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Research Article

Investigation of Thermal and Energy Performance of Double Skin Facades in Hot Climate Regions in Turkey

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Keywords

Double skin facades, Energy performance, Energy saving, Architectural design decisions.

Abstract

Double-skin facade systems are essential to minimize energy losses and provide maximum efficiency from the energy used. In this study, a corridor-type double-skin façade system was applied to the south front of the fifth floor of a five-story office building designed in Alanya, Antalya, in the hot climate region of Turkey. In addition, the usefulness of double skin facade systems in hot climate regions is determined by evaluating thermal and energy performance comparatively over three different parameters: material type, cavity widths between the two walls, and window opening ratios on the facade. This research is aimed to raise awareness around the comparative use of brick walls, wood, and composite panels with opaque qualities within the scope of material, with 1 m, 1.5 m, and 2 m as the width of the gap between the two walls. For all materials, thermal performance and energy performance decreased as the window opening ratio on the facade increased and as the cavity between the two walls decreased. However, worse performance was observed in the use of wood because of the low U- Value compared to the single-skin façade (SSF) building. In contrast, excellent performance was seen in using brick walls and metal panels compared to the SSF building, and overall, the metal panel showed the best performance. In the metal sample with a WWR of ten percent, the most significant reduction (27%) in annual cooling load can be seen.

1. Introduction

The construction sector has a significant impact rate of 50% on natural resource consumption and is directly effective in degrading the natural environment [1]. In Turkey, approximately 43% of the total energy consumption is used for industry, 37% for construction, and 20% for transportation [2-5]. The energy demand of the built environment is proportionally great and is increasing day by day. It is possible to say that a significant part of the energy is spent on air conditioning systems in the form of heating, cooling, and ventilation in buildings. With the increase in energy consumption on the planet, energy resources decrease, energy costs increase, and energy saving becomes critical.

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In addition to responding to human needs in the best way, buildings need energy-efficient, ecological, variable, and comfortable designs that rely on technological developments [6-12]. Obtaining maximum efficiency from energy use and keeping energy losses to a minimum are the main objectives of the building envelope system research. In addition, providing optimal comfort conditions in the indoor environment has prepared the ground for double-walled systems with improvements in construction and material technology. Double-skin façade (DSF) systems, which depend on many design decisions, are becoming widespread globally and bring positive features for thermal and energy performance. Due to its effect on thermal performance, DSFs are usually designed with glass, which provides an advantage in cold climates, but is not considered a good solution because it causes overheating in hot climates. For this reason, it is more appropriate to use opaque materials as outer wall material in hot regions. In the literature, there are various studies on the application of DSFs in hot climates. Double-skin façades (DSFs) have been offered as an efficient option for controlling interactions between internal and external environments among the emerging advanced façades [13-25]. Thermal performance and energy performance of hybrid DSFs were evaluated by Goes and Silva [26] in Brazil and Abdul Majid and Ghazali [27] in Malaysia, while double skin facade energy performance in hot-humid climate was examined by Göksal Özbalta and Yıldız [28], and Alakavuk [29], who examined an approach that can be used for the design of double-skin glass facade systems in hot climate regions; Alakavuk's evaluation in the province of Izmir are among the DSF studies in the literature. According to studies by [19, 30-33], tropical climates have a greater danger of the DSF's outer warming. Rahmani et al. [34], Torres et al. [35], Radhi et al. [36] , and Ahriz et al. [37] have investigated the effects of the DSF's cavity depth on the amount of solar heat passed through the cavity and the consequent temperature and airflow rates produced. According to the findings, regulating solar gain and heat transfer may be achieved by optimizing the cavity size between 0.7 and 1.2 m. And in the case of materials, The best technique to lower cooling demands is through the screen's optical characteristics, especially SHGC and U-value [36, 38-40] . However, literature on the application and study of DSF systems in hot and humid climate regions is insufficient and has not found much application in Turkey. From this point of view, in this study, the effect of design decisions in the form of window opening ratios on the façade and ventilated cavity widths between the two walls on thermal and energy performance are discussed with an emphasis on DSFs in hot climate regions.

1.1. Purpose and Scope

People spend most of their time in their work areas, and energy saving is very important in working environments within the scope of a sustainable life. For this reason, office buildings from the building groups were preferred within the scope of the study. It was assumed that the office building was designed here by choosing the province of Antalya, Alanya, a hot climate region in Turkey.

In the study, a corridor-type DSF system was implemented by applying ventilation grilles in the form of an external air curtain on the south facade of a five-story office building. This is thought to provide the best data performance in hot climates. Three different parameters were considered for comparison: the outer wall material, the cavity width between the two walls, and the window opening ratio on the façade. Brick walls, wood, and metal panels, all widely used in Turkey, were used as the exterior wall materials.

In this study, variable parameters for the thermal and energy performance of the building, within the framework of the design decisions, such as the window opening ratios on the facade, the type of outer wall materials to be selected as opaque, and the cavity width between the walls, of a five-story office building planned to be built in Alanya, Antalya province, a hot climate region in Turkey. These factors were used for the evaluation. In addition, data on design criteria will be obtained at the point of dissemination of research and applications of DSF systems in hot climate regions.

2. Methodology

In the study, first of all, a comprehensive literature review on DSF was done. Subsequently, an energy performance analysis of the building was modeled using the EnergyPlus simulation program in DesignBuilder [41], and the study was completed in five stages (Figure 1).

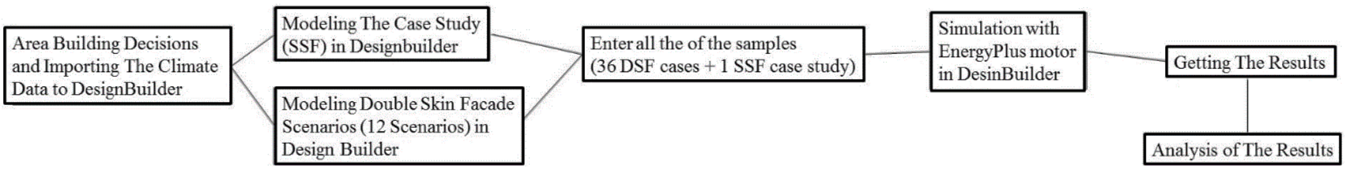


Figure 1. Study flow chart

First, the parameters for the area and climate of the building to be modeled in a hot climate were determined. In this context, it was decided to use an office building to be built in the Alanya district of Antalya province, which is located in the first-degree day zone. Figure 2 shows the annual climate data of the Alanya district (imported from [42]). Outdoor dry bulb temperature (°C), outdoor dew point (°C), direct solar radiation (kW/m²), and diffuse solar radiation (kW/m²) show high values in summer, while atmospheric pressure (Pax10^) 3) have higher values in winter. However, wind speed (m/s), wind direction (°), sun height (°), and sun azimuth angle (°) vary by month.

