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The Effect of External and Internal Shading Devices on Energy Consumption and Co2 Emissions of Residential Buildings in Temperate Climate

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Abstract

The use of shading devices to reduce energy consumption can be considered one of the more common methods, its efficiency and impact on reducing carbon emissions have been less considered. At the purpose of this study is to evaluate the energy consumption and efficiency of internal and external shading devices that are currently widely used in residential buildings and consequently their effect on reducing carbon emissions. To investigate this, a typical residential building in Gorgan was modeled. The base of this, two types of interior shading of curtains and roller shades and two external shades overhangs and mat roller shades were examined. In this research, a model with 20 shading device modes was simulated. The modeling and the energy simulations were performed by Design-Builder (Version 6.1.6.005). According to the base-design geometry of the building appropriate shading options were proposed for the south façade and windows were double-glazed (DG). The output data showed that a white curtain with a medium-density openness factor of 3% has the highest efficiency in reducing energy consumption. However, purpose shading could save the annual energy consumption of the building by 4.3% compared to the base case, thus potentially saving up to 9.74 kg of CO2/m2 in the hottest months of the year and 2.45 kg of CO2/m2 annually. While most researchers are looking for sophisticated technologies, some simple methods such as the use of proper shadings can play a significant role in reducing carbon emissions and environmental sustainability.

Keywords: Internal shading device, External shading device, Energy efficiency, Temperate climate, Residential building, CO_2 emissions.

1. Introduction

The building sector with a consumption of more than 40% of energy is the biggest energy consumer in Iran. The average energy consumption of buildings in Iran is more than 2.5 times the global average. And more than 98.5% of the energy used in buildings in Iran is provided by oil or gas products. This makes the construction and housing sector one of the main sources of pollutants (about 26.4% of carbon dioxide emissions) (Nasrollahi, 2011). Iran's CO2 emissions rank 7th in the world (European Commission., 2017). And its final energy consumption is around 175.7 Mtoe, of which the residential sector is responsible for approximately 30% (IEA, 2015). The first stage of reducing energy consumption is finding weak points and trying to improve conditions. Facades play an effective role in reducing energy demand because they are the boundary between inside and outside the buildings (Mohamadi and Daraio, 2020).

Today, one of the simple and common methods that can be easily implemented in Iran is the use of the shading device (Mohammad, 2013). Adjusting the desired light luxury and preventing direct sunlight and heat loss in winter are the advantages of using shading devices (Kim et al., 2012). Shadings may be installed internally or externally, may be fixed or movable, which again may be manual or automated. Several research studies evaluated the performances of shading devices. Whereas External shadings intercept the solar radiation before reaching the building interior, shadings that are installed internally, the solar radiation incident on the glazing system gets absorbed and it is then re-radiated inwards causing the cooling load to increase (Fazeli et al, 2019).

In the traditional view, the energy-saving effect of an internal shading device is far lower than that of an external one (Ye et al., 2016). But if internal shading devices can get a similar energy-saving effect to external ones, and be used instead of external ones, the designers can be free to design the appearance of buildings, can be more convenient to change the devices, and can reduce the expense of construction. Karimpour et al. (2017), evaluated the effect of 3 window glazing types and 4 interior shades in high-rise residential buildings results showed that optimized interior roller shade can reduce 14% energy consumption in Tehran with a hot and dry climate. The performance of internal woven roller shades was also assessed in terms of energy efficiency and visual comfort using Energy-Plus by Singh et al. (2015), it showed movable shading devices are more advantageous than fixed shading devices since they can be controlled effectively to block the direct solar radiation in summer and allow them in winter.

The performances of indoor and outdoor shading devices have been compared by Atzeri et al. (2014) in terms of thermal and visual comfort and overall energy use. Simulations using Energy Plus showed that the use of

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shades improved thermal comfort, however, internal shades could cause an increase in energy demand with particular orientations and glazing types. Many studies have compared the influence of different types of shading devices on the energy needs and cooling or heating demands in buildings (Tzempelikos and Athienitis, 2007; Corrado et al., 2001). Energy Plus was evaluated by Evola et al. (2017) in southern Italy. Twenty-nine different types of shading devices including louvers, blinds, curtains, etc. were considered to identify the most suitable solution. The effects of solar shading strategies on thermal comfort were also evaluated for low- income tropical housing in Uganda using Energy Plus by Hashemi and Khatami. (2017) Results revealed that the shading strategies like curtains and overhangs were most effective during the hottest period of the year.

Ahmed. (2012) studied the effect of protrusion length of overhang and fins on the thermal performance of residential buildings in Egypt and found that a protrusion of 38 cm or more could result in a decrease of 2 ^{0} c indoor temperature in all four orientations. However, for the northern façade, protrusion above 38 cm had no significant reduction in indoor temperature. Yao et al. (2018) investigated the effect of passive measures on thermal comfort and energy conservation in the residential building of china. They used projection factor (PF) and defined it as the ratio of the overhang depth to the window height, and it is used to study different external shading configurations. The results showed that use of proper overhang on the south façades according to climate condition and optimal WWR can help designers towards the achievement of comfortable and low-energy houses as a passive strategy.

Aldawoud. (2013) modeled a typical office building located in Phoenix, Arizona, the U.S in Design Builder software. He assessed the impacts of external solar shading devices and the electrochromic glazing system on the energy performance of buildings. It is derived from the study that the effects of external shading devices and electrochromic glazing vary according to different external and internal load conditions. The outcome also shows that the electrochromic glazing provides a highly critical reduction in yearly peak cooling loads by controlling solar heat gains in hot summer days provided that all windows are mounted on the east, south, or west façade. On the other hand, well-designed overhangs and vertical fins provide recession in cooling loads.

Yao. (2014) carried out a study in a six-story high residential building in Ningbo city, China. A south-facing room in this building was modeled in Energy Plus. The field measurements and simulations showed that movable solar shading devices had a crucial effect on energy performance, indoor thermal and visual comfort. Therefore, he concluded that movable shading devices should extensively be used in the hot summer and cold winter zones of China. Several simulation studies have been performed by Huang et al. (2014) to evaluate the performance of different popular energy-efficient window designs in cooling dominant climates showing that the comprehensive performance of overhangs is better than that of interior blinds. Five common shading configurations in five climate zones defined by ASHRAE have been compared by Babaizadeh et al. (2015) to provide guide decisions about the design of shading systems in various types of facilities.

There are very few studies on the effect of shadings on reducing carbon emissions. Al-Touma et al. (2018) investigated the potential savings in spaces energy demands, and consequently in primary energy and CO2 emissions, by the installation of blind shadings and application of shading and lighting controls in four different façade orientations in Qatar. Results have shown that shading control was singlehandedly able to reduce the space total energy demand by 11.6% in north-oriented offices and 24.8% in east-oriented offices, thus potentially saving up to 24.5 kg of CO2/m2 annually.

A very recent review on shading device types used different building types and different climatic regions has been proposed by Kirimtat et al. (2016) underlining the importance of simulation modeling to address the problem. The real sky is constantly changing, the optimum state of the shading device would ideally be adaptive and dynamic. Thus no single optimum solution can be expected. Instead, multiple optimum solutions for multiple sky condition scenarios most likely suit better in this case. To address this issue, computational building performance modeling and simulation is a powerful tool for exploring the potential and solving the optimization problem. Numerous design variations and scenarios can be assessed within a relatively short time and a relatively low cost (Loonen et al., 2013). Many studies on the use of computational simulation for predicting the performance of adaptive or dynamic shading device have been performed by various researchers, particularly in the past six years (Giovannini et al., 2015; Aelenei et al., 2016; Jayathissa et al., 2017; Jayathissa et al., 2017; Valladares-Rendón et al., 2017; Attia et al., 2018), in addition to the experimental studies (Ayoub, 2018; Kim et al., 2012; Kostantzos et al., 2015; Elzeydi et al., 2016; Elzeydi, 2017; Lim et al., 2012). Reviews and studies on adaptive and/or optimized shading devices or systems for application in the tropics are provided in Refs. (Lau et al., 2016; Al-Masrani et al., 2018; Mangkuto et al., 2018).

The performance of shading devices differs largely at a different locations under various climate conditions. However, there is still a lack of studies on the comparison internal shading and external ones in a temperate climate, furthermore, most of the studies focused on office buildings. On the other hand, by the study on research literature, we find that very few studies have been done on the effect of shadings on reducing carbon emissions. While today, attention to environmental issues has become particularly important, and solutions that reduce environmental pollution should be a design priority. The south-facing façade of a typical residential building in the north of Iran (Gorgan city) was considered in this paper.

