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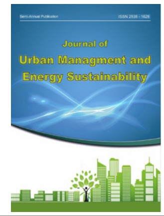

ORIGINAL RESEARCH PAPER

Studying the importance of thermal control of walls and transparent walls in the hot and dry climate of Kashan

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ABSTRACT

For the time being, Controlling and reducing energy consumption is very important and it seems that the amount of energy lost and the cost of it must be clarified. The thermal functions of the building can be separated and studied in two parts: walls and transparent walls. It seems that in hot and dry climates, due to the intensity of the received radiation, it is very important to control the incoming radiation from the window. For this purpose and to make a comparative comparison, a four-story commercial-office building was selected in the hot and dry climate of Kashan City. Therefore, the thermal performance and the amount of energy consumption of this building in the four modes of the basic mode, modified walls, modified transparent walls with the help of shading devices, and the comprehensive mode (modified walls and modified transparent walls) is examined. The results of this research show that modification in walls reduces the amount of primary energy consumption by more than 19%, in transparent walls by more than 20%, and in the comprehensive mode by more than 27%. This can reduce the annual cost by more than 22% in walls, more than 24% in transparent walls, and more than 33% in comprehensive mode.

Running Title: Thermal control of walls and transparent walls in the hot and dry climate

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1. Introduction

A significant part of the energy consumed in buildings is used to provide comfortable conditions. Energy consumption in developed countries is estimated to be about 20-40% of the total energy consumption (Xia et al. 2014). It is necessary to know precisely what effect each part of the building and its thermal performance has and what costs it will entail. When the costs and the period of return on investment are known or can be talked about in a limited way, the period of return on investment will be shorter and it will be easier to justify the owners and contractors. The energy loss in buildings can be divided into two parts. The first part is energy loss through external walls and ceilings, and the second part includes transparent walls. The control of wasted energy through the walls is very important due to the size, the presence of thermal bridges, the windows facing the radiation of the last roof, etc. The most careful components in heat transfer through transparent walls can be considered to include area, thickness, density, and material(Weir and Muneer 1998). On the other hand, windows are one of the most inefficient components in the building industry in energy conservation, and preventing this waste by increasing the thermal efficiency of windows will reduce energy consumption and greenhouse gas production(Hui and Kwok 2006). The most important components affecting heat transfer in windows can be considered as area, heat transfer coefficient, building orientation, shading and external environment conditions(Hassouneh, Alshboul, and Al-Salaymeh 2010). Double-glazed windows are a solution and answer to reducing the transfer and loss of energy through convection, but the incoming radiation can be controlled with the help of shading devices and smart glasses(Mustafa, Almehmadi, and Alqaed 2022). In recent years, many efforts have been made to create smart windows to have a dynamic control over the energy received through radiation. Some of these materials or methods, despite their remarkable performance, have not been welcomed by some people due to economic, and political issues or lack of attention, and it seems that information about the economic control of incoming radiation to buildings is not being received. Especially in hot and dry climates, it is one of the most important factors that can be used to justify initial investments and public health reception, and its importance has not been paid enough attention. In this research, while presenting and reviewing the literature on the subject, the thermal performance of a building is investigated and compared separately between walls and transparent walls, to express the importance of the role of radiation and the necessity of using shading devices.

2. Material and method

Considering the importance of radiation control through windows in the hot and dry climate of Kashan, an attempt is made to evaluate its thermal effects compared to other components of the building. Therefore, a building in the hot and dry climate of Kashan is selected and studied, and evaluated in four cases. The first state is the current state of the building without any modification in the function of walls and transparent walls. In the second mode, walls are modified and evaluated using the EC+ standard. The third mode of the building will only be equipped with shading devices and will be evaluated. The fourth mode is the sum of the second and third modes and the corrections of walls and transparent walls are applied to them. Thermal performance measurement is done in four modes by modeling in Design Builder software. The modeling engine of this software is EnergyPlus and it can be considered one of the most accurate energy modeling software that performs thermal analysis according to the location, physical characteristics of the building, architecture, and building performance. For evaluation in design builder software, the information of the site, such as the high of the neighbor buildings, the width of streets, etc. are introduced, and Based on the location the .epw file of Kashan is used. Then these four situations will be compared with each other and the amount of saving in the annual cost will be calculated.

3. The literature review

Among climatic elements (radiation, humidity, sun, and wind), radiation is the most important and effective element and its control is very important. Sunlight is necessary to provide natural lighting in buildings. The amount of heat that reaches the Earth from the sun is 1.94 calories per square centimeter per minute, which is called the constant value of the sun(modern et al. 2019). In reality, the amount of heat that reaches the earth is less than this amount because a part of the sun's rays is reflected and scattered outside the atmosphere after hitting the surface of the clouds, particles in the air, etc. (Zhang, Zhang, and Jin 2018). It can be said that the intensity of the received radiation depends on the distance from the sea, the angle of the sun, orientation, etc. The position of the sun in any position and at any time is determined by the two components of the radiation angle[1] and the radiation direction[2](Weir and Muneer 1998). The radiation that the building receives includes direct radiation with short wavelength; scattered radiation from the sky with short wavelength; short-wavelength reflected radiation from surrounding surfaces; Rays emitted from the earth and warm volumes with long wavelength, which is called thermal reflection; Radiation emitted from buildings to the sky with a long wavelength, which is called thermal reflection(Ma et al. 2021). Direct and scattered radiation can be considered the most effective radiation in creating light and heat in buildings. The maximum radiant heat of the sun reaches the Earth when the air is clear(Wang et al. 2018). As an example, research has shown that the southern walls of the building received up to 75% of radiant energy on sunny days, while this amount reaches 7% on cloudy days and 18% on semi-cloudy days. Therefore, calculations in this field are generally based on sunny days(Al-Yasiri and Szabó 2021). Architecture and the necessity of windows are so intertwined that they can be separated(Heschong 1979). The window is an essential element for all buildings (except for special cases) and not only its role and function in air conditioning, providing adequate light, communication with the outside of the building is of great importance; But its psychological effects are also undeniable(Ceballos et al. 2018).

