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Using Passive cooling technology in Residential/Office Buildings in hot climate cities of Iran to manage energy consumption

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Abstract

In recent years, using of air-conditioning devices at summer season has been increased considerably specially in cities that are located in hot climate regions. Most of big cities of Iran are in hot and dry climate area, so utilizing of air conditioning system has been growth noticeably in last decay. According to scientific collected data, consumption of electricity in an average apartment is around 35% of total electricity consumption. Also the consumption of electricity in hot season is two times greater than cold season. So, it is clear that using air-conditioning and cooling systems is the main reason of this great amount of energy consumption and near 30% of energy use in air-conditioning systems. Considering of this subject, efforts to decrease saving electricity in these big cities is an important national issue. In this paper regarding to applications of passive energy technology in residential or office buildings, new methods have been investigated to improve new buildings in these cities. After investigation of these innovative methods for using passive energy in cooling and air-condition system, two methods has been collected that are suitable for big cities of Iran which are located in hot climate regions. Using advance cool tower in buildings and passive radiative cooling are two appropriate methods for very effective summer cooling strategies and effect of these methods on energy management in these cities has been study analytically.

Key words: Passive cooling, Sustainable Architecture, Energy, Buildings

1. Introduction

The most research about energy consumption in buildings has been carried out in developed countries, but regarding to population growth and developing the numbers of buildings in big cities of developing countries and limitations of energy sources and increasing of energy cost in these countries, applications of sustainable architecture with low energy consumption has been noticed in recent years [1]. One of the most valuable forms of energy is electricity. In Iran from 2000 till 2009 the consumption of electricity has been increased sharply. Figure (1) shows the rate of energy consumption (Electricity) and it reached from 96(Twh) to near 170(Twh).

According to scientific data near 35% of total energy has been used in buildings and near 30% of this amount of energy consumes in cooling and air-conditioning systems [2]. Most of big with high population cities of Iran is located in hot and dry climate and using of passive cooling technologies can be a merit method to manage energy demand and summer-peak load in these in these cities. Additionally, construction strategies and sustainable building design can be a way to develop environment friendly cities [3].

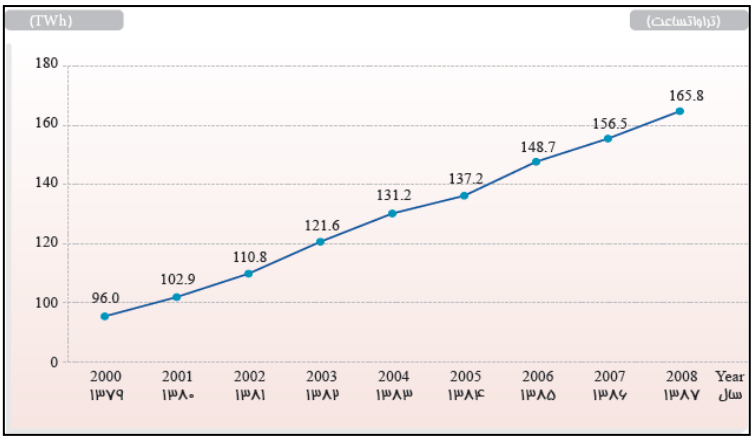

Fig 1: Increasing of electricity consumption in 10 recent years in Iran

Passive cooling technology is reasonable for all buildings owners economically compare to mechanical devices for air conditioning (active ventilation).If passive cooling systems are well integrated and generally accepted by the population, it would be an important step to create a more sustainable architecture in developing countries.
Passive cooling method maximizes the efficiency of the residential building by minimizing heat gain from the external environment and heat loss to the following natural source of cooling. Most passive cooling technologies are dependent on climate. In the hot and dry climatic region in Iran, the continental climate is effective, so a climate analysis was carried out assesses applicability and efficiency of these technologies.

2. Passive cooling technology

Passive cooling technologies are the methods to use natural principle in buildings such as sunshine, wind force, natural ventilation, air temperature, humidity to eject heat from interior space of residential building to prepare thermal comfort. Passive design methods contain optimizing solar orientation, heat insulation, and best rating area of window to wall, structure, shading and natural ventilating of buildings [4]. Therefore, passive cooling has also proven to provide excellent thermal comfort and indoor air quality, together with very low energy consumption. There are many different passive cooling methods but some of them are not suitable for hot-dry climate and they are good for hot-humid weather.
Passive cooling techniques can be classified in three main categories [5]:

- Solar and Heat Protection Techniques
- Heat Modulation Techniques
- Heat dissipation techniques

