300: The experimentation of improved evaporative cooling wind tower in real office building

Yasmina Bouchahm
Laboratory of bioclimatic Architecture and Environment (A.B.E)

Abstract

The wide use of air conditioning to meet the high load of cooling building in hot arid climate region in Algeria became a real problem. Since these systems have a high impact on the peak electricity load, and cause environmental problem associated with ozone depletion, global warming, urban heat island and affect the indoor air quality.
Recently, as means to reduce energy consumption of air conditioning systems, wind towers have been used as an alternative solution to meet summer thermal cooling .However; the cooling potential of wind towers technique was investigated in real exiting building in Ouargla city of Algeria (hot and arid climate); Measurements have been performed under two conditions “with and without evaporative potential”. A mathematical model of wind tower has been developed and validated using the measured data. For a more effective evaporative cooling, a number of improvements on wind tower design was proposed and calculated. Hence, results showed better performance with the improvements, a decrease of 18°C has been found
Therefore, the new design of the wind tower is constructed in another office building under the same climatic condition. The results of monitoring the performance of the building incorporating the new design during summer 2007 demonstrates and confirms the simulations finding in addition to that a better decrease of 22.3°C has been reached with this evaporative cooling wind tower.
Thus the thermal summer comfort has been established, the air conditioning active system has not been used at all for the whole summer period.
Keywords: Summer comfort, evaporative cooling, construction of wind tower, monitoring.

1. Introduction

One of the modest and oldest methods used for air conditioning in hot dry climates is the passive evaporative cooling wind tower. The device consists of single or multiple towers equipped with a water-vapour supply placed on the top. During the constant injection of water, droplets descend through the tower and conditions close to saturation along its length. Cool air descends the tower and exits at its base where it is delivered to the adjacent spaces. Several experiments have been carried out, namely by Givoni [1], Cunningham et al [2] and Erell et al [3] as well as Belarbi et al [4], to extend its effectiveness to both outdoors and indoors for uses such as domestic, offices and refurbishments.

Fully evaporative cooling wind tower was developed and constructed in existing office building in hot arid region of Algeria. Integrating simulated results on this new one, which consist on improving the geometry components such as height of the wetted column. The humidification system, as adopted a new design of water spraying, has been added to the wind tower for better passive evaporative cooling.

The concept has been revived as being one of the corrective measures that could be taken to protect the built environment against “degradation of fragile ecological zones, damage to natural resources, chemical pollution.

2. Experiment purpose

Renewed interest in passive cooling in 1980s led the development of a number of cool towers, in which air was drawn into the tower through gravity-shut dampers designed to prevent air escaping on the lee side Bahadori [5], or through wetted pads similar to those used in desert coolers Cunningham ; [2], Thompson et al [6], based on these theoretical considerations.

An evaporative wind tower was developed and constructed as an improvement to an existing one. The new wind tower incorporates the results of experiments conducted to establish the performance of wind tower found in Ouargla houses as well as guide lines of better new design computed to improve the evaporative cooling potential of the wind tower Bouchahm [7],

As it was found by Erell [3]; Bahadori[8], the evaporative cooling is the only economically viable solution for cooling in arid climate. Hence, their widespread adoption depends not only on their acceptance by Algerian designers and the public, but also on improvements in performance and the installation of demonstration projects.

In this purpose a passive evaporative air cooling wind tower conforming to the new design proposed by simulation (Capcool [7]), has been constructed to cool an office building as its evaporative cooling potential has been improved

3. Experiment setup

From simulation results it has been found that air temperature can be significantly reduced by only improving the two determinant factors of the wind tower configuration: a higher height of wetted column (h) and a smaller size of the clay conduits partition inside the tower (by increasing their number). The number of the clay partition introduced inside the shaft is responsible on the increase of surface heat and mass transfer Bouchahm [7].
According to these results, a prototype improved wind tower is constructed at Hassi Messaoud, Algeria for passive evaporative cooling of an office building under the same climatic condition as Ouargla, hot and dry, as shown in figure 1.