1. The angle formed between the extension of the sun's rays and the surface of the horizon.

2. The angle created between the image of the radiation beam on the horizon plane and the true north direction.

It should be noted that light-transmitting openings are generally the weakest element of the building in terms of thermal performance, and it easily transfers heat between two cold or hot environments inside and outside(Wahid et al. 2017). To reduce this effect, solutions and methods are used to reduce this energy loss. Double-glazed or triple-glazed windows are the most common types of energy-efficient openings used to control the heat in homes(Arıcı and Kan 2015). There are two or three glass frames that are separated with the help of air or other gases to reduce heat transfer(Massa Gray and Schmidt 2016). The main gases that are used to reduce heat transfer in double- or triple-glazed windows are argon and krypton, which, due to their high mass number and low mobility, have less displacement than normal air and convective flow(Ahady, Dev, and Mandal 2022). It minimizes the inside of the window and reduces heat transfer through it(Aguilar et al. 2017).

Smart windows are an attempt to control incoming radiation by changing their characteristics for maximum adaptation to the environment. A smart window is a window that can prevent the passage of some solar waves or allow some of them to pass more easily, thus keeping the building in a more favorable condition in terms of energy efficiency(Aburas et al. 2019). One of the smart ways is the use of three-layer coatings, dielectric-metal-dielectric (DMD), which is a 2004 research with a middle layer of silver for hot and dry weather. It was evaluated with the help of software and three dielectrics TiO2, WO3, and ZnS were used in this research the results of this research showed that this glass can withstand a temperature difference of more than 8 degrees Celsius. From other similar energy-efficient windows, the type of dielectric used does not have much effect on the energy efficiency of the window, and dielectrics can be evaluated and chosen(Durrani et al. 2004). Another type of smart window is windows whose carbon is placed in two alternating states. In these glasses, liquid crystals are placed in a laminate, and if the voltage is applied, the crystals are randomly arranged and light passes through. Another way to control transparency is to use heat-generating solar lamps, and in this way, these glasses can be controlled by sunlight(Schittich 2018). Some smart windows are formed by changing the ability to reflect sunlight using chromogenic such as thermochromic, photochromic, chromic gas, and electrochromic(Cao et al. 2018). In photochromic windows, light, thermochromic, temperature, hydrogen chronic gas, and in electrochromic windows electricity are the driving factors in them(Kamalisarvestani et al. 2013). Smart windows can be classified into active and inactive groups. In inactive systems, the change in the window is done automatically according to the environmental conditions, and in active systems, we need a stimulus for this state change(Akalp and Özyılmaz 2023). Therefore, it can be said that windows with chromic gas, liquid crystals, and windows with suspended particles are in the group of active systems, and the dielectric-metal-dielectric system and chromic materials are passive systems (Long and Ye 2014). One of the most effective ways to control the heat flow in buildings with a significant amount of transparent windows or special climatic conditions is to control the incoming radiation with the help of shading devices and radiation barriers(Fakourian and Asefi 2019). Wide glass facades are associated with the greenhouse phenomenon and cause an increase in the internal temperature of buildings due to low shading(Seraj, Danesh, and Sanayeean 2014). Research has studied the effect of controlling incoming radiation in double skin facades in a hot and humid climate and states that controlling incoming radiation in double skinning the facade with a depth of 50 to 70 cm will require minimum cooling energy consumption(Gashniani and Yazdani 2022). On the other hand, it is stated that controlling the radiation entering the buildings can reduce the heating and cooling load in the buildings, and if the radiation is permanently prevented, it is possible to increase the heating load in the cold seasons. Bring hot and dry areas. Therefore, it is suggested to take into account the measures that are necessary to understand the necessity of shade or sun in different seasons in order to control energy consumption and reduce the load of cooling and heating(Leão 2016).

4. Results and Discussion

To evaluate the thermal performance of the building, Design Builder software is selected and the specifications of materials and general characteristics are introduced according to the software. The evaluation was done in Kashan City. The city of Kashan has a hot and dry climate, and according to the statistical studies of the Meteorological Organization - Kashan Synoptic Station - there are 2942 hours of sunshine on an annual average in Kashan, and the average temperature of hot air is 34 degrees Celsius and the average temperature of cold air is 4.8 degrees Celsius. To evaluate the impact and importance of radiant barriers, a commercial and office building (Kashan commercial complex) in Kashan is selected. For evaluating the building, the neighboring units and their levels were clarified for the software. It's a commercial and office building on the main street of Kashan. The building around it is a one or two-story building. Figure 1 is the site plan of the Kashan commercial complex. The dimensions of the openings in this building are 3.5 x 5.3 and 0.8 x 1.1 meters. The total area of the facade is more than 330 square meters; therefore, more than 35% of the facade is made up of transparent walls. In figure2 the facades of the building are shown.

The thermal performance of this building will be evaluated and investigated in four basic conditions, modified walls, modified transparent walls, and modified walls and transparent walls (comprehensive mode). The basic state of the building's current condition. The specifications of the windows are stated in table one, and the windows of this building are single-glazed. The condition of the building is considered in the first mode without any insulation. It's considered based on its current situation. so the thermal resistance of the floor structure is equal to 1.9 W/m^2.K, the thermal resistance of the walls is equal to 1.52 W/m^2.K, the roof is equal to 2.36 W/m^2.K and this value is for the floor structures adjacent to the soil is equal to 1.7 W/m^2.K. The modified condition of the building in the second mode is based on the national building regulations by modifying the specifications of the walls and adding insulation and thickness based on the regulations.

