

The Application of Passive Downdraught Evaporative Cooling in China. A case Study: the Tuman River Resort Kashi, Xinjiang

HUANG XUAN¹ AND BRIAN FORD²

¹ March, PhD student

^{2nd} Floor SRB, School of the Built Environment,
University of Nottingham, University Park, Nottingham NG7 2RD UK
Email: laxhx3@nottingham.ac.uk

² Institute of Architecture, School of the Built Environment,
University of Nottingham, University Park, Nottingham NG7 2RD UK.
Email: Brian.Ford@nottingham.ac.uk

ABSTRACT: Air conditioning is now recognized as a significant factor in global warming and climate change. With China accounting for a fifth of the world's population, it accounts for nearly 15 per cent of the world's greenhouse gas emissions, making it second only to the United States. The JOULE research project into Passive Downdraught Evaporative Cooling (PDEC 1996-1999) concluded that in architectural and engineering terms a mixed mode approach (PDEC + back-up system) is technically and economically viable, and is competitive against conventional air-conditioning. This paper therefore focuses on the development of a PDEC cooling system to replace the conventional air conditioning and reduce the cooling energy consumption in China. A project in Xinjiang, China is applying PDEC and Porous Ceramic Evaporators system to cooling a retail-hotel building. Two different passive evaporative cooling systems (PDEC & Porous Ceramic) are proposed for ventilation and cooling strategy.

Analyze the regional climate and building characteristic in China revealed that there are huge potential for energy-saving in hot-dry regions of China. Considering the propitious results, the system could prove to considerably decrease energy consumption in wide range of buildings and provide a substitute to conventional air-conditioning.

Keywords: Global warming, Passive downdraught evaporative cooling (PDEC), hot -dry climate, air conditioning, and energy-saving.

1. BACKGROUND

In recent years, sustainability has become an increasingly important architectural concern. As factors such as energy consumption, pollution and the rise in global

temperature have created a situation where integrating building design and cooling systems is now essential.

At the same time, the population is increasing and in the last four decades

energy consumption has risen dramatically. If we refuse to take these factors into consideration and continue to use only conventional systems and technology, this situation can only get worse and may even reach critical proportions. So building design should seek to reduce the demand for fossil-based energy.

Ford had demonstrated that in hot areas a number of passive cooling techniques offer considerable potential in reducing demand for fossil fuel energy in the cooling of buildings (Ford and Hewitt, 1996). Within these passive cooling techniques, evaporative cooling is a generally viable technique and passive draught evaporative cooling (PDEC) is a particular technique which will potentially become a substitute for conventional air-conditioning.

Passive draught evaporative cooling is a process that uses the evaporation of liquid water to produce cool and humid air. It is a technique that has been used for several centuries in parts of the Middle East, notably Iran and Turkey. In the Middle Eastern tradition, there is a long history of using various techniques to encourage evaporative cooling both within and between buildings (Ford, 1999). Obviously, previous research has indicated that the principles of passive evaporative cooling have been understood for a long time, however, apply this traditional technique to contemporary buildings is a significantly design issue. Recently, some research has focused on the application of PDEC to new building and in the refurbishment of existing buildings.

The Authors, in collaboration with the Professor Brian Ford (School of The Built Environment, Nottingham university) and Professor Wang Xiaodong (Xinjiang institute of architecture design), provided design advice and developed a natural ventilation and passive cooling strategy for the Tuman River Resort Building in Kashi,

Xinjiang. This paper illustrates the proposed strategy for two passive evaporative systems: a) a passive draught evaporative cooling atrium (PDEC Tower) and b) a wall integrated porous ceramic evaporative cooling system (Evapcool wall).

The objective was to develop a natural ventilation and passive cooling strategy able to provide comfort conditions throughout the year to the occupants of the Resort multi-function building.

2. POTENTIAL FOR PDEC IN KASHI, XINJIANG

Xinjiang locates in the northwest of China, which has approximately 1.66 million square kilometers, occupying China's national territory area of nearly 1/6, and contains the population of approximately 20 million.

