Evaporative cooling process adaptive for Baghdad city climate

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ABSTRACT

Human has developed a board rang of passive cooling techniques in various parts of the world up to a very impressive level of maturity: cliff dwellings through the world (ground cooling), wind towers (convective and mass cooling), sprinkling water with fountains (evaporative cooling), and whitewash (sun protection). All these cooling techniques were based on careful design in which heat and mass transfer principles did not make use of any mechanical energy: they were totally passive. The concept of evaporative cooling is that when water evaporates it absorbs a large quantity of heat from its surroundings. Evaporation occurs at whatever time the vapor pressure of water is lesser that the water vapor in the surrounding atmosphere. The phase change of water from liquid to the vapor state is accompanied by the release of a large quantity of sensible heat from the air that lowers the temperature of air while its moisture comfortable increases. The most familiar example of this is the cooling effect of evaporating perspiration on the human skin. In Iraqi, climates, body temperature is partially controlled by the rapid evaporation of perspiration from the surface of the skin. In hot climates with high atmospheric moisture the cooling effect is less because the high moisture content of the surrounding air. In both situations, however, the evaporation rate is raised as air movement is increased. Both of these facts can be applied to natural cooling of structures. The provision of shading and the supply of cool, dry air will enhance the process of evaporative cooling. Evaporative cooling is only effective for comfortable cooling in dry climates. When outdoor humidity rises, the cooling capability of direct evaporative systems declines unless occupants are willing to suffer with high humidity. Evaporative cooling techniques can be broadly classified as passive and hybrid.

1. BAGHDAD CLIMATE AND HOUSE TYPOLOGY

1.1. Baghdad city and climate

Baghdad is the capital of Iraq. The city of Baghdad was founded in AD762 by Abu Jafar al-Mansur, the second Abbasid caliph, on the west bank of the Tigris River. Circular walls enclosed the city and, although it's original name was Madinat as-Salam (City of the Peace), it was more popularly known as the Round.

Baghdad's climate is hot and dry in summer, cool and damp in winter. Spring and fall are brief but pleasant. Between May and September the average daily maximum temperature is 41 °C, and the high may reach 49 °C at midday in July and August. Intense daytime heat is mitigated by low relative humidity (10 to 50 percent) and a temperature decline of 17 °C or more at night.

Table 1: Bagdad climate description for one year

Baghdad, Iraq					
January	**February**	**March**	**April**	**May**	**June**
Dry October	Dry May	Dry September	V Dry July	V Hot V dry July	X Hot X dry July
July	**August**	**September**	**October**	**November**	**December**
X hot X dry July	X hot X dry July	X hot dry July	Warm dry July	Dry May	Dry October

1.2. Baghdad house typology

The houses from Baghdad are characterized by a small number of relatively small openings in the external façade, and a large number of openings that open onto the inner courtyard.

Figure 1. Houses typology from Baghdad (Google earth)

The inner courtyard is a garden and the center of household activities: all the rooms are set around it and open onto this gathering place. In large and medium sized houses, a fountain is placed in the center of the courtyard to freshen the air; Trees are also grown in many traditional courtyards, adding shade and life to this exclusive area.

Traditional Baghdad houses are known to be friendly environments, and are friendly in both their design and structure. For example, courtyards are equipped with many elements that help humidify the air (trees and fountains); they also use the IWAN as an open summer sitting room facing north. The thick walls and roofs are good insulators and help stabilize room temperature, while the variable roof heights and protruding elements in the facade provide shade.

2. EVAPORATIVE COOLING SYSTEM

2.1. Overview

Evaporative methods can be used to enhance the cooling rates in convective cooling systems. One way of doing this is to bring the outdoor air into the house through a moist filter or pad. Passive cooling methods with earth tubes and / or cool towers use the same principles but utilize natural systems for air driver and distribution. If underground intake pipes are made from a porous material, and ground above them is well cool and watered, some evaporation will occur at the inner surface of the pipe. Cool towers utilize wet cooling pads, and the force of gravity. Heavier, cool air "falls", via gravity, into the house and its momentum floods the habitable area. The cool tower exploit, as well as that of the earth cooling tubes, can be improved and distribution comprehensive, by the placement of thermal chimney "drivers" which can pull the cooled air through the house with an increase in both air quantity and velocity. In the either case, the cooler air now has an upper relative humidity, but this is not usually a problem and can even be a benefit in Baghdad climates.