The main concern of this study is to carry out an accurate shading device for energy efficiency and thus the reduction of carbon emissions in the building. This can be verified by simulating the energy performance of the appropriate shading system with solar irradiation and air temperature control strategies. Design builder software enables the simulations of both external and internal shadings and their cooling, heating, and lighting loads. Overhang and mat roller shades were selected as external shading because they were common in this temperate climate from past to present. Curtains and roller shades are also more practical in residential buildings in Iran,They can be installed readily and automatically controlled. The main contribution of this study is thus an optimized computational model for external and internal shading devices for a typical residential building in a temperate climate.

2. Research Methodology

2.1 The Study Building and Area

The building understudy was a 4-story residential building located in Gorgan, Golestan Province of Iran. The specifications of the building are summarized in Table1.Gorgan is characterized by a temperate climate although hot and humid summer weather. Figure1,2 illustrates the monthly minimum and maximum average dry bulb temperatures, relative humidity percentage and average sunlight hours of Gorgan as obtained from the Energy Plus weather database.

Table 1

Specification of the study building

Specification	**Parameter**
Gorgan	Location
Residential	Type of building
4	No. of floors
0.032Person/m^2	Occupancy
3m	Floor height
1.5m	Window height
30%	Window to wall ratio
246.4 m^2	Typical floor area
49.2o m^2	South-facing wall area
South windows	Direction of opening
Double Glazing	Window glass
54.43 ^{0}E	Longitude
36.50 ^{0}N	Latitude
160 m	Altitude

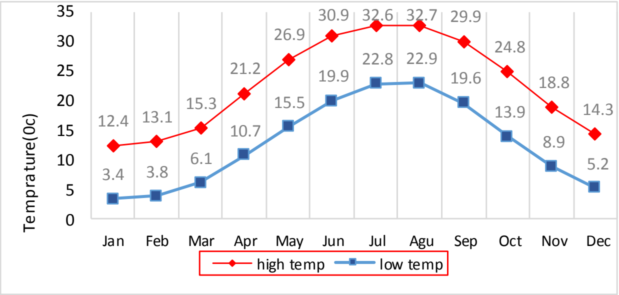

Fig.1. Monthly minimum and maximum dry bulb temperatures of Gorgan

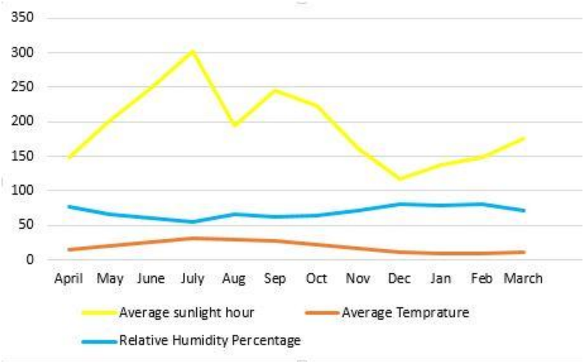

Fig. 2 .Relative Humidity Percentage, Average Sunlight Hours and Average Temperature of Gorgan

Based on the average wind statistics, the direction of the prevailing wind in the study area (the wind that has the highest frequency of wind) is from the west, southwest and south, respectively, throughout the year(Modiri et al,2012). Figure 3 shows the wind speed (in knots) and the direction of the annual wind in the design area.

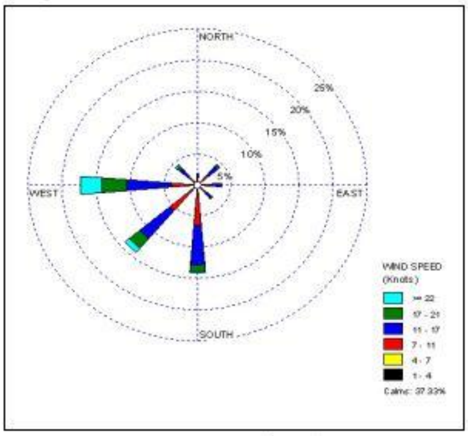

Fig. 3.The Wind-Rose of Gorgan
(Source: Modiri et al, 2012)

2.2 Modeling and simulation

The modeling and energy simulations were performed by Design- Builder, which is a digital platform for extensive energy analysis of buildings (http:// designbuilder.co.uk /software /product-overview). The base case was considered without any solar shading, but the walls and roof compiled with national Iranian building code-19 (Iranian building code 19, 2009). Only south-facing windows on the 4th floor were shaded. It is well-known that in the northern hemisphere, the south-facing windows can be effectively shaded by horizontal overhangs and other shading devices (Los Alamos National Laboratory Sustainable Design Guide, 2002). First, modeling was done for a typical 4-story building, then to analyze the energy performance of each floor (light and energy), controlled conditions for that floor and uncontrolled conditions for other floors were considered, see figure 4, 5. This step was performed for all floors and after evaluating each floor, the results of the simulation of 4 floors were compared with each other. The solutions to reduce the energy consumption of this research in the category that has the most consumption and receives disturbing light, applied and re-evaluated for that floor.

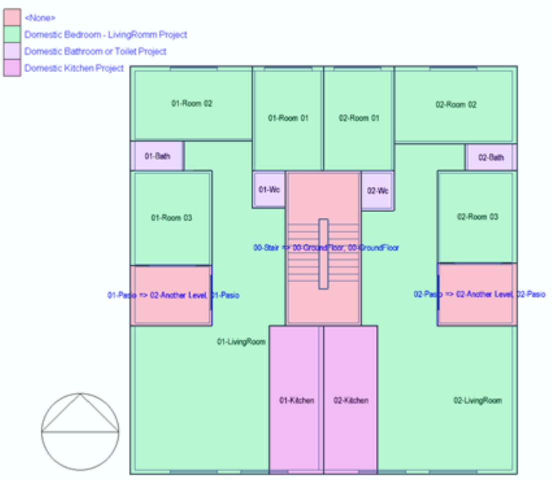

Fig. 4. Plan of residential building model

Material input data for simulation shows in table 2.There are two flats per floor. The total area of the 4th floor is 246.4m^2. Kitchen and living room zones are located south of the building and shading devices were applied on their windows. Windows are double glazed and the specifications of the windows are summarized in Table 3. It is important to note that the building has neighbors on the east and west fronts, which are important to consider in the simulation process due to the shadow they have on the building. Thermal comfort boundaries were set at 21.2^{0}c for the heating and 24.4 ^{0}c for cooling (Roshan et al., 2017).

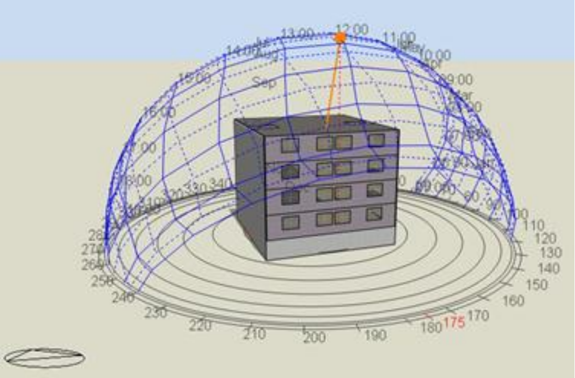

Fig. 5.The typical residential building used as a baseline model in the simulation process and its sun path in the hottest month

The clothing unit thermal resistance is 1 clo during the winter season (from 1st October to 30 April), and 0.5 clo during the summer (from 1st May to 30th September). The Heating system is Radiator with a coefficient performance of 0.7 and cooling system is Split device coefficient 3 and domestic hot water is supplied through the electric package. The considered Light Power Density (LPD) is 15 W m-2, with LED lamps installed on the ceiling. Artificial lights switch on depending on the level of natural illumination, to maintain 200 lux illuminating level (The Iranian Building Code 19, 2009; The Iranian Building Code 13, 2003). The movable shading devices are closed when the total external radiation on the window surface goes over 150 W m-2. This setpoint value has been chosen considering that people don't usually shut the shades when solar radiation is below 50-60 W m-2 while they usually need to close them above 250–300 W m-2 (Inoue et al., 1988; Newsham et al., 1944; Reinhart et al., 2003). A second control criterion is based on outside air temperature 24^{0}c. When the outside temperature exceeds 24^{0}c, the shading layer covers the whole window.

