanger with a diameter (5 cm or 2 inches) at the airflow rate 42.4 m^3 / hr. The temperature of the test room and ambient air begins to rise, recording the highest values of 32.4°C and 40.4°C respectively at 12 o'clock due to increase the intensity of solar radiation w / m^2 714. The daily temperature of ambient air temperature 37.6°C, water temperature 25.6°C, the daily temperature difference between ambient air temperature and test room 6.6°C, the maximum daily difference between ambient air temperature and heat exchanger 13.9 °C at 11 o'clock and with a total difference of 10.8°C. The temperature increases as the air flow is low and the water temperature is the main factor affecting the temperature of the heat exchanger.

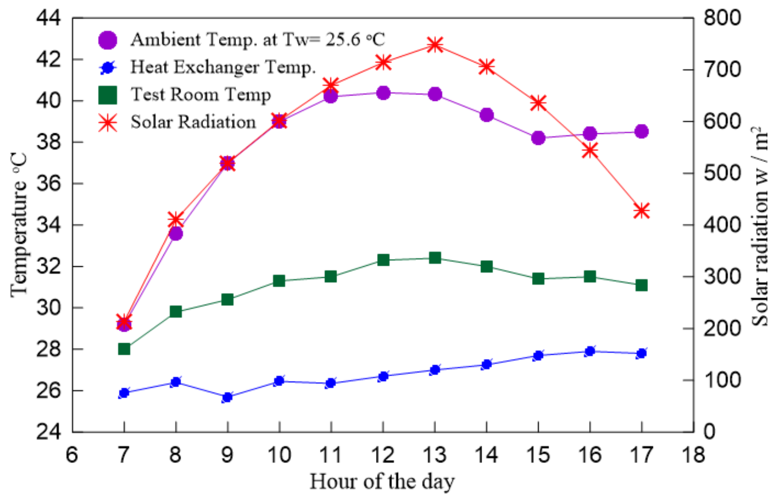


Fig. 4. The temperature and solar radiation variation with time at air flow rate. (Q̇ = 42.4 m^3 / hr)

Figure 5 represents the difference between the results of the experimental and theoretical temperature by using a diameter 5 cm hydrothermal exchanger during daylight hours at the rate of air flow 28.3 m^3/hr. The difference between experimental and theoretical results reached the maximum value of 2.9% at 11 o'clock ambient air temperature 38.2°C. The results showed that the different rate of total temperatures for experimental and theoretical results amounted to 2%. Moreover, it was calculated for different hours of the day using the computational program

(MATLAB). This percentage is close to reality because the temperature measuring device used to be accurate reading with two decimal, the theoretical calculations can be done with more accurate to make the results closer to reality.

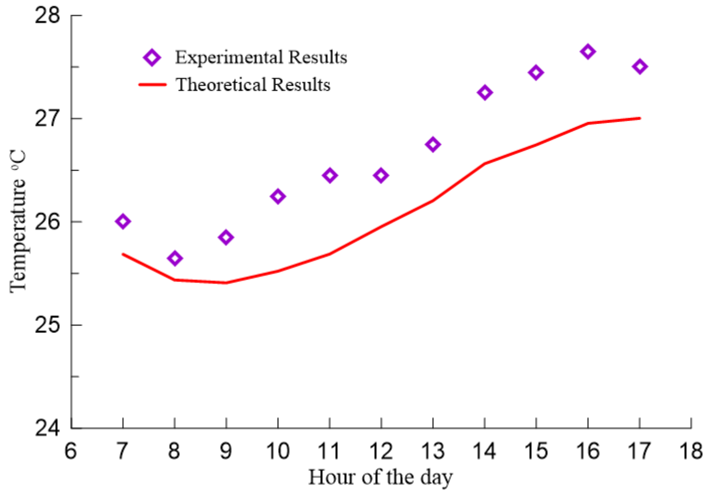


Fig. 5. The difference between the theoretical and experimental results at the air flow rate ($\dot{Q}$ = 28.3 m^3 / hr)

Figure 6 represents the difference between experimental and theoretical cooling effectiveness. It was used a water heat exchanger with a diameter 5 cm during daylight hours. The maximum experimental cooling effectiveness was about 94.5 % and the minimum experimental cooling effectiveness was 90.7 % at the air flow rate 28.3 m^3 /hr. The difference between theoretical and experimental results was 4.6 %. At the air flow rate 42.4m^3/hr the maximum cooling effectiveness be 93.4% and the lowest experimental cooling effectiveness 86.7% at 3:00 pm at a difference of experimental and theoretical results was 4.7%. The cooling effectiveness increases as the temperature of the heat exchanger approach the water temperature.