In some times of Baghdad's summer, they may be a time of higher humidity, south and south west desert monsoon season. While sensible heat continues to be mitigated by passive cooling techniques, the latent heat contained in the humid air is more difficult to dissipate, which renders evaporative cooling less effective. The rate of evaporation is greatly enhanced in such a system because a much larger surface area is exposed to the night air. With all evaporative cooling methods, it is important to maximize airflow across the exposed water. Fresh air must be continually available to replace the humid air being built up near or over the water. Failing this, air will be quickly saturated with water vapor, and the evaporation and cooling rates will decline abruptly.

Two-stage evaporative system can also be combined hybrid solar systems using the same storage (rock bed) system for both seasons. This type of systems is necessarily suited for new construction because of the requirement for the rock bed, which is most effectively located beneath the structure. It works well during hot, humid periods in the southwest using only slightly more power than direct evaporative cooling and the comfort attained is similar to that of refrigerated air-conditioning. Atypical system consisting of two evaporative coolers and a large rock bed is shown in illustrative examples at the end of this part. At night, one evaporative cooler cools the rock bed while the other cools the house using a one-stage evaporative cooler. During the day, hot outside air is drawn through the night-cooled rock bed where it is pre-cooled before entering the main house evaporative cooler. Since no moisture has been deposited in the rock bed, the pre –cooled air has not had moisture introduced into the house. A good-looking feature of this type of system is the combining of heating and cooling system in order to make the best possible use of components during the whole year. An air heater may be used to provide hot air during the heating season to the rock bed where the rock bed, fans, ducts and many of the control systems are used both during the heating and cooling season.

3. EVAPORATIVE COOLING SYSTEMS TYPES

There are two diverse approaches to cooling house by evaporative cooling systems. The first is to cool outdoor air directly through evaporation, after that introduce that air into the house. The air is humidified while its temperature is lowered and the indoor moisture content is elevated above the outdoor level. This is the direct evaporative cooling affecting the users and the interior materials in the cooled space. The airflow for direct evaporative cooling can be induced either by mechanical devices – fans – or passively by natural processes – utilizing the wind, temperature difference, or water spray in passive evaporative cooling towers. The second approach is to cool a given element of the house, such as the wall, roof, windows, doors, etc. The cooled element, in turn, serves as a heat sink and absorbs, through its interior surface, the heat that penetrates into the building through the envelope or that part of heat generated indoors. This approach is indirect evaporative cooling. With such systems the indoor radiant and air temperatures are lowered without elevating the indoor moisture content of the air.

3.1. Direct cooling systems

This system applied to comfort cooling by application the simply add moisture to a moving air stream to cool the air while add to its humidity. In this system can be used of vegetation for evapotranspiration, as well as of fountains, pools and ponds where the evaporation of water results in lower temperature in the room. The procedure of cooling is only work for a moving air stream;

therefore this approach requires a source of air drier than the air in the living space that must be cold. An important procedure known as “Volume cooler” is used in traditional architecture. The system is based on the use of tower water contained in a jar or spry is precipitated. External air introduced into the tower is cooled by evaporation and then transferred into the house. A contemporary version of this technique uses a wet cellulose pad installed at the top of a downdraft tower, which cools the incoming air. Natural down-draft evaporative cooler are devices recently developed at the University of Arizona’s environmental research laboratory. These towers-like devices are equipped with wetted pads sprays at the top which provide cool air by gravity flow. These towers are often described as reverse chimneys; just as the column of warm air in a chimney rises, the column of cool air, in this instance, falls. The air flow rate depends on the efficiency of the evaporative cooling device, tower height and cross section, as well as the resistance to air flow in the cooling device. The experiment shows that the cooling tower decreased the temperature from 41, 7ºC air surrounding to 23, 3ºC at the 3:00pm internal space. The wind tower, is used in many hot arid countries, literally scoops air from the prevailing wind stream. The incoming air is evaporative cooled as it passes over receptacles of water, and warm air is expelled via leeward openings. Others systems that can be useful to be used for Baghdad’s climate are wetted layers or volumes of water, spring water, and vegetation, that take place in the front of external doors, windows, catching wind, perforate faces in facades, or special volumes, in which warm air stream penetrated via wetted front or volume to be cold.

