

Depth optimisation of double skin façade, considering thermal properties: Case study of Karaj, Iran

Peiman Pilechiha^{1,2}, Mohammadjavad Mahdavinejad^{2*}, Seyed Naser Mirhosseini¹ and Javad Ahmadi²

¹Kowsar Institute for Higher Education, Qazvin, Iran.

²Department of Architecture, Tarbiat Modares University, Tehran, Iran.

Accepted 23 July, 2019

ABSTRACT

The main idea of designing buildings with double skin facades is to achieve sustainable architectural goals. Considering the importance of reducing energy consumption in buildings as well as various factors preventing energy loss, it is regarded that how deep the cavity between double skins is in most appropriate building with double skin façade in a particular climate in terms of optimal use of heating and cooling energy, and it is determined that how much energy is used by each floor in the building to meet the residents' comfort. The method used in this research is modeling and software calculations. A chamber with the length of 5 m, the width of 4 m and height of 3 m in three floors with double skin facades at 20, 40, 60, 80 and 100 cm depths was modeled to be compared with a single skin façade using ECOTECT 10. After defining it in the Energy Plus software, cooling and heating load of the chamber was analyzed. The main purpose of this study is to investigate the thermal performance of double skin facades with different depths in the climate of Karaj city. First, the validity of ECOTECT and Energy Plus software was investigated, and then the results were obtained regarding the use of double skin façade compared with the simple façade. The results showed DSFs have a great ability in order to minimize cooling and heating load during operation periods of building even in hot climates such as Tehran. Finally, comparing heating and cooling energy consumption for all depths with respect to environmental factors, it was annually selected that double skin façade with a depth of 20 cm is the best option which results in about 34% reduction in energy consumption.

Keywords: Double skin façade, reduction in energy consumption, energy consumption, thermal comfort.

*Corresponding author. E-mail: mahdavinejad@modares.ac.ir.

INTRODUCTION

Today, a significant part of the energy is wasted through the façade in buildings; therefore, sustainable architecture has been developed to save energy and reduce air pollution. One of the most effective strategies to reduce energy consumption in buildings is to use double skin façade designed to achieve sustainable architectural goals (Hien et al., 2005). Another reason is its strength and beauty with the aim of meeting mental comfort in humans. In addition to reducing energy consumption in terms of the visual relationship between people living in the building and outside, double skin glazed façade is considered important, and due to the integrated use of

glass in the exterior façade, it has become attractive to design for engineers.

The considerable superiority of double skin façade to glazed facades (except the ones with low-E glasses [Hee et al., 2015]) can be seen in greenhouse effect in glazed facades causing a great deal of heat rise in buildings. Also, the use of wide glazed surfaces with poor shading leads to rising air temperature inside these buildings; this results in increased energy consumption in order to achieve thermal comfort as well as environmental pollution. The performance of double skin facades is different in warm and cold seasons. Shading devices that

fall between double skins are also used to absorb solar radiation; the heat absorbed by the shading device can be guided into the building in the cold seasons by the movement of air existed between two skins.

It seems that the performance of double skin façade varies in different conditions and climates; however, how it performs is important. Now, these questions arise that:

1. How much are the variations created in the heating and cooling energy consumption on each floor (for 4 persons)?
2. Which depth of double skin façade is more appropriate for the considered chamber in the Karaj climate?
3. How much is thermal energy consumption reduced in the relevant climate by the help of double skin façade?

The effectiveness of double skin facades depends on many factors including building type and use, number of building floors, climate, and the depth between double skins in particular, etc.

The thermal performance of the double skin facades is strongly dependent on climatic conditions and due to different climatic conditions; the type of suitable selective system will be different from each other. When the sun's radiation shines to the outer skin layer, some of it is reflected, absorbed and transmitted. The sun's radiation that passes through the outer glass is absorbed by the inner layer, causing the interior wall to warm up, and some radiation with a long wavelength of reflection reaches the outer wall again, where it is also somewhat reflected and absorbed, and the absorbed quantity is re-dispersed on both sides of the glass, thus an important part of the sun's radiation is trapped in the cavity, which includes the temperature rise of the interior air cavity, this process is known as the greenhouse effect.

