An Investigation of the Effect of Sunspace on Energy Consumption in Climatic Conditions of Tehran and Tabriz

Alireza Zolfaghari*, **Abdolazim Zarei**, **Abolfazl Farsad**

Mechanical Engineering Department, University of Birjand, Birjand, Iran
* P.O.B. 97175/376 Birjand, Iran, zolfaghari@birjand.ac.ir

Abstract

This research deals with the thermal performance of a building with and without a sunspace as a passive element of the building structure in two different climates of Tehran and Tabriz. For this purpose, DesignBuilder software is utilized to simulate and analyze the test case. Results indicate that a double window sunspace with a schedule in summer time can thermally enhance the performance of the building, and also it leads about 16.2% of heating load reduction for Tabriz and 15.2% for Tehran. Moreover, for cooling load these results were about 15.1% and 14.2%, respectively.

Keywords:
Passive solar systems, sunspace, energy consumption

1- Introduction

Solar energy is one of the most important source of renewable energies. This type of energy can be utilized in buildings in two ways: active and passive solar systems. One of the most popular passive solar energy systems is “attached sunspace”. Recent studies have proven that a sunspace can efficiently reduce the heating load of a building if being attached to its southern wall [1]. Among renewable energy sources, Iran has a high solar energy potential in order to using the solar technologies such as sunspaces. But, only few studies have been conducted in Iran in this regard. Sadeghi et al [2] analyzed different geometries and shapes of the sunspace for a building in Tehran. Saghafi and Yazerlou[3] investigate the effectiveness of using a sunspace in scorching climate of Yazd only. Balilan et al[4] also studied the effects of using a sunspace on the energy consumption of a building in London. Greg et al [5] also analyzed the thermal performance of four sunspaces for a building in Portugal. Another research has been conducted to prove the energy efficiency of sunspace in [6]. There seems to be a lack of a comprehensive overview to conduct a comparison between the effects of the mentioned system on both heating and cooling loads and in different climates; therefore, this article aims at considering different climates and analyse the changes of thermal loads due to attaching sunspace in both summer and winter.

2- Methodology

This research is based on theoretical studies, computer modeling and simulation, using DesignBuilder 4.7 software. The basic test building is a rectangular single zone (8 m wide x 6 m long x 2.7 m high) with no interior partitions, the material of which is shown in Table 1, compared with the same building carrying a sunspace on the southern wall (Figure 1). The sunspace is attached to the building through no hole; it is defined as a cavity in the software. Also the climatic conditions of Tehran and Tabriz have been shown in table 2. Results were obtained annually so that it presents a comprehensive set of data for both heating and cooling loads.

Table 1 Material of the building (light weight mass)

a) Wall construction			
Element	Thickness(m)	Density(kg/m^3)	C_p(J/kg-K)
Plasterboard	0.012	950	840
Fiberglass Quilt	0.066	12	840
Wood siding	0.009	530	900
b) Roof construction			
Element	Thickness(m)	Density(kg/m^3)	C_p(J/kg-K)
Plasterboard	0.010	950	840
Fiberglass Quilt	0.1118	12	840
Roof Deck	0.019	530	900

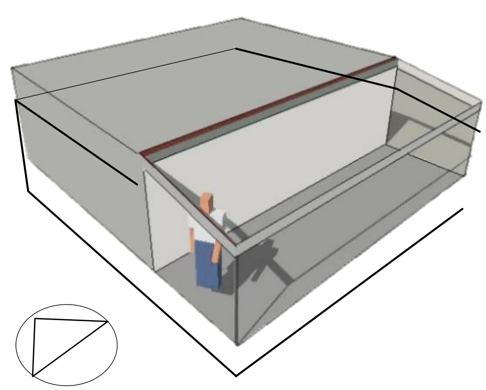

Fig. 1 The base building carrying a sunspace on its southern wall

Table 2 Climatic conditions of Tehran and Tabriz.

	Avg. winter Temp. (°C)	Avg. summer Temp. (°C)	Latitude (deg.)	Longitude (deg.)	Height from sea level (m)
Tehran	-3.6	38.7	35.68	51	1188
Tabriz	-11.2	35.7	37.8	46	1365

3- Validation

In order to investigate the accuracy of DesignBuilder's results, a test case (case 600 of ANSI/ASHRAE Standard 140-2001) has been considered. The results indicate a very good agreement in comparison with the results of ANSI/ASHRAE Standard 140-2001.

4- Results and discussion

The resuls of this study are presented in three most important areas of effects of adding the sunspace to the base building:

4-1 Thermal loads

The annual heating loads of the building with and without the sunspace for the two mentioned climates are shown in Table 3. As shown in Table 3, the heating load has been reduced in both climates and it is justified due to the higher temperature provided on the southern wall during winter, which brings less heat loss from this side of the building. Also, the annual cooling loads of the building with and without the sunspace for climatic conditions of Tehran and Tabriz are shown in table 4. Cooling load also decreased as a result of adding the sunspace to the building. This could be justifeied by considering that the sunspace prevents a fraction of the sun light from meeting the southern wall of the base building. With this regard, althogh the temperature of the sunspace rises over the outside dry bulb during summer in both climates (figures 2 and 3), it reduces the radiation and therefore the heat gain through this wall.