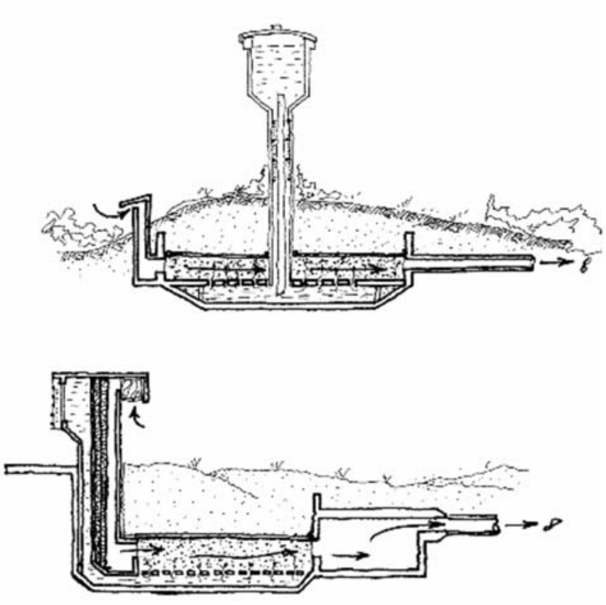

Figure 2: Underground hybrid cooling unit

For intelligent cooling system, mechanical forces can be used to drive air stream from the cooler sources by conducts to living space that must be cold, the capacity of this ventilator can vary between (20-50W).

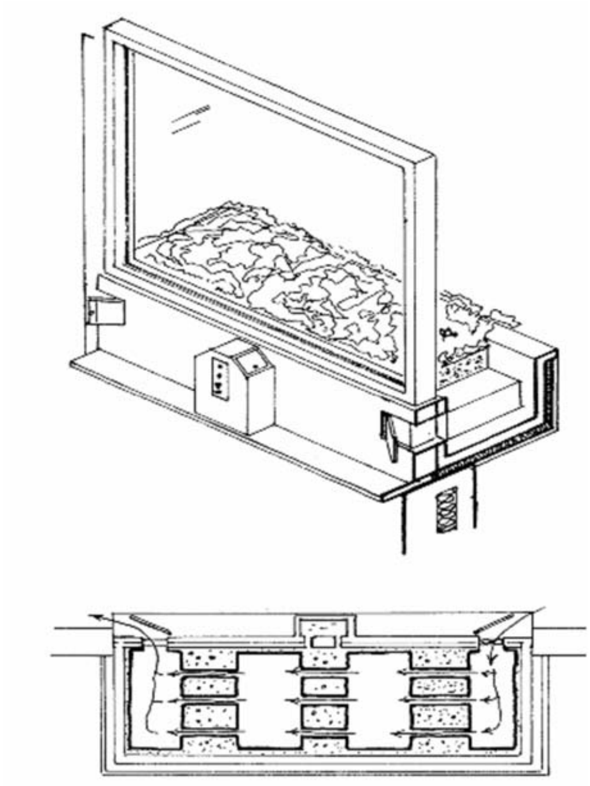

Figure 3: Window hybrid evaporative cooling unit

Water quality is important to the longevity and performance for any direct evaporative system. Minerals in the supplied water will concentrate in the sump and eventually begin to create scale or deposits on the pads. These deposits can severely degrade the efficiency of the systems, so a water treatment system such filters, such as changing periodically of the water can be useful. Direct cooling system include also establishment of an wet obstacle for cooling, this obstacle can be from straw, plastics thread lines (net) with water which raining down (simulation of natural raining form), warm airflow through this net to be cold. ‘

3.1.1. Cooling by fretwork profiled front

This arrangement consist of interior kernel spaces include wet sand or other material connected by special canals using for function the capillary phenomenon , all these systems existing in a perforate front, where natural warm airflow passing through the fretwork front , which captured cool from the front.