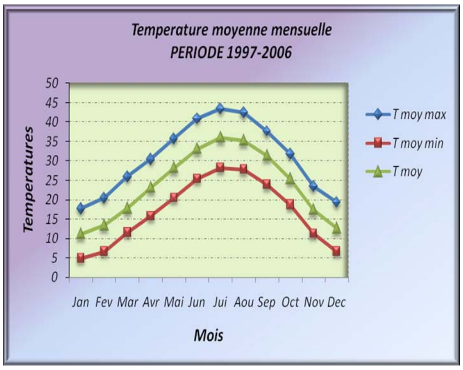


Fig1 (a) Air temperature from weather station (Hassi Messaoud , Algeria)

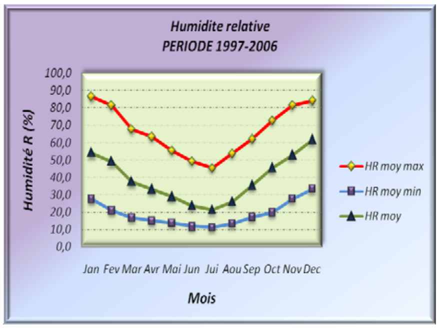


Fig 1(b) Relative humidity of the air from weather station (Hassi Messaoud , Algeria)

The schematic design of experimental cooling wind tower is shown in figure 2. A 8.50m multidirectional wind tower is oriented with respect to the prevailing wind. It is built in the balcony of an office building with red brick and covered with rough mortar to avoid sharp corners. Its interior cross section is 1.00 – 1.00m². A 49 clay partitions introduced inside the shaft with a diameter of 10cm as recommended by the simulation results in order to increase heat and mass transfer which achieve better temperature depression. Manufactured water spraying pipes as shown in figure 3 are installed at the top of the wind tower to provide evaporative cooling action. The conduits of 6.5m high introduced inside the wind tower as recommended by simulation, are made of brick which is cut in two parts to facilitate the build of the conduits since no manufacture could make it. A pool is covered with piece of earthenware which collects the excesses water droplets at the bottom of the tower so a pump would recirculated the water.

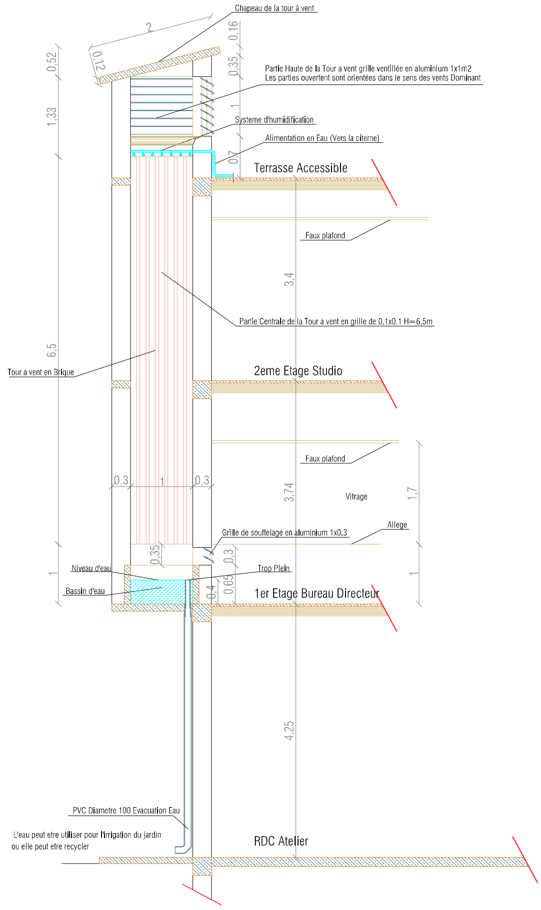
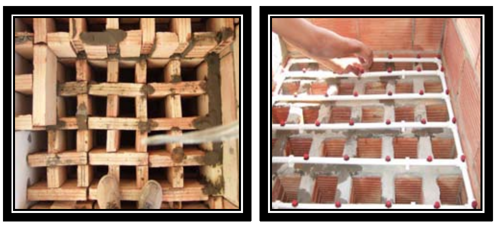