Xinjiang stands in the centre of Eurasia, far from both the Pacific and the Atlantic Oceans, leading to an arid and rainless, typical type of inland dry climate. The rainfall precipitation in south is few, annual rainfall precipitation is only 58mm, however, the annual evaporation is huge, reaching 2000-3000mm.

The project of the Tuman River Resort has 116309 m² building areas, which includes retail-hotel buildings (91787 m²), theatre (7250 m²), administration office (3600 m²) and reception centre (3036 m²). The experimental building for passive cooling, one of the retail-hotel buildings, has 1577 m². The building incorporates a three-storey atrium surrounded by perimeter cellular rooms. The rooms on the first and second floor are hotel rooms and ground floor is a retail area.

The location of this project is in Kashi which is a typical south city in Xinjiang. During the summer (Jun.-Aug.) daily

maxima dry bulb temperature is above 35°C, RH minima is below 30% and Wet-bulb temperature generally is lower than 21°C. The Dry/Wet Bulb Temperature depression is generally greater than 14°C (Figure 1). The Dry/Wet depression is commonly used as a benchmark for the climatic applicability of passive evaporative cooling. The greater the depression the greater is the potential for evaporative cooling (Schiano and Ford, 1999).

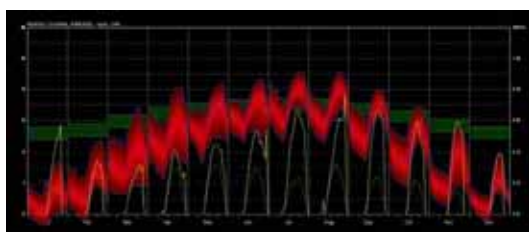


Figure 1: Weather data for Kashi (Chinese Standard Weather Data)

Considering the unique climate characteristics in Kashi, it is ideal for the application of evaporative cooling and to replace conventionally air conditioning.

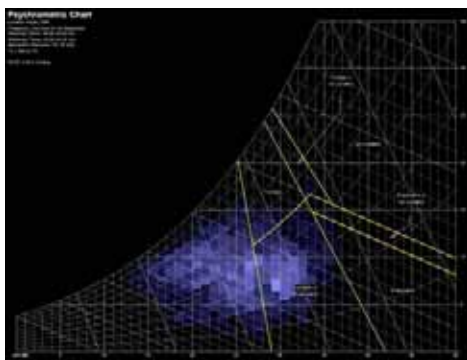


Figure 2: Psychrometric chart with weather data of Kashi and indication of cooling strategies evaporative cooling

The psychrometric chart, generated by the Ecotect Weather Tool, plots the summer weather data for Kashi. The tool identifies the climatic conditions and appropriate cooling strategies (Fig. 2). It is evident that most of the time of summer, the weather is warm and hot-dry and, therefore, the most

appropriate strategies are convective and evaporative cooling. Using the same model, it is possible to identify the predicted comfort zones and the increase in comfort zones by using the evaporative cooling and some others strategies (Figure 3, 4).

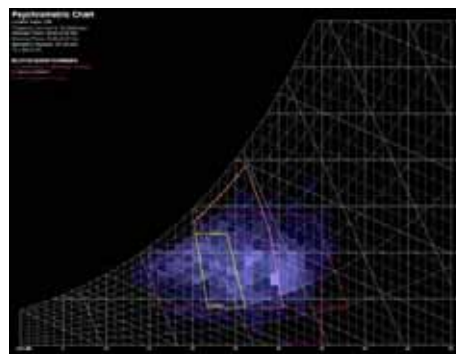


Figure 3: Comfort zones increase by direct evaporative cooling + natural ventilation + exposed mass + night ventilation

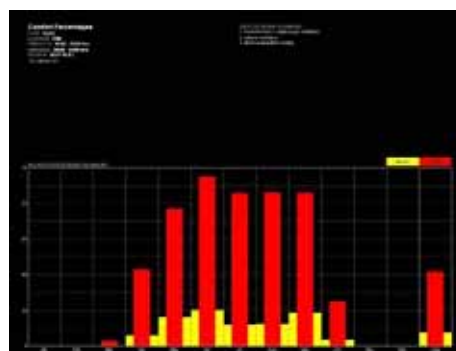


Figure 4: Comfort percentages increase in summer

3. ENVIRONMENTAL DESIGN STRATEGIES

Due to budget constraint the symmetrical plan needed to be separated into two parts. In the left part air-conditioning and right side passive evaporative cooling system is applied. The choice can be explained by the fact that the right part faces the summer prevailing wind, this can enhance evaporative cooling performance (Figure 5, 6).