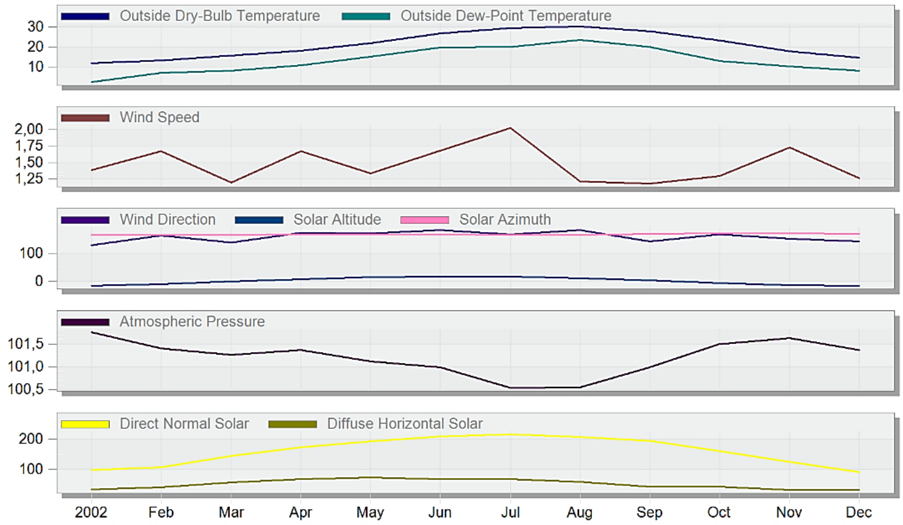


Figure 2. Annual climate data of the Alanya district of Antalya province.

In this context, the office building was modeled, and the parameters to be compared were processed separately in a module. Afterward, data were obtained on the window opening ratio on the façade, the wall material, and the variation of the cavity width between the two walls. The comparative results of these data were obtained, the results were analyzed, and the study was completed.

In the study, comparisons were made on DSF system design decisions over three different parameters. The outer wall material is in the form of the cavity width between the two walls and the window opening ratio on the façade. As the basic model, a five-story high mid-rise office building positioned in an east-west direction was designed according to the climate data of Alanya district (Figure 3). The walls in the building are made of brick, and Low-E Glass is used in the windows. While the building is mechanically ventilated, mechanical ventilation is not provided in December, January, and February, and ventilation is not provided from the vents. While the heating system of the building works with gas energy, the cooling system uses electrical energy. However, the heating system is off between April and September, and between December and February, the cooling system is off. When the air temperature in the office rises to 32 °C, the cooling system comes on; when it drops to 13 °C, the heating system comes on. The office building has been designed to be approximately 18.5 m² per person, and a maximum of 8 people work in the units on the south façade. The staff take five days off a year and are in the office between 08:00 and 18:00 on other days. However, computers, office equipment, and other devices are also in operation.

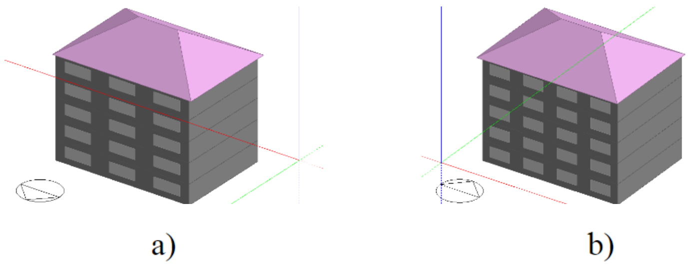


Figure 3. Office building: basic building model a) northwest direction, b) southeast direction.

The general floor plans are 17x24 m, the units oriented to the north are divided into 3, every 6x8 m in length, and the unit on the south-oriented façade is arranged as an open office with dimensions of 6x24 m. The east and west facades are designed as deaf facades; there are no window openings, while there are window openings on the north and south facades. The windows are a height of 1.80 m and are positioned 1 m from the ground (Figure 4).

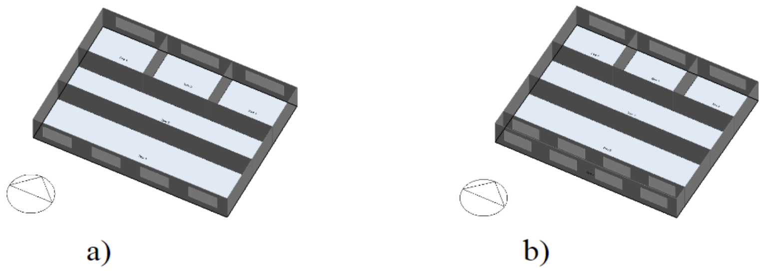


Figure 4. Office building a) Floor plan model, b) DSF application model

In the study, a corridor-type double wall was applied on the south façade of the five-story office building, which is thought to provide the best data performance due to the office building's location in a hot climate zone, and simulation analysis was performed on the unit used as an open office on this facade. Since it is thought that the joint air circulation between the floors without interruption can cause the facade to overheat in this region, the multi-story DSF system was not preferred. In this study, the width of the cavity between the two walls was handled in three different ways and was determined as 1 m, 1.5 m, and 2 m. Brick, wood, and metal panels, which are widely used in Turkey, were tested as the outer wall material for the DSF, and the material section taken from the DesignBuilder program is given in Figure 5.

a) b) c)

Figure 5. Sections of the outer wall materials used in the DSF: a) brick, b) wood, c) metal panel.