Fig 2: The schematic design of experimental cooling wind tower (8.5m height, wetted column of 6.5m)



A B

Fig 3 Construction of the clay conduits inside the tower to be wetted (cross section of 1m:1m with partition of 10cm in diameter, a total number of conduits 49/m2. (A), water -spraying pipes (B)

Fig 4: The construction of the wind tower Water was provided directly from the tank. The water was provided from an existing tap on the exterior that could be easily controllable.

4 Results analysis

The results of preliminary series measurements carried out over a short period only (May 2007) [7], were very encouraging. The performance tests were limited to the operation of water spraying system in purely wind-driven mode of operation.

Air temperature and humidity are measured in specially designed screens to protect the sensors from contact with water spray or sun radiation (at inlet); a thermo hygrograph with a thermograph are used to measure them at the outlet of the tower. The air temperature and relative humidity (at both outlet and inlet) are hourly recorded for summer season.

Two series of experiments were conducted. Measurements of tower's performance were initially made in dry operational mode in June, for purpose of assessing its aerodynamic characteristics without the contribution of water supply system. The second stage of the experiment was during which the spraying system was active and working continuously

One first test took place on 21 th of May 2007. At the beginning of the watering the clay partitions and the wall surfaces inside the wind tower only small drop is recorded, as far as the total height of the 49 clay conduits are watered a significant decrease on air temperature is recorded at 16.54pm as the inside clay partitions are well wetted and when the outdoor temperature (at the inlet) reached a maximum of 41°c the tower exit air temperature is only 26°c. This means that better efficiency could be reached by the improved design wind tower constructed to cool the office building. The results shown in figure5 were very encouraging.

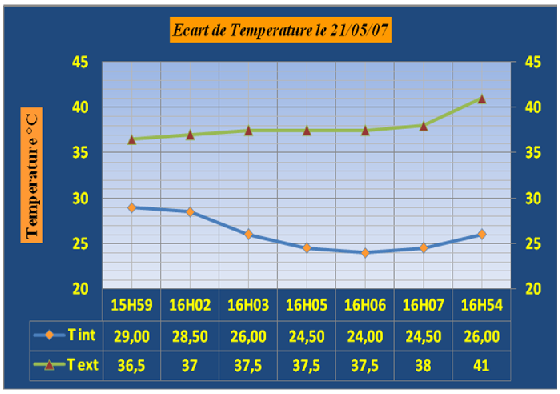


Fig 5 The first results from the measurement on May 2007

Experiments were conducted again during the summer of 2007 from June until august. The hourly temperatures, relative humidity, of the air entering and leaving the wind tower were measured during two weeks each month.

Results are shown in figures 6 and 7 at 24th of July where the water in system was inactive (without humidification) and the 31st of the same month when the water spraying system was operating.

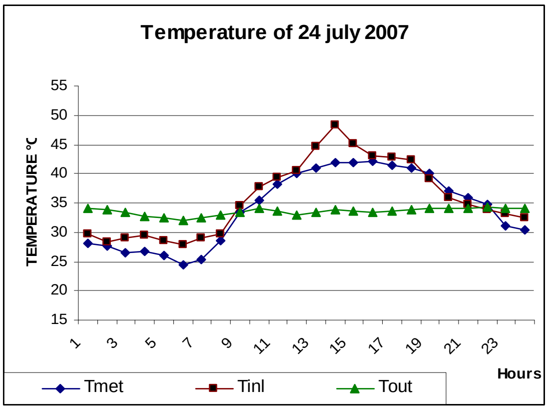


*Fig 6 (A): Air temperatures comparison (Tmet from the weather station; Tinl at the head of the wind tower; Tout leaving the tower). **Without humidification***