The purpose of modifying the transparent walls of the building in the third state is to control the incoming radiation with the help of shading devices. Also, in this section, the windows are considered to be 4 and 6 mm double-glazed windows filled with argon, but the walls and ceiling are considered to be following the basic condition. In these studies, lighting control is considered for the building so that artificial light is not used if the necessary light is provided naturally. The load related to the equipment in the commercial sections was considered to be 8 W/m² and 11 W/m² in the administrative sections (Iran 2021). To study the building in the third mode, it is necessary to define the characteristics of the shading devices. In these studies, a movable shading device has been used, which can be opened or closed with the help of

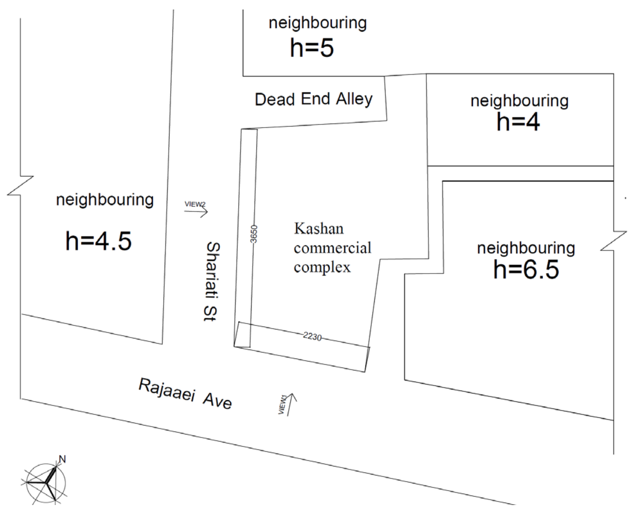

Figure 1: the site plan of the building.

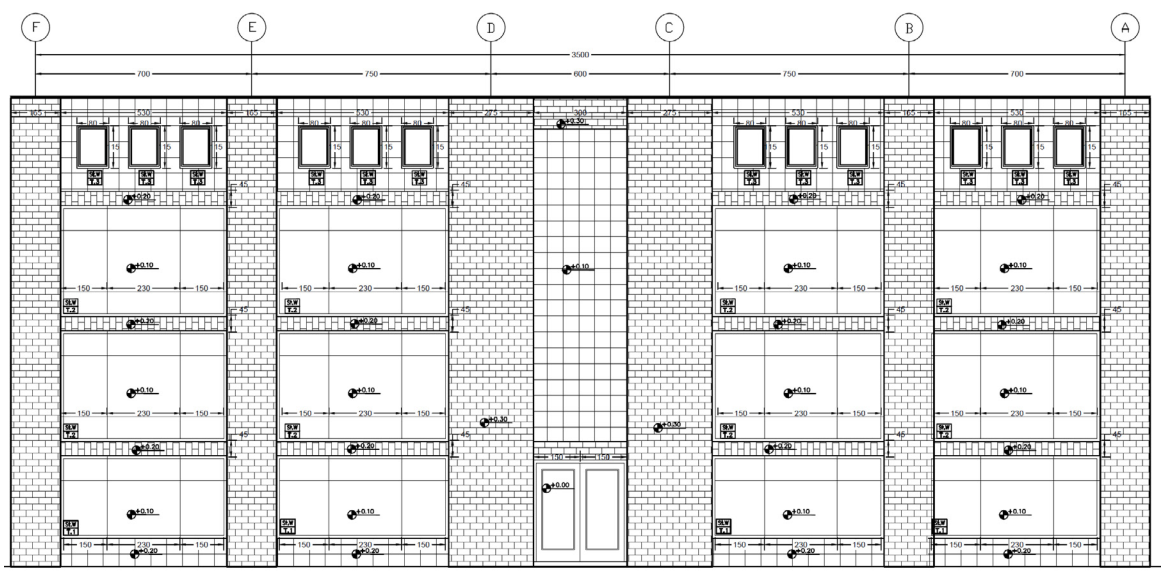

Figure 2: The current state of the building façade.

thermal sensors within the defined temperature range. The suitable range of thermal comfort for commercial buildings is considered to be between 24 and 27.5 degrees Celsius(Avantaggiato 2022). The sides of this shading device are made of FRP profiles and the cover of this shading device is considered to be made of PVC. The advantages of FRP profiles include high and significant tensile strength, corrosion resistance, no electromagnetic properties, high fatigue strength, low weight, and low thermal conductivity(Bank 2006). The most important disadvantages of these profiles are low width strength, low elastic modulus, prone to fiber breakage and separation, low durability of glass fibers in wet environments, low durability of glass fibers in alkaline environments, The coefficient of thermal expansion is high(Najafabadi et al. 2018). The fourth mode or comprehensive mode also includes the simultaneous modification of walls and transparent walls in the building. The state of the walls in the second mode is defined based on EC^+ conditions and the thermal resistance in the modified state for the floor structure between the floors is 1.9 $W/m^2.K$, in the external walls it is equal to 0.507 $W/m^2.K$, in the roof structure it is equal to 0.327 $W/m^2.K$ and in floor structures adjacent to the soil will be equal to 1.0 $W/m^2.K$.

Table 1 shows the physical characteristics of selected PVC coating and FRP profiles. The state of the building in the fourth mode may be also equal to the sum of the modifications applied in the third and fourth mode

The performance of this building will be evaluated in four defining modes in the lighting, cooling, and heating sectors. Based on Figure 3 and Table 2, it can be said that the amount of energy consumed in lighting will increase by 3.7% in the cases where the transparent walls are modified (third and fourth cases). This increase in the lighting sector is due to the reduction of incoming radiation during the hours of the day when the heat transfer through radiation is not favorable and shading devices reduce the incoming light and the effective depth of light in the interior parts. In the energy consumption for heating, in the second mode that the walls have been modified, the energy consumption has decreased by more than 50%, and when only the transparent walls have been modified, this reduction will be equal to 40%. In the amount of energy consumed for cooling in the case that only the transparent walls or only the walls are modified, it is reduced by 21% and 18%, respectively, and when the walls and transparent walls are modified at the same time, this decrease reaches 34%. In the separate comparison of the primary energy consumption

Table 1: Physical characteristics of used PVC and Physical characteristics of used FRP.