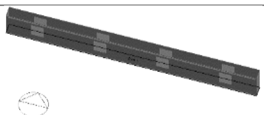
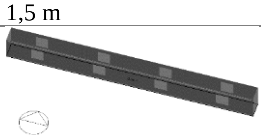
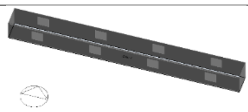
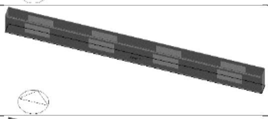
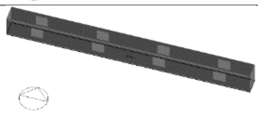
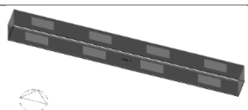
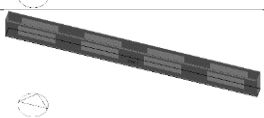
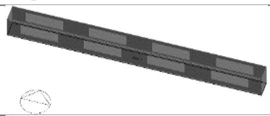
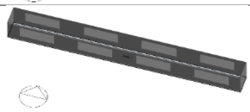
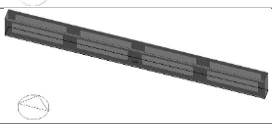
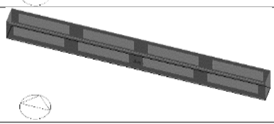
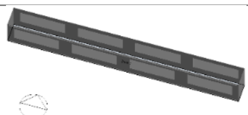
Ventilation types differ according to the outdoor conditions and according to the openings on the interior and exterior façades; these systems; air evacuation system, air supply system, static buffer zone, external air curtain, and internal air curtain, are examined under five headings. In this study, vents were applied as external air curtains to minimize the excess heat of the façade as a form of ventilation. Within the scope of the study, the material thicknesses and U values obtained from the DesignBuilder program of the brick, wood, and metal panel used in the double walls of the basic office building model are shown in Table 1.

Table 1. The thickness and U values of the materials used in the DSF office building.

Material	Thickness (m)	U Values (W/(m².K))
Brick wall	0,268	0,563
Wood	0,013	3,896
Metal Panel	0,235	0,286

A 30% window opening rate was used for each unit on the north façade, and natural light was provided to the spaces. On the south façade, the window opening ratios were a minimum of 10% to ensure that the interior receives natural light and a maximum of 40% to keep the ratio of opaque surfaces on the facade higher than the transparent surface ratio in order to prevent the building from overheating, 10%, 20% on the inner and outer walls; the Window to Wall Ratio (WWR) was 30% and 40%. However, ventilation vents have been applied to the façade in the form of an external air curtain. (Table 2).

Table 2. South front DSF designs developed depending on the cavity width between the two walls and the window opening ratios on the facade.

Facade Designs		Width of Space Between Two Walls		
		1 m	1,5 m	2 m
Window opening ratio on the facade	10%			
	20%			
	30%			
	40%			

3. Results

A DSF system was applied to the south façade of the office building designed in Alanya, which is located in the first-degree day zone, using brick, wood, and metal panels, which are widely preferred in Turkey. Window openings of 10%, 20%, 30%, and 40% were applied on the inner and outer walls of the south facade, and thermal performance and energy performance were analyzed by leaving 1 m, 1.5 m, and 2 m wide cavities between the two walls. While the heating of the building is provided by gas energy, electrical energy is used for cooling. In the evaluation of energy performance, the electricity of the units (Wh/m²), system fans (Wh/m²), system pumps (Wh/m²), auxiliary energies (Wh/m²), heating energy (gas) (Wh/ m²) and cooling energy (electricity) (Wh/m²), total energy consumption is taken into account. In this context, the focus is on cooling energy consumption and thermal performance, and energy performance in total energy consumption. It is noted that lighting is not considered in this research.

The thermal performance and energy performance of the building before any DSF design was added to the office building are shown in Table 3. Heating energy is not used between April and November in the building, and cooling energy is not used between December and February. The lowest heating energy consumption is in March, and the highest consumption is in January. On the other hand, while the lowest cooling energy consumption is in April, the highest consumption is observed in August. Considering the total energy consumption, the lowest is in December, while the highest is in August.

Table 3. Energy consumption of an SSF office building

	Heating (Wh/m²)	Cooling (Wh/m²)	Total (Wh/m²)
January	570,7425	0	6537,346
February	22,66483	0	5711,932
March	2,683435	1021,363	7468,581
April	0	969,0313	6582,602
May	0	1526,774	7974,549
June	0	2424,673	8631,889
July	0	3022,667	9149,95
August	0	3881,984	10347,01
September	0	3252,06	9363,412
October	0	1710,353	7926,507
November	0	1161,286	7356,235
December	11,96844	0	5638,47

As a result of the application of a DSF system with a cavity width of 1 m between the two walls and the outer wall of which is made of brick material to the south facade of the office building, the cooling energy consumption in the whole building is doubled, depending on a WWR of 10%, 20%, 30%, or 40%. The consumption values before cladding are shown in Figure 6. According to the graphic, it has been determined that the DSF building designs applied with 10% and 20% WWR on the facade showed better performance than SSF building throughout the year. Compared to an SSF building, the best thermal performance was found at 10% facade opening, and there was a positive performance difference of 20% throughout the year. These two front opening ratios provided better performance, especially in the hottest months. On the other hand, at a 30% window opening rate, better thermal performance was seen in May and November than in an SSF building. However, at a 40% window opening rate, there was more cooling energy consumption than in an SSF building, and it has been determined that the thermal performance is not better than an SSF building, unlike other WWR percentages.

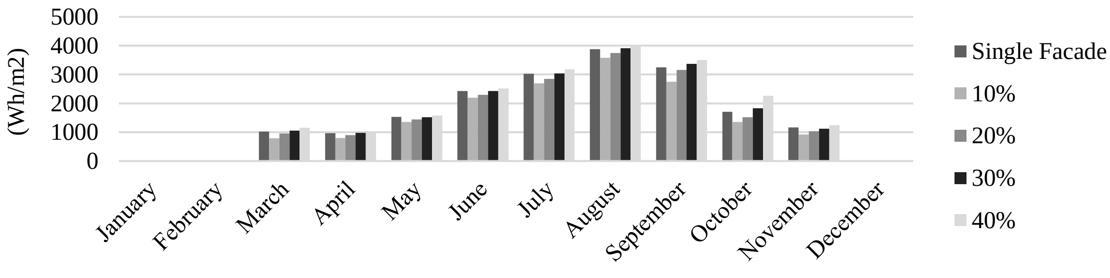


Figure 6. Cooling energy consumption of the DSF office building with a brick wall according to the facade window opening ratios of 1 m cavity width.

According to Figure 7, the thermal performance of the DSF building, applied with 10% and 20% WWR, shows better thermal performance throughout the year, especially in the hottest months, compared to the SSF building, and the best performance was seen especially in the hot summer months at 10% opening rate. At a 30% window opening rate, better thermal performance was seen in May, June, August, and November compared to the SSF facade, and cooling energy consumption was higher at 40% throughout the year, unlike other opening rates.