Table 2
Properties of building components

Building components	**Material**	**Thickness**	**Conductivity**	**Specific heat**	**Density**	**Heat transfer coefficient**	**Thermal resistance coefficient**
		m	W/m-k	J/Kg-K	Kg/m^3	W/m^2-K	M^2-K/W
EXT WALL	Granit stone	0.02	2.8	1000	2600	1.044	0.958
	Cement mortar	0.03	0.72	840	1860		
	Brick	0.2	0.30	840	1000		
	Cement plaster	0.03	0.72	840	1860		
	plaster	0.15	0.40	1000	1000		
CEILING	Asphalt insulation	0.005	0.23	1000	1100	2.056	0.484
	Lime cement mortar	0.05	0.38	1000	1200		
	Concrete slab	0.25	1.40	840	2100		
	Cement plaster	0.03	0.72	840	1860		
	plaster	0.015	0.40	1000	1000		

Table3
The specifications of windows

Window layers	**Thickness (mm)**	**Heat transfer (w/m^2-k)**	**Solar heat gain (SHGC) coefficient**	**Sunlight transmission coefficient**	**Visible transmittance**
External clear glass	6	2.534	0.724	0.648	0.791
Argon gas	13				
Internal clear glass	4				

Heating system is Radiator with a coefficient performance of 0.7 and cooling system is Split device coefficient 3 and domestic hot water is supplied through the electric package. The considered Light Power Density (LPD) is 15 W m-2, with LED lamps installed on the ceiling. Artificial lights switch on depending on the level of natural illumination, to maintain 200 lux of illuminating level (The Iranian Building Code 19, 2009; The Iranian Building Code 13, 2003). The movable shading devices are closed when the total external radiation on the window surface goes over 150 W m-2. This setpoint value has been chosen considering that people don't usually shut the shades when solar radiation is below 50-60 W m-2 while they usually need to close them above 250–300 W m-2
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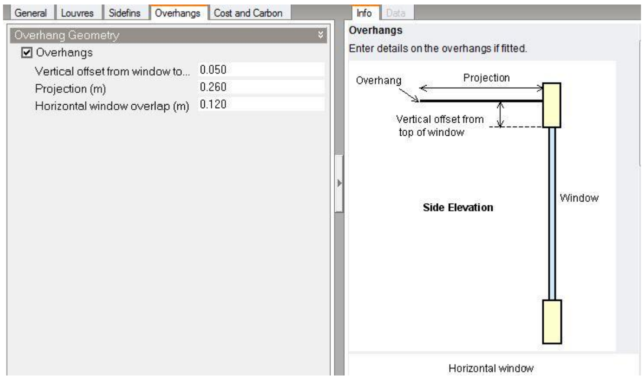
2.3 External shading devices

2.3.1 Overhangs

Horizontal fixed overhangs are simulated on top of southern windows on the 4th floor. Overhang material is cast concrete (lightweight) with thermal conductivity of 0.38 W / m-k, a specific heat of 1000 J / kg-K, a density of 1200 Kg / m3, and a thickness of 0.06 m (Figure 6).



☑ Overhangs
Vertical offset from window to... 0.050
Projection (m) 0.260
Horizontal window overlap (m) 0.120

Overhangs
Enter details on the overhangs if fitted.

Fig. 6. Overhang specifications

These overhang specifications are recommended by many studies conducted in the temperate, taking into account day-lighting and aesthetic considerations, as well as the view angle requirements from the internal spaces (Sheikhzadeh et al., 2006; Kasmai, 2003; Al-tamimi et al.,2011).three different projection depths, were modeled, 0.26m, 0.41m and 1m. These three depths were accounted for by the formula of latitude, solar angle, azimuth, and sun condition. Case 1: No shading was applied. Case 2: Overhang with 0.26m depth calculated based on optimum overhang depth formula (Lee and Tavil, 2007).

$$D=h \, \mathrm{Cos}\,(Z+N)/\tan\beta \qquad (1)$$

Where D is overhang depth (m), h is the height of the shadow that is created based on the depth of the overhang on the glass, Z is sun azimuth on the longest day of the year (21st June) at noon, N is the angle between the line perpendicular to the window and the south and β is Radiation angle based on Gorgan sun path diagram on the 21st June at noon (Razmjouyan, 2015).
$D=1.5\ \mathrm{Cos}\,(180+0)/\tan(80) = 0.26$
Case3: overhang with 0.41m depth. The way to calculate the proper depth of a south window overhang for the Prescott latitude (36.5∞) is to divide the height from the window sill to the lowest point on the overhang by 3.6 (the Shade Line Factor [SLF] for Prescott). The formula is:

$$W = H/SLF \qquad (2)$$

W: The horizontal dimension of the overhang
H: Height from the window sill to the lowest point of the shading element or overhang
SLF: Shade Line Factor for location (Watson and Labs, 2009).

$W=1.5/3.6=0.41$

Case 4: Overhang with 1m depth. According to the Iranian National Building Code-19, suitable angles for window overhangs, in different directions of the building, for 216 cities are provided. In this appendix table for each city, the angle of the horizontal overhang for different window orientations is stated. According to this data, β angle for the southern windows of Gorgan is 55 degrees (The Iranian Building Code 19, 2009). See Figure 7.

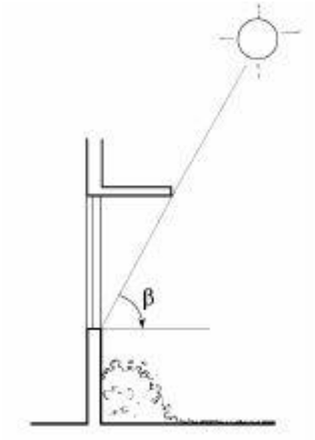


Fig .7.Vertical section of horizontal overhang angle (Source: The Iranian Building Code 19, 2009)

Tan β=window height/overhang depth (3)
Tan (55) =1.5/overhang depth
Overhang depth = 1(m)

2.3.2 Mat roller shades

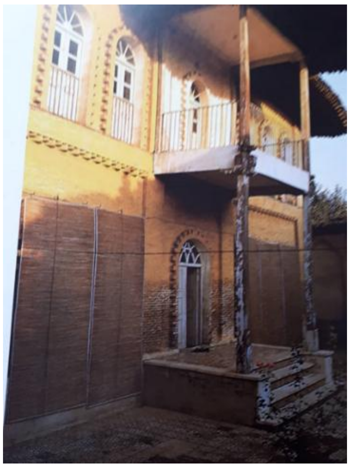


Fig. 8.Taghavi house, mat roller shades in southern windows, Ghajar period (Source: New life - old structure a selection of valuable structures, 1372).

In the past, in the city of Gorgan, mat roller shades were used as a shade behind the windows, which were rolled in summer and taken off in winter. See Figure 8.

"Reed" is an organic building material with good resistance to moisture and water erosion. This material contains a large amount of silicone that makes it durable and flexible for use as a structure. Although reed is flammable, its high silica concentration keeps insects and other vermin away from it. The straw stem form makes it suitable for all types of functions in the building (Almusaed and Almssad, 2015). Reed is an excellent thermal and acoustic insulator. Relative durability and Flexibility in construction are the most important properties of "straw" materials (Lauren, 2000). "Reed" also has disadvantages. Its natural durability is less than wood. It must be modified with preservatives to increase its durability in open spaces (Almusaed and Almssad, 2015). According to the Environmental Protection Agency, 24 wetlands have been registered in the Ramsar Convention, including the wetlands of the Miankaleh Peninsula and Gorgan Bay in this area (The Iranian Environmental protection Agency, 2020).

Today, due to its reasonable price and the plant being native to this area, its use as a cover behind windows and balconies is prevalent. However, due to the unevenness of the reeds, the distance between the reeds when closing together varies (Figure 9).

In this study, the effect of mat reed distances on energy consumption has been investigated. The mat was analyzed with reed spacing of 1 mm, 2 mm, 3 mm, 5 mm, 8 mm, and 1 cm. The mechanical properties of Iranian native reed are in table 4 (Feizabadi and Rezaei, 2015).

