Journal of Engineering and Applied Sciences 11 (9): 2009-2013, 2016
ISSN: 1816-949X

EnergyPlus Validation of a Courtyard House in Yazd-Iran

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Abstract: Computer simulation has been used for simulating physical process and various researches have been conducted based on the simulation softwares. Careful evaluation of the simulation results is an important point for developers and users. Validation is the key method to respond to this issue. This study studies the EnergyPlus validation as simulation program for researchers and building designers. The focus of the study is on main parameter of air temperature inside the room. Validation was tested comparing simulation results and experimental data. The comparison of the results presented EnergyPlus can predict indoor temperature with good accuracy and it can be used by designers and researchers to evaluate thermal comfort and energy use.

Key words: Validation, simulation, energyplus, courtyard house, temperature

INTRODUCTION

More than 4 decades, engineers and researchers have used computers to simulate physical process (Oberkampf and Trucano, 2002). In general, computer simulation modelling of a building's thermal performance is a well-known theoretical procedure widely used in practice and many programs have been developed for this purpose. It is employed in the design process and provides accurate and cost effective results (Laouadi and Atif, 1998; Ji and Cook, 2007; Wang *et al*., 2009). It is a useful tool for engineers and designers to calculate the inside and outside condition of buildings. Acceptable results were achieved in terms of the energy usage and improvement of thermal comfort. In this stage, building designers can study and predict the performance of various aspects of the building before construction. They can predict thermal comfort parameters of each space and optimize relative parameters to achieve better living conditions and reduce energy consumption. Since the temperature difference between the outside and inside is one of the factors affecting energy consumption, predicting the inside temperature can be used to help low-energy buildings design.

Oberkampf and Trucano (2002) believed although simulation brings along many advantages, users and developers of the software have faced new issues by developing the computer simulation. They should know how they can rely on computer simulation and have confidence in the simulation results. Validation is the key method to answer to the issue. Also, they described the validation of computer simulation as follows: "Validation is the assessment of the accuracy of a computational simulation by comparison with experimental data." Validation is connected to the physic issue and real world (Oberkampf and Trucano, 2008). The American Society of Mechanical Engineers standard describes validation as follows:

"Validation which is defined as the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model." EnergyPlus software is a modular, structured code founded on the most general properties and abilities of DOE-2.1E and BLAST. This simulation tool import and production data into text files. Loads calculated at a user-specified time period (15 min default) by a heat balance engine are approved at the same time period to the building systems simulation module. This module with a variable time period, computes the electrical system reaction and heating and cooling system and plant. This combined result gives a more accurate space temperature prediction crucial for comfort and health of occupants and computing system and plant sizing.

MATERIALS AND METHODS

Building and model description: To evaluate EnergyPlus validation, experimental air temperature study which has been done by Foruzanmehr and Nicol (2008) in Yazd, Iran was selected to compare the result of EnergyPlus simulation with its measuring data. They examined hourly data of eight locations in a vernacular courtyard house (Lariha house) and recorded them for three days: 19th, 20th and 21st June 2007 thus, it can be an acceptable experimental test to evaluate software results in terms of air temperature indoor. The EnergyPlus version in this study is 8.2 for simulation. The Lariha house is a courtyard residential building. The house is located in Yazd, Iran with latitude of 31.88°N and longitude of

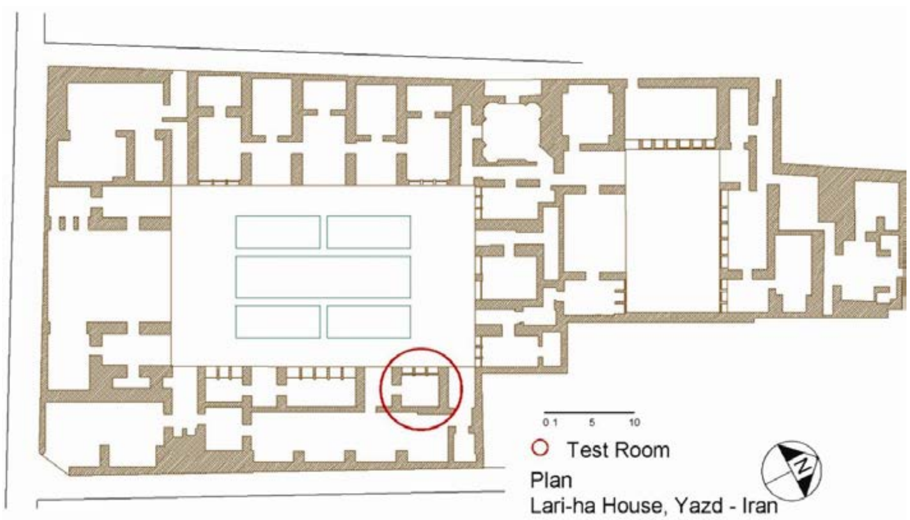

Fig. 1: Plan of Lariha house (Ganjnameh, 2005)

