Current Trends in Technology and Sciences
ISSN : 2275-0535
9th Symposium on Advances in Science & Technology (9thSASTech 2014), Mashad, Iran

Assessing the Effect of Window, its Shape and Shading Devices on the Heating and Cooling Energy Consumption (In the Region of Mashhad City)

Shiva Sabeti Ashjaee
Master of sustainable architecture, Iran university of science and technology, Sabeti.shiva@gmail.com

Mohsen Faizi
Professor, school of architecture, Iran university of science and technology, Mfaizi@iust.ac.ir

Fateme Mehdizade Seraj
Professor, school of architecture, Iran university of science and technology, f.mehdizadeh@iust.ac.ir

Amir Saam Zarif Zarouri
Master of architecture student, Imam Reza university of Mashahd, Amir.zarif.7@gmail.com

***Abstract* – Nowadays, saving energy is more important than past due to the population growth and utilizing more resources as a consequence of it. Given to 30-40% of energy consumption in the buildings and existing potential to save energy and the main role of window in the energy consumption in buildings, this study attempts to assess the effect of window, its shape, proportion and type on the heating energy consumption and the effect of shading devices on the cooling energy consumption in residential buildings in Mashhad city. For this purpose, a model with the area of 250 m2 was defined by Design Builder software, in which two variables of the direction and the percentage of the window wall ratios were considered. Then, by keeping window wall ratios constant, the windows' proportion in wall was assessed and finally the effect of hangover on the cooling of building was simulated. By reviewing analyses, it is observed that the shape and dimensions of the windows to the East and South have significant effects on the heating energy consumption and also the use of shading devices above the windows to the East, West and South is recommended.**

***Keyword* – windows, energy simulation, heating and cooling load, Shading devices, Mashhad.**

1. Introduction

Globally, buildings are responsible for between 30 and 40 percent of all primary energy use, greenhouse gas emissions, and waste generation [1]. Lighting, heating, and cooling represent most of the total energy use in a typical building. In resident buildings, heating is the largest consumer of energy[2].

The amount of energy consumed through heating, cooling or lighting in a building is mainly influenced by its fenestration system. Of several products in the system, windows, which can provide light, view and fresh air to the resident, play the most important role in a building's energy consumption [3]. Since the overall heat transfer coefficient (or U-value) of windows is normally five times greater than those of other components of a building's envelope (e.g., walls, doors, etc.), and about 20-40% of energy in a building is wasted through windows [4], the design and selection of a proper window system is one of the important strategies for effectively conserving the energy of a building [5].

Many studies were performed to calculate the effect of windows' dimensions on the amount of heat passing through the window out and it was said that the Window Wall Ratios, in compared with the two factors of the shape of window and the direction of building, is the most important characteristics of window in terms of its effects on the change of total energy consumption [6]

In recent years, more books, theses and articles were discussed about window but their discussion was more related to the kind of glass and/or airflow through the window. And also these issues have been discussed more in American and European countries [7] and [8] but, the effects of window's dimensions on the thermal comfort has been discussed in Asian countries less.

Building energy simulation plays a decisive role in research on energy efficiency in buildings. Building energy simulation is a powerful analytical method for building energy research and evaluation of architectural design [9] and it is also a cost and time saving device. It aims to imitate the real physical conditions in a building by creating a mathematical model that represents all energy flow paths in a building as well as their interactions [10]. Simulation can be used for evaluation of buildings from the viewpoint of energy efficiency as well as optimization of energy performance of buildings[11].

DesignBuilder is used for simulation of buildings. DesignBuilder is the first comprehensive user interface to the EnergyPlus dynamic thermal simulation engine. It combines rapid building modeling and ease of use with state of the art dynamic energy simulation. This program analyses the effects of design alternatives on key design parameters such as: annual energy consumption, overheating hours, and CO2 emissions[12].

2. Mashhad City

Mashhad city, the capital of Khorasan Razavi province, is located in the Northeast of Iran. It is limited by Hezar-masjed mountain ranges in northeast and Binalood mountain ranges in west and south. The city is located at 36.20º North latitude and 59.35º East longitude. Its altitude is 934 meters [13].

Mashhad city is in semi-arid and warm climate with cold winters and hot summers [14]. According to meteorological data of Mashhad city in last 10 years, its maximum and minimum annual temperature is 43.5 ° C in July and -15 ° C in January respectively. Its heating degree day is 58% of the year, whereas its cooling degree day is 25% of the year.