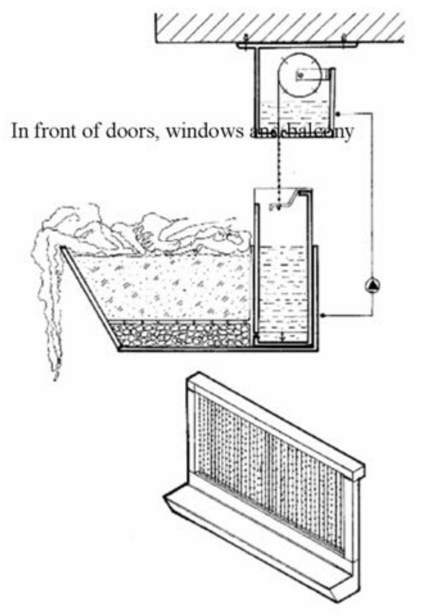

Figure 4: Window Passive evaporative cooling unit.

This front can take place in the front of opening on façade or in the front of house, or such as shading covering element or volume.

3.1.2. Cooling by using of cold water storage in a tank

Water is come directly from water station by steel pipes locate underground; therefore this water is permanent cool. The idea of this cooling system consists of an envelope of brick, steel, plastic or solid well thermal isolate, including a spiral plastic or steel form which covered water storage tank situate underground or above of earth surface in special tight space. The warm air inters via the tank space components to get in final a cool with helping of an exhaust fan.

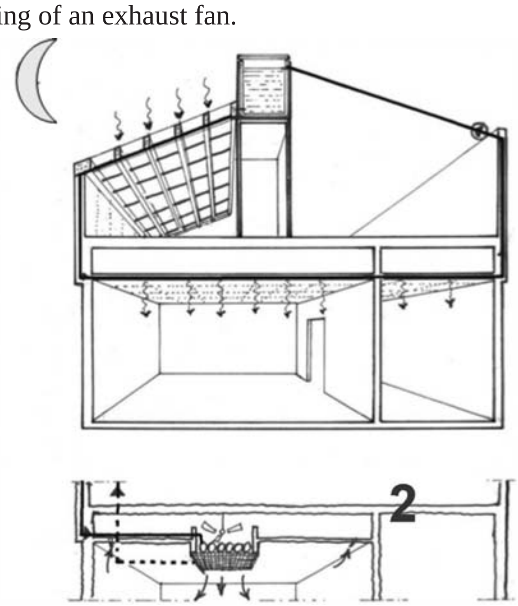

Figure 5: Cooling by radiant system.

A tank of water is located in a special tight space which is located between the underground and the artificial ceiling or any others solutions. The condition of this situation is tightly and well thermal insulated of cooling space.

3.2. Indirect cooling systems

This system of cooling to reduce the external air temperature is characteristically accomplished in swine conveniences through the use of evaporative cooling pads. As air is drawn through wet cooling pads, water is evaporated into the air causing the temperature to be reduced at the same time as increasing the moisture level. Indirect evaporative cooling techniques include roof spray and roof bond systems, earth cooling tubes. Airs in this situation don't need adding moisture. This systems are very expensive and consumption more energy than direct system.

3.2.1. Roof spray system

The exterior surface of roof is kept wet using sprayers. The sensible heat of the roof surface is converted into latent heat of vaporization as water evaporates. Night spray on roof surface cools water by evaporation and radiation to 5 to 8ºC below minimum night air temperature. This cools the roof surface and a temperature gradient is created between the inside and outside surfaces causing cooling of the house.

3.2.2. Roof bond system

The roof bond consists of a shaded water pond over a non-insulated concrete roof. Evaporation of water to the dry atmosphere occurs during day and nighttime. The temperature within the space falls as the ceiling acts as a radiant cooling panel for the space, without increasing indoor humidity levels. The limitation of this technique is that it is confined only to single storey structure with flat, concrete roof and also the capital cost is quite high.

4. CONCLUSIONS

Evaporate cooling can be "direct" if bay air is blown directly in the wet media, in this case evaporative cooling provides sensible cooling while increasing latent content of air. Evaporative cooling can also be indirect, when outside air cooled directly through the evaporative cooler transfers its "coolth" to the indoor air to be conditioned through an air to air heat exchanger. In that case, evaporating cooling provides sensible cooling while keeping constant the latent capacity of air.

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