Figure 5: First floor plan, Kashi

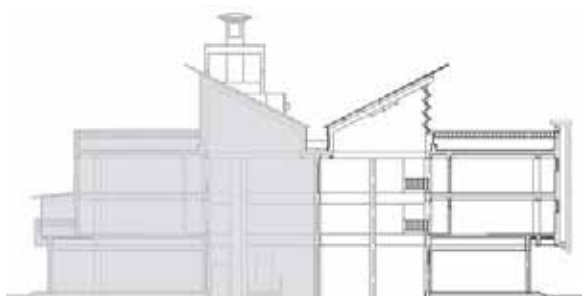


Figure 6: Section, Kashi

The implementation of passive draught evaporative within the central 14 meter high atrium provides cooling air to the room which can connect the atrium by using micronisers. However, some of rooms in the corner can not connect the atrium. To provide passive cooling in these rooms it was proposed to adopt passive draught cooling using porous ceramic. These two different provides an opportunity to compare air-conditioning with passive cooling and compare the two types of passive evaporative cooling.

3.1 PDEC Using Micronisers

Summer

Passive evaporative cooling and ventilation will be provided by a PDEC atrium. The air is cooled at high level by mean of water misting nozzles supply by Ingeniatrics S.L. and delivered by windows in the corridor to the occupancy spaces. The room air will be then exhausted through the perimeter opening (louvers) at high level (Figure 7).

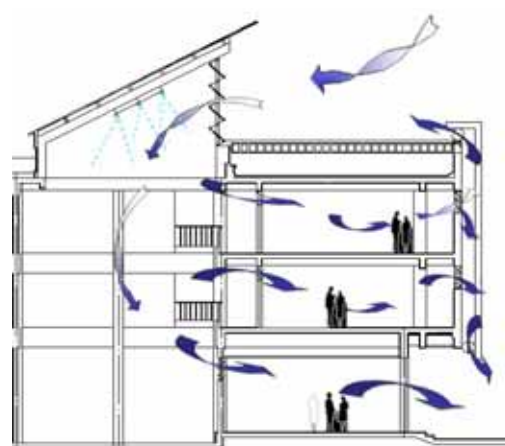


Figure 7: Summer Strategy , Kashi

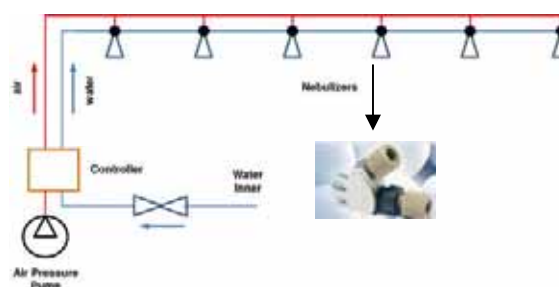


Figure 8: Ingeniatrics Microniser system

The PDEC system relies on 3 lines of 20 nebulizers each one (Figure 8). Predicted air consumption 400 l/min with a pressure of 2 bars in the line of nebulizers. Possible volumes of water to provide by the installation: from 10 l/h to 60 l/h. For a volumen of water of 30 l/h and a pressure of 2 bars in the line of nebulizadores, the average size of droplets is 1,5 microns, being the diameter of 90% of the droplets inferior to 4 microns. And the energy consumption of our system is between 350 and 400 KJ/l.

The PDEC system is controlled by a Control panel, it start, stop and purge in automatic operations by temperature and RH sensors. The PDEC system also operates in conjunction with the motorized dampers. When the system is on, both the motorized dampers at top of the atrium and high level vents at corridor are set to fully open.