Physical characteristics of PVC							
1	Conductivity	0.17 W/m.K	5	Visible transmittance	0.59	References	(Hillman and Stark 2001), (Mongkollapkit et al. 2010)
2	Solar transmittance	0.55	6	Visible reflectance	0.07		(Panagiotou and Levendis 1994), (Hillman and Stark 2001)
3	Solar reflectance	0.36	7	Long-wave emissivity	0.90		(Panagiotou and Levendis 1994)
4	Thickness	0.0002 m	8	Long-wave transmittance	0.00		(Hillman and Stark 2001)
Physical characteristics of FRP							
1	Density	2 Gr/cm³	7	Di Electrical strength	13 Kv/mm	References	(Najafabadi et al. 2018)
2	Water absorptivity rate	0.2%–0.6 %	8	Elongation at rupture	2.5 %		(Bank 2006)
3	Tensile strength	200-600 MPa	9	Hardness	45-70 Barcol		(Sólyom, Di Benedetti, and (Balázs 2018)
4	Bending strength	460 MPa	10	Impact strength	279 Kj/m²		(Guades et al. 2012) (Pecce and Cosenza 2000)
6	Compressive strength	547 MPa		Thermal expansion coefficient	10-6/°c		(Najafabadi et al. 2018)

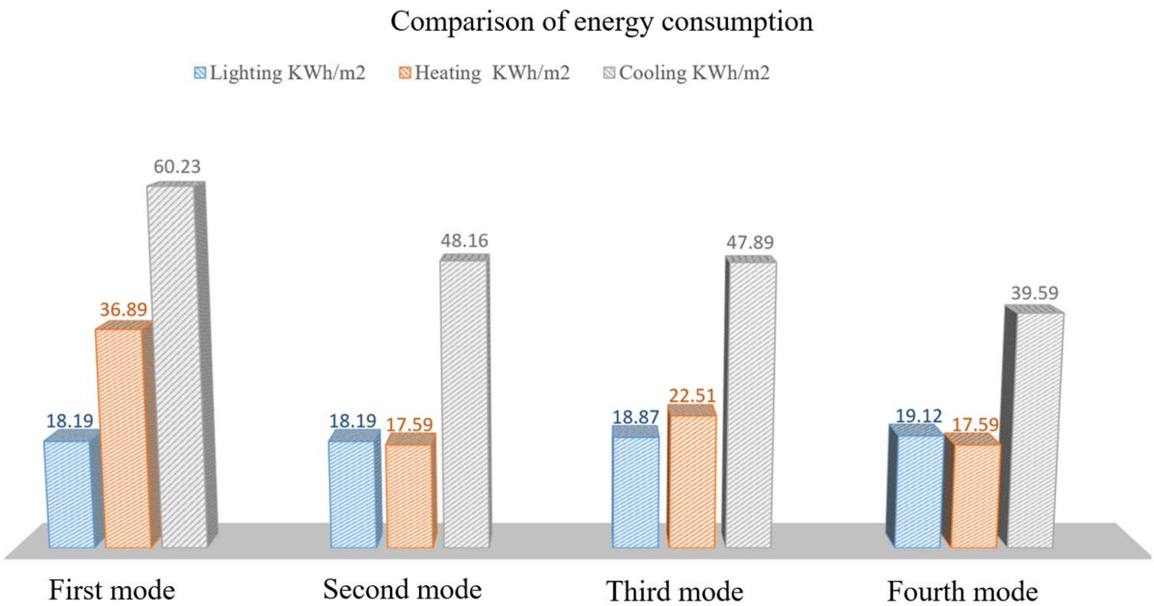

Figure 3: Comparison of energy consumption separately in different sections of cooling, heating, and lighting (basic mode, modified walls, modified transparent, and the comprehensive mode)

Table 2: Comparison of energy consumption in three modified modes compared to the basic mode (first mode).

energy consumption	Second mode modified walls	Third mode modified transparent walls	Fourth mode modified walls and transparent walls
lighting	0%	+3.7%	+3.7%
heating	-51%	-40%	-51%
cooling	-18%	-21%	-34%

in the second and third modes, the effect of the modified wall is significantly stronger than the transparent walls, but in the cooling section, it can be said that the effect of radiation control will be more effective a little bit through transparent walls.

Considering the efficiency of Iranian power, the amount of primary energy consumption can be obtained through (electricity consumption ×3.7+gas consumption×1) (Norouzi, Bashash jafarabadi, and Meybodi 2021). Through this connection, all energy carriers in their base state are analyzed and integrated, and according to Iran's 37% efficiency of power plants, 3.7 kW/h of electricity is created by burning each cubic meter of gas in power plants. In contrast, in terms of the high efficiency of gas transmission (90%), a coefficient of 1 is used to calculate the amount of base gas consumed(Mobseri, Tahooni, and Asl 2017). In Figure 4 and Table 3, the primary energy is compared in four defined modes. Based on this image, the primary energy consumption in the basic state is reduced by more than 19 and 20% in the second and third modes, This value reaches more than 27% in the fourth mode. This comparison shows that the control of incoming radiation to buildings is not only less important than the walls in reducing the primary energy consumption, but it is almost equally important.

In the following, the effective temperature on each floor of the building is checked and shown in four modes. Figure 5 shows the effective temperature of the building on the ground floor in four conditions and dry temperature. According to this comparison, the effective daytime temperature on the ground floor in the second mode (modified

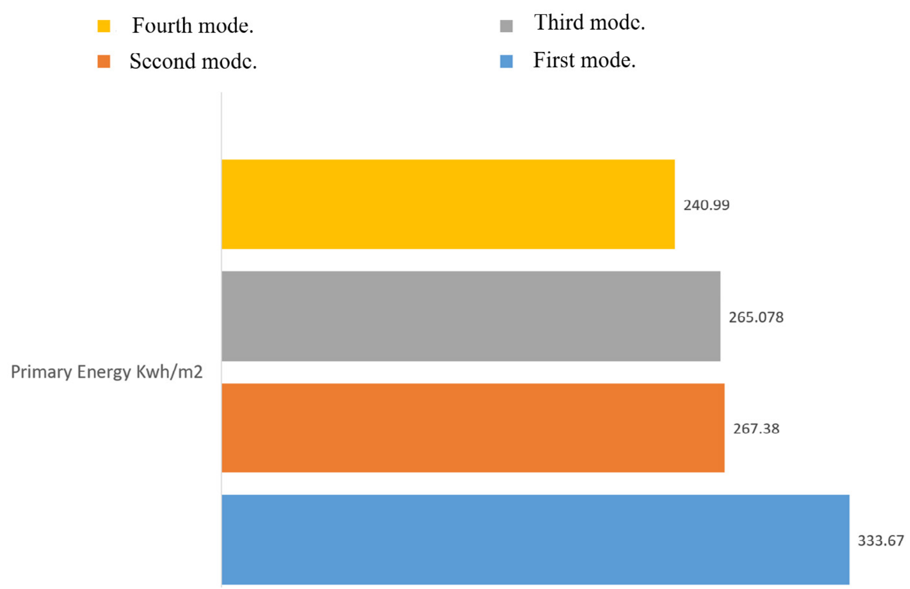

Figure 4: Comparison of primary energy consumption in four modes (1. basic state, 2. modified walls, 3. modified transparent walls, 4. the comprehensive mode)