3. Cool tower technique

The hot ambient air enters the tower through the opening in the tower and is cooled when it comes in contact with cool tower and thus become heavier and sinks down. After a whole day of heat exchange the wind tower become warm in the evening. Then at night the cooler ambient air comes in contact with the bottom of the tower through the rooms. This system can work very effectively in hot and dry types of climate. Direct evaporative cooling system contains evaporation of water in warm dry ambient air at a high level of the building. This process decreases the air temperature and raises its moisture, so this passive cooling technique is suitable for most weather condition of big cities of Iran in summer season. Figure (2) shows the mechanism of building ventilation by using cool tower techniques. This figure illustrates a numerical model of air temperature reduction a long a cool tower. In this modeling, outdoor hot air with 36◦C enters the cool tower of building and its temperature decreases to near 21◦C [6].

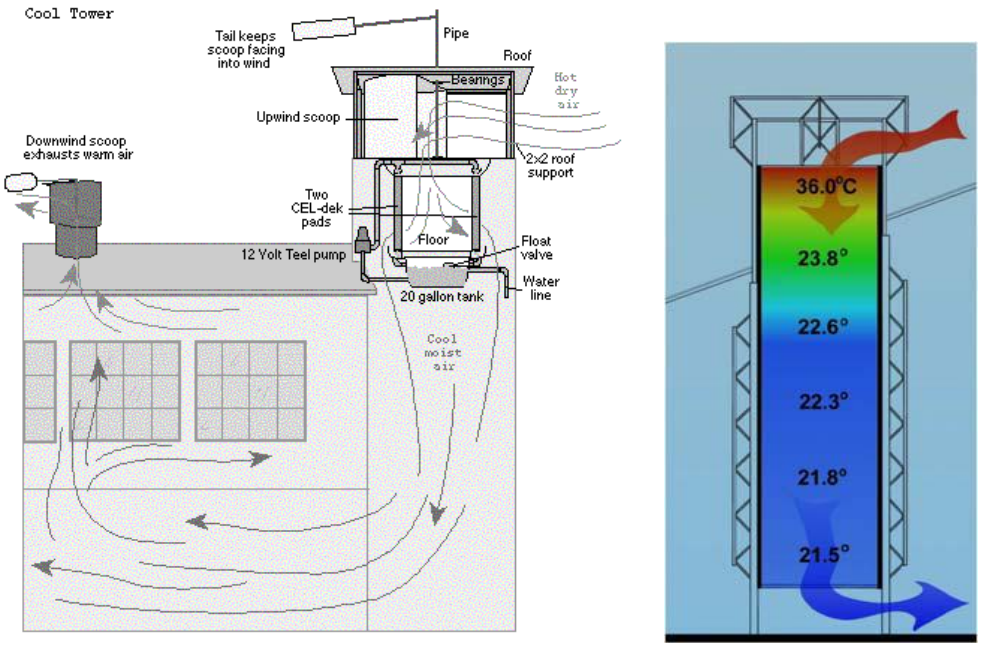

Fig.2. passive cool tower mechanism and air temperature reduction in cool tower

4. Radiative cooling technique

Radiative cooling method is based on the heat loss by long-wave radiation (thermal radiation) from a body towards another body of lower temperature. In the case of buildings, passive radiative cooling where the building envelope radiates towards the sky and gets cooler. This method can be applied in new buildings and for these constructions some parameters such as roof, slab cooling, and space for roof must be considered. This passive cooling technique has many benefits:

- Lower cooling energy
- Low operating costs

- Low operating maintenance
- System with water storage can improve buildings fire

Radiative cooling method based on the physical principle of heat transfer:

$$Q = \sigma(\varepsilon_1 T_1^{\,4} - \varepsilon_2 T_2^{\,4})$$

In this equation Q is the radiative heat exchange flux between the radiating roof and the sky. ε_1 and ε_2 are radiating roof emissivity respectively. T_1 and T_2 are the roof temperature and sky temperature.

Principles of passive radiative cooling system:

A. Movable insulation systems

Movable insulation systems are applied on the roofs of buildings. This system consists of an insulating material that can be moved over the roof of the building. During the day the mass covered by an insulating layer to minimize heat storage in the thermal mass due to solar radiation. This layer can be operated manually or automatically [7].