RESEARCH BACKGROUND

A great deal of simulation research has been done to investigate the behavior of double skin facades. Afshin Mehr et al. (2016) have used double skin facades to reduce the use of air conditioners in order to achieve thermal comfort. Mehdizadeh Seraj et al. (2015) investigated the effect of the number of internal and external layers of double skin facades on energy consumption. Hadianpour et al. (2015) have assessed the capacity of using double-skin facades in architectural design in Iran's warm and dry climate. Ghanbaran and Hosseinpour (2014) have investigated the efficiency of the idea of double skin facades in the climate of Tehran. Hoseggen (2008) showed that the cost of heating energy can be reduced up to 20% by well-designed double skin façade. Gratia and Herde (2004) concluded that greenhouse effect and middle-part ventilation in a sunny day results in an appropriate comfort condition in the

building. In another study, they examined parameters such as the level of solar radiation, orientation and use of shading devices, and provided strategies in regard to greenhouse effect (Gratia and De Herde, 2007a). In another research, they studied the effect of appropriate position and the color of shading devices on the cooling consumption in an office building with double skin façade (Gratia and De Herde, 2007a). In another investigation, they also examined how to use natural ventilation in an office building with double skin façade (Gratia and De Herde, 2007b). They believed that the use of natural strategies reduces energy costs (Gratia and De Herde, 2007c). Pomponi et al. (2017) analyzed double skin façade in two different climate zones, and the best result was achieved in London through using double skin façade which provided 85% of internal comfort conditions, while it is 61% for Rio. Su et al. (2017) concluded that the structural parameters of DSF significantly affect the thermal performance of DSF.

INTRODUCING DOUBLE SKIN FAÇADE

A double skin façade is a form of building skin consisting of two layers of interior and exterior façade made of different glasses that are separated and can act as air conditioner (Afshin Mehr et al., 2016). These layers may or may not insulate air (Poirazis, 2004). There is a path for air flowing between these two skins (Loncour et al., 2004); it can be ventilated naturally or mechanically. In most cases, such a collection is managed automatically and by controlling systems (Poirazis, 2004). This system is also known by other names, including ventilation façade, ventilated wall, double façade, double cover and double glazed façade (Sayadi et al., 2012).

Layers of double skin façade

External skin: It usually contains a toughened glass. The external façade can be all glazed (Allan, 2006). Internal skin (external wall of interior space): It can be double glazed (transparent, solar controlling, absorbing glass, etc.) (Figure 1). Usually, this skin is not fully glazed; there are glazed openings, and in other parts, materials with high thermal mass can be used to save heating energy throughout the day. Internal openings can be opened and closed by users to create natural ventilation (Allan, 2006).

Cavity: Middle cavity can be ventilated completely naturally or mechanically. The width of this space usually varies between 200 mm and 2 m. It affects how to maintain the façade (Allan, 2006).

Investigation of the thermal performance of double skin façade is strongly dependent on climatic conditions. Due

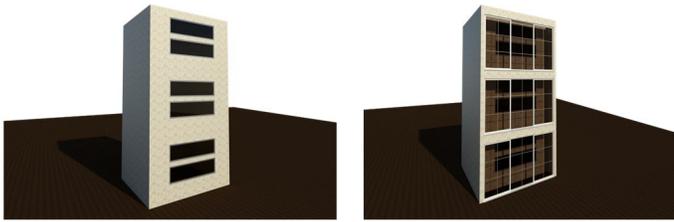


Figure 1. Left: base model with single skin facade. Right: research model with double skin façade.

to different climatic conditions, type of system appropriately selected for façade will be different (Baldinelli, 2009). In fact, double skin façade cannot effectively be a function of air conditioning system during warm days of summer; it can only reduce the interior temperature a few degrees compared with the external temperature (Benedetto, 2008).