Table 4
Mechanical properties of Iranian native reed

Special Weight Kg/m^3	**560-960**
Effective thermal conductivity W /m.k	0.23
Heat transfer coefficient W / m^2.K	1.91
Thermal resistance W/m^2.k	0.52
Tensile strength N / mm2	35-300
Compressive strength N / mm2	64-110
Fire resistance (seconds to fire)	61.2 without modification
Shape properties	Hollow circular stem

Fig. 9. Iranian native mat roller shade shape

So case 5: mat roller shade with 1mm distance between reeds, case 6: mat roller shade with 2mm distance between reeds, case 7: mat roller shade with 3mm distance between reeds, case 8: mat roller shade with 5mm distance between reeds, case 9: mat roller shade with 8mm distance between reeds, case 10: mat roller shade with 1cm distance between reeds were simulated.

2.4 Internal shading device

2.4.1 Curtains

Curtains in residential buildings are still the most widely used as interior shades that are available in a variety of designs and colors.3 different colors of white, grey, charcoal bronze with 3 different openness factors 1%,3%,10% according to fabric factory properties were simulated (Table 5)(Mermet sun control textiles, 2020).

Table 5
Curtain fabric Specifications

Color	**Alternatives**	**Openness factor (%)**	**thickness (mm)**	**Tv**	**Rs**	**As**	**Ts**	**Rv**
white	Case 11A	1	0.5	27	62	10	28	71
	Case11B	3	0.48	17	70	12	18	80
	Case 11C	10	0.45	17	70	12	18	79
Grey	Case 12A	1	0.5	16	31	50	19	32
	Case 12B	3	0.48	7	30	60	10	29
	Case 12C	10	0.45	4	33	59	8	32
Charcoal Bronze	Case 13A	1	0.5	2	6	93	1	6
	Case 13B	3	0.48	2	6	92	2	6
	Case 13C	10	0.45	12	6	82	12	5

(Source: Mermet sun control textiles)
Notes: Tv: visible transmittance, Rs: solar reflectance, As: solar absorbance, Ts: solar transmittance, Rv: visible reflectance

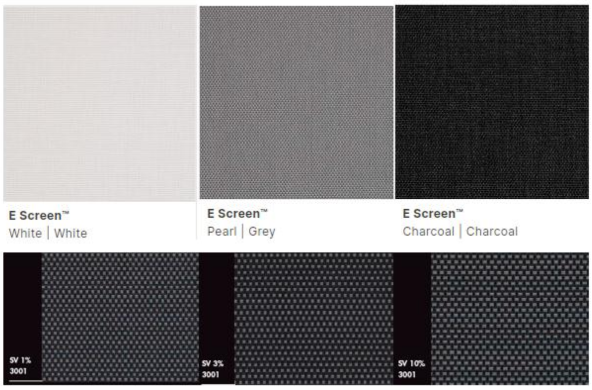


Fig. 10. Color and openness factors of fabrics.

2.4.2 Roller shades

Although the use of curtains is still more common in residential buildings, due to the modern and attractive appearance of roller shades, people are more interested in using them. Roller shades are also available in different designs, colors, and thicknesses in the market. For better comparison like curtains they were simulated in 3 different colors; white, grey, charcoal bronze with 3 different openness factor 1%,3%,10% according to fabric factory properties (table 6) (Mermet sun control textiles, 2020).

Table 6
Roller shades fabric Specification

Color	Alternatives	Openness factor (%)	thickness (mm)	Tv	Rs	As	Ts	Rv
white	Case 14A	1	0.52	11	75	11	14	80
	Case 14B	3	0.43	13	73	11	16	78
	Case 14C	10	0.41	22	66	9	25	70
Grey	Case 15A	1	0.52	3	29	66	5	30
	Case 15B	3	0.43	8	27	63	10	27
	Case 15C	10	0.41	14	26	58	16	14
Charcoal Bronze	Case 16A	1	0.52	1	4	95	1	4
	Case 16B	3	0.43	4	5	91	4	5
	Case 16C	10	0.41	12	3	85	12	4

(Source: Mermet sun control textiles)

2.5 Reliability of DesignBuilder Program

The use of DesignBuilder as a reliable energy simulation program for buildings (https://www.designbuilder.co.uk/software/product-overview, 2018) and its capability in emulating the energy and thermal behavior of Iran buildings has been well established (Fathalian and Kargar Sharifabad, 2017; Zomordian and Tahsildost, 2015; Johari and Masoudinejad, 2018). The accuracy of this commercial software package has been validated using the BESTest (Building Energy Simulation Test) procedure adopted by the United States Department of Energy (USDOE) and the international community for verifying building energy simulation programs (Taleb and Sharples, 2011). Zarif and Jamie.(2018) simulated an official building in Mashhad, Iran, by using DesignBuilder, and the predicted energy consumption was validated with measured data for three months; the average discrepancy was 8 % a similar study in Semnan has reported reasonable agreement between the simulated energy consumption and the actual utility bills(Fathalian and Kargar Sharifabad, 2017).). Zarif and Jamie.(2018) simulated official building in Mashhad, Iran, by using DesignBuilder, and the predicted energy consumption was validated with measured data for three months; the average discrepancy was 8 % a similar study in Semnan has reported reasonable agreement between the simulated energy consumption and the actual utility bills(Fathalian and Kargar Sharifabad, 2017).

Zomordian et al. (2015) simulated the annual energy consumption of an existing educational building and then compared it to the actual energy consumption of the building. By modifying software inputs based on field perceptions, the main parameters causing the difference between the predicted and actual energy consumption in the building have been identified. Based on the results of this study, Design Builder software has a good performance in predicting energy consumption and internal temperature of spaces according to construction conditions, equipment, and climate.

3. Results and Discussions

3.1 External shading devices overhangs and mat roller shades data analysis

Horizontal overhangs with three different depths, 0.26m, 0.41m, and 1m in terms of heating, cooling, and lighting consumption were examined by Design-builder software. According to output data overhang with 0.26m depth with 3.4% annual energy consumption reduction is optimized and overhang with 0.41m with 3.2% and 1m projection with 1.2% annual energy consumption reduction was shown. In addition to reducing cooling consumption, the 0.26m overhang also reduces heating loads and only slightly increases light consumption. However, increasing the depth of the protrusion shows the cooling load decreases, but the heating and lighting load increases, so that in the one- meter protrusion, the heating consumption is also higher than the base model. See Figure11.

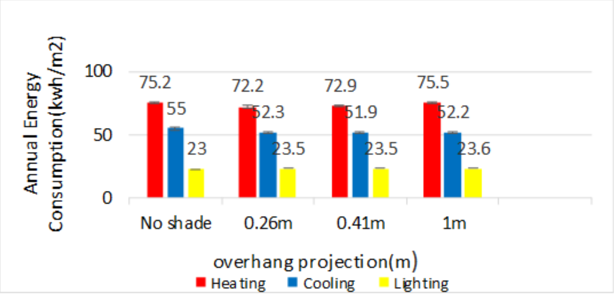


Fig. 11. Overhangs heating, cooling, and lighting annual energy consumption.

Mats with reed distances of 1 to 3 mm has similar behavior in terms of energy consumption for cooling, heating, and lighting and reduce 3.8% annual energy consumption.

But lighting consumption in the mat with a reed spacing of 3 mm is slightly less. The mat with a reed distance of 5 mm has similar behavior in terms of reducing the heating load, its cooling load is less than before, while it has a more favorable situation in terms of lighting consumption. Mats with 8 mm and 1 cm reed distances have similar heating and lighting loads but reducing cooling consumption is less than others.

Therefore, mats with reed spacing of 5, 8 mm, and 1 cm have an annual energy consumption reduction of 3.8%, 3.7%, and 3.5%, respectively. Nevertheless, the difference between them is miner, but mat with 3mm distance between reeds have better lighting reduction from 1 and 2mm reeds distance and also have better cooling reduction from 5mm reeds distance (Figure12).

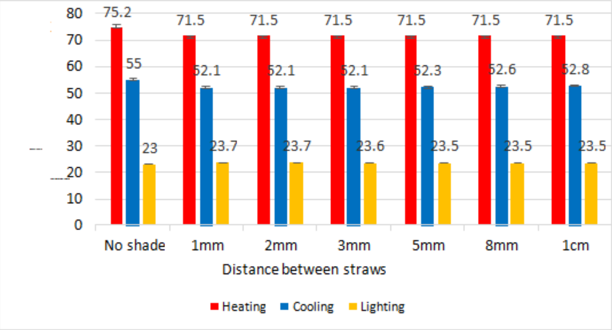


Fig. 12. Mat roller shades heating, cooling, and lighting annual energy consumption

As the distance between the reeds increases, so does the energy consumption. This is while the heating loads are the same at all distances from the reeds and increasing the distance between the reeds only affects the cooling and lighting loads. Increasing the distance between the reeds from 1 mm to 1 cm reduces the saving cooling energy consumption from 5.3% to 4% and improves the lighting consumption by only 1%.