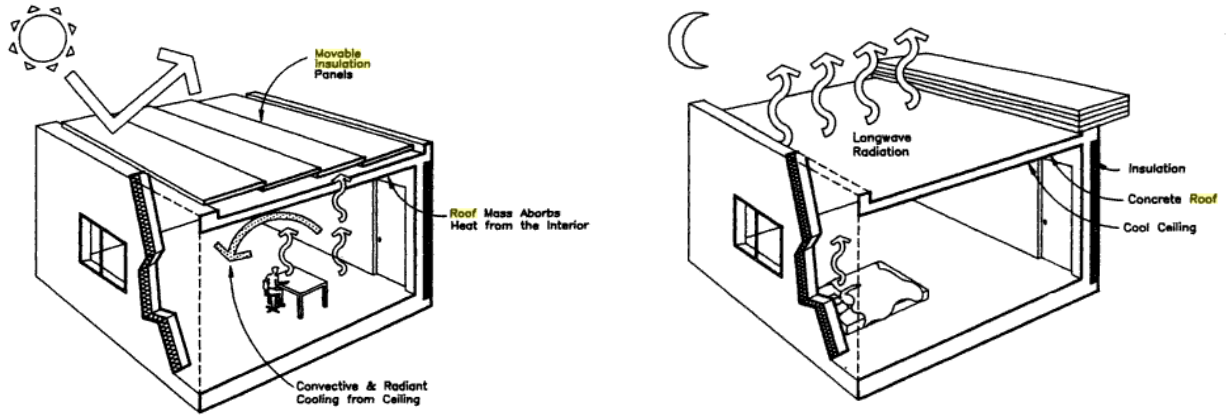

Fig.3. Movable insulation system for passive cooling technique

This system has two main disadvantages:

1- Additional cost of moving panel device

2- This method is completely passive and it is not interesting for multi-storey buildings

B. Hybrid radiative cooling system

Because of the disadvantages of movable insulation systems using of hybrid radiative cooling system is suitable for new constructions and buildings. To design effective radiative cooling method, hybrid systems are used:

- Movable thermal mass (water)
- White cap-T system
- White cap-F system
- White cap-R system

In movable thermal mass method, a water reservoir (pond) is fixed on the roof and the water is the reservoir mass for heat and it circulates between the roof and the building. By day it is covered by an insulation layer and during night, it cools down by radiation. This system is not economically because of the additional costs for a reinforced buildings structure.

In a white cap-T system spray-cooled water drains from the roof at night and is stored in a storage tank. When the building requires cooling during the day, cold water can be pumped from the storage tank to cooling coils in a forced-air cooling system. This system is an effective cooling system to eliminate mechanical ventilation devices.

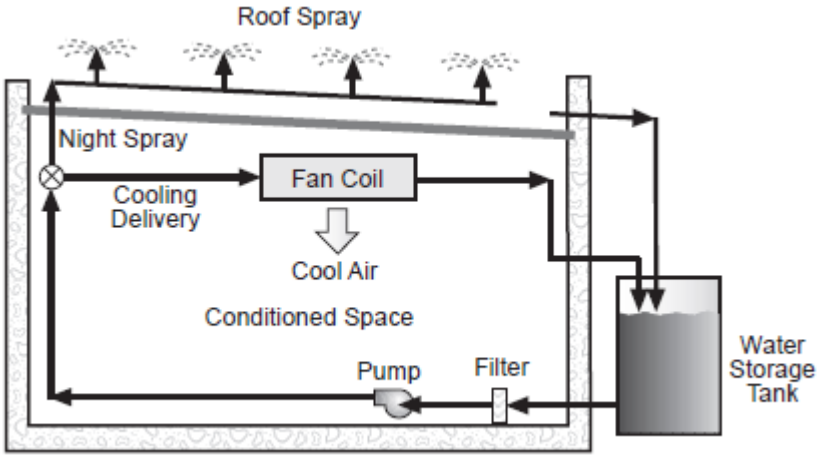

Fig.4. The white cap-T system spray-cooled water technique

In the whitecap-F system channels the spray-cooled water directly through coils in the floor slab and the cooling energy is stored in the thermal mass of the floor. Fig.5. shows the operation of White cap-F system.