Table 3: The amount of primary energy reduction in four defining modes.

mode	energy consumption KWH/M²	The amount of reduction compared to the base mode
basic state	333.67	
modified wall	267.38	-19.8%
modified transparent walls	265.078	-20.5%
comprehensive mode	240.99	-27.7%

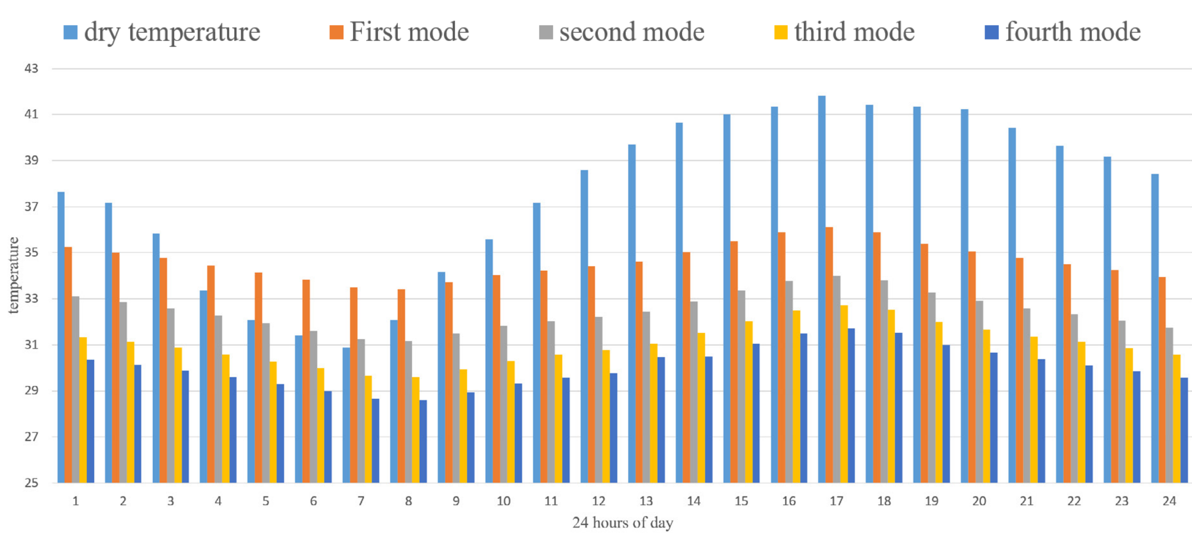

Figure 5: Effective temperature changes 24 hours a day in four different modes on the ground floor of the building.

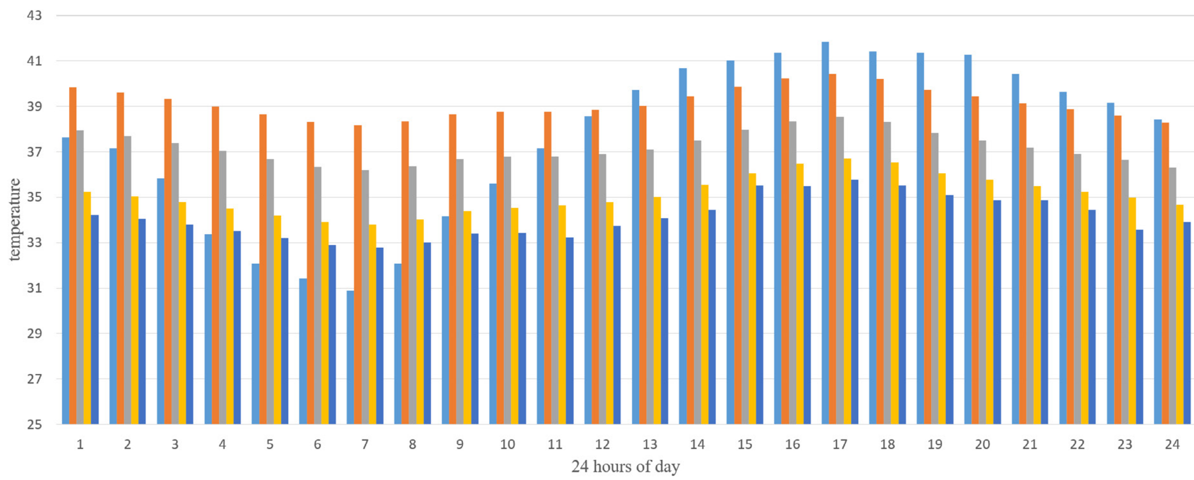

Figure 6: Effective temperature changes 24 hours a day in four different modes on the first floor of the building.

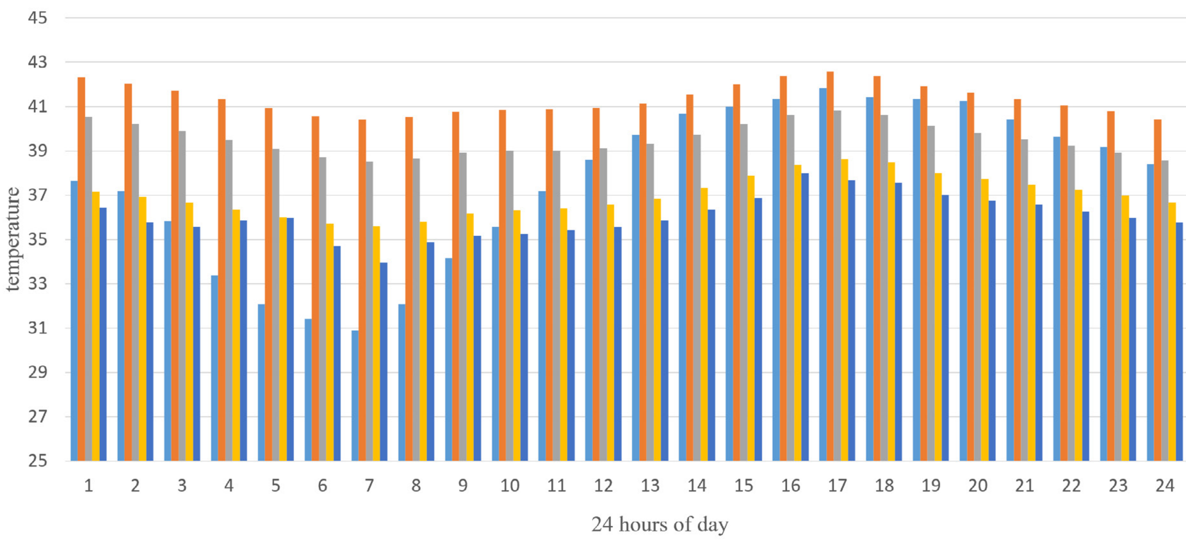

Figure 7: Effective temperature changes 24 hours a day in four different modes on the second floor of the building.