3. Method and Materials

To assess the effects of window on different walls, a zone of 3*5*5 m was used. The analysis was performed in same conditions and the walls of each side was as same as the others. The default of software for living room and materials was considered in accordance with the conventional construction. The material of concrete walls with brick superficies and 25mm internal insulation and also the materials of roof and floor[1] were given to all 4 modes in software so that the conditions would be same.

Since the vernacular architecture of each climate has an appropriate pattern for the compatible architecture with the climate of the region; in this study, the factor of WWR was assessed in several local residential building in Mashhad city that its range was between 20-40% for windows in different directions (WWR=20-40%). Then, the 12-year average of weather has been assessed in according to Mahoney table. This factor suggests the medium window with the dimensions of 20-40% of the façade.

4. The Effect of Openings in Different Directions

The range of 20-40% of window façade ratios in the climate of Mashhad city was extracted by assessing the local building and analyzing Mahoney table. Since the effects of overhangs on window prevents the direct absorption of sunlight and the rate of heat loss from inside to outside of building is not significant and also the need of heating and cooling during the year are 58% and 25% respectively, in this simulation, the warm period analysis is negligible.

In this simulation, in each wall, 3 modes of openings with WWR equals to 20%, 30% and 40% were simulated. The desired window model in each mode is placed in one of the main geographical directions and this is repeated in 4 directions. Then, the outputs of Solar Gains Exterior Windows (kWh), External infiltration and Zone sensible heating (kWh) would be evaluated for six cold months of year by Design Builder software that according to this simulation, the dimensions of windows in each wall are determined to be optimal. In this simulation, the double-walled glass was studies.

- As shown in figure 1 and 2, given to the more solar energy absorption (1663.4 kWh in winter) and also less required heating (437.3 kWh in winter), WWR=40% is more suitable in southern front.
- The WWR=20% is more suitable in northern front. In compared with other dimensions, it has the same solar energy absorption and the least required heating and energy dissipation in winter (with 283,4 kWh of solar energy absorption, 814kWh of required heating and -652kWh of energy dissipation in winter).
- The WWR=40% is more suitable in eastern front. In compared with other dimensions, it has the same solar energy absorption and the least required heating and energy dissipation in winter.
- As shown in figure 1 and 2, the WWR=20% is more suitable in western front. In compared with other dimensions, it has the same solar energy absorption and the least required heating and energy dissipation in winter.

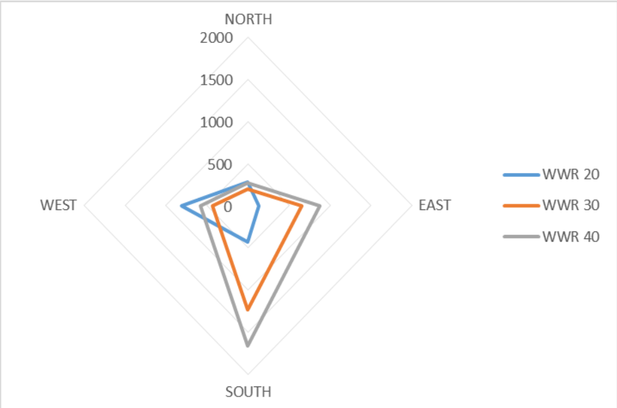

Fig.1. Solar energy absorption (kWh) in cold six-month of year

[1] The U-value of the components of the thermal envelope of all simulated are as following: Exterior Wall: 0.35 W/m²K - Roof: 0.25 W/ m²K - Floor (adjacent to earth): 0.25 W/ m²K - Windows: 1.96 W/ m²K - Frame:3.633 W/ m²K