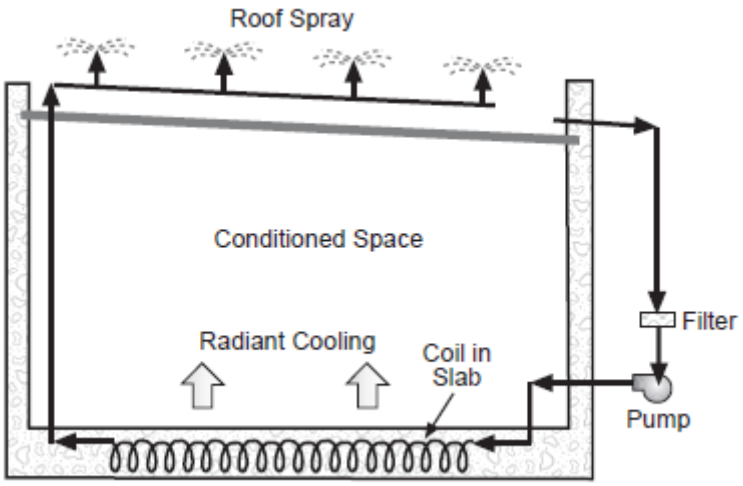

Fig.5. The whitecap-F system spray-cooled water technique

In the original Whitecap-R system, the roof is constructed to allow a layer of water to stay on the roof surface at all times. Interlocking, polystyrene panels float on the surface of the water. These panels are coated with a white, fire resistant, protective coating and insulate the water layer and roof from heat gain during the day. Spray nozzles are mounted flush with the upper surface of the panels and the spray-system piping runs on the roof surface below. Water is pumped to the nozzles from the water layer on the roof.

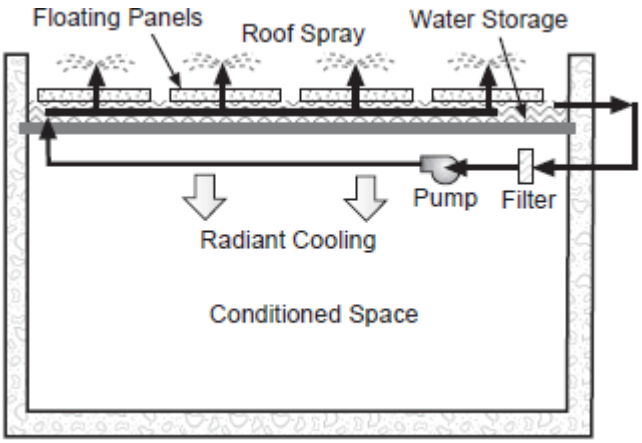

Fig.6. The whitecap-R system spray-cooled water technique

In the analyzing of potential use of the passive cooling technique in Iran, the effect of passive cooling technique is dependent with the climatic condition and potential use of passive cooling design strategies is variation with the different regions. So, it is important to study climatic region of the case study cities for selecting appropriate passive cooling method. In general no air conditioning system would be required if proper passive cooling techniques are adopted.

5. Conclusions

The building sector energy consumption is quite high and is expected to further increase because of improving standards of life and swelling world population Air conditioning use has increasingly penetrated the market during the last few years and greatly contributes in the upsurge of absolute energy consumption. Building energy conservation and environment sustainable development are two main designing factors to choose passive cooling techniques in hot summer area of Iran. Passive cooling strategies and especially passive and hybrid ventilation proved to be effective to decrease cooling demand during summer and the thermal losses were significantly affected by the ventilation characteristics. For the research on passive cooling strategies the regional climate analysis is important to select proper passive or hybrid cooling strategies. Use of passive cooling techniques (cool tower and radiative cooling) has some advantages and limitations. Regarding to these effective applications of passive cooling methods is helpful for the improvement of the indoor thermal environment and the comfort in summer and reduces the energy consumption.

Refrences

[1] Kurt W. Roth, Detlef Westphalia . (2002) Energy Consumption Characteristics of Commercial Building HVAC Systems Volume III: Energy Savings Potential, TIAX Reference No. 68370-00, Cambridge, MA 02140-2390.
[2] www.moe.org.ir
[3] Manioglu G.,Yilmaz Z.(2008) Energy efficient design strategies in the hot dry area of Turkey, Journal of Building and Environment, no43, 1301-1309.
[4] Junli Zhou, Jiasheng Wu, Guoqiang Zhang, Yan Xu.(2006). Development o the passive Cooling Technique in China, 6th international conference for enhanced building operations,9-3.
[5] Santamouris M., Assimakopoulos D(1996).Passive Cooling of Buildings, James and. James Science Publishers, London, U.K.
[6] Michele Zinzi, Marco Citterio (2010). Experience on Passive Cooling Techniques for Buildings, ASIEPI P193-Passive Cooling Techniques for Building.
[7] Bourne, R., C. Carew. (1996). Design and Implementation of a Night Roof-Spray Storage Cooling System. Proceedings of the 1996 ACEEE Summer Study on Energy Efficiency in Buildings, Washington, D.C.