3.2 Internal shading device curtains and roller shades simulation results

According to simulation output data, a white curtain with a 3% openness factor has shown a 4.3% reduction in annual energy consumption and showed the greatest annual saving energy in comparison to other curtains. All curtains show an approximately 2% increase in lighting consumption, which is higher in grey and dark ones, but this increase is a miner. All curtains has a 5.3% reduction in heating load and a medium- density (3% openness factor) white curtain with a 6% reduction in cooling load has the highest energy consumption reduction and a high density (1% openness Factor) dark curtain with a 4.2% reduction in cooling load has the least effect in reducing energy consumption. Based on the simulation output data, it is observed that the color of the curtain has a greater role in reducing energy consumption than its density (openness factor), see Figure 13. Therefore, a medium-density white curtain with a 4.3% reduction in energy consumption is the optimal curtain and a low density dark curtain with a 3.3% reduction in energy consumption has the least reduction.

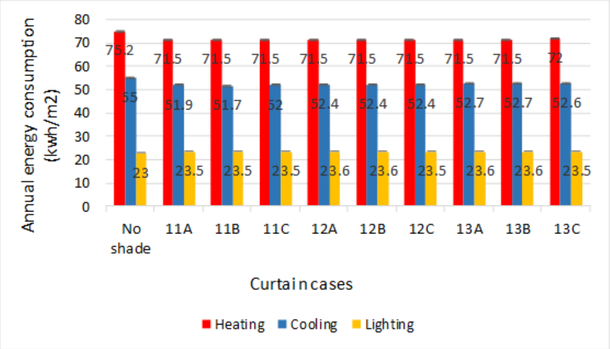


Fig. 13. Curtains heating, cooling, and lighting annual energy consumption

Artificial lighting energy consumption in white roller shades with different openness factors are the same, but with changing color from white to charcoal, it increases from about 2% to 3%. White roller shade with 1% openness factor saved 4.2% annual energy consumption and this is an optimized roller shade. It decreased 5.9% cooling load and 5% heating load. All the dark roller shades increased cooling loads and lighting consumption compared to the base model. Charcoal roller shade with 1% openness factor behaves similarly to unshaded windows. As a result, it does not reduce annual energy consumption, see Figure14.

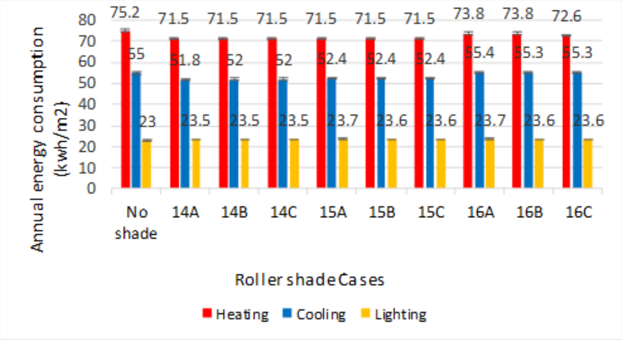


Fig. 14. Roller shades heating, cooling, and lighting annual energy consumption

The reduction of heating load in curtains and roller shades is the same, but dark curtains are more effective in reducing the cooling load than dark roller shades, so dark curtains with high density (1% openness factor) reduce the cooling load by 4.2%, but dark roller shades with high density (1% openness factor) increase cooling consumption by close to 1%.

3.3 Comparison of exterior and interior shading devices

Horizontal overhangs cannot be adjusted to temperature and solar on windows as they are fixed in all weather conditions. Therefore, in all seasons they have a specific behavior in reducing or increasing thermal loads and they show less energy consumption reduction than other shading devices (optimal mode 3.4% annual saving). Whereas mat roller shades annual reduction energy consumption is the same with grey curtains and grey roller shades with different openness factor (optimal mode 3.8% annual saving), white curtain with 3% openness factor and white roller shades with 1% openness factor are shown 4.3% and 4.2% annual energy consumption reduction. This result shows that because heating is the dominant need of this region if the interior shade with appropriate features is selected, it can play a more effective role in reducing energy consumption, see Figure15 and 16.

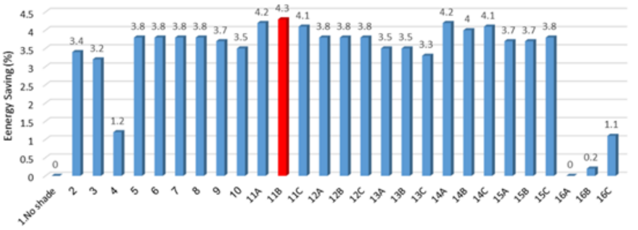


Fig. 15. Comparison of annual energy consumption of all cases studied

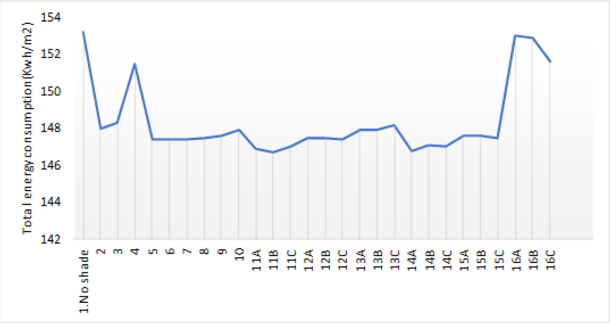


Fig.16. Comparison of energy saving potential of all cases studied

3.4 Combination of optimized exterior and interior shading devices

According to the above descriptions, optimum shading devices were identified. Many studies in different climates recommended a combination of interior and exterior shading devices for better energy-saving results (sheikhzadeh et al., 2006; Fatahi et al., 2017).The combination of the white curtain with a 3% openness factor and 0.26 depth overhang has the same reduction in energy consumption that of white roller shade 1% openness factor and the optimized overhang. These combinations showed a 3.8% and 6.6% reduction in heating and cooling annual consumption and increased lighting consumption by less than one percent, see Figure 17.

Table 7
Combination of optimized exterior and interior shading devices

Alternatives	**Combination of optimized internal and external shading devices**
Case 17	White curtain with 3% openness factor + 0.26 depth overhang
Case 18	White roller shade with 1% openness factor +0.26 depth overhang
Case 19	White roller shade with 1% openness factor + Mat roller shade(3mm reed distances)
Case 20	White curtain with 3% openness factor + Mat roller shade(3mm reed distances)

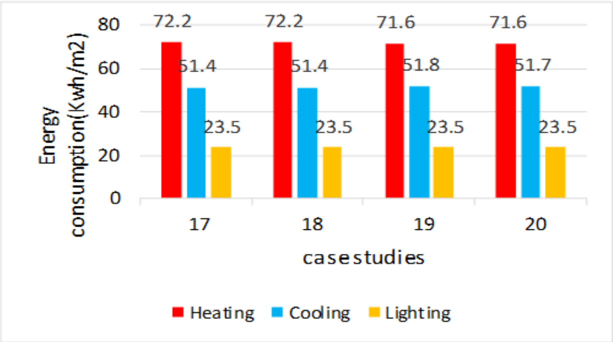


Fig.17. Heating, cooling and lighting annual energy consumption of optimized combination case studies

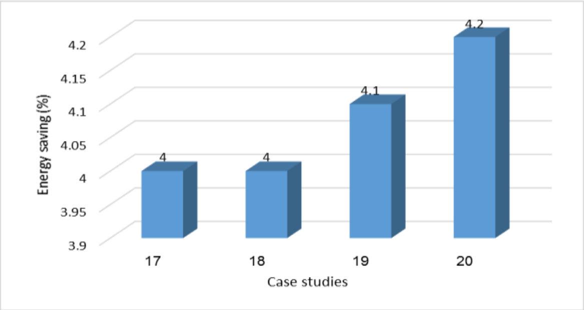


Fig. 18 Total energy saving of optimized combination case studies

According to the output data (Table 8), a combination of optimized external and internal shadings have shown the greatest reduction in cooling loads, but because they have less heat load reduction than internal shades, they are not optimum. This corroborates with the study of Ye et al. [60] if external and internal shading devices use the same material and have the same geometric dimensions, the effectiveness of the internal shading is inferior to the external ones. However, by adjusting the solar transmittance, solar reflectivity, and distance between shading device and window, internal shadings can achieve good energy performances, sometimes even better than some external ones. The study also observed that the shading devices showed better energy performance when controlled with air temperature and solar irradiation compared to fixed overhangs. Yao et al [59] showed movable solar shading has a significant performance in terms of energy, indoor thermal and visual comfort, and can be widely used in hot summer and cold winter zone of China. But in a temperate climate, this energy reduction is less than hot and dry weather, like Sghiouri et al. [48] research shows that the thermal comfort is improved by using shading device, and the optimized overhangs reduce the cooling demand by 4.1% for Casablanca's Mediterranean climate. The discrepancies are obviously due to the variations in climate, building type, and size, location, shading strategy, etc. Furthermore, while the previous studies considered shading devices for hot and dry climates and schedule control systems for office buildings, few have focused on residential buildings and temperate climate. But this study simulated common external and internal shading devices in a temperate climate, which can improve energy consumption by choosing proper shading by architects and designers without any additional costs. And even it is good for renovating old residential buildings if they have this information as an architect or interior designer.