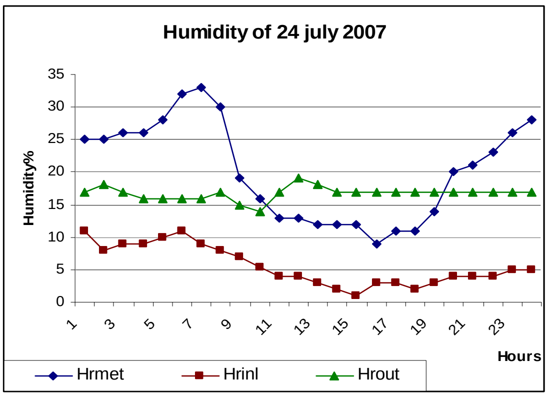


*Fig 6 (B): Air relative humidity comparison (Hrmet from the weather station; Hrinl at the head of the wind tower; Hrout leaving the tower). **Without humidification***

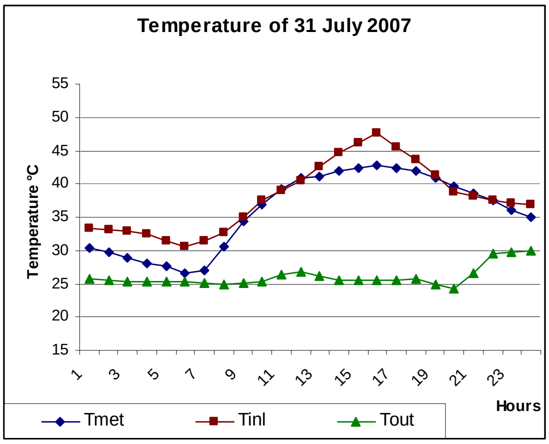


Fig 7 (A) : Air temperatures comparison (Tmet from the weather station; Tinl at the head of the wind tower; Tout leaving the tower).
With humidification

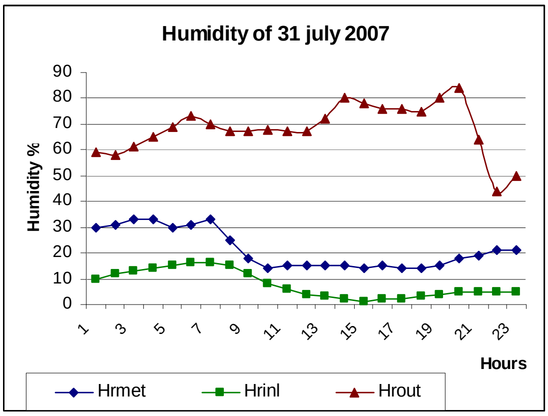


Fig 7(B) : Air relative humidity comparison (Hrmet from the weather station; Hrinl at the head of the wind tower; Hrout leaving the tower). ***With humidification***

5 Discussion

Evaporative process is the subject of numerous investigations focused on the understanding and characterization of physical phenomena involved. The amount of heat absorbed in the process of water evaporation (its latent heat) is very high in comparison with other modes of heat transfer common in building.

This investigation came to demonstrate the performance of wind tower for passive evaporative cooling in hot and arid regions of Algeria. The measurements took place for summer period from May until August, hourly for two weeks for each month with and without humidification.

The measurement at the 24th of July the hottest month in this region was selected since it is to be the same period where the simulation with Capcool model took place, hence comparison would be relevant. The first experiment was conducted without humidification. At 14pm when the weather station recorded the maximum temperature of 42°C , at the inlet it was 48.3°C whereas the measured temperature at the outlet was only 33.5°C with a depression of about 14.5°C.

However, the relative humidity was recorded at the same time, the values were very low since the one given by the weather station was 12%, at the inlet it was only 2% and the air delivered to the office space was at 17% (better than both of them but steal uncomfortable). So the wind tower with no humidification provides sensible cooling only.