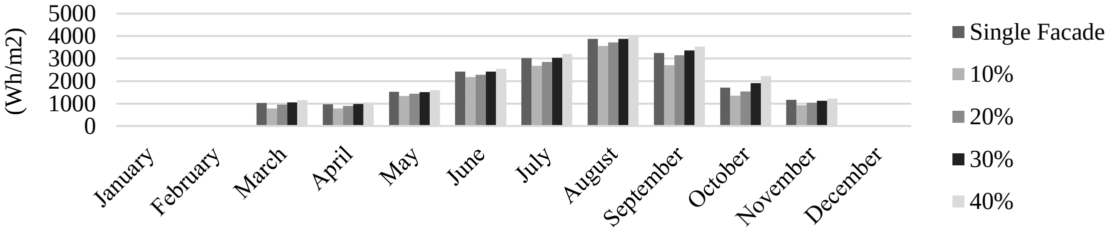


Figure 7. Cooling energy consumption of a DSF office building designed with a brick wall according to the façade window opening ratios of 1.5 m cavity width.

As a result of the application of a DSF system with a cavity width of 2 m between the two walls, the outer wall of which is made of brick material, and depending on the WWR of 10%, 20%, 30%, and 40%, the cooling energy consumption in the whole building and the pre-double wall consumption values are shown in Figure 8. According to this, the best thermal performance was found at a 10% window opening rate throughout the year, especially in the hottest months, and better thermal performance was seen compared to an SSF building with less cooling load consumption all year at a 20% window opening rate. On the other hand, 30% better thermal performance was determined throughout the year, except for the months of September and October. At a WWR rate of 40%, worse thermal performance was seen compared to the SSF building.

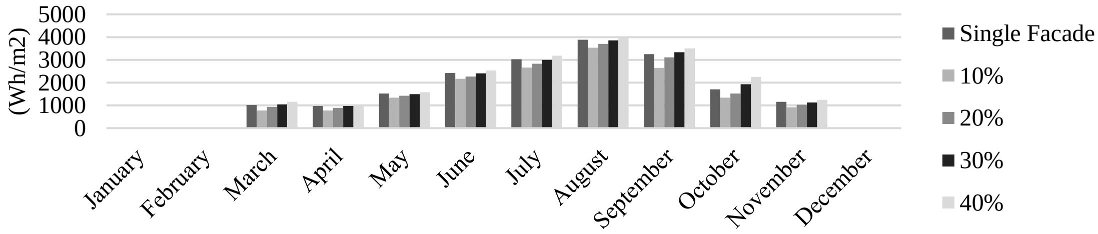


Figure 8. Cooling energy consumption of a DSF office building designed with a brick wall according to the façade window opening ratios of 2 m cavity width.

According to Fıgure 9, better thermal performance than the SSF was observed with a window opening rate of 10% only in November, and worse thermal performance than a single-skinned building was observed throughout the year at WWRs of 10%, 20%, 30%, and 40%.

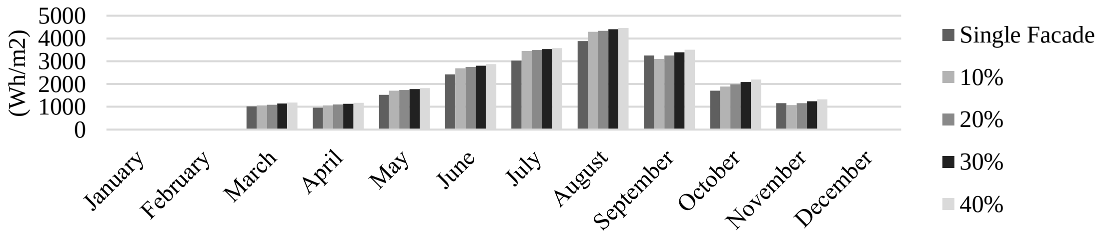


Figure 9. Cooling energy consumption of a DSF office building designed with wood material, according to the façade window opening ratios of 1 m cavity width.

According to Figure 10, better thermal performance was observed in September and November with a 10% window opening rate and better thermal performance in November with a 20% rate. On the contrary, better thermal performance was observed between 10% and 20% in other months and 30% and 40% in the year. Thermal performance was determined to be worse than that of a single-skinned building throughout.

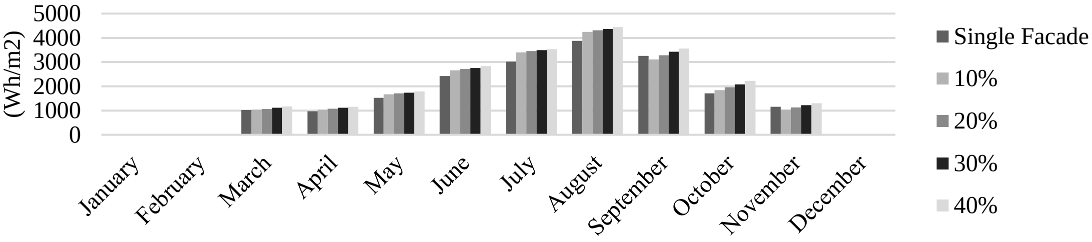


Figure 10. The cooling energy consumption of the DSF office building with wooden material, according to the façade window opening ratios of 1.5 m cavity width

According to Figure 11, better thermal performance was determined than the single-skinned facade in September and November at a 10% window opening rate and in November at 20%. Apart from this, at WWRs of 10%-20% in other months and 30%-40% were seen to be worse in thermal performance in the year-round single-walled façade.

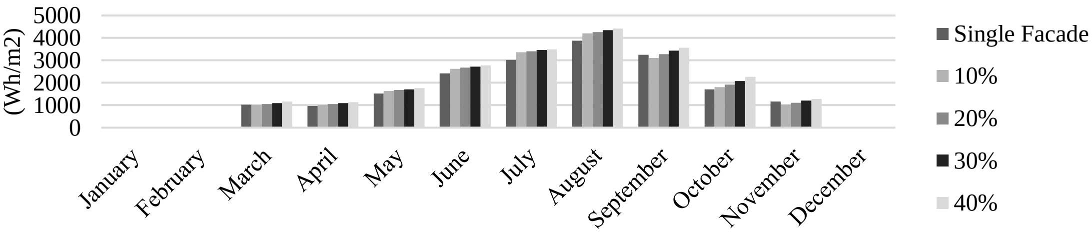


Figure 11. The cooling energy consumption of the DSF office building with wooden material, according to the façade window opening ratios of 2 m gap width.