Table 8

Comparison of heating, cooling and lighting saving energy of all cases

Saving (%)				**Total(kwh/m^2)**	**Lighting load(kwh/m^2)**	**Cooling load(kwh/m^2)**	**Heating load(kwh/m^2)**	**Options**
Total	**Lighting**	**Cooling**	**Heating**					
......	....	....	....	153.2	23	55	75.2	Case1
3.4	-2.1	5	4	148	23.5	52.3	72.2	Case2
3.2	-2.1	5.7	3.1	148.3	23.5	51.9	72.9	Case3
1.2	-2.6	5.1	-0.3	151.5	23.6	52.2	75.5	Case4
3.8	-3	5.7	5	147.4	23.7	52.1	71.5	Case5
3.8	-3	5.3	5	147.4	23.7	52.1	71.5	Case6
3.8	-2.6	5.3	5	147.4	23.6	52.1	71.5	Case7
3.8	-2.1	5	5	147.5	23.5	52.3	71.5	Case8
3.7	-2.1	4.4	5	147.6	23.5	52.6	71.5	Case9
3.5	-2.1	4	5	147.9	23.5	52.8	71.5	Case10
4.2	-2.1	5.7	5	146.9	23.5	51.9	71.5	Case11A
4.3	-2.1	6	5	146.7	23.5	51.7	71.5	Case11B
4.1	-2.1	5.5	5	147	23.5	52	71.5	Case11C
3.8	-2.6	4.8	5	147.5	23.6	52.4	71.5	Case12A
3.8	-2.6	4.8	5	147.5	23.6	52.4	71.5	Case12B
3.8	-2.1	4.8	5	147.4	23.5	52.4	71.5	Case12C
3.5	-2.6	4.2	5	147.9	23.6	52.7	71.5	Case13A
3.5	-2.6	4.2	5	147.9	23.6	52.7	71.5	Case13B
3.3	-2.1	4.4	4.3	148.2	23.5	52.6	72	Case13C
4.2	-2.1	5.9	5	146.8	23.5	51.8	71.5	Case14A
4	-2.1	5.5	5	147.1	23.5	52	71.5	Case14B
4.1	-2.1	5.5	5	147	23.5	52	71.5	Case14C

3.7	-3	4.8	5	147.6	23.7	52.4	71.5	Case15A
3.7	-2.6	4.8	5	147.5	23.6	52.4	71.5	Case15B
3.8	-2.1	4.8	5	147.4	23.5	52.4	71.5	Case15C
0	-3	-0.7	1.9	153	23.7	55.4	73.8	Case16A
0.1	-2.6	-0.5	1.9	152.9	23.6	55.3	73.8	Case16B
1.1	-2.6	-0.5	3.5	151.5	23.6	55.3	72.6	Case16C
4	-2.1	6.6	4	147.2	23.5	51.4	72.2	Case17
4	-2.1	6.6	4	147.2	23.5	51.4	72.2	Case18
4.1	-2.1	5.9	4.1	147	23.5	51.8	71.6	Case19
4.2	-2.1	6	4.8	146.9	23.5	51.7	71.6	Case20

3.5 CO$_2$ Emissions

As shading control blocks solar radiation transmission into the space and savings energy demands are quantified, reductions energy and CO2 emissions could be then estimated. For natural gas, which is the dominant source of heating energy for residential building in Iran, a factor of 1.084 and for electricity as cooling and lighting source 3.167 convert from site energy to primary energy (Fayaz and Kari, 2009). Also, each kilowatt-hour of primary energy is estimated to emit 183.6 grams of CO2 (Yoon et al., 2014). Hence, any reduction in energy demand and consequently primary energy consumption will ultimately have a proportional reduction in CO2 emissions. Updated simulations are run and results are shown in Fig. 19 and Table 9. Note that reductions in primary energy and CO2 emissions and normalized per square meter of floor area. The results showed that all shades are effective in reducing carbon emissions and this effect is greater in the hottest months of the year (May to Sep) see Fig.20. According to the output data, the optimal combination of overhang and curtain shades has the highest reduction in carbon emissions, and this amount is 9.74 kg Co$_2$/ m2 in the hottest months of the year and 2.45 kg Co$_2$/ m2 annually. The difference between other optimal shadings is miner and they have a similar effect in reducing carbon emissions.

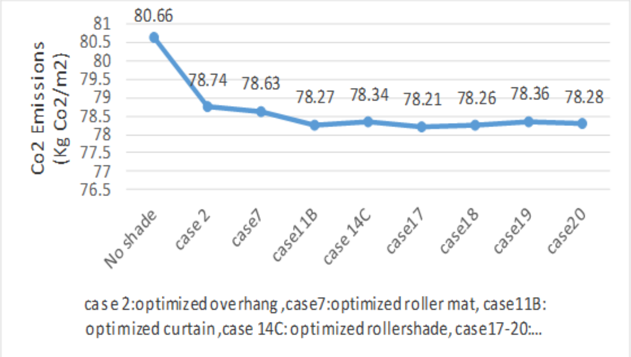


Fig .19. Annual Co$_2$ Emissions of optimized shadings

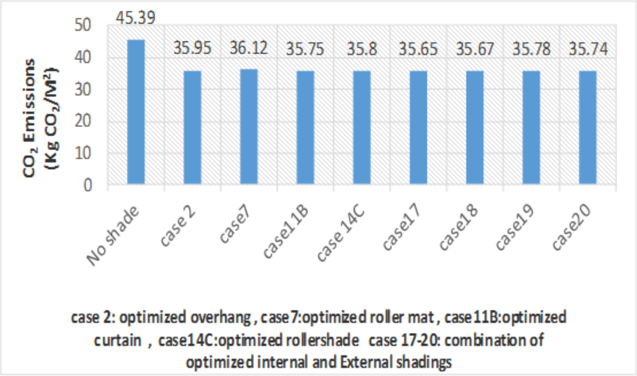


Fig. 20 .Carbon emissions of optimal shadings in the hottest months of the year (May to Sep)

According to Table 9, the results show that the optimal shadings can reduce carbon emissions by about 2.38 up to 3% per year and 20.79 up to 21.45% in the hottest months of the year.

Table 9
Co$_2$ emissions reduction with optimized shadings

Reductions in CO2 Emissions[kg CO2/m2]

Optimized Shadings	Annually	The hottest months of year (May to Sep)	Saving (%)	
			Annually	May to Sep
Case 2	1.92	9.44	2.38	20.79
Case 7	2.03	9.27	2.51	20.42
Case 11B	2.39	9.64	2.96	21.23
Case 14C	2.32	9.59	2.87	21.12
Case 17	2.45	9.74	3.03	21.45
Case 18	2.40	9.72	2.97	21.41
Case 19	2.30	9.61	2.85	21.23
Case 20	2.38	9.65	2.95	21.26

4. Conclusion

Iran is a country regarded as a high consumer of energy and emitter of CO2. A large proportion of energy consumption in the building sector is consumed for providing thermal comfort in the indoor spaces without attention to environmental pollution.

This paper has presented simulation-based results from an investigation of two exterior and two interior shading devices and a combination of their optimized ones. This method was used to consider the optimal shading system for a typical residential building with a temperate climate in the north of Iran. The performance of shading devices was evaluated in terms of total energy demand, the individual energy demands for heating, cooling, and artificial lighting. Energy consumption (heating, cooling, and lighting) were studied to demonstrate comparable results of performances of the optimized ones. Shading is one of the most effective means of reducing the cooling loads but we can't neglect its effect on the heating loads and lighting. Reducing energy consumption leads to reduced carbon emissions, so the effect of optimal shadings on reducing carbon emissions was investigated.