RESEARCH METHOD

The researcher initially collected climatic data in Karaj; they were extracted from Meteororm software as a climatic file with EPW format. The research method is modeling and software calculations. A chamber with the length of 5m, the width of 4m and height of 3 m for 4 persons in three floors with double skin facades at 20, 40, 60, 80 and 100 cm depths was modeled to be compared with a simple façade using Energy plus version 8.9. EnergyPlus is a building performance simulation program that combines the best capabilities and features from BLAST and DOE-2 along with new capabilities. EnergyPlus comprises completely new code written in Fortran 90. It is primarily a simulation engine (Crawley et al., 2000).

After defining it in the BES (building simulation software) software, cooling and heating load of the chamber was analyzed. The considered chamber has two windows with 3×0.80 m dimensions; they have been single glazed made of usual glass with 6 mm thickness. Also, double skin façade contains a double glazed window; the type of its inner and outer glass is usual with 6 mm thickness and 13 mm of air within it. The heat transfer coefficient of the double glazed window is considered equal to $u_{gl} \left[\frac{w}{m^2} \cdot k \right] 2/8$ (Energy Saving, 2017).

In order to properly use simulation tools in the design and evaluation process, it is necessary to examine their validity through scientific methods (Zomorodian and Tahsildoust, 2016). In another research, Shemirani et al. (2014) introduced ECOTECT in the field of architecture as more preferred software than others. Research conducted by Neto and Fiorelli in 2008 in Brazil shows that Energy Plus software simulates energy consumption of the building with a precision of about $\pm 13\%$, which is an

acceptable value (Neto and Fiorelli, 2008).

Karah where the study is conducted has moist mid-latitude climate with mild winters. This is categorized as Cfa in Koppen Zone which is a temperate climate without dry season and a hot summer. Its climate is similar to Sao Paulo (Brazil), New Orleans (Florida, USA) and Durban (South Africa). Karaj is located in latitude of 35.776, longitude of 50.827 and elevation of 1271.0. The annual average temperature in Karaj is 14°C with the highest and lowest monthly temperature of 2 and 25°C respectively.

INVESTIGATING THE BASE SAMPLE

Based results of simulation done by researchers, remarkable conclusions have been revealed. The main parameters in order to compare the exact thermal performance of facades were annual cooling and heating load. The amount of heating and cooling energy consumption can be shown in the ground, first and second floors of a chamber during a year. According to Figure 2, it can be said that the amount of energy used to heat the chamber is different depending on its altitude so that it is 3541 kWh for the ground floor, 2062 kWh for the first floor and 2505 kWh for the second floor. Also, the amount of cooling energy increases depending on its altitude, so that it is 2369 kWh for the ground floor, 3630 kWh for the first floor and 3656 kWh for the second floor.

INVESTIGATING THE HEATING AND COOLING ENERGY CONSUMPTION IN REGARD TO 5 MODELS MONTHLY

In this section, the energy consumption of a cavity with double skin façade at depths of 20, 40, 60, 80 and 100 cm is examined. First, heating and cooling energy consumption is analyzed with respect to different floors (Figure 3), and then the total heating and cooling load in different depths are studied and assessed (Figure 4).

Annual heating and cooling load on the ground floor

The peak of heating energy consumption is observed in December, which is 853 kWh in double skin façade with 80 cm depth, and the lowest consumption is 786 kWh in double skin façade with 20 cm depth.

In this regard, the peak of cooling energy consumption is observed in August, which is 541 kWh in double skin façade with 100 cm depth, and the lowest consumption is 444 kWh in double skin façade with 80 cm depth.