Table 3 Heating load comarison and the effect of sunspace

	State	Heating load
Tabriz	Without sonspace	5268 kWh
	With sunspace	4412 kWh
	% reduction	16.2%
Tehran	Without sonspace	2972 kWh
	With sunspace	2519 kWh
	% reduction	15.2%

Table 4 cooling load comparison and the effect of sunspace

	State	cooling load
Tabriz	Without sonspace	504.7 kWh
	With sunspace	428.5 kWh
	% reduction	15.1%
Tehran	Without sonspace	1652.0 kWh
	With sunspace	1416.5 kWh
	% reduction	14.2

The indoor temperature is also shown in figure 4 and 5, which is an evidence that shows sunspace average temperature is higher than that of the zone in winter.

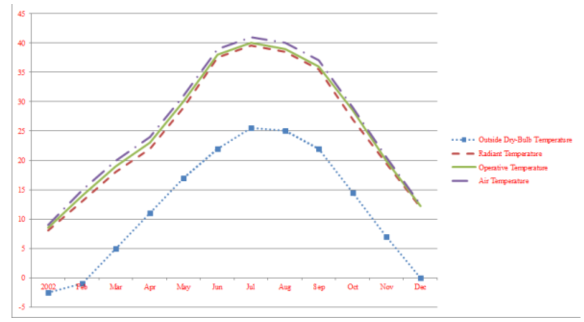

Fig. 2 Annual variations of sunspace temperature in Tabriz.

Fig. 3 Annual variations of sunspace temperature in Tehran.

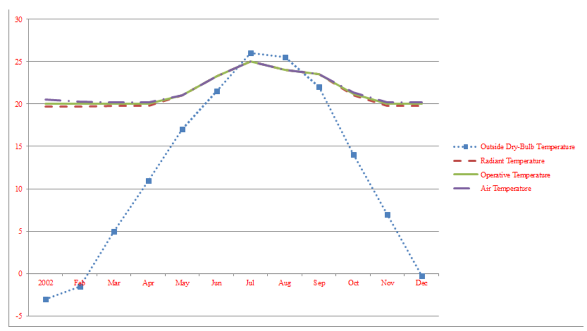

Figure. 4 Annual variations of indoor temperature in Tabriz climatic conditions.

Figure. 5 Annual variations of indoor temperature in Tehran climatic conditions.

4-2 Energy consumption and CO_2 production

As shown in table 5 the energy consumption of the building and consequently CO_2 production are reduced. Due to decrease of heating and cooling loads gas and electricity consumption are respectively decreased.

Table 5 Energy consumption and CO_2 production comparison

	State	CO_2	electricity	Gas
Tabriz	Without sonspace	1397.3	112.2	6197.9
	With sunspace	1196.2	95.2	5191.1
	% reduction	14.4	15.1	16.2
Tehran	Without sonspace	1045.3	367.2	3467.3
	With sunspace	911.5	314.8	2963.7
	% reduction	12.8	14.28	15.2

5- Conclusion

The main aim of this study is to demonstrate that using a well designed sunspace in the structure of a building can positively affect the thermal performance of the building, both in winter and summer in different climates. To do so a building was designed and thermally analyzed with and without a sunspace in two climatic conditions of Tehran and Tabriz; and the results indicated that using a sunspace with an oppening to be just oppened in some times of the summer can enhance the performance of the building thermaly in regard with both cooling and heating loads; therefore, the energy consumption of the building decreases and consequently the building produces less CO_2. It is also noticed that the amount of both heating and cooling load reductions are much for Tabriz climate, which indicates that sunspace's performance is better in cold climate.

6- References

[1] S.A. Kalogirou, *Solar Energy Engineering Processes and Systems*, Second Editting, pp. 349-357, Waltham: Academic Press, 2014

[2] H. Sadeghi, M.K. Jamshidi, A. Rafatjah, An investigation of proper sunspace pattern for a residetial building in Tehran, *Proceedings of The 1st International Conference and exhibition on solar energy*, Tehran, Iran, May 19-20, 2014. (in Persian فارسی)

[3] M.J. Saghafi, T. Yazarlou, An investigation of the effect of sunspace on heating load reduction of winter occupated spaces of Yazd's traditional houses, *Proceedings of International Conference science and engineering*, Dubai, UAE, December 1st, 2015. (in Persian فارسی)

[4] L. Balilan Asl, D. Satarzadeh, M. Gane, An investigation of sunspace placement in zero energy building design, *Proceedings of 1st national Conference on clean energy*, Hamedan, Iran, April 25th, 2013. (in Persian فارسی)

[5] G. J. Schoenau, A.J. Lumbis, R.W. Besant, Thermal Performance of Four Sunspaces in a Cold Climate, *Energy and Buildings*, Vol. 14, pp. 273-286, 1990.

[6] A. Monge-Barrio, A. Sánchez-Ostiz, Energy efficiency and thermal behaviour of attached sunspaces,in the residential architecture in Spain. Summer Conditions, *Energy and Buildings*, Vol. 108, pp. 244-256, 2015.