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Studying of thermal behavior of facades in order to determine the optimal appearance in terms of energy consumption (Case study: An office building in Tehran)

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Abstract
In hot and dry climates, protecting the building from receiving light and heat energy is one of the first measures to optimize energy consumption. The present study, which has been done by software simulation method, with the aim of determining the most suitable facade in terms of energy consumption, investigates the thermal behavior of facades of an office building in the climate of Tehran. In order to achieve the best option, the thermal behavior of the selective facades on both north and south fronts are evaluated. Findings from calculations show that the annual energy consumption, including: cooling, heating and electric lighting is less on the south side than on the north side. Also, assuming other operating conditions are stable, "movable" awnings perform better than "fixed" awnings. In terms of the type of facade, the "kinetic facade" with the ability to adjust its components such as direction of rotation, opening and closing, has a good performance in reducing the amount of energy consumed by the building compared to other facades. So that this facade with the ability to reduce the amount of energy consumption of the building by 42.3% compared to the conventional single-skin facade, the most optimal facade is determined.

Keywords: Hot and dry climate, Energy analysis, Thermal behavior, Double Skin Façade, Kinetic façade.

1. Introduction

The facade of the building is one of the parameters determining the amount of energy consumption of the building, which can increase the heating load of the building due to energy loss in the cold season and the cooling load due to solar radiation energy and space heating. This part of the building is the boundary between controllable space inside and uncontrollable space outside, and is exactly where a lot of energy loss occurs in this part; Therefore, by controlling the amount of energy loss and permeability of the exterior skin of the facade, the energy consumption of a building can be greatly reduced. In addition, the skins, as elements that provide natural light in buildings, play an important role in determining the amount of energy consumed by the lighting system. Considering the growing importance of energy issues and the need to maximize the use of renewable resources on the one hand and the need to use design solutions to reduce the energy consumption of the building on the other hand, the authors of the present study, Investigating and comparing the energy performance of four facade system models in the climate of Tehran.

Studies on energy consumption in office buildings show that in Iran, the cooling and air conditioning system with 34% has the highest share and the lighting and heating and cooling systems with 25% and 21% respectively, the next ranks of energy consumption of a building. They have an office. This amount of consumption is observed during working hours despite relatively high daylight in Iran. On a global scale, about 30% of office electricity consumption is spent on space lighting. [1] And this is while the city of Tehran has an average of 3025 hours of natural light during the year, which is deprived of a high percentage of the building area. [2]

2. Material and Method

The present study was performed by software simulation and modeling and its basic information (Tehran weather information and office building information under study); collected using library and field resources. In the next stage, an office building was modeled using four types of single-skin facade systems, double-glazed facade, double-skin with canopy and movable in Rhino and Grace Hopper software. The thermal behavior of the proposed skins was investigated using the Climate Studio plugin to simulate

the building in the climatic conditions of Tehran. Finally, to know the effect of the proposed facades on the energy consumption of the building, the thermal behavior of each was compared with each other. Figure 1 shows the process of conducting this research.

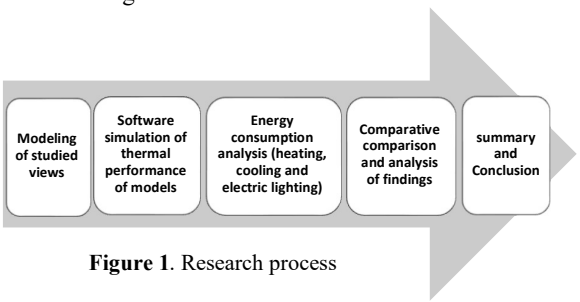

Figure 1. Research process

To determine the proposed models, the single-skin facade, which is common in most facades; was chosen as the base model. Since it is very common today to place glass facades in office buildings; the best way to use all-glass facades is to use double-skin facades. So this type of facade, which has been a suitable solution in the design of office buildings for the past twenty years [3], was selected as the second research model.

In another example of double skin facades, the canopies, as a thermal regulator, are placed in the middle space (cavity) and reduce the cooling load of the interior space by a considerable amount [4]. This type of facade, which acts as a passive solar system and significantly reduces the heating load of the building in the cold period and increases the cooling load of the building and the cooling energy consumption in the heating period by increasing the temperature of the middle cavity, was determined as the next research model.

The fourth proposed model is a modular dynamic system that can be installed on the facade of the building and while reducing energy consumption, provide comfort for residents. This type of facade, which is called a moving facade, is mainly used to control and improve the four major environmental variables (control of solar thermal energy; control of sunlight; control of ventilation and energy production) in the building. [5] And it can be very effective in reducing energy consumption. These four proposed models are presented in Figure 2.

1-Basic research model	2-Double-skin façade glass
	
3-Double-skin façade with shading	4-Kinetic facade

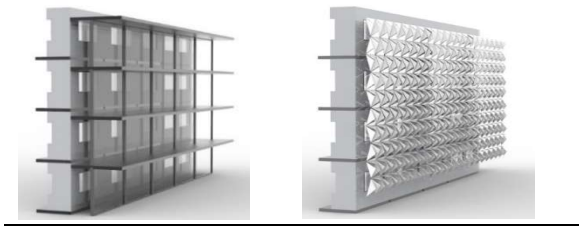

Figure 2. Proposed facade models

The building under study is a four-story office-service complex located in Zafaranieh, Tehran, the ground floor of which has a service use. The location and architectural plan of this building along with the studied spaces are presented in Figure 3.