Annual heating and cooling load on the first floor

The peak of heating energy consumption is observed in

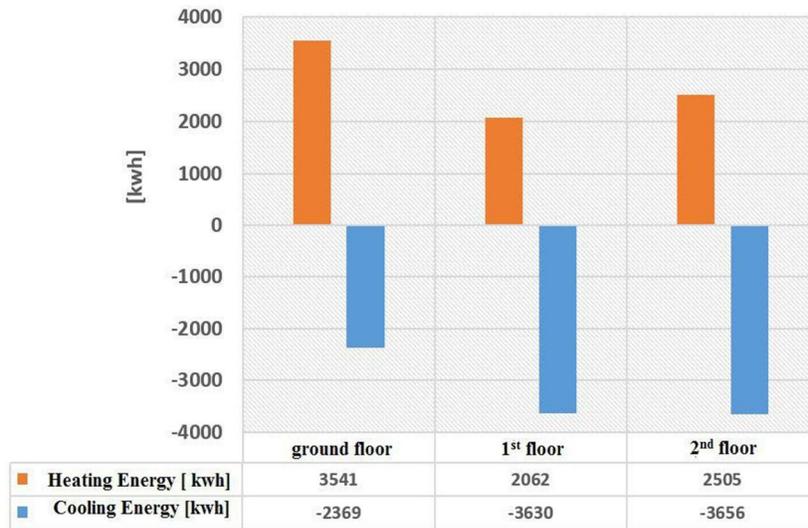


Figure 2. Annual consumption of heating and cooling energy.