According to Figure 12, the thermal performance of the DSF building, applied with 10% and 20% WWR, provided better thermal performance throughout the year compared to the single-skinned building, and the best performance was seen especially at a 10% opening rate in the hottest months. While 40% performance was worse than the single-skinned building throughout the year, 30% better thermal performance was detected only in December, and worse performance was detected in the other months.

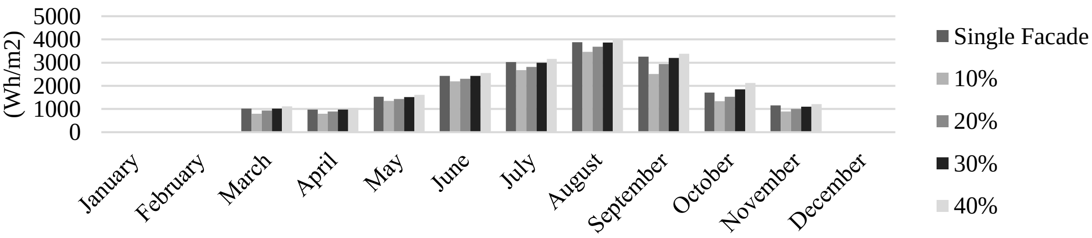


Figure 12. The cooling energy consumption of the DSF office building with metal panels, according to the façade window opening ratios of 1 m cavity width.

The outer wall consists of metal panels, and the cavity width between the two walls is 1.5 m. As a result of the application of the DSF system to the south façade of the office building, cooling energy consumption in the whole building doubled according to WWRs of 10%, 20%, 30%, and 40%. The consumption values before the wall are shown in Figure 13. Accordingly, while the best performance was seen at a 10% opening rate, especially in the summer months, the thermal performance of the DSF building, which is applied with 10% and 20% WWR, provides better thermal performance throughout the year than the single-skinned building. Better thermal performance was observed in May, June, July, August, and November at a rate of 30% compared to a single-skinned building, and at this rate, worse performance is detected in other months and 40% throughout the year.

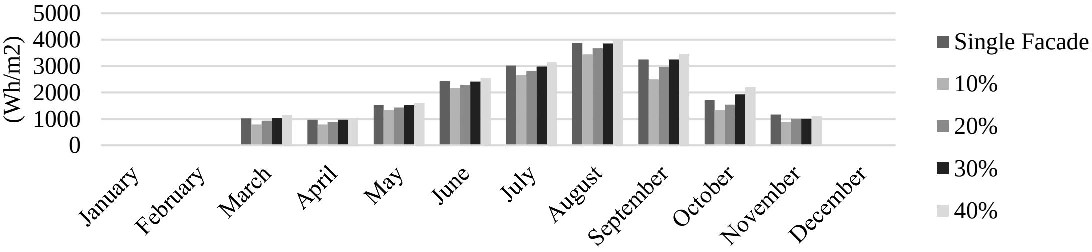


Figure 13. The cooling energy consumption of the DSF office building with metal panels, according to the façade window opening ratios of 1.5 m cavity width

With the application of the DSF system, whose outer wall is made of metal panels and whose cavity width between the two walls is 2 m, applied to the south façade of the office building, the cooling energy consumption in the whole building is determined by the 10%, 20%, 30% and 40% WWR. The consumption values before it is made are shown in Figure 14. According to the graphic, while the best performance is observed at a 10% opening rate, especially in the hottest months of the year, the thermal performance of the DSF building applied with 10% and 20% window opening ratios provided better thermal performance than the single-skinned building in all months of the year. While 30% worse thermal performance was detected only in March and November compared to a single-skinned building, better performance was seen in other months. Contrary to the others, 40% showed the worst performance analysis throughout the year.

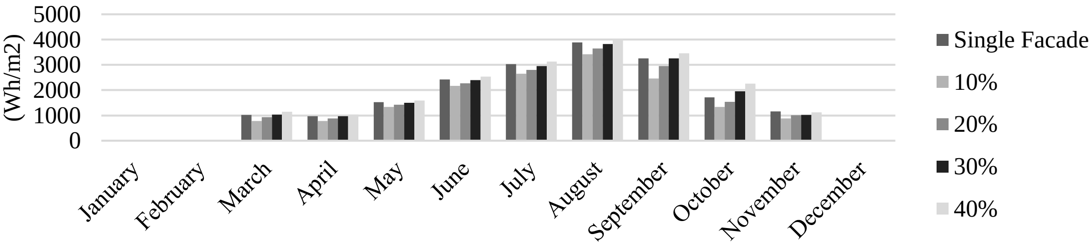


Figure 14. The cooling energy consumption of the DSF office building with metal panels, according to the façade window opening ratios of 2 m cavity width.

According to Figure 15, the total energy performance between December and February shows approximately equal performances in single-skin and DSF buildings. It has been determined that DSF building designs applied with 10% and 20% WWR on the facade show better performances in spring and summer compared to single-skinned buildings, while the best energy performance is found at a 10% façade opening rate. Better energy performance was seen in the window opening rate of 30% in May and November compared to the single-skinned building, and 40% showed more energy consumption than a single-skinned building.

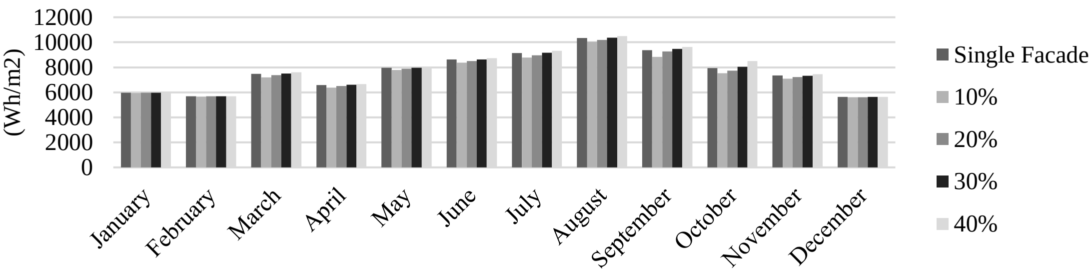


Figure 15. The total energy consumption of the DSF office building with a brick wall, according to the façade window opening ratios of 1 m cavity width.