Therefore an introduction of humidification would be much required in this condition. When water is introduced into the system, evaporative cooling occurs. As air flows through the conduits, water evaporates into the air stream adiabatically, and the moisture content or humidity ratio of air increases. Dividing the height of the column into small sections, and assuming constant moisture content within each section, this will increases surface heat and mass transfer. Thus, much lower temperature and higher humidity would be obtained.

The passive evaporative cooling wind tower simulated previously (Bouchahm) in the arid region of Algeria, dry ambient air was drawn in at the top of the tower and cooler when the entered clay column is fully humidified and well watered the process of heat and mass transfer is occurring so air temperature delivered at the bottom is decreased significantly (latent heat).

It was found that most of the temperature depression occurred relatively, where the air approached saturation. On 31th of July 2007 at 16 pm while the weather station temperature was 42.8°C the inlet temperature was 47.6°C the measured one at outlet was only 25.5°C with a depression of 22.1°C.This values showed much better temperature compared to the one when the watering system was inactive of about 7°C. In addition the experimented wind tower has performed better than the model simulated which gave a depression of 18°C when the watering system is operated since the results showed a difference of 3°C and may be more for other days.

The measured humidity of air at the same time gave a Hrmet at 15%, Hrinlet was at its minimum of 2%, with the humidification an important increase was shown so the delivered air reached a 76 %.

The experiment results obtained show a drop of temperature with an increase of humidity of the air going into the office.

6 Conclusion

The cooling output of a wind tower is determined by the reduction in air temperature and by the increase of air humidity rate through it. Experiments with a novel tower design showed that substantial temperature depression could be generated through a watering system and the humidification of the full clay column, hence heat and mass transfer occurs. This elevates the humidity on the air which to be delivered in the office space. The main significance of these results is that they validate the new design simulated with much better results.

The experiment concludes that the exit air temperature from the tower and the humidity rate are controlled almost exclusively by the temperature difference between the cooler and wetted air inside and the hotter dry air outside the tower. They seem to be proportional to watering system and to the design details of the wind tower. The performance of the system is very impressive; it is recommended that these new design of wind tower should be manufactured to facilitate its incorporation in existing and the designs of new buildings. They can replace artificial air conditioning system currently employed in Algeria, as they have the advantage to reduce their impact on

the peak electricity load, and avoid environmental problem associated with ozone depletion, global warming, and urban heat island and establish the indoor air quality.

References

1. Givoni B., (1994). Passive and low energy cooling of buildings.Published by John wiley&Sons .

2. Cunningham W.A., Thompson, T.L., (1986) Passive cooling with natural draft cooling towers in combination with solar chimneys. In: Proc. PLEA Conf. Pecs, Hungary.pp. 23–24.

3. Erell, E., Etzion, Y., Pearlmutter, D., Guetta, R., Pecornik, D., Krutzler, F, (2005). A novel multi-stage evaporative cool tower for space cooling. 2005. Part 1: Aerodynamic design. In: Santamouris, M. (Ed.), Passive and Low Energy Cooling for the Built Environment, Santorini, Greece, May 19–21,.

4. Belarbi R, Cristian G, Francis A (2006). Modeling of water spray evaporation: Application to passive cooling of buildings. Solar Energy 80. 1540–1552

5. Bahadori MN (1985). An improved design of wind towers for natural ventilation and passive cooling. Sol Energy; 35(2):119-29.

6. Thompson TL, Chalfoun NV, Yoklic MR (1994). Estimating the performance of natural draft evaporative coolers. Energy Convers Manage; 35(11):909–15.

7. Bouchahm Y (2003). Une investigation sur la performance thermique du capteur pour un rafraichissement evaporatif passif dans les regions chaudes et arides, cas de Ouargla. These de doctorat d'état , Constantine, Algeria

8. Bahadoria M.N., M. Mazidib, A.R (2008). Dehghanic Experimental investigation of new designs of wind towers. Renewable Energy 33 2273–2281