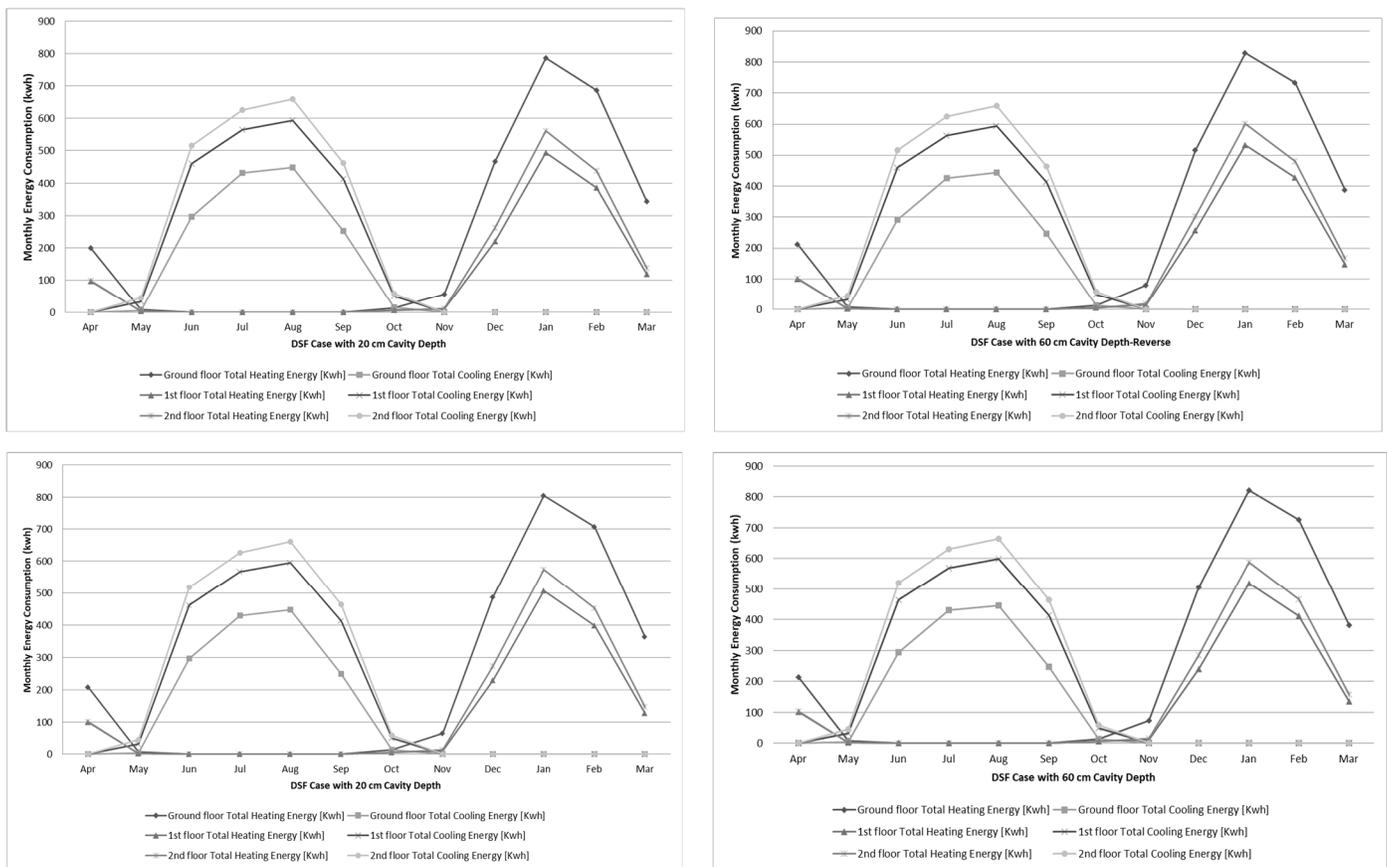


Figure 3. Investigating heating and cooling energy consumption for 5 models monthly.