The total energy consumption of the DSF office building with a brick wall at a cavity width of 1.5 m is shown in Figure 16, depending on WWRs of 10%, 20%, 30%, and 40%. The total energy performance in single-skin and DSF buildings between December and February showed approximately similar values. It has been determined that DSF building designs show better performance in spring and summer than single-skinned buildings at 10% and 20% window opening ratios on the façade, while the minor energy consumption is found at a 10% façade opening ratio. At a 30% window opening rate, better energy performance is observed in May, June, August, November, and December compared to a single-skinned building. At the rate of 40%, worse energy performance was determined compared to the single-skinned building.

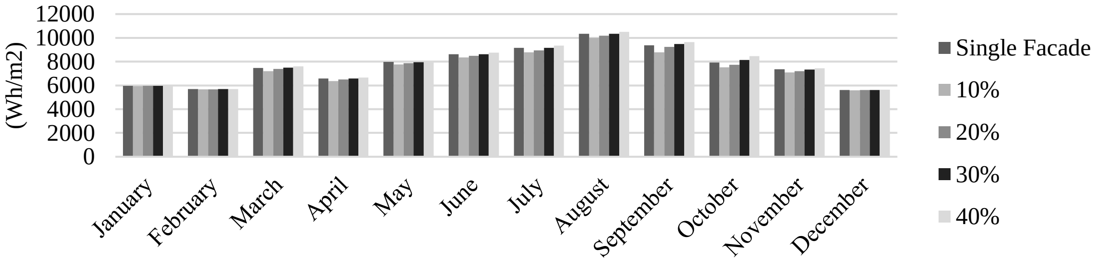


Figure 16. Total energy consumption of the DSF office building with a brick wall, according to the façade window opening ratios of 1.5 m cavity width.

The total energy consumption of the DSF office building designed with a brick wall with a 2 m cavity width is shown in figure 17, depending on WWRa of 10%, 20%, 30%, and 40% on the facade. Accordingly, approximately similar values were seen in total energy performance in single-skin and DSF buildings between December and February. While the best energy performance was found at the 10% opening rate, it has been determined that DSF building designs perform better than single-skinned buildings in spring and summer in both 10% and 20% WWR. At a 30% window opening ratio, worse energy performance is observed in September and October compared to a single-skinned building, while it performs better in other months. Regardless of the type of façade, at a rate of 40%, worse energy performance was poorer compared to the single-skinned building.

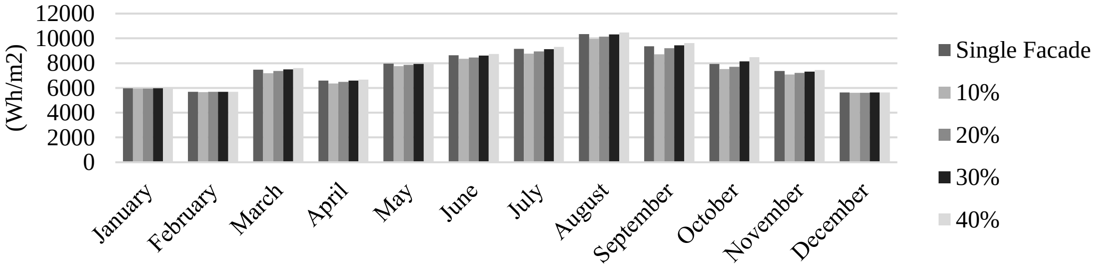


Figure 17. The total energy consumption of the DSF office building with a brick wall, according to the façade window opening ratios of 2 m cavity width.

The total energy consumption of the DSF office building designed with wood at a 1 m cavity width is shown in Figure 18 according to WWRs of 10%, 20%, 30%, and 40% on the facade. Better energy performance was seen compared to the SSF building in November at a window opening rate of 10%, while the energy consumption was 20%, 30%, and 40% higher than the single-skinned building throughout the year, except for this month, 10%.

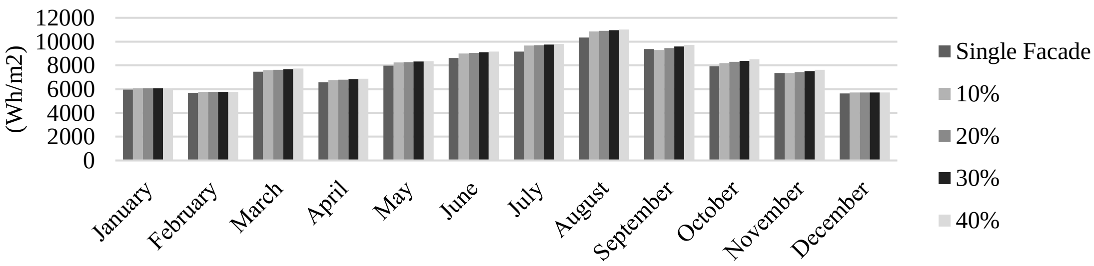


Figure 18. Total energy consumption of the DSF office building designed with wooden material, according to the façade window opening ratios of 1 m cavity width

The total energy consumption of the DSF office building made of wood, with a cavity width of 1.5 m, is shown in Figure 19 according to WWRs of 10%, 20%, 30%, and 40%. In this context, while better energy performance was seen compared to a single-skinned building in September and November at a 10% window opening ratio, 20%, 30%, and 40%, energy performance throughout the year was higher than that of a single-skinned building.

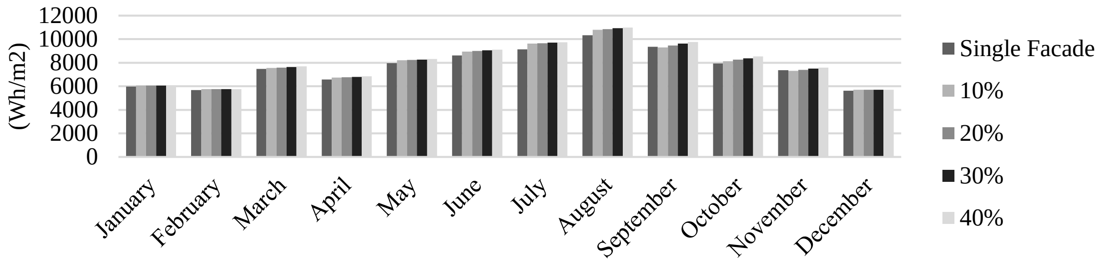


Figure 19. The total energy consumption of the DSF office building with wooden material, according to the façade window opening ratios of 1.5 m cavity width

The total energy consumption of the DSF office building, which was built using wood at a 2 m cavity width, is shown in Figure 20 according to the window opening ratios on the façade at 10%, 20%, 30%, and 40%. According to the graphic, less energy consumption was observed compared to a single-skinned building in September and November with only 10% façade openness, while 20%, 30%, and 40% energy consumption throughout the year was higher than that of a single-skinned building.

