Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 1997–2002

Energy Procedia

www.elsevier.com/locate/procedia

9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

Simulation of courtyard spaces in a desert climate

Omar Al-Hafith[a], Satish B K[b], Simon Bradbury[c], Pieter de Wilde[d]

a,b,c,dPlymouth University, ADA School, Plymouth, PL4 8AA, UK,

Abstract

Within the global trend of looking for energy efficient and environmentally comfortable buildings, the courtyard pattern has been investigated by many authors as an interesting solution for hot regions. Computer simulation tools have been used for this purpose, as they provide wide-ranging possibilities that cannot be obtained in field experiments, including assessing different building design variants under identical climate conditions. However, simulation of courtyards remains challenging, as courtyards are building spaces that are partly open to the outdoor climate and typical building simulation tools are not designed to cope with such situations. This research investigates the capabilities of DesignBuilder in simulating the courtyard thermal behavior. DesignBuilder has been selected due to its wide use amongst architects and building service engineers, and because of its inclusive measurements and validated accuracy. Software simulation results have been compared with real life measurements. The results show that DesignBuilder simulation results are quite different from measured results, raising doubts over the applicability of the software in this specific context.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

Keywords: DesignBuilder; Simulation software; Courtyard pattern; Baghdad

1. Introduction

Since the energy problem in the 1970s, there has been an increasing worldwide interest in designing more environmentally responsive buildings to reduce the energy consumption, keep the environment and have thermally comfortable buildings [1]. In order to achieve this aim, researchers and designers have widely used computer simulation as the main approach to develop and determine buildings' energy performance. This approach provides the opportunity to evaluate and determine the impact of various factors on buildings performance in an early design stage, in different scenarios and without the limitations of field experiments [2, 3]. Therefore, a large number of simulation tools, such as Energy Plus, IES-VE, TRNSYS and DesignBuilder, has been developed and are now widely used for this purpose [4, 5]. However, the validity and the accuracy of simulation results remains a critical issue [6]. Among the challenging situations in which simulation tools' capabilities to simulate accurately are still

1876-6102
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.
10.1016/j.egypro.2017.12.401

questionable is the prediction of the performance of semi-outdoor spaces such as a courtyard and an atrium. The reason is that such spaces are affected by a number of complicated and integrated internal and external factors, while most simulation tools are designed for a regular situation with rooms that are fully enclosed [7]. This study aims to investigate this challenge. It examines the DesignBuilder simulation tool's capability to simulate courtyard buildings. The reason for choosing this building pattern and this simulation tool is the significant environmental performance of the former [8, 9 ,10], and the wide use of the latter [11, 12].

Regarding the courtyard pattern, it has been advocated for being a thermally efficient pattern for the hot climate regions [8, 9, 10]; it has been shown by many studies that it provides, relatively, a thermally comfortable indoor environment without needing mechanical cooling. For instance, Mohammed [13] showed through an experiment that there are cases where the outside temperature is 35ºC, whilst the maximum temperature in a courtyard space is 30ºC and in a similar closed space in a non-courtyard house it is 40ºC. Al-Saud et al [14] demonstrated through another experiment in a courtyard house in Saudi Arabia, that the courtyard can provide conditions where the internal temperature is lower than outside by up to 9ºC, even without any mechanical cooling. Analyzing the courtyard pattern performance shows that it depends on two strategies to achieve this performance: protecting buildings from heat gain and having sufficient natural ventilation [15, 16]. During the day time, buildings are protected from the direct solar radiation and outside conditions by being attached and shielding each other, which helps to avoid having excessive heat gain [17, 18]. In the night, courtyard surfaces radiate their stored heat (accumulated during the day) to the sky, which helps to remove surplus heat [19]; this causes pressure difference that stimulates air movement, which further helps to cool the space. The light hot air in the courtyard and the surrounding spaces goes up to be replaced by cold one through the courtyard by the buoyancy and wind forces [7, 20, 3].

DesignBuilder, on the other hand, is a simulation tool that provides a user-friendly interface to the Energy Plus simulation engine, making it a tool of choice for various professionals such as architects and building services engineers. It produces a comprehensive simulation that takes into consideration a wide-ranging of local sub-hourly climatic and environmental factors. Its accuracy has been validated by BESTest procedure, which is developed by the International Energy Agency and considered by many agencies for validating computer simulation tools [11,12]. In this research, a model of a courtyard building was built and DesignBuilder was assessed according to its ability to simulate the courtyard space environmental performance.

2. Research aim and methodology

DesignBuilder includes a toolset called 'Draw void perimeter' that can be used to model a courtyard, but it considers the modeled courtyard as an unmeasurable external space. Accordingly, to determine the possibility of using DesignBuilder for simulating courtyards, this research considers using alternative ways to model the courtyard space. It explores the validity of results for the courtyard and the surrounding spaces' conditions when the 'Draw void perimeter' tool is used as well as in the case of the other alternatives.

To achieve this aim, DesignBuilder was used to simulate a real courtyard house in Baghdad, which won the first prize as the best environmental design in Iraq in 1992. DesignBuilder simulation results were compared with the real life thermal measurements of the selected house taken from a previous study. The real measurements included the outside temperature, the hourly air temperature in the courtyard and the maximum and the minimum air temperature in a number of internal spaces on the 27th of August [18]. With considering reflecting all of the house properties to have comparable results, six different configurations were modeled and simulated in which everything is identical, but six ways were used to model the courtyard space. To show the software abilities in simulating the courtyard space thermal behavior, the research considered using only natural ventilation as a cooling strategy without any mechanical cooling. The simulation captures the air temperature with a focus on relating the temperature with the cooling impact of shading, natural ventilation and surfaces radiation to the sky, which are the main courtyard cooling strategies. As there are several undefined and unpredicted factors that might affect the thermal conditions in the real measurements, such as people activities, having simple mechanical cooling or heating sources, the research focused on the comparison of the thermal pattern, not the absolute values.