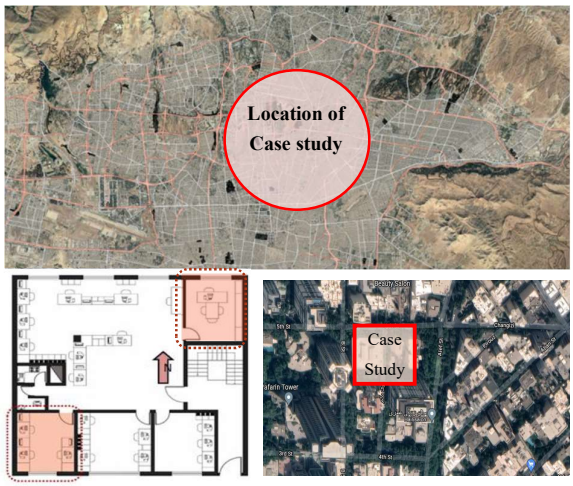

Figure 3. Location, site plan and plan of the building under study

The simulation of analyze was performed on an office space with 220 square meters of infrastructure, which consists of five separate office spaces. Two rooms with the same dimensions of 3 by 5 meters and a height of 2.80 meters, one on the south side and the other on the north side of the building, and only one wall is in contact with the outside environment, on which a window measuring 230 by 160 centimeters at a distance of one meter It is installed from the floor of the room. The material of the window is single-walled glass with a thickness of 6 mm and a transmittance of 60% visible light. The outer wall of the building is made of 30 cm thick brick and the inner walls and roof are simulated with 5 cm thick white plaster and the floor of the space is simulated with gray ceramics.

3. Results and Discussion

Findings from the simulation of energy consumption of office building in the studied views show that assuming that the ratio of window area to wall area is 40%, the energy consumption of the room in the northern zone is higher than the southern zone.

Regarding the effect of the type of views, it can be acknowledged that; In the case of a two-skin building, the

skin has a high heat capacity and acts as an insulator, so the cooling and heating load of the room relative to the base façade varies considerably. Now if the moving view replaces the two-skin view; the study room will face less cooling load than other facades. In other words, the moving view has a greater effect on the cooling load and the two-skin type view has a greater effect on the heating load than other views.

The study of the effect of the presence of canopies in the facade also shows that during the cold period for a double-skinned facade without a canopy, the amount of annual heating energy consumption in the office space will be zero While in the same period in the two-skin facade equipped with a canopy system, the temperature of the middle cavity decreases due to the reduction of direct solar absorption by the inner skin and the amount of heating energy consumption increases. During the heating period, the user provides the thermal comfort of the environment by adjusting the canopy and opening it at a fixed angle. In fact, in such scenes. Receiving the sun's heat and penetrating it into the building during the day will not result in anything but increasing the internal heat of the building and thus increasing the cooling cost. But if the moving view replaces the two-skin view, in this case it will have the greatest effect on reducing the cooling load. Because the Kinetic facade operates intelligently and adjusts the canopy environment by considering the light and brightness in such a way that while preventing glare in the space, it also avoids creating a cooling load. For this reason, to further reduce the cooling and heating load of the room, the use of a Kinetic facade in the building is recommended, which has a greater effect on reducing the heating load. Table 1 shows the reduction of cooling, heating and electric lighting loads in the studied facades with the presence of canopies. The values in this table indicate that using a two-skin view instead of a single-skin view can reduce energy consumption by about 30.67%. If the moving view replaces the two-skin view, this reduction will reach 40.5%. The findings of this analysis indicate the proper and optimal performance of the moving view in reducing the amount of energy consumed.

Table 1. The amount and percentage of annual reduction in energy consumption in the studied models

Reduction of energy consumption / studied facades		Double skin façade with canopy	Kinetic façade
Cooling load	Percentage	**37.47**	**40.44**
	kWh/m^2	**-1015.17**	**-1095.37**
Heating load	Percentage	**23.89**	**39.24**
	kWh/m^2	**-711.83**	**-1169.08**
Electric lighting load	Percentage	**0**	**61.8**
	kWh/m^2	**-6.62**	**-444.81**
	Percentage	**26.85**	**42.29**
Total energy consumption	kWh/m^2	**-1720.38**	**-2709.26**

4. Conclusions

In hot and dry climates, protecting the building from receiving light and heat energy from the sun is one of the first steps to create thermal comfort for residents and users. Therefore, determining the most suitable façade system for office buildings that impose the least energy load on the building in terms of energy consumption was the main concern of the present study. In order to achieve the best option, the thermal behavior of four single-skin facade systems with fixed canopies, two glass skins, two skins with movable canopies and movable facades was investigated to calculate its effects on the energy consumption of the building. After simulating the studied facades in the climatic conditions of Tehran and performing thermal analyzes on them in both the northern and southern fronts of the building, the results of the analysis were presented in the form of monthly and annual graphs of cooling, heating and electrical lighting loads. Examination of the obtained values from these diagrams showed that the use of two-skin facade and Kinetic facade reduces energy consumption in the building. Meanwhile, the effect of the moving view in this reduction is much more than the two-skin view. Although the use of double-skinned facades in both types (all glass and with canopies) increases the light load, but its effects in reducing the heating load are very significant. This type of facade, by meeting the heating needs of the building during the cooling period, provides more favorable conditions than the single-skin facade. Animated view also; With the ability to adjust its components such as the direction of rotation, the amount of opening and closing and according to the environmental conditions of the desired climate, the amount of light and heat entering the building and by reducing light and energy loss and glare control, Provides user comfort. This type of facade reduces the amount of energy consumption in the building by increasing the absorption of solar energy in winter and decreasing its absorption in summer. Other results of the present study include the effect of canopies in reducing energy consumption, which if the canopy is mobile, the amount of this reduction will be much more than the fixed canopy.
In a general conclusion, the thermal performance of the Kinetic facade can be evaluated as favorable compared to other facades studied in this research, the idea of using this type of facade can be a good way to optimize energy consumption.

5. References

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