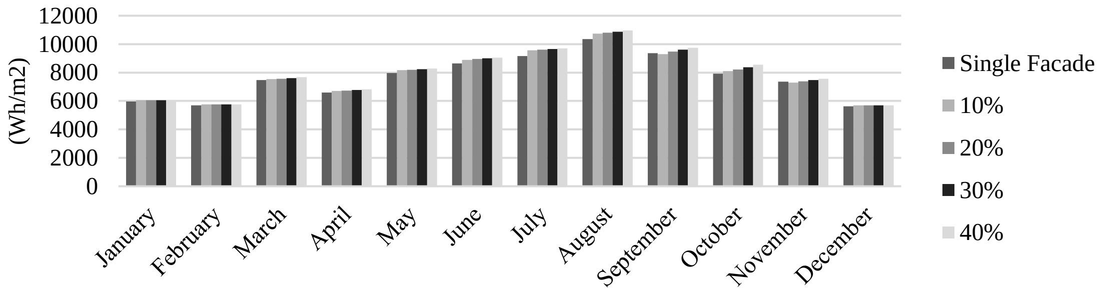


Figure 20. Total energy consumption of the DSF office building designed with wood material, according to the façade window opening ratios of 2 m cavity width.

According to Figure 21, approximate values are shown in total energy performance in single-skin and DSF buildings between December and February. While the best energy performance was found at a 10% opening rate, it was observed that DSF building designs performed better than single-skinned buildings in spring and summer at both 10% and 20% WWR. At the 30% window opening rate, less energy consumption was observed in May, June, July, August, and November compared to a single-skinned building, while it performed worse at 30% in other months and worse at 40% throughout the year.

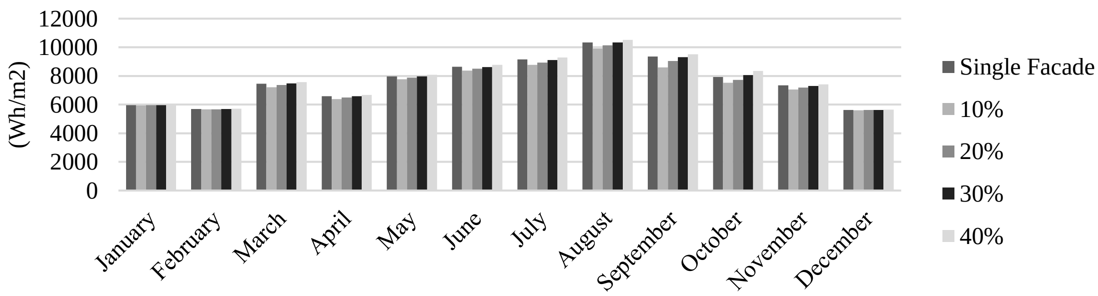


Figure 21. The total energy consumption of the DSF office building with metal panels, according to the façade window opening ratios of 1 m cavity width

According to Figure 22, it has been observed that there are approximately similar values in total energy performance in single-skin and DSF buildings between December and February. The DSF building designs with 10% and 20% WWR have lower energy consumption in spring and summer compared to single-skinned buildings, and a 10% facade opening rate showed the best energy performance. However, at a 30% window opening rate, less energy consumption was seen between May-August and November compared to a single-skinned building; except for these months, energy consumption was higher at 30% and 40% throughout the year.

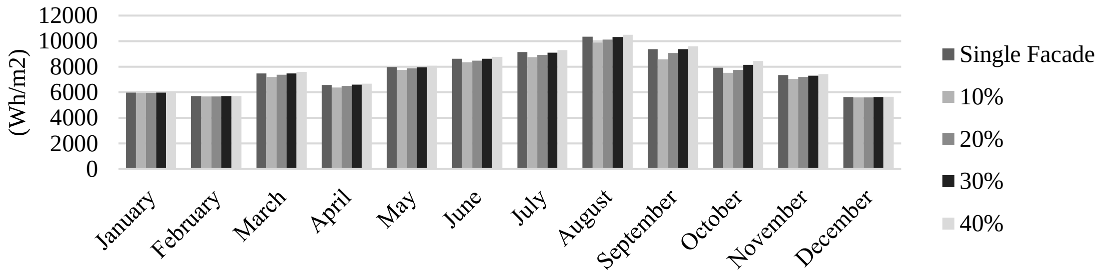


Figure 22. Total energy consumption of the DSF office building with metal panels, according to the façade window opening ratios of 1.5 m cavity width.

Within Figure 23, the energy performance of single-skinned and DSF buildings is approximately at the same level between December and February. While the 10% facade opening ratio has the best energy performance, 10% and 20% WWR had less energy consumption in DSF building designs in spring and summer compared to single-skinned buildings. On the other hand, there was a difference in the 30% ratio resulting in more energy consumption in October and March compared to a single-skinned building, and 40% showed worse energy performance throughout the year.

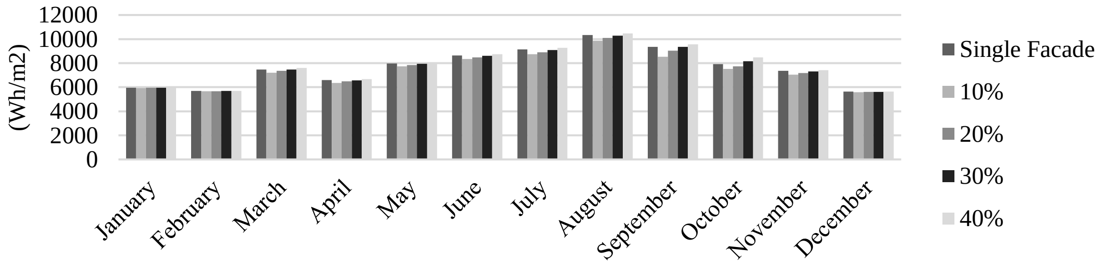


Figure 23. Total energy consumption of the DSF office building with metal panels, according to the façade window opening ratios of 2 m cavity width.