Night Time Convective Cooling

When the external temperature drops below 23°C, which occurs frequently at summer night, useful convective cooling is promoted. The air is come in from perimeter windows and exhausted through the atrium at high level by buoyancy forces reversing the daytime air movement pattern under draught cooling. The night cooling is controlled via the motorised dampers.

Mid-season Ventilation

The use of natural ventilation for cooling the building will depend on the external temperature. When the outdoor temperature are blow internal temperatures, indoor cooling can be achieved by natural ventilation (Figure 10). This will be mostly during mid-season days (spring and autumn).

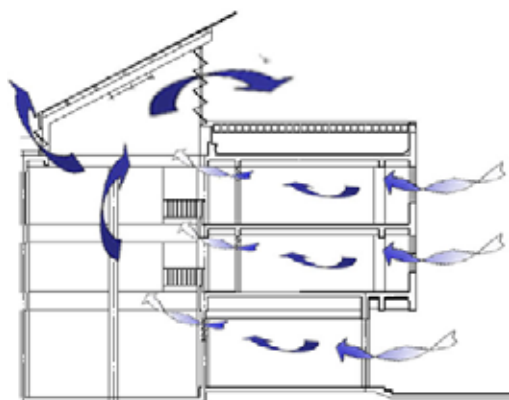


Figure 9: Summer night cooling and mid-season ventilation strategy, Kashi

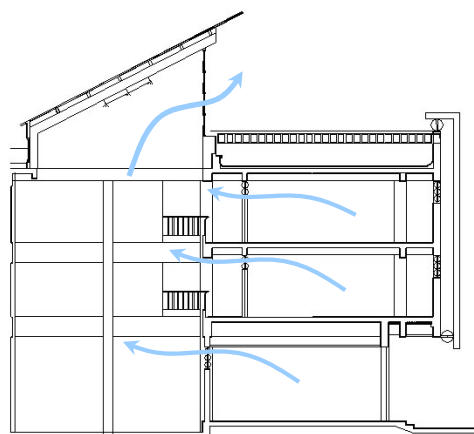


Figure 10: Winter strategy, Kashi

Winter

In winter, the outside temperature is approximately -5°C. Close the openings to prevent the heat lose. For fresh air, the perimeter louvers will be cracked open to allow minimum fresh air into the rooms and exhausted by stack effect though the atrium top (Figure 10).

3.2 PDEC Using Micronisers



Figure 11: Room in the corner and can't connect with the atrium, Kashi

Summer

For these room in the corner, passive evaporative cooling will be provided by a wall integrated porous ceramic evaporative cooling system (Figure 11). The system incorporates an external supply air grille at high level and internal grille at low level. The ceramic panel will deliver cooled air into the room at low level and exhaust through the other side perimeter windows (Figure 12). Whenever, in peak conditions, the level of air movement is not sufficient for the comfort of the occupants a low wat exhaust fan may be operated to increase the airflow.

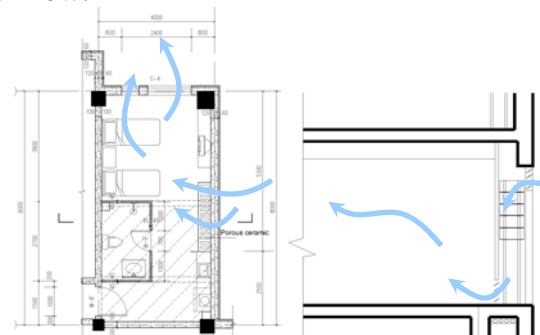


Figure 12: Room plan and section for Porous Ceramic and ventilation strategy, Kashi

Winter

In winter, the openings will close for prevent the heat lose. During the winter the ceramic panels will be emptied of water to enhance the insulative properties of the walls.

4. POTENTIAL FOR APPLICATION IN CHINA

China released details of its greenhouse gas emissions for the first time in a report released on 9 November, 2004. The report showed that China is the biggest producer of these gases after the United States (China's Initial National Communication on Climate Change, 2004) (Figure, 13).