Table 4: Effective day temperature changes of the modified modes compared to the basic mode in the building floors.

floor	Second mode modified walls	Third mode modified transparent walls	Fourth mode modified walls and transparent walls
Ground	-1.14	- 0.72	-1.28
first	-1.91	-2.17	-2.61
second	- 1.78	- 2.17	- 2.77
third	-1.78	- 2.31	- 2.82

walls) will decrease by 1.14 degrees compared to the first condition. This is equal to 0.72 degrees Celsius in the third case (modified transparent walls) compared to the basic mode, and in the fourth mode, it will be equal to 1.28. In Figure 6, the effective temperature changes of the first floor of the building in four different states are shown and compared. This comparison shows that the

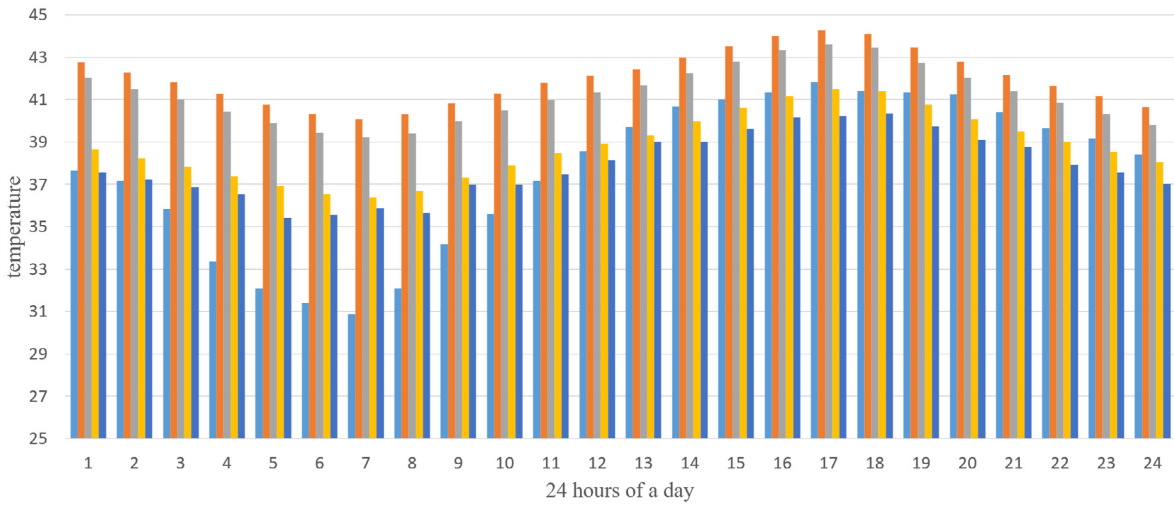

Figure 8: Effective temperature changes 24 hours a day in four different modes on the third floor of the building.

Table 5: The amount of annual energy cost in the building in four modes: basic mode, modified walls, modified transparent walls, and comprehensive mode

modes	electricity consumption	gas consumption	Total	The cost difference with the base mode	Saving compared to the basic state
Basic mode	2,440,382,848 (Rials) 53559/1 $	25,555,106/3 (Rials) 6877/65 $	2,465,937,954/3 (Rials) 60,436/75 $		
Second mode modified walls	1,899,249,696 (Rials) 45,403/9 $	13,021,285/91 (Rials) 3,385/5 $	1,912,270,981/9 (Rials) 48,789/4 $	553,666,972/3 (Rials) 11,647/3 $	-22.45%
Third mode modified transparent walls	1,688,718,336 (Rials) 40,370/9 $	13,014,650/5 (Rials) 3,383/8 $	1,701,732,986/5 (Rials) 43,754/7 $	564,084,968 (Rials) 16,682/05 $	-24.78%
Fourth mode modified walls and transparent walls	1,620,436,741/4 (Rials) 3,8738/6 $	12,890,321/5 (Rials) 3,351/4 $	1,633,327,062/9 (Rials) 42,090 $	832,610,892 (Rials) 18,346/75 $	-33.76%

effective temperature of the first floor in the cases of modified walls, modified transparent walls, and modified walls and transparent walls is 1.91, 2.17, and 2.17, respectively. 2.61 degrees Celsius will be an effective temperature reduction. According to Figure 5, these values for the second floor will be 1.78, 2.17, and 2.77, and on the third floor, according to Picture 6, they will be 1.78, 2.31, and 2.82, respectively. Naturally, with the increase in height and the decrease in the shading of the buildings on the sides, the effective temperature will decrease further. The modification of transparent walls will be more significant and effective in this reduction than the modification of walls, but the effect of modifying walls is also undeniable.

5. Estimation

The proposed conditions for a certain building with certain physical conditions and in four situations were investigated and evaluated. In the first mode or the base mode, the building is examined. The second mode is the condition that the thermal performance of the walls of the building has been modified according to the regulations. In the third mode, the transparent walls are modified, and the fourth mode is the state in which the walls and transparent walls are modified. According to the tariff approved by the Islamic Republic of Iran, the price of each kilowatt-hour can be considered equal to 6400 Rials and each cubic meter of gas is 1500 Rials. The international price of energy consumption in 2022 in the domestic sector is equal to 0.153 dollars for each kilowatt hour of electric energy and 0.039 dollars for each cubic meter of gas consumption(www.globalpetrolprices.com). Based on this, in Table 5, the cost of gas and electricity consumption is stated and compared in four defined modes with domestic and international prices. According to this comparison, the modification of walls will reduce the annual cost by more than 22%, which will be more than 550 million Rials (more than 11 thousand dollars). This amount will be more than 24% and equal to more than 560 million Rials (more than $16,000) in the improvement of transparent walls. In the comprehensive state, compared to the basic state, this reduction is more than 33% and will result in an annual cost reduction of more than 830 million Rials (more than 18 thousand dollars).