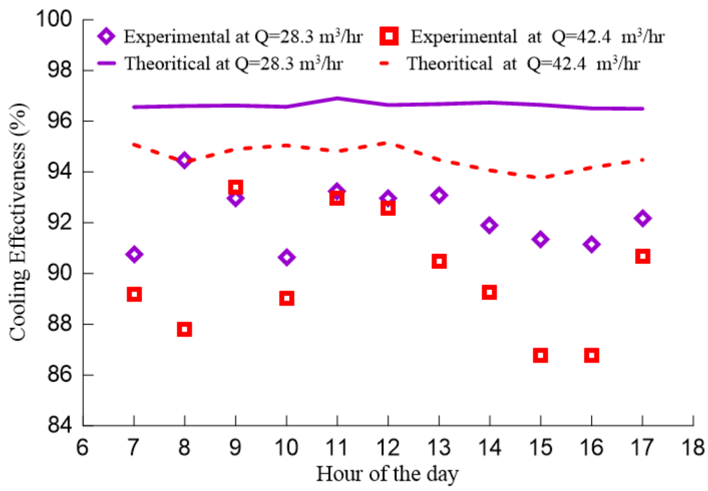


Fig. 6. The difference between the experimental and theoretical cooling effectiveness

Figure 7 The relationship between the relative humidity of the test room over time using the diameter thermal exchanger 5 cm at the rate of air flow 28.3 and 42.4 m^3/hr notes in the form that the external relative humidity curve starts to decline gradually with time to reach the lowest value at 13 because of high temperatures where relative humidity is inversely proportional to temperature.

The results showed that the rate of relative humidity within the test room was 33, 32.8% for the flow rate 28.3_and 42.4 m^3/hr, respectively. The optimized relative humidity was 15% when the external relative humidity was about 17%.

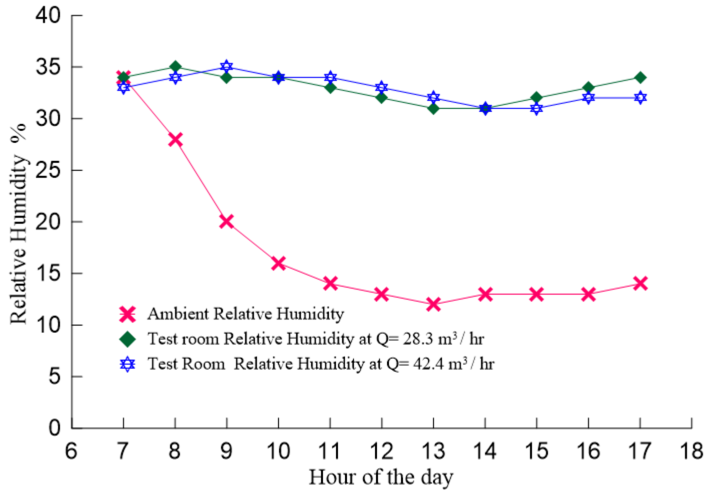


Fig. 7. Relative humidity at a different rate of airflow

Figure 8 shows the ground temperature at different depths with Time. The curves at the depth of (0.5, 0.75, 1 and 3) m are stable, but either the curve at the depth of 0.25 m is unstable. The solar radiation has more effect on the ground's temperature 0.25 m. It is noted the lowest temperature of 38.5°C per hour (12) at the value of solar radiation 701 w/m^2 depth of 0.25 m. The results showed that the temperature at the depth of 3 m is 22°C.

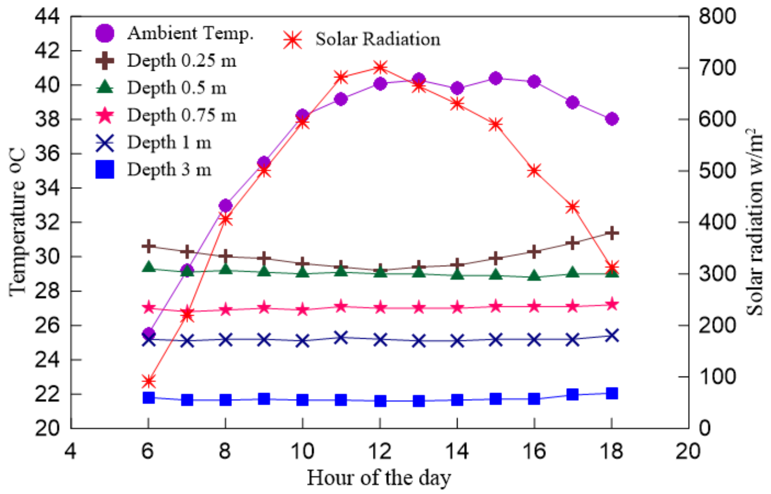


Fig. 8. The effect of solar radiation intensity to ground temperature

Figure 9 and 10 illustrate the effect of atmospheric conditions on the temperature of the aqueous thermal exchanger 5 cm and the length 9 m of the air flow rate 28.3 and 42.4 m^3/hr using the ANSYS program. In Figure 9 and 10, it is observed that the temperature is gradually decreasing, with temperatures emerging from thermal exchanger 27℃ of the ambient air temperature rate of 45 °C. The results are presented in Figure 9 which show that the temperature decrease is faster than the Figure 10 due to the air flow rate 28.3 m^3/hr and the temperature of the water is the main factor influencing heat exchanger temperature (comparison in Table 2).