External shading has many limitations, especially in high-rise buildings. They are difficult to install and expensive to maintain and repair. This study proves that if internal shadings are designed well, they can be as effective as external shadings. Overhangs are fixed and they can't be adjusted by sun position and weather conditions.

Due to environmental conditions adjustment, mat roller shades reduced energy consumption more than overhangs, this indicates that the movable shadings are more desirable in this climate. Horizontal overhangs are more effective in reducing cooling loads and exterior mat roller shades are more effective on heating loads. The output data also confirms that white curtains with a 3% openness factor and white roller shades with a 1% openness factor show the greatest reduction in energy consumption and this proves that heating is the dominant need of this area. Examining the carbon emissions rate shows that the optimal shadings are effective and the composition of the optimal overhang and curtain shading has the highest reduction in carbon emissions. So that during the hottest months of the year, it shows 21.45% and 3% reduction annually and it means 9.74 kg co_2/m^2 in May to Sep months and 2.45 kg co_2/m^2 annually. White curtain shading, which was optimal in terms of reducing energy consumption, has a similar result and miner difference in terms of reducing carbon emissions in Compared with combining it with overhang, So overhang can be avoided due to the cost of construction and maintenance and only can use curtains to reduce energy consumption and subsequently reduce carbon emissions. If we use internal shades with proper features (solar transmittance, solar reflectivity,..), we will have higher efficiency than external ones, which require more effort for installation and maintenance costs.

According to this reasoning combination of optimized external and internal shadings didn't show a significant effect on reducing energy consumption. Thus, engineers may consider using internal shading to substitute for external shading to save costs. And architects and engineers should think about internal shading as a viable option for improving energy efficiency.

References

1) Aelenei, D., Aelenei, L., Pacheco Vieira, C. (2016). Adaptive façade: concept, applications, research questions, Energy Proc; 91: 269–275.
2) Ahmed, A. A. E. M. M. A. (2012). “Using simulation for studying the influence of vertical shading devices on the thermal performance of residential buildings (Case study: New Assiut City),” Ain Shams Eng. J. 3(2):163–174
3) Al Touma, A., Ouahrani D. (2018). Quantifying Savings in Spaces Energy Demands and CO2 Emissions by Shading and Lighting Controls in the Arabian Gulf. Journal of Building Engineering, 18: 429-437. https://doi.org/10.1016/j.jobe.2018.04.005
4) Aldawoud, A. (2013). Conventional fixed shading devices in comparison to an electrochromic glazing system in hot, dry climate. Energy Build, 59:104–10. http://dx.doi.org/10.1016/j.enbuild.2012.12.031.
5) Al-Masrani, S.M., Al-Obaidi K.M., Zalin N.A., Isma M.I.A. (2018). Design optimization of solar shading systems for tropical office buildings: challenges and future trends, Sol. Energy, 170:849–872.
6) Almusaed, A., Almssad, A. (2015). "Building Materials in Eco-energy Houses from Iraq and Iran", Case Studies in Construction Materials, 2: 42-56.
7) Al-tamimi, NA., Fairuz, S., Fadzil, S. (2011).The potential of shading devices for temperature reduction in high-rise residential buildings in the tropics. Procedia Eng, 21:273–82. http://dx.doi.org/10.1016/j.
8) Attia, S., Bilir, S., Safya, T., Struck, C., Loonen, C., Goia F. (2018). Current trends and future challenges in the performance assessment of adaptive façade systems, Energy Build. 179:165–182.
9) Atzeri, A., Cappelletti, F., Gasparella, A. (2014). Internal versus external shading devices performance in office buildings, Energy Procedia, 45:463–472.
10) Ayoub, M. (2018). Integrating illuminance and energy evaluations of cellular automata controlled dynamic shading system using new hourly-based metrics, Sol. Energy, 170:336–351.
11) Babaizadeh, H., Haghighi, N., Asadi, S., Broun, R., Riley, D. (2015). Life cycle assessment of exterior window shadings in residential buildings in different climate zones. Build Environ .90:168–77.
12) Corrado,V., Filippi,M., Serra,V.(2001). A detailed analysis of the effects of external shading systems on window solar gain in China 2000/Napoli 2001, The Seventh REHVA World Congress, 15–18September, Napoli, 2001.
13) Elzeyadi, I., Abboushi, B., Hadipour, H., Reviera, L. (2016). High performance façades: measuring the impacts of dynamic shading prototypes on indoor environmental quality using yearly simulations and field tests, Proceedings of PLEA Cities, Buildings, People: towards Regenerative Environments, Los Angeles, CA, pp.1023–1032.

14) Elzeyadi, I. (2017). The impacts of dynamic façade shading typologies on building energy performance and occupant's multi-comfort, Architect. Sci. Rev. 60:316–324.
15) Evola, G., Gullo, F., Marletta, L. (2017). The role of shading devices to improve thermal and visual comfort in existing glazed buildings. Energy Proc. 134: 346–355. http://dx.doi.org/10.1016/j.egypro. 09.543.
16) Fatahi, Sh., Tanba, A., Normohamadi, R. (2017). Investigating the Role of Shading devices in Thermal Comfort of Hot and Humid Climate of Iran (Case Study of Residential Texture in Ahvaz), National Conference on Basic Research in Civil Engineering, Architecture and Urbanism,Tehran, pp 17-18. (In Persian). https://civilica.com/doc/789658/.
17) Fathalian, A., Kargar Sharifabad,H.(2017). Energy Building Simulation for Office Building with DesignBuilder Software and Its Validation with Energy Bills, 3rd Iranian Heat and Mass Transfer Conference, Iran, (In Persian). Babol, Dec2017, https://civilica.com/doc/698797/.
18) Fayaz, R., Kari, B. M. (2009). Comparison of energy conservation building codes of Iran, Turkey, Germany, China, ISO 9164 and EN 832. Applied Energy, 86, 1949-1955.
19) Fazeli, N., Mahdavinejad, M., Bemaniyanc, M.R. (2019). Dynamic Envelope and Control Shading Pattern for Office Buildings Visual Comfort in Tehran, Space Ontology International Journal,8(3): 31-40.
20) Feizabadi, M., Rezaei, N. (2015). Possibility of its development in native constructions "Reed" Investigation of the use of materials in North of Iran. 3th International Congress on Civil Engineering, Architecture and Urban Development. Shahid Beheshti University, Tehran, Iran, 29-31 December 2015, P-4. (In Persian).
21) Giovannini, L., LoVerso, V.R.M., Karamata, B. M. (2015). Andersen, Lighting and energy performance of an adaptive shading and day lighting system for arid climates, Energy Proced 78: 370–375.
22) Hashemi, A., Khatami, N. (2017). Effects of solar shading on thermal comfort in low-income tropical housing. Energy Proc.111: 235–244. http://dx.doi.org/10.1016/j.egypro.2017.03.025.
23) Huang, Y., Niu, JL., Chung TM. (2014). Comprehensive analysis on thermal and day lighting performance of glazing and shading designs on office building envelope in cooling-dominant climates. Appl Energy, 134:215–28.
24) Inoue, T., Kawase, T., Ibamoto, T., Takakusa S., Matsuo Y. (1988). The development of an optimal control system for window shading devices based on investigations in office buildings, ASHRAE Transactions. 94.
25) Jayathissa, P., Luzzatto, M., Schmidli, J., Hofer, J., Nagy N., Schlueter, A. (2017). Optimizing building net energy demand with dynamic BIPV shading, Appl. Energy .202:726–735.
26) Jayathissa, P., Zarb, J., Luzzatto, M., Hofer, J., Schlueter, A. (2017). Sensitivity of building properties and use types for the application of adaptive photovoltaic shading systems, Energy Proc .122:139–144.
27) Johari, S., Masoudinejad, M. (2018). Analysis and selection of applications in building energy consumption simulation, International Congress of Leading Contemporary Architecture and Urban Planning in Islamic Countries, Iran, Mashhad, (In Persian). May 2018 https://civilica.com/doc/809546/.
28) Karimpour, A.R., Diba, D., Eetesam, E. (2017).Analysis of interior shades efficiency on energy consumption by Using simulation models (case study: residential building in Tehran), Hoviat shahr journal, 30(11)17-30. (In Persian).
29) Kasmai, M. (2003). Climate and Architecture, Khak publication, Second edition, Isfahan, Iran. P.52-54. (In Persian).
30) Kim, G., Lim, H.S., Lim, T.S., Schaefer, L., Kim, J.T. (2012). Comparative advantage of an exterior shading device in thermal performance for residential buildings, Energy Build. 46:105–111.
31) Kirimtat, A., Koyunbaba, BK., Chatzikonstantinou, I., Sariyildiz, S. (2016). Review of simulation modeling for shading devices in buildings. Renew Sustain Energy Rev. 53:23–49.
32) Konstantzos, I., Tzempelikos, A., Chan, Y. (2015). Experimental and simulation analysis of daylight glare probability in offices with dynamic window shades, Build. Environ.87:244–254.
33) Lau, A.K.K., Salleh, E., Lim, C.H., Sulaiman, M.Y. (2016). Potential of shading devices and glazing configurations on cooling energy savings for high-rise office buildings in hot-humid climates: the case of Malaysia, Int. J. Sust. Built Environ.5: 387–399.
34) Lauren, F. (2000). Green Building Materials City of Santa Monico, USA.
35) Lee, E.S., Tavil, A. (2007). Energy and visual comfort performance of electrochromic windows with overhangs; Building and Environment .42: 2439–2449.
36) Lim, Y.-W., Kandar, M.Z., Ahmad, M.H., Ossen D.R. (2012). Abdullah A.M, Building façade design for day lighting quality in typical government office building, Build. Environ.57:194–204.
37) Loonen, R.C.G.M., Trčka, M., Cóstola, M., Hensen, J.L.M. (2013). Climate adaptive building shells: state-of-the-art and future