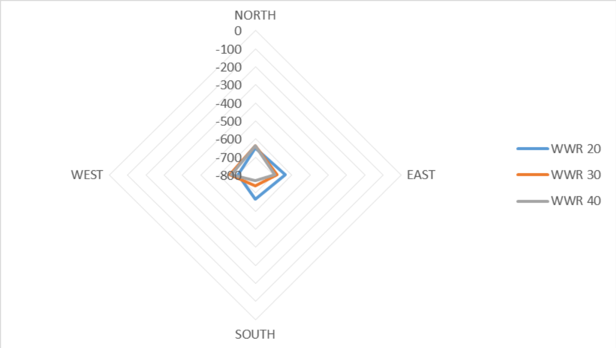

Fig.2. The rate of energy dissipation (kWh) in the cold six-month of year

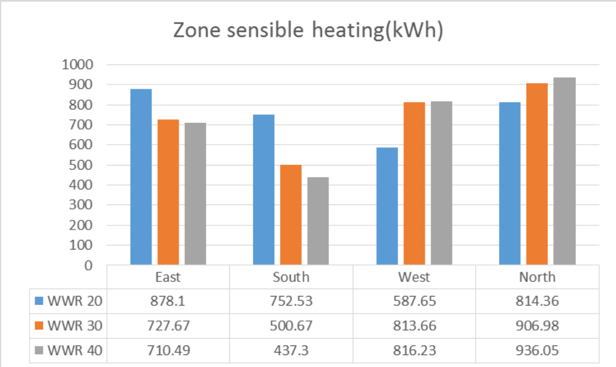

Fig.3. Zone sensible heating (kWh) in cold six-month of year in different geographical directions

According to above chart, the effects of window on the reduction of thermal energy consumption on the southern side is more than other windows in other directions. If the least thermal energy consumption is considered in a model with window on the southern side with WWR=40%, the window facing the West with WWR=20% helps the reduction of thermal energy consumption as much as 25.58%, the effect of window facing the West with WWR=40% and the window facing the North with WWR=20% is as much as 38.45% and 46.3% respectively.

5. Simulation of the Window Facing the South and East

5.1. Analysis of window proportions

According to the graph above, the WWR = 40% in the southern and eastern side is more appropriate. So, the proportions of window by 40% was analyzed and six modes were evaluated. The characteristics of windows' dimensions used in model in this simulation:
Widows 1: h2*2.7,OKB=0.8 -2: h2*2.7 ,OKB=0.2- 3:h2*1.5, OKB=0.4- 4:h1.3*4.3,OKB=0.8- 5:h2*0.7,OKB=0.8- 6: h2*0.7,OKB=0.4
As can be seen, in model "East1" and "South1", in compared with other models, the required heating in cold six-month of year is the lowest.

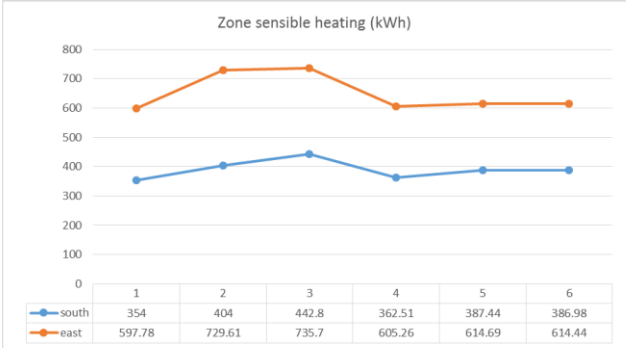

Fig.4. Zone sensible heating (kWh) in cold six-month of year in windows facing the South and East with WWR=40%[2]

5.2. Shading devices

Given to the solar energy absorption in winter and preventing it in summer, it is necessary to use shading devices in climate with hot summer. In this study, after resulting that the window proportions in model "East1" and "South1" need the lowest required heating in winter, the overhang was evaluated and analyzing each of them in summer were performed. In this simulation, the characteristics of overhang are as follows:
1: East1 and South1: windows without shading devices
2: East2 and South2: Louvers (Blade depth:0.05- vertical Spaceing:0.1- Distance from window 0.1- material: wood block)
3: [15]: east3: Sidefins(projection=0.32 -Horizontal offset from window left=0- material:wood block)
south3: Overhang(Projection=0.81m, vertical offset from top of window=0- material:wood block)
As the Figure5 suggests, in window facing the South, the light intensity is reduced as much as 50% by using external louvers or overhang. The effect of louver on the window facing the South(the model south1) in warm six-month of year reduces the cooling energy consumption as much as 26% and this reduction is about 20% by using overhang. It is certainly recommended that in Mashhad city, the shading devices are used on the south side in summer.
The effects of shading devices on windows facing the East are also significant. If the louver is used on the window facing the East, the savings in energy consumption for cooling will be as much as 39.8% and if the sidefins are used, it will be as much as 23.45%.

[2] Proportions of window in model 5 and 6 was extracted by assessing the local building.