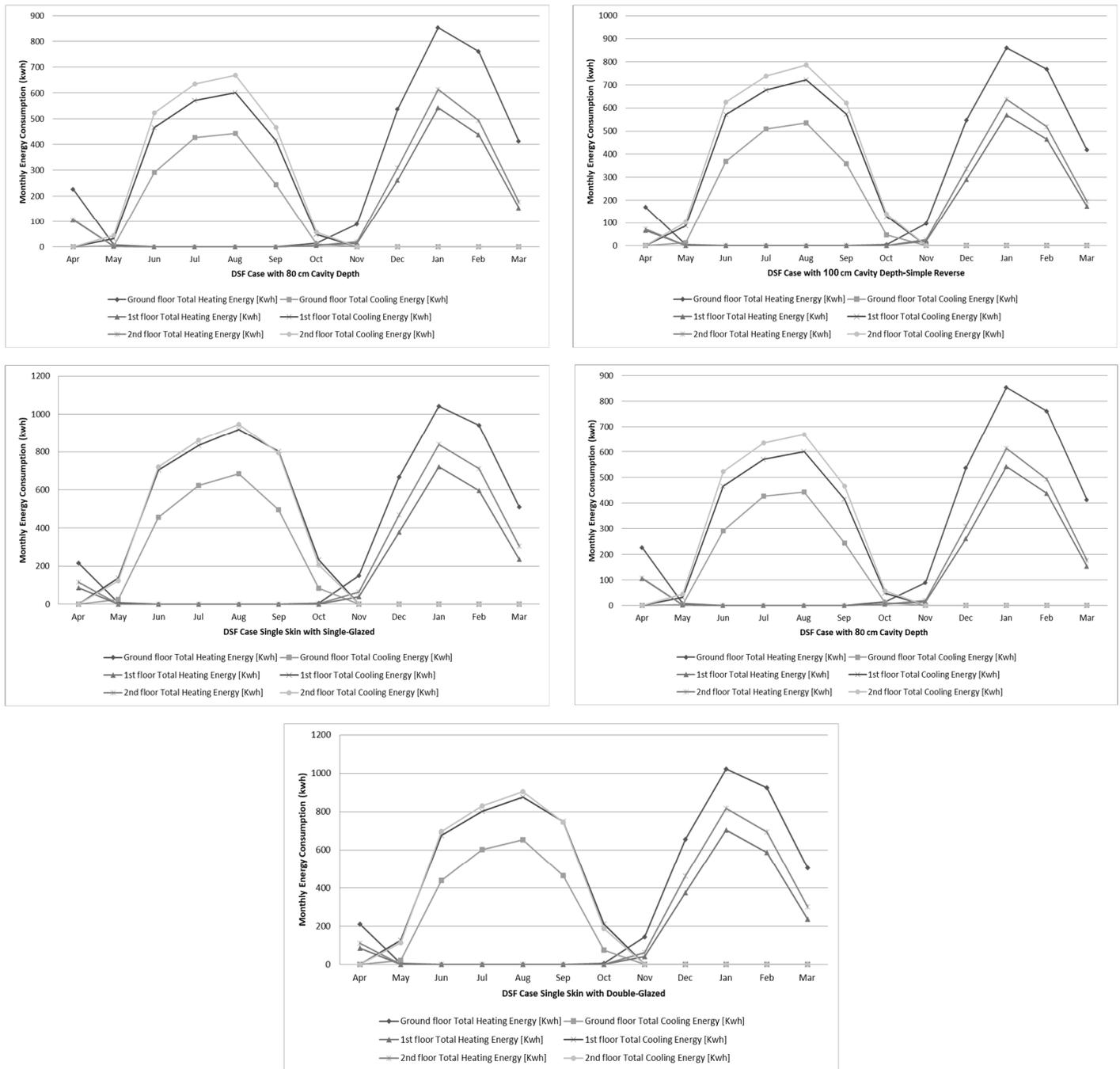


Figure 3. Continues.

December, which is 547 kWh in double skin façade with 100 cm depth, and the lowest consumption is 495 kWh in double skin façade with 20 cm depth.

In this regard, the peak of cooling energy consumption is observed in August, which is 730 kWh in double skin façade with 100 cm depth, and the lowest consumption is 594 kWh in double skin façade with 20 cm depth.

Annual heating and cooling load on the second floor

The peak of heating energy consumption is observed in December, which is 616 kWh in double skin façade with 100 cm depth, and the lowest consumption is 561 kWh in double skin façade with 20 cm depth. In this regard, the peak of cooling energy consumption is observed in

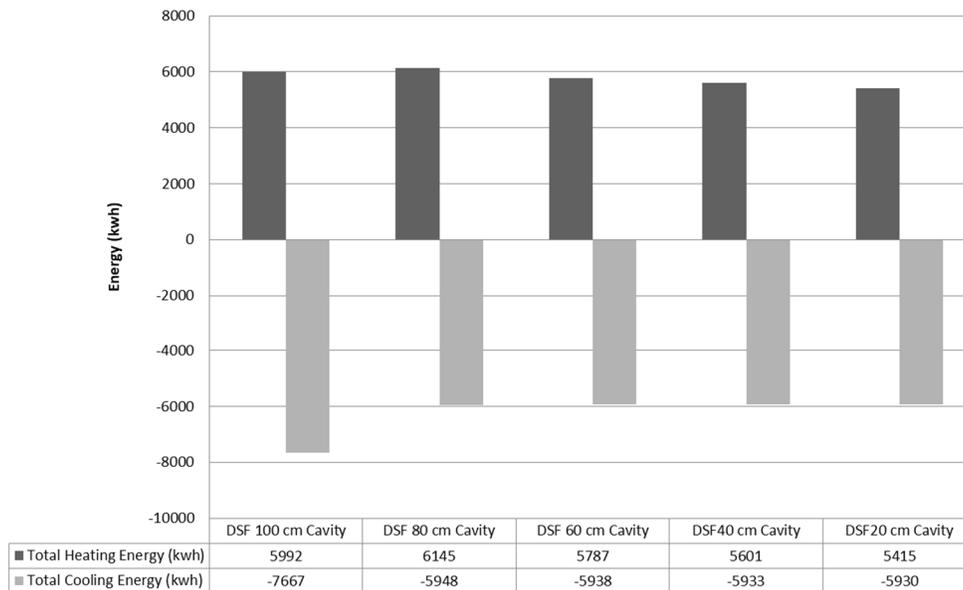


Figure 4. Investigating heating and cooling energy consumption for 5 models annually.

August, which is 794 kWh in double skin façade with 100 cm depth, and the lowest consumption is 659 kWh in double skin façade with 20 cm depth.

INVESTIGATING HEATING AND COOLING ENERGY CONSUMPTION FOR 5 MODELS ANNUALLY

According to Figure 4, it can be seen that the heating and cooling energy consumption increases from double skin façade with a depth of 20 cm to the depth of 80 cm, while cooling energy consumption from the depth of 20 cm to the depth of 100 cm is no exception. However, the consumption of heating energy from the depth of 80 cm to 100 cm shows another behavior, which is reduced by about 2.5%.