challenges, Renew. Sustain. Energy Rev.25:483–493.

38) Mangkuto, R.A., Feradi, F., Putra, R.E., Atmodipoero, R.T., Favero, F. (2018). Optimization of daylight admission based on modifications of light shelf design parameters, J. Build. Engineer.18:195–209.
39) Modiri,M.,Zahab.N,S.,Alibakhshi,Z.,Afsharmanesh ,H.,Abasi,m.(2012). Investigating the proper direction of buildings based on sunlight and wind direction (Case study: Gorgan city), Scientific-research quarterly Geography (Regional Planning) Journal.2:141-156.
40) Mohammad, Sh. (2013). Study of thermal behavior of common material in wall structure, case study; residential building in Tehran, architecture and urbanism fine arts press .18(1):69-78. (In Persian).
41) Mohammadi, M., Daraio, J.A. (2020). Improving the Energy Efficiency of Existing Residential Buildings by Applying Passive and Cost-Effective Solutions in the Hot and Humid Region of Iran. Space Ontology International Journal.9(4):77-96.
42) Nasrollahi, F. (2011). Architectural and urban planning criteria to reduce the energy consumption of buildings, National energy committee of Iran press. P .2-5. (In Persian).
43) New life - old structure a selection of valuable structures. (1372). Ministry of housing and development publication, Tehran, Iran, p-71. (In Persian).
44) Newsham, G.R. (1994). Manual control of window blinds and electric lighting: implications for comfort and energy consumption, Indoor Environment. 3 (3).
45) Razjouyan, M. (2015). Comfort design with climate, Shahid Beheshti University press, Second edition.P-187. (In Persian).
46) Reinhart, C.F.,Voss, K. (2003). Monitoring manual control of electric lighting and blinds, Lighting Research and Technology.35 (3).
47) Roshan,G.R., Farrokhzad, M., Attia,S. (2017). Defining thermal comfort boundaries for heating and cooling demand estimation in Iran's urban settlements. Building and environment 121:168-189.
48) Sghiouri, H., Mezrhab, A., Karkri, M., Naji, H. (2018). Shading devices optimization to enhance thermal comfort and energy performance of a residential building in Morocco, Journal of Building Engineering.18: 292-302. https://doi.org/10.1016/j.jobe.2018.03.018
49) Sheikhzadeh, GH.A ., Khorasanizadeh, H., Sabzposhani, M. (2006). Investigation of shading devices and determining their effect on building cooling loads.Fifth Conference on Optimizing Fuel Consumption in Buildings ,Tehran, Iran.p-8.
50) Singh, R., Lazarus, I.J., Kishore, V.V.N. (2015). Effect of internal woven roller shade and glazing on the energy and day lighting performances of an office building in the cold climate of Shillong. Appl. Energy.159:317–333. http://dx.doi.org/10.1016/j.apenergy.2015.09.009.
51) Taleb, H.A., Sharples, S. (2011). “Developing sustainable residential buildings in Saudi Arabia: A case study,” Appl. Energy, Jan.88:383-391.file:///C:/Users/Reviewer/Downloads/1-s2.0-S003809.
52) The Building Architectural Design. (2002). Chapter 4: in Los Alamos National Laboratory Sustainable Design Guide, p. 57.
53) The Iranian Building Code 13. (2003). Design and implementation of electrical installations of buildings. Iranian Building Code National Committee, Tehran, Iran, (In Persian). 2003.prd.behdasht.gov.ir/uploads/IranNR-13.pdf.
54) The Iranian Building Code 19. (2009).Energy Conservation. Iranian Building Code National Committee, Tehran, (In Persian). Iran. Revised 7 Dec 2014 from prd.behdasht.gov.ir/uploads/IranNR-19.pdf.
55) Tzempelikos, A., Athienitis, A. K. (2007). The impact of shading design and control on building cooling and lighting demand, Sol. Energy ,81(3)369–382.
56) Valladares-Rendón, L.G., Schmid, G., Lo, S.-L. (2017). Review on energy savings by solar control techniques and optimal building orientation for the strategic placement of façade shading systems, Energy Build.140: 458–479.
57) Watson, D., Labs, K. (2009). Climate design: Energy-Efficient building principles and practices. Translated by Ghobadian V,Faze Mahdavi M,11th edition, University of Tehran Press. P-177. (In Persian).
58) Yao, J. (2014). An investigation into the impact of movable solar shades on energy, indoor thermal and visual comfort improvements. Build Environ. 71:24–32. http://dx.doi.org/10.1016/j.buildenv.2013.09.011.
59) Yao, R., Costanzo, V., Li, X., Zhang, Q., & Li, B. (2018). The effect of passive measures on thermal comfort and energy conservation. A case study of the hot summer and cold winter climate in the Yangtze River region. Journal of Building Engineering, 15: 298–310. https://doi.org/10.1016/j.jobe.2017.11.012 Available at http://centaur.reading.ac.uk/74023/
60) Ye, Y., Xu, P., Mao, J., Ji, Y. (2016). Experimental study on the effectiveness of internal shading devices, Energy Build. 111:154–163.
61) Yoon, Y. B., Kim, D. S., & Lee, K. H. (2014). Detailed heat balance analysis of the thermal load variations depending on the blind location and glazing type. Energy and Buildings, 75, 84-95.

62) Zarif, M., Jamei, A. (2018). The role of various types of external canopies in order to optimize the thermal behavior of buildings in low-income housing, International Conference on Civil Engineering, Architecture and Urban Development Management in Iran, Tehran, (In Persian). Aug 2018, https://civilica.com/doc/847188/.
63) Zomordian, Z., Tahsildost, M. (2015). Validation of energy simulation software in buildings: with an experimental and comparative approach, Iranian Energy Journal, 18:115-131. (In Persian). http://necjournals.ir/browse.php?mag_id=52&slc_lang=fa&sid=1.

Online References

64) Designbuilder Software Product Overview. [Online]. Available: https://www.designbuilder.co.uk/software/product-overview. [Accessed: 05-Feb-2018].
65) EUROPEAN COMMISSION. (2017). Energy Performance of Buildings Directive (2010/31/EU), Retrieved 11 Dec, 2017 from https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings/nearly-zero-energy-buildings.
66) IEA. (2015). Energy balance statistic, Retrieved 11 July, 2017, from https://www.iea.org/Sankey/#?c=Islamic Republic of Iran&s=Final consumption.
67) Mermet sun control textiles, the brochure of thermal and optical fabrics properties, Retrieved Sep 19, 2020, from http;//www.sunscreen-mermet.com.
68) Portal of the Iranian Environmental Protection Agency, Retrieved Feb 23, 2020, from http;//www.doe.ir.