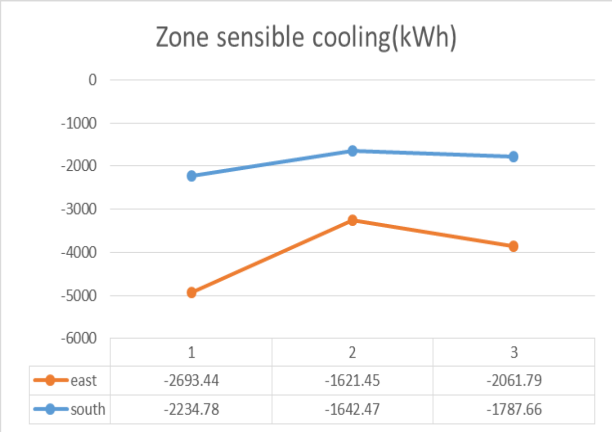

Fig.5. Evaluation of overhang in windows facing the South and East with WWR=40%

6. The Simulation of the Windows Facing the North and West

6.1. Analysis of window proportions

Based on the above graph, WWR=20% was evaluated in windows facing the North and West.

The characteristics of windows' dimensions were used in model in this simulation:

Widows 1: h2*1.5,OKB=0.8 -2: h2*1.5,OKB=0.2- 3:h1*3, OKB=0.4- 4:h2*.7,OKB=0.8- 5:h2*0.7,OKB=0.4

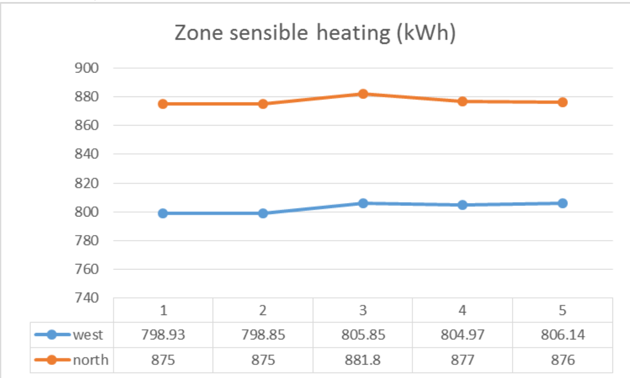

Fig.6. Analysis of the proportions of window facing the North and West in cold six-month of year with WWR=20%[3]

As the table above suggests, the proportions of windows facing the North and West have no significant effects on the solar energy absorption and heat dissipation in winter. Therefore, the use of any proportions as much as 20% is allowable.

6.2. Shading devices

Given to the low effects of the proportions of windows facing the North and West in the climate of Mashhad city, in this part, random selection was used to simulate the effect of shading devicess. In this study, the moving and usable overhangs in summer were considered.

[3] Proportions of window in model 5 and 6 was extracted by assessing the local building.

In this simulation, the characteristics of overhangs are as follows:

1: West1 and North1: windows without shading devices

2: West2: louver (Blade depth:0.05-vertical Spaceing:0.1- Distance from window 0.1- material: wood block)

North2: Sidefins (projection=0.8m -Horizontal offset from window =0 -material:wood block)

3 [15]:

West3: Sidefins(projection=0.45 -Horizontal offset from window right=0- material:wood block)

north3: Sidefins (projection=0.2m -Horizontal offset from window =0 -material:wood block)

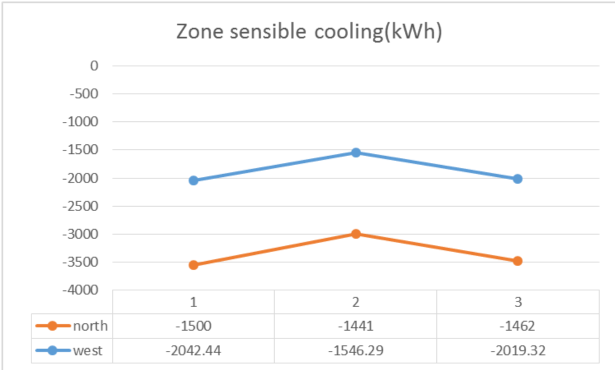

Fig.7. Evaluation of the overhang on windows facing the North and West in cold six-month of year with WWR=20%

The effect of shading devices on the windows facing west is also significant. The effect of louver on window facing the West in warm six-month of year reduces the cooling energy consumption as much as 24.29% and this reduction is about 23.45% by using sidefins.

Based on the above data, the northern overhang with a depth of 20 cm reduces the cooling energy consumption as much as 10% in summer.