INVESTIGATION OF ANNUAL ENERGY CONSUMPTION OF DOUBLE SKIN FAÇADE WITH THE DEPTH OF 60 CM AND BASE SAMPLE

In this section, the thermal energy consumption is investigated in three floors with respect to two models of double skin façade with the depth of 60 cm and the base sample without double skin façade. As shown in Figure 5, it can be said that double skin façade with a depth of 60 cm has a more significant effect on the reduction of energy consumption than the base sample. In the base sample, the energy consumption is 17763 kWh per year, and it is 11725 kWh in double skin façade, which results in 34% of energy saving over a year.

CONCLUSION

It could be asserted that double skin as a passive system and one of the well-known solar façades have proved its utility around the world; however, there are lack studies in the climates with hot summer with cold winters such as Tehran in Iran. This study has tried to investigate the thermal performance of a box-window double skin façade against a single skin building as a base case using simulation with a powerful BES software of EnergyPlus ver8.9. With a brief sensitivity analysis data drove from the current study could be a starting point of a fully developed comprehensive and validated future topic in the field of DSFs studies as well.

Due to the high cost of projects related to the optimization of energy consumption, the use of energy simulation methods in buildings was considered an important category. Similarly, the comparison of annual heating and cooling energy consumption for 5 models showed that double skin façade with a depth of 20 cm is the best option for reducing energy consumption (depths of 20 cm: 36%, depths of 40 cm: 35%, depths of 60 cm: 34%, depths of 80 cm: 32%, and depths of 100 cm: 23% reduction in energy consumption). The more depth of space, the higher energy consumption; however, due to its low depth and lack of access, this cavity requires to be kept clean and is not considered as an appropriate option. Therefore, a double skin façade with the depth of 60 cm should be used in these models which responds to a set of needs and reduces energy consumption by 34%, which is significant. Finally, it should be noted that although the depth of a cavity between two skins has

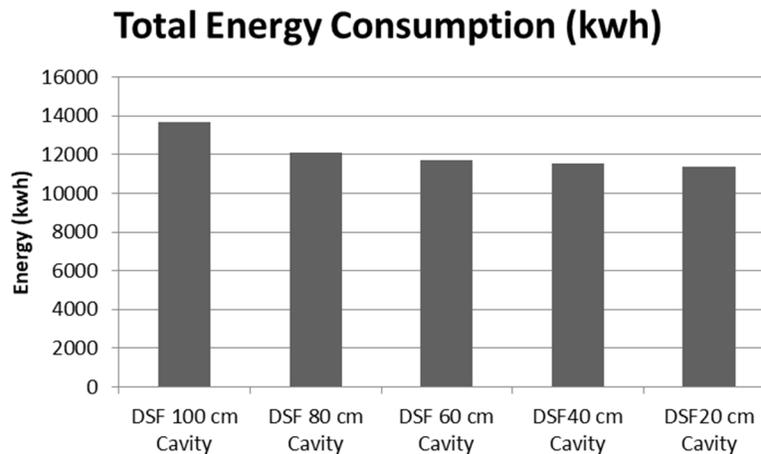


Figure 5. Annual energy consumption of double skin façade with the depth of 60 cm and base sample.

been considered in this project, other parameters also contribute to increasing the performance of double skin façade. Further studies such as investigating the type of glass, size, and position of the appropriate opening, the place of shading elements, etc. can affect the reduction of energy consumption in these facades