6. Conclusion

This research studies the effect of incoming radiation on buildings and compares the energy consumption in a four-story building in Kashan and its thermal performance in four modes: basic mode, modified walls, modified transparent walls, and modified walls and transparent walls. Modifying walls means adding insulation, controlling thermal bridges, and providing the necessary thicknesses, etc., based on national building regulations. Modifying transparent walls means controlling the radiation entering the building through shades and using double-glazed windows. Comparing the changes in reducing energy consumption separately in the lighting, cooling, and heating sectors shows that the effect of modified walls is more effective in heating, and modified transparent walls will have a more effective effect in cooling. The addition of shading devices will increase the amount of energy consumed in the lighting sector, therefore, the comparison of the primary energy consumed in these three defined modes is compared to the basic mode. This comparison shows that the second, third, and fourth modes will reduce energy consumption by more than 19%, 20%, and 27%, respectively. This comparison shows that the control of incoming radiation to buildings in reducing primary energy consumption is not only less important than the walls, but it is equally very important. The investigation of the effective daytime temperature shows that the modification of the walls of the building on the ground floor has a lesser effect than the modified non-transparent walls due to the shading of the surrounding buildings. These changes are more effective on the second, third, and fourth floors in the modified transparent walls, and the simultaneous modification of the modified walls and transparent walls at the same time can decrease the effective temperature on the upper floors by about 3 degrees. The financial estimate based on the reduction of energy cost in the case of modified walls modified transparent walls, and the comprehensive mode compared to the basic mode, respectively, is more than 22%, 24%, and 33% of the annual cost. Reduce. This reduction based on Iran's 1400 price will be more than 550 million Rials, 560 million Rials, and 830 million Rials respectively, which will be more than 11 thousand dollars, 16 thousand dollars, and 18 thousand dollars based on the annual world price. This reduction can justify initial investments.

References

Aburas, Marina, Veronica Soebarto, Terence Williamson, Runqi Liang, Heike Ebendorff-Heidepriem, and Yupeng Wu. (2019). 'Thermochromic smart window technologies for building application: A review', Applied Energy, 255: 113522. https://doi.org/10.1016/j.apenergy.2019.113522

Aguilar, J. O., J. Xamán, Y. Olazo-Gómez, I. Hernández-López, G. Becerra, and O. A. Jaramillo. (2017). 'Thermal performance of a room with a double glazing window using glazing available in Mexican market', Applied Thermal Engineering, 119: 505-15. https://doi.

org/10.1016/j.applthermaleng.2017.03.083

Ahady, Shambalid, Nirendra Dev, and Anubha Mandal. (2022). 'Solar radiation control passive strategy for reduction of heating and cooling energy use in arid climate: Case of Afghanistan', Indoor and Built Environment, 31: 955-71. https://doi.org/10.1177/1420326X211050114

Akalp, Sevilay, and Havva Özyılmaz. (2023). 'The Effect of Solar Control Elements on Building Energy Consumption ın Hot Dry Climate Regions the Case of Diyarbakir', Journal of Ecological Engineering, 24: 112-23. https://doi.org/10.12911/22998993/157022

Al-Yasiri, Qudama, and Márta Szabó. (2021). 'Incorporation of phase change materials into building envelope for thermal comfort and energy saving: A comprehensive analysis', Journal of Building Engineering, 36: 102122. https://doi.org/10.1016/j.jobe.2020.102122

Arıcı, Müslüm, and Miraç Kan. (2015). 'An investigation of flow and conjugate heat transfer in multiple pane windows concerning gap width, emissivity and gas filling', Renewable Energy, 75: 249-56. https://doi.org/10.1016/j.renene.2014.10.004

Avantaggiato, M., Belleri, A., Oberegger, U. F., & Pasut, W. (2022). 'Unlocking thermal comfort in transitional spaces: A field study in three Italian shopping centers', Building and Environment, 188. https://doi.org/10.1016/j.buildenv.2020.107428

Bank, Lawrence C. (2006). Composites for Construction: structural design with FRP materials (John Wiley & Sons).

Cao, Ding, Cheng Xu, Lu Wenya, Chuanxiang Qin, and Si Cheng. (2018). 'Sunlight-Driven Photo-Thermochromic Smart Windows', Solar RRL, 2: 1700219. https://doi.org/10.1002/solr.201700219

Ceballos, Francisco C., Peter K. Joshi, David W. Clark, Michèle Ramsay, and James F. Wilson. (2018). 'Runs of homozygosity: windows into population history and trait architecture', Nature Reviews Genetics, 19: 220-34. https://doi.org/10.1038/nrg.2017.109

Durrani, Saeed, E. Khawaja, Ali Al-Shukri, and Mohammad Al-Kuhaili. (2004). 'Dielectric/Ag/dielectric coated energy-efficient glass windows for warm climates', Energy and Buildings - ENERG BLDG, 36: 891-98. https://doi.org/10.1016/j.enbuild.2004.02.003

Fakourian, Flora, and Maziar Asefi. (2019). 'Environmentally responsive kinetic façade for educational buildings', Journal of Green Building, 14: 165-86. https://doi.org/10.3992/1943-4618.14.1.165

Gashniani, Gholipoor, and Yazdani. (2022). 'Investigating the use of double-skin facades to use the wind of Manjil city to ventilate buildings', Renewable and new energies, 9: 110-18.

Guades, Ernesto, Thiru Aravinthan, Mainul Islam, and Allan Manalo. (2012). 'A review on the driving performance of FRP composite piles', Composite Structures, 94: 1932-42. https://doi.org/10.1016/j.compstruct.2012.02.004

Hassouneh, Kholoud, A. Alshboul, and Ahmed Al-Salaymeh. (2010). 'Influence of windows on the energy balance of apartment buildings in Amman', Energy Conversion and Management - ENERG CONV MANAGE, 51: 1583-91. https://doi.org/10.1016/j.enconman.2009.08.037

Heschong, L. (1979). Thermal Delight in Architecture (MIT Press).