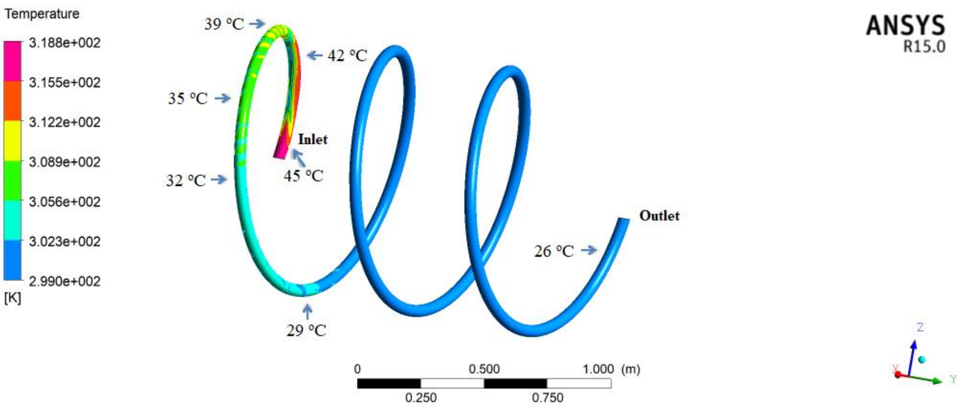


Fig. 9. The temperature of the heat exchanger at air flow rate ($\dot{Q}$ = 28.3 m^3 / hr)

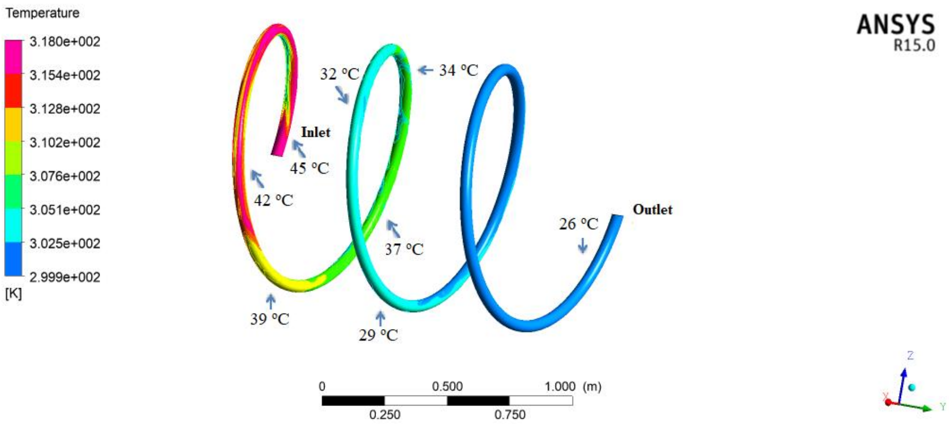


Fig. 10. The temperature of the heat exchanger at air flow rate ($\dot{Q}$ = 42.4 m^3 / hr)

Table 2
A comparison between the theoretical and experimental results for different air velocities.

Time	Air Velocity = 2 m/s , Q=28.3 m^3/hr			Air Velocity = 6 m/s , Q=42.4 m^3/hr		
	Exp. Temp.	Theo. Temp.	Different %	Exp. Temp.	Theo. Temp.	Different %
7	26	25.68	1.20	25.9	25.68	0.84
8	25.65	25.43	0.83	26.4	25.86	2.04
9	25.85	25.40	1.70	25.7	25.51	0.71
10	26.25	25.52	2.77	26.45	25.59	3.22
11	26.45	25.68	2.88	26.35	26.07	1.05
12	26.45	25.95	1.87	26.7	26.31	1.43
13	26.75	26.20	2.03	27	26.41	2.179
14	27.25	26.56	2.52	27.25	26.60	2.38
15	27.45	26.74	2.56	27.7	26.85	3.049
16	27.65	26.95	2.51	27.9	27	3.209
17	27.5	27	1.80	27.8	27.35	1.612
Average	26.65	26.10	2.06	26.83	26.29	1.97

5. Conclusions

The theoretical and experimental study was carried out to cool the building and achieve a comfortable weather inside the buildings in the areas of Iraq, saving costs and reducing a load of cooling by using the heat exchangers, also we can concluded the following

i. There is a possibility of achieving a suitable weather for living in buildings at the hot summer by using heat exchangers in the region of study.
ii. The possibility of reducing cooling load, energy consumption and costs.
iii. The suitable length of the heat exchanger depends on the air velocity and the ambient temperature.
iv. Well Water temperature is the main element that effects on the outlet temperature of the heat exchanger.
v. Temperature reduction rate by using heat exchanger reached 10 to 15^o C.
vi. The heat exchanger is not suitable in areas experiencing water scarcity.
vii. The temperature at depth 3 m between 21-22^{o}C, so that the use of underground heat exchanger at this depth is suitable. The maximum solar radiation effect on the ground's temperature happened in depth 0.25 m.
viii. The improvement in relative humidity reached to 15-20%.

Acknowledgment
This research was funded by a grant from the University of Tikrit Iraq (Free Grant).

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