International Journal of Sustainable Built Environment (2016) **5**, 99–113

HOSTED BY

ELSEVIER

Gulf Organisation for Research and Development

International Journal of Sustainable Built Environment

ScienceDirect
www.sciencedirect.com

CrossMark

Investigation of Iranian traditional courtyard as passive cooling strategy (a field study on BS climate)

Farzaneh Soflaei [a,*], Mehdi Shokouhian [b], Seyed Majid Mofidi Shemirani [c]

[a] *School of Architecture, Tsinghua University, Beijing, China*
[b] *Department of Civil Engineering, Morgan State University, Baltimore, MD, United States*
[c] *School of Architecture, University of Science and Technology, Tehran, Iran*

Received 23 April 2015; accepted 16 December 2015

Abstract

The use of passive systems for climate control in providing indoor thermal comfort minimizes global trends in increasing the energy demand for active systems of climate control which has unacceptable negative impacts on the natural environment. This concept is ignored for designing of contemporary buildings which care less about the environmental impacts. The main objective of this study is to investigate the concept of the traditional central courtyard as a passive cooling strategy for improving indoor thermal comfort in the BS climate of Iran. An empirical field study was conducted to analyze three important courtyard design variants including orientation, dimensions and proportions, as well as opaque (walls) and transparent surfaces (windows), in fourteen valuable traditional houses in five ancient cities located in the BS climate of Iran. Results of this quantitative study, show that Iranian traditional central courtyards were designed based on a careful attention to orientation and geometrical properties regarding the physical and natural parameters to act as an effective passive cooling system. In conclusion, all data sets were integrated to propose a physical–environmental design model for central courtyards as a useful passive strategy which can be generalized for the wider use of environmentally sustainable design principles in future practice concerning courtyards for buildings in BS climate.

Keywords: Passive cooling strategy; Iranian traditional central courtyard; BS climate; Physical–environmental design model

1. Introduction

Passive cooling is a building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or nil energy consumption (Santamouris and Asimakoupolos, 1996). This approach works either by preventing heat from entering the interior (heat gain prevention) or by removing heat from the building (natural cooling). Natural cooling utilizes on-site energy, available from the natural environment, combined with the architectural design of building components, rather than mechanical systems to dissipate heat (Niles and Haggard, 1980). One of the most successful samples of climatic responsive architecture is traditional courtyard houses which were designed with the careful attention to the climatic requirements and socio-cultural contexts. They were responding

* Corresponding author.
E-mail address: farzaneh.soflaei@gmail.com (F. Soflaei).
Peer review under responsibility of The Gulf Organisation for Research and Development.

http://dx.doi.org/10.1016/j.ijsbe.2015.12.001

Symbols

A_{total}	total house area
A_{cy}	area of courtyard
A_{cs}	total area of closed spaces
A_N	area of the north part
A_S	area of the south part
A_E	area of the east part
A_W	area of the west part
L_{cy}	courtyard length
W_{cy}	courtyard width
H_{cy}	average height of courtyard
A_{cy}	area of courtyard
SH_{cy}	shape of courtyard
N_{wt}	number of areas assigned to water in the courtyard
SH_{wt}	shape of the area assigned to water in the courtyard
A_{wt}	total area assigned to water in the courtyard
N_{sl}	number of areas assigned to soil earth in the courtyard
SH_{sl}	shape of area assigned to soil earth in the courtyard
A_{sl}	total area assigned to soil earth in the courtyard
A_{Nel}	area of courtyard north elevation
A_{sel}	area of courtyard south elevation
A_{Eel}	area of courtyard east elevation
A_{Wel}	area of courtyard west elevation
A_{Tel}	total area of the elevations
A_{ONel}	area of openings in courtyard north elevation
A_{Osel}	area of openings in courtyard south elevation
A_{OEel}	area of openings in courtyard east elevation
A_{OWel}	area of openings in courtyard west elevation

to the most environmental challenges over a long period of time, and used various passive cooling techniques such as Showdan, Khishkhan, Shabestan, Hozkhaneh, central courtyard, wind catcher, air-vent of dome roof, etc. for improving indoor thermal comfort in the hot climate of Iran (Soflaee and Shokouhian, 2005).

This research focuses on the concept of Iranian traditional central courtyards as natural cooling strategy, and its potential application for improving indoor thermal comfort in BS climatic as a case study. Traditional central courtyards in Iran as one of the oldest civilizations in the world go back to 3000 BC (Edwards et al., 2005), and as a design pattern has been used for different functions such as cooking, praying, working, playing, gathering and even sleeping during the hot summer nights. They have roots in Persian-Islamic culture and social perceptions; inspire the sense of introspection with respect to privacy in Islamic ideology. In addition to ideological, social, and cultural characteristics, Iranian traditional central courtyard provided other benefits in hot arid regions. It creates a self-sufficient microclimate area between the outdoor and indoor environments, when it is decorated with trees, flowers and shrubs, not only does it offers a beautiful setting and calm environment, but also supplies shades and increases the relative degree of humidity of the courtyard area as a microclimate modifier.

The saving in the cooling energy needs of the building due to the passive cooling performance of the courtyard was determined by some scholars (Rajapaksha et al., 2003; Toe and Kubota, 2015; Fardeheb, 2007; Rajapaksha, 2004). The passive cooling of the courtyard consists of the following features: (a) The shading effects of the walls of the courtyard on the ground and the south-facing wall and windows of the building, (b) The shading effects of the trees on the ground and on the south facing the windows of the building, (c) The effects of the pool, the lawn, shrubs and flowers in lowering the courtyard ground temperature, (d) The wind-shading effects of the courtyard walls and trees on the infiltration rate of air through the building. All these features reduced the heat gains of the traditional courtyard houses of the building (Safarzadeh and Bahadori, 2003). Protection from or prevention of heat gains encompasses all the design techniques that minimize the impact of solar heat gains through the building's envelope and of internal heat gains that are generated inside the building due to occupancy and equipment (Santamouris and Asimakoupolos, 1996). Microclimate and site design are one of these techniques, by taking into account the local climate and the site context; specific cooling strategies can be selected to apply which are the most appropriate for preventing overheating through the envelope of the building. The microclimate can play a huge role in determining the most favorable building location by analyzing the combined availability of sun and wind (DeKay and Brown, 2014). Previous research has identified that the level of thermal comfort in a courtyard is determined by the microclimatic factors on it, particularly solar radiation and wind. The effect of these parameters may be evaluated with respect to the courtyard's geometry, dimensions, proportions and its orientation as the most influential design variants to provide appropriate thermal comfort in the courtyards (Meir et al., 1995; Meir, 2000; Almhafdy et al., 2013; Givoni, 1976). This research attempts physical–environmental analyses of the traditional central courtyard as the passive cooling technique in BS climatic of Iran to propose an appropriate design model for contemporary sustainable buildings.

2. Literature review

Despite abundant research and literature on the passive performance of buildings in general, the use of "courtyards" in buildings for passive climate control in particular