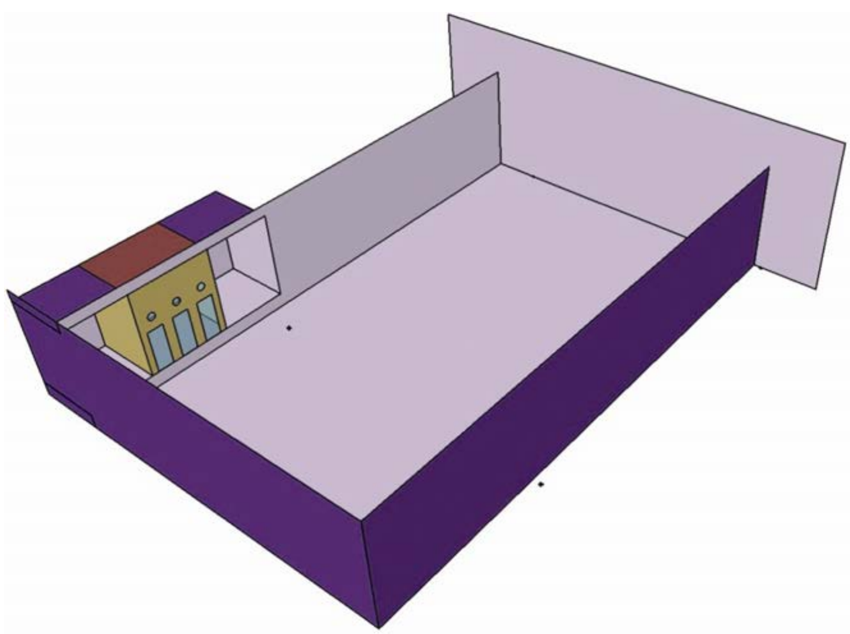

Fig. 2: The 3D geometric EnergyPlus Model of Lariha house

54.28°W. The courtyard house is a single-level building. Figure 1 shows the floor plan of the courtyard house. The 3D geometric model of the courtyard house was created based on architectural drawings with SketchUp (Fig. 2). The courtyard house has rooms around the courtyard that were drawn as shadow surfaces and only test room was simulated with walls, roof, floor and windows so that EnergyPlus would simulate the possible shadow casts on the test room during the period of the simulation days. This stage is important because, the geometry of courtyard affect solar radiation received. The correct angle was fixed to reflect the actual building orientation. The data of floor plan includes specifying the house elements (ground floor, internal and external walls, ceiling and windows). The details of house elements and windows were set up with open studio, EnergyPlus interface. Having completed the geometry and assigned all the building elements, the next step in the model development was to describe the zone within space for thermal simulation targets. This zone description was very easy and there was one zone. The indoor thermal performance of the courtyard house was

Table 1: Thermal properties of materials used at this research

Materials	Conductivity (W/m.k)	Density (kg m^{-3})	Specific heat (J/kg.k)
Adobe 250	0.80	1850	900
Stucco	0.57	1300	837

Table 2: The constructions used at this research

Exterior wall (from outside)		Interior wall (from outside)		Ceilling (from outside)		Floor (from outside)	
Material	Thickness (cm)	Material	Thickness (cm)	Material	Thickness (cm)	Material	Thickness (cm)
Adobe	75	Stucco	2.5	Adobe	75	Adobe	25
Stucco	2.5	Adobe	75	Stucco	2.5		
		Stucco	2.5				

Table 3: Thermal properties of glass used at this research

		Solar energy		
Variable	Nominal thickness	Transmittance	Reflectance	Conductivity (W/m.k)
Clear	4 mm	81%	0.075%	0.90

essentially calculated and analysed to compare the hourly inside air temperature of the zone of courtyard house in 3D EnergyPlus.

The OpenStudio provides facilities for adjusting and defining courtyard house data. The courtyard house elements and window of the model were adjusted and defined in the construction details. In this modelling study, the construction details were defined and specified to match as close as possible to the actual conditions. In general, the construction details of the real building are listed in Table 1-3. The wall, roof, floor and glazing constructions for the 3-D model were wholly simplified consuming public elemental construction materials and specified from the Iran National Building Regulations.

For simulation purposes, since there were not any occupants at the room, the number of people were assumed and set to 0. Also, the door and the windows of the room during the process of text day were completely closed, so the infiltration air rate and the ventilation air rate for zone were assumed and set to 0 ach (which assumes no ventilation air is introduced into the room from outside). Also, because there were not any people, lamps and equipment during the process, the sensible and latent heat gains from occupants, lighting and equipment for the zone were set to 0.

The next stage of developing the EnergyPlus courtyard house model was to set a weather data file as the courtyard house simulation in EnergyPlus is driven by weather conditions. In EnergyPlus database, the weather files of many cities worldwide including Yazd have already been recorded. Before constructing the 3-D Model of the courtyard house, weather data file must be changed because there may be some differences between EnergyPlus weather data and weather data for the simulation 3 days. Therefore, such data may not represent the simulation day weather conditions for the city of Yazd and may influence the accuracy of the predicted results as compared to the experimental data.