7. Conclusion

In this study, the area of window and its shape in different direction and the effect of shading devices on them and on the cooling and heating energy consumption were evaluated. The results shows that these 3 factors have more effects on the thermal behavior of the housing in Mashhad city. The research shows that:

- The window facing the South has more effect on thermal energy absorption and reduction of heating energy than the windows facing other main geographical directions. Then, the windows facing the West, East and North have more effects on the heating of building in winter respectively.
- The effect of window's area on the heating energy consumption of building is the greatest on all the walls. So, it is recommended that WWR=40% in windows facing the South and East and WWR=20%

in windows facing the North and West are considered as design principles by architectures.

- The form and dimensions of the windows facing the East and South also have a significant effect on energy consumption for heating, while this issue in windows facing the West and North depends on other factors and the type of architect's scheme.
- Given to the great influence of shading on the windows facing the East, West and South, the use of appropriate shading devices in these three sides is recommended.

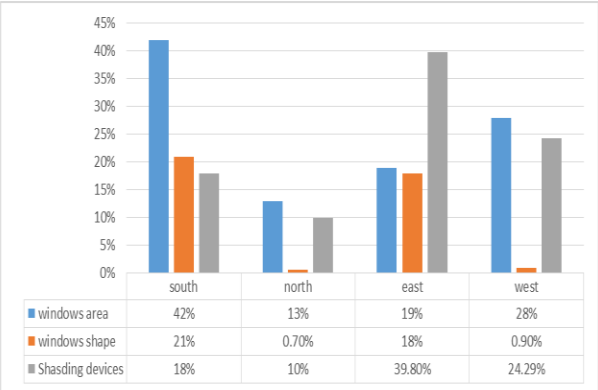

Fig.8. The effect of factors related to windows facing different directions in Mashhad city.

ACKNOWLEDGMENT

I thank the doctor Faizi and the doctor Seraj for guidance on the MA thesis : Thermal energy efficiency of residential buildings in Mashhad, with special attention to the facade By utilizing the vernacular architecture in Iran University of Science and Technology Department architecture and urbanism in September 2014.

REFERENCE

[1] United Nations Environment Programme (UNEP). "Buildings and climate change: status, challenges and opportunities", 2007.

[2] U.S. Department of Energy (DOE). "buildings energy data book", 2010.

[3] J.W. Lee, H.J. Jung, J.Y. Park, J.B. Lee, Y. Yoon. "Optimization of building window system in Asian regions by analyzing solar heat gain and daylighting elements". Renewable Energy 50, pp. 522-231, 2013.

[4] Bulow-Hübe H." Energy-efficient window systems: effects on energy use and daylight in buildings", PhD thesis, Division of Energy and Building Design Department of Construction and Architecture, Lund University, Lund (Sweden), 2001.

[5] Haglund K.," Decision-making methodology & selection tools for high performance window systems in U.S. climates", BEST2, Strategic Issues in Building Design, WB13e4; 2010.

[6] Ebrahim poor, A. Mohamad Kari, B. "A new method for the design of the window with respect to energy consumption", The journal Science - Mechanical Engineering Modares, Tehran, pp.88-77, 2011.

[7] Haglund K. "Decision-making methodology & selection tools for high performance-window systems in U.S. climates". BEST2, Strategic Issues in-Building Design, WB13e4;. 2010.

[8] Apte J, Arasteh D., "Window-related energy consumption in the US residential and commercial building stock". Lawrence Berkeley National Laboratory,2008.

[9] Hensen, J. L. M., Clarke, J. A., Hand, J. W. and Strachan, P. "Joining forces in building energy simulation, Building Simulation 93 Conference, International Building Performance Simulation Association", pp. 17-23. Adelaide Australia,1993.

[10] Rizos, I. "Next generation energy simulation tools: Coupling 3D sketching with energy simulation tools", unpublished thesis University of Strathclyde, 2007.

[11] Nasrollahi, F. "Climate and Energy Responsive Housing in Continental Climates", Universitätsverlag der TU Berlin, ISBN: 978-3-7983-2144-1. Berlin Germany, 2009.

[12] DesignBuilder Software Ltd. DesignBuilder Software," www.designbuildersoftware.co.uk/[accessed 10.05.2008].", 2008.

[13] "https://amar.mashhad.ir/" (Statistics and Data Analysis management of Mashhad municipality)

[14] Iran Meteorological Organization. 2009. Synoptic Stations Statistics," http://www.weather.ir/."

[15] Kasmaee, M. fayaz, R. "Design Basics fixed canopies in different climatic zones in Iran". BHRC. Tehran, Iran, 2010.