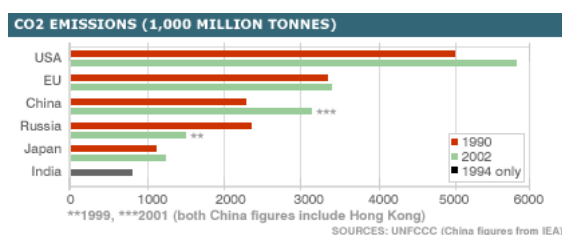


Figure 13: CO2 Emissions. From UNFCCC (China figures from IEA).

Table 1: Air-conditioning proportion in Residential Buildings of Urban and Rural in China, 2003-2005

Source: China Statistical Yearbook 2003-2005

A.C.	2003		2004		2005	
	Ur.	Ru.	Ur.	Ru.	Ur.	Ru.
	61.8	3.5	69.8	4.7	80.7	6.4

2004 year in China, around 69.8% (108 Million set) of urban residential building and 4.7% (5 Million set) of Rural residential building are air-conditioned which together consumed 60.96 billion KWh, moreover, in the recent years, this number increased approximately 6% for every year. Air-conditioning proportions in Residential Buildings in China from 2003 to 2005 are

shown in Table 1 in terms of urban and rural. And the expanding demand for air-conditioning (a.c.) in commercial building is also significantly. In 2004, commercial building consumed 32.82 billion KWh.\

Since the liberalization of the economy starting in the late 1980s, China has witnessed dramatic increases in both the rate of building construction, and the energy used to heat and cool buildings. While the building construction industry is rated as one of China's biggest energy consuming industries, which is accountable for 37 percent of the country's total energy consumption.

Comparing to 1984, the floor area of new construction has increased by almost ten times, from 138 to 1321 million m² per year (CSP 1985, 2001). Over the same time period, building energy use intensity in W/m² has also increased, especially in central and south China (hot regions) where there has been a dramatic growth in air conditioning.(Hogan, Watson, Huang, Lang, Fu, and Lin, 2001).

The region urgently needs more in-depth research on how we can adapt to the unavoidable aspects of climate change, as well as how we can reduce our greenhouse gas emissions.

Thus, the huge potential for energy-saving in hot regions of China's construction projects, if some techniques can be developed to replace the conventional air conditioning and reduce the cooling energy consumption, will not only help ease the pressure of energy supply in the country, but also have a positive impact on the changes in global weather.

5. CONCLUSION

Passive Downdraught Evaporative Cooling is a viable technique for providing

cooling to the Tuman River Resort Building in Kashi. From weather data analysis it is clear that passive cooling system can provide fresh air at a temperature approximately 25°C.

The annual water consumption for the passive cooling system of this building is estimated to be 13.5 m³. And the electricity consumption is estimated to be 1500kWh, compare to conventional air conditioning, predicted to save around 12500kWh/yr, which equates to 8500 Yuan saving and 10 ton of carbon dioxide emissions.

The success of passive Downdraught Evaporative Cooling applied to the central atrium space within Tuman River Resort Building in Kashi, demonstrates the scope for replication throughout hot-dry area in China.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

- [1] Ford, B., Diaz, C. and Hewitt, M., (2003), Passive Downdraught Cooling, Architectural Integration in Seville.
- [2] Ford, B., (2001), Passive Downdraught Evaporative Cooling: principles and practice, Environmental Design, 2001.
- [3] Ford, B., and Hewitt, M.G., (1996), Passive Downdraught Evaporative Cooling in Non-domestic Buildings, A review of the current State of the Art. European Conference on Architecture, Berlin, March 1996.
- [4] Ford, B., Schiano, P.R., (1999), The application of downdraught evaporative cooling systems in Non-domestic

Buildings. A case study: the Green Office, Tehran.

- [5] CSP (1985, 2000), China Statistical Yearbook 1985, 2000, China Statistics Press, Beijing, China.
- [6] Hogan, J., Watson, R., Huang, Y.J., Lang, S.W., Fu, X.Z., and Lin, H.Y. (2001), "Development of China's Transition Zone Energy Code for Residential Buildings", Third International Conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings, Changsha, China.