REFERENCES

- Afshin Mehr V, Aref F, Shanesaz M (2016).** Numerical analysis of double-skin facades for the summer season. *Naghsh-e Jahan J*, 5(2): 77-85.
- Allan D (2006).** Modeling Double Skin Façade. A Thesis Submitted for the Degree of MSc Energy Systems & the Environment, Department of Mechanical Engineering, University of Strathclyde, Glasgow UK.
- Baldinelli G (2009).** Double skin facade for warm climate regions: Analysis of a solution with an integrated movable shading system. *Building Environ*, 44: 1107-1118.
- Benedetto A (2008).** Double Skin Façade & Its Benefits. Dissertation Report, International line, 92, Copenhagen Technical Academy.
- Crawley DB, Lawrie LK, Pedersen CO, Winkelmann FC (2000).** Energy plus: energy simulation program. *ASHRAE J*, 42(4): 49-56.
- Ghanbaran A, Hosseinpour A (2014).** Investigating thermal behavior of double skin facades in the climate of Tehran. *J Sustain Architect Urban Dev*, 2: 43-53.
- Gratia E, De Herde A (2004).** Natural ventilation in a double skin façade. *Energy Building*, 36: 137-146.
- Gratia E, De Herde A (2007a).** The most efficient position of shading devices in a double-skin façade. *Energy Building*, 39: 364-373.
- Gratia E, De Herde A (2007b).** Guidelines for improving natural daytime ventilation in an office building with a double-skin façade. *Solar Energy*, 81: 435-448.
- Gratia E, De Herde A (2007c).** Are energy consumptions decreased with the addition of a double-skin? *Energy Building*, 39: 605-619.
- Guideline for 19th Discussion of the National Building Regulations (**Energy Saving**), (2017). Fifth ed., Tehran: To see Iran Publication.
- Hadianpour M, Mahdavinnejad MJ, Bemanian MR, Haghshenas M (2015).** Capacity assessment of using double-skin facades in architectural design in Iran's warm and dry climate in order to reduce energy consumption. *Fine Arts J*, 3: 29-38.
- Hee WJ, Alghoul MA, Bakhtyar B, Elayeb O, Shameri MA, Alrubaih MS, Sopian K (2015).** The role of window glazing on daylighting and energy saving in buildings. *Renew Sustain Energy Rev*, 42: 323-343.
- Hien WN, Liping W, Chandra AN, Pandey AR, Xiaolin W (2005).** Effects of double glazed facade on energy consumption, thermal comfort and condensation for a typical office building in Singapore. *Energy Buildings*, 37(6): 563-72.
- Hoseggen R, Wachenfeldt BJ, Hanssen SO (2008).** Building simulation as an assisting tool in decision making, Case study: With or without a double skin façade? *Energy Building*, 40: 821-827.
- Loncour X, Deneayer A, Blasco M, Flamant G, Wouters P (2004).** Ventilated Double Skin Facade, Classification & Illustration of Facade Concepts, Research, Development & Innovation, Belgian Building Research Institute, Department of Building Physics, Indoor Climate & Building Services. October (2004).
- Mehdizadeh Seraj F, Danesh M, Sanayeian H (2015).** The effect of the number of internal and external layers of double skin facades on the energy consumption in office and educational buildings (Investigating Faculty of Basic Science's Building, Iran University of Science and Technology). *Environ Sci Technol J*, 3: 181-190.
- Neto A, Fiorelli F (2008)** Comparison between detailed model simulation and artificial neural network for forecasting building energy consumption. *J Energ Building*, 40: 2169-2176.
- Poirazis H (2004).** Double Skin Façades for Office Buildings, Literature Review Department of Construction and Architecture, Division of Energy and Building Design, Lund Institute of Technology.
- Pomponi F, Barbosa S, Poorang A, Piroozfar E (2017).** On the intrinsic flexibility of the double skin façade: A comparative thermal comfort investigation in tropical and temperate climates. *Energy Procedia*, 111: 530-539.
- Sayadi E, Madahi M, Mohammadpour A, 2012.** Sustainable Architecture. Tehran: Lotus.
- Shemirani MM, Ghiaei M, Tahbaz M, Mahdavinia M (2014).** Methodology for selecting application software for energy simulation in the field of architecture. *Urban Identity*, 13: 45-55.
- Su Z, Li X, Xue F (2017).** Double-skin façade optimization design for different climate zones in China. *Solar Energy*, 155: 281-290.
- Zomorodian Z, Tahsildoust M (2016).** Validating energy simulation software in the building: An experimental and comparative approach. *Iran J Ener*, 18(4): 115-132.

Citation: Pilechiha P, Mahdavinnejad M, Mirhosseini SN, Ahmadi J (2019). Depth optimisation of double skin façade, considering thermal properties. Case study: Karaj, Iran. *Afr J Eng Res*, 7(3): 57-63.