Hillman, RP, and TD Stark. (2001). 'Shear strength characteristics of PVC geomembrane-geosynthetic interfaces', Geosynthetics International, 8: 135-62. https://doi.org/10.1680/gein.8.0190

Hui, Sam C. M., and M. Kwok. (2006). Study of thin films to enhance window performance in buildings.

Iran, Office of National Building Regulations of. (2021). "Topic 19: Energy saving." In. Iran.

Kamalisarvestani, M., Saidur Rahman, Saad Mekhilef, and Farhood Sarrafzadeh Javadi. (2013). 'Performance, materials and coating technologies of thermochromic thin films on smart windows', Renewable and Sustainable Energy Reviews, 26: 353-64. https://doi.org/10.1016/j.rser.2013.05.038

Leão, M., Leão, E. F. T. B., Sanches, J. C. M., & Straub, K. W. (2016). 'Energy efficiency evaluation of single and double skin façade buildings: a survey in Germany. '.

Long, Linshuang, and Hong Ye. (2014). 'How to be smart and energy efficient: A general discussion on thermochromic windows', Scientific reports, 4: 6427. https://doi.org/10.1038/srep06427

Ma, Nan, Dorit Aviv, Hongshan Guo, and William W Braham. (2021). 'Measuring the right factors: A review of variables and models for thermal comfort and indoor air quality', Renewable and Sustainable Energy Reviews, 135: 110436. https://doi.org/10.1016/j.rser.2020.110436

Massa Gray, Francesco, and Michael Schmidt. (2016). 'Thermal building modeling using Gaussian processes', Energy and Buildings, 119: 119-28. https://doi.org/10.1016/j.enbuild.2016.02.004

Mobseri, Tahooni, and Sabzchi Asl. (2017). 'A review of methods to increase efficiency in thermal power plants and a study of Shazand power plant'.

Modern, nazvari, bakhshi, afsharmanesh, and abbasi. (2019). 'Investigating the proper direction of building placement based on sunlight and wind direction (case study: Gorgan city)'.

Mongkollapkit, Narudol, Apisit Kositchaiyong, Vichai Rosarpitak, and Narongrit Sombatsompop. (2010). 'Mechanical and morphological properties for sandwich composites of wood/PVC and glass fiber/PVC layers', Journal of applied polymer science, 116: 3427-36. https://doi.org/10.1002/app.31882

Mustafa, Jawed, Fahad Awjah Almehmadi, and Saeed Alqaed. (2022). 'A novel study to examine dependency of indoor temperature and PCM to reduce energy consumption in buildings', Journal of Building Engineering, 51: 104249. https://doi.org/10.1016/j.jobe.2022.104249

Najafabadi, Esmaeil Pournamazian, Milad Bazli, Hamed Ashrafi, and Asghar Vatani Oskouei. (2018). 'Effect of applied stress and bar characteristics on the short-term creep behavior of FRP bars', Construction and building materials, 171: 960-68. https://doi.org/10.1016/j.conbuildmat.2018.03.204

Norouzi, Nima, Zahra Bashashjafarabadi, and Seyyed Mohammad Yahya Meybodi. (2021). 'An Economic Evaluation of the Use of Wind Farms in Iran, Taking into

Account the Effect of Energy Price Liberalization Policy', Universal Journal of Business and Management, 1: 49-61. https://doi.org/10.31586/ujbm.2021.010104
Panagiotou, Thomai, and Yiannis Levendis. (1994). 'A study on the combustion characteristics of PVC, poly (styrene), poly (ethylene), and poly (propylene) particles under high heating rates', Combustion and flame, 99: 53-74. https://doi.org/10.1016/0010-2180(94)90082-5
Pecce, Marisa, and Edoardo Cosenza. (2000). 'Local buckling curves for the design of FRP profiles', Thin-walled structures, 37: 207-22. https://doi.org/10.1016/S0263-8231(00)00023-9
Schittich, C. (2018). material+finishes. (Berlin: Stefan Widdess.).
Seraj, Danesh, and Sanayeean. (2014). 'The effect of the number of inner and outer layers of two-layer facades on the energy consumption of administrative and educational buildings (a study of the building of the Faculty of Basic Sciences, Iran University of Science and Technology).', Environmental Science and technology.
Sólyom, Sándor, Matteo Di Benedetti, and György L Balázs. (2018). 'Effect of surface characteristics of FRP bars on bond behavior in concrete', Aci Sp, 327: 41.1-41.20.
Wahid, Mazlan Abdul, Seyed Ehsan Hosseini, Hasanen M. Hussen, Hussein J. Akeiber, Safaa N. Saud, and Abdulrahman Th Mohammad. (2017). 'An overview of phase change materials for construction architecture thermal management in hot and dry climate region', Applied Thermal Engineering, 112: 1240-59. https://doi.org/10.1016/j.applthermaleng.2016.07.032
Wang, Zhe, Richard de Dear, Maohui Luo, Borong Lin, Yingdong He, Ali Ghahramani, and Yingxin Zhu. (2018). 'Individual difference in thermal comfort: A literature review', Building and Environment, 138: 181-93. https://doi.org/10.1016/j.buildenv.2018.04.040
Weir, G., and T. Muneer. (1998). 'Energy and environmental impact analysis of double-glazed windows', Energy Conversion and Management, 39: 243-56. https://doi.org/10.1016/S0196-8904(96)00191-4
www.globalpetrolprices.com.
Xia, Jianjun, Tianzhen Hong, Qi Shen, Wei Feng, Le Yang, Piljae Im, Alison Lu, and Mahabir Bhandari. (2014). 'Comparison of Building Energy Use Data between the United States and China', Energy and Buildings. https://doi.org/10.1016/j.enbuild.2014.04.031
Zhang, Zhongjun, Yufeng Zhang, and Ling Jin. (2018). 'Thermal comfort in interior and semi-open spaces of rural folk houses in hot-humid areas', Building and Environment, 128: 336-47. https://doi.org/10.1016/j.buildenv.2017.10.028

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