Since, the field study was carried out on 19th, 20th and 21st June 2007, the existing Yazd's weather data in EnergyPlus for the same days should be edited to properly model the metred conditions. During the field study, the outside air temperatures (dry-bulb) were investigated by Foruzanmehr and Nicol (2008) and therefore it could directly change the existing dry-bulb temperature data for the simulation 3 days. Apart from having similar weather conditions, this was also very significant that the geometry of the built 3D EnergyPlus Model (including construction details of wholly the courtyard house elements) was maintained as close as possible to the actual experimental conditions of the actual courtyard house and its surroundings. To achieve better prediction consequences that have good agreement with the field experimental consequences, it is significant for EnergyPlus to produce similar simulation conditions.

The model was simulated for experimental conditions: 20th June. For simulation run, the model was 'pre-conditioned' for 6 h. It is done in order to ensure that the stated results are reflective of any thermal storing effects of the structure. The resulting data from the simulation day is analysed.

RESULTS AND DISCUSSION

The prediction results of indoor air temperature of a courtyard house was compared and validated with the experimental results to evaluate the capability and accuracy of the EnergyPlus Model in simulating courtyard hous's indoor thermal performance. Figure 3 shows the measuring temperature results from experimental study and simulation results after simulation. The variance in air temperature in the room in the courtyard house between the experimental condition and EnergyPlus prediction was in the range of 0-1.8°C for simulation day. However, during the simulation day the EnergyPlus prediction consequences show a reasonably good agreement with the experimental data as exposed by Fig. 3. The accuracy of the simulation results is very

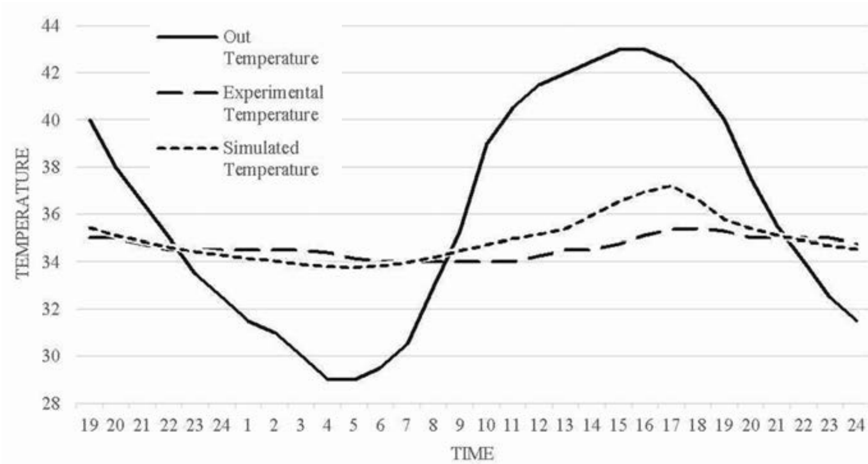

Fig. 3: Average experimental/predicted air temperatures for test day

much dependent on the similarity of the weather data in the weather file and the real local weather conditions. Therefore, the difference between the real weather conditions during experimental and the simulated weather data from EnergyPlus weather file has caused moderate changes between the experimental and predicted dry-bulb temperature. In addition to the difference in weather conditions, the differences between the predicted and experimental results might also be due to the following: Inaccurate specifications of thermal property data, particularly for the windows, had led to different prediction of solar penetration in the model, whereas in the real building solar penetration could be much smaller or higher than that of the EnergyPlus Model, thus, resulting in different prediction of the indoor net heat gain in the model. As a consequence of doubts about the thermal features of the current construction materials, the thermal features of house factors including the glazed elements of the EnergyPlus Model were specified and estimated using the construction data from the Iran National Building Regulations.

In the actual building, some infiltration airflow paths permitted the inside heat to be dissipated. The infiltration rates in the EnergyPlus Model were set on zero ACH and the values could be less than that of the real building, though. Hence, more heat changing in the EnergyPlus Model led to different prediction of the indoor heat changing. In the EnergyPlus Model, the fixed ground temperature was specified based on EnergyPlus weather data. There is a tendency for the heat changing from ground surface. Since, mean temperature of air on 19-21th June in EnergyPlus weather data is higher than the mean temperature of air experimental, it may be overestimated in the model. All these would result in higher prediction of the indoor heat gain in the EnergyPlus Model.

CONCLUSION

The EnergyPlus computer simulation of the room of the courtyard house in Yazd, Iran has been studied in this study. In general, it was found that EnergyPlus program tends to overestimate its prediction results. For day simulation, the difference in air temperature over the 24 h between the experimental and predicted is in the range of 0-1.8°C in the room. Despite the moderate differences between the experimental and predicted results, it is evident from this study that the developed 3D EnergyPlus Model is capable to model thermal stratification within courtyard house with reasonably accurate results. As such, this is the most obvious advantage that computer modelling method can offer. Its application is particularly useful in the design stage where a few design options can be examined before the final design is established.

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