For the use of brick walls, wood materials, and metal panels on the outer wall, DSF designs were created by using 10%, 20%, 30%, and 40% WWR separately using cavity widths between the walls of 1 m, 1.5 m, and 2 m. Results are shown in the below figure. According to these, it has been determined that both the best thermal performance and the best energy performance are provided when 10% of the façade is open with a 2 m cavity width between the walls; these results were in common for all materials. In this context, it becomes possible to evaluate the effects of the materials that will provide the best thermal and energy performance on the building in a common denominator.

The comparison of the thermal performance of the DSF office building due to the use of the brick wall, wood, and metal panel as the outer wall material is given in Figure 24. While making the comparison, the width of the cavity between the two walls was chosen as 2 m, and 10% was used as the window opening on the façade. There is no cooling energy consumption in the office building during the winter months. According to the graphic, the best thermal performance compared to the single-skinned building was provided by the metal panel. It performed very well, especially in the hot summer months. However, the brick wall performed relatively close to the metal panel compared to the single-skin building. Wood material, on the other hand, consumed more cooling energy than a single-skinned building and performed worse than the other two materials.

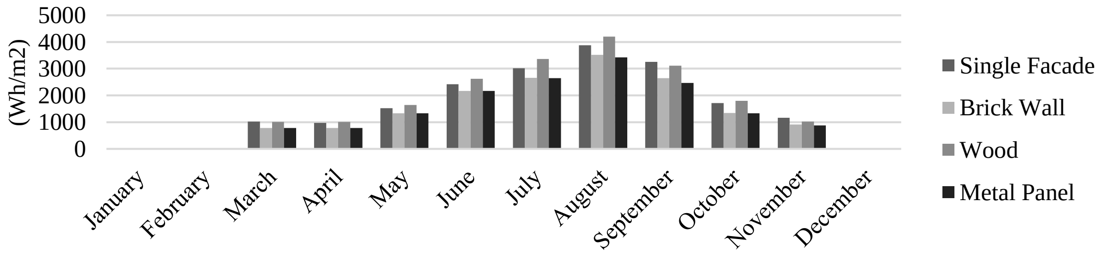


Figure 24. The effect of the use of brick walls, wood materials, and metal panels in the outer wall material on the cooling energy consumption of the DSF building.

According to Figure 25, between December and February, the SSF building and the brick wall, wood, and metal panel had approximately similar performances, while the worst performance was observed in wood materials. While the metal panel showed the best energy performance, the brick wall had a performance close to the metal panel and less energy consumption than the SSF building. In September and November, the wood material also showed a better energy performance compared to the SSF building; however, except for these two months, the energy consumption of wood material was higher than that of the SSF building.

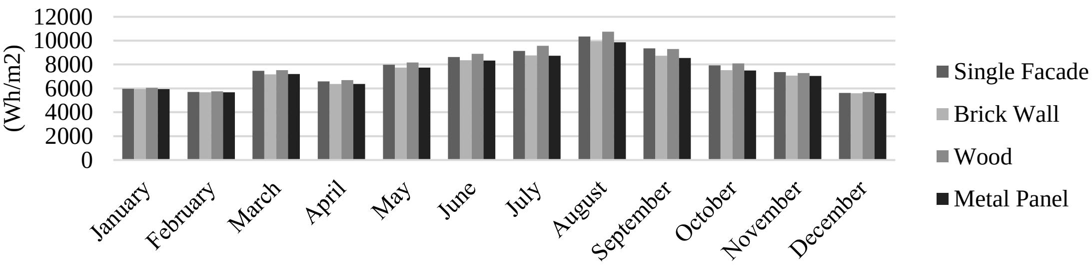


Figure 25. The effect of the use of brick walls, wood materials, and metal panels in the outer wall material on the total energy consumption of the DSF building.

4. Conclusion and Discussion

The problem of increasing the use of DSFs to become widespread in hot climates has been due to the inconvenience of using glazed DSFs in hot climates. Considering that the lighting is not included in the research, each design decision taken in the application of DSF systems has significant effects on the thermal and energy performance of the building. It is concluded that the fact that a façade surface that consists of opaque surfaces at a higher rate than the glass has a measurable effect on energy saving by improving the thermal and energy performance of buildings in hot climates, and the use of suitable material becomes one of the most critical design decisions. Findings from this study and other studies demonstrated that choosing the right material for the skins of DSFs may be done most successfully using a material's optical qualities, such as SHGC, U-value, reflectivity, and opacity. According to all of these issues, the results show that;

- In the brick example, the cooling load of the SSF building is 18,970 Wh/m^2, and in the case of double-walled buildings, this amount is reduced by 20% in three cases with a WWR of 10%. The results show that the amount of cooling load decreases as the distance increases, but this decrease is not significant. Due to not considering any shading factor, according to the results obtained in the hot and humid climate of Analia, in cases with a WWR of 40%, the amount required for cooling the building is up to 6% higher than in the single-paned case.
- In using brick walls and metal panels as exterior wall materials, it has been determined that the thermal and energy performance of the DSF building throughout the year is better than that of the SSF building, regardless of the cavity widths between the two walls and at a WWR rate of 10% and 20% of the façade window openings. At a 30% window opening rate, better performance was observed compared to the SSF building only in some months, and at a 40% window opening rate, worse performance was observed compared to the SSF building. In the use of wood materials, there is generally more cooling energy and total energy consumption in each design compared to an SSF building.
- In the wooden case sample, the amount of annual cooling load required in all cases is higher than in the main case sample, with the difference that this amount is lower than all others in the WWR of 10% with a cavity of 2 meters and by 5%. And the significant increase in the WWR is 40 percent, with a cavity of 1 meter by 15 percent.
- In the case of metal, except for DSF with 40% WWR, all cases have a lower cooling load than the case of the sample. This amount of reduction is due to not considering the issue of shading in the case WWR of 10%, and the cavity of 2 meters is maximum, the amount of this annual cooling load reduction is 26%.
- For all opaque materials, thermal and energy performance decreased as the window opening ratio on the façade increased, and thermal performance and energy performance increased as the cavity width between the two walls increased. The metal panel was seen to be the best performing outer wall material. Although wood is an opaque material, it has been found that the thermal and energy performance of a DSF building designed with the use of wood on the outer wall is worse than an SSF building, and it is not recommended to use wood material for the outer wall.
- However, to further improve the performance of the brick wall and metal panel materials, which are opaque outer wall materials that exhibit optimum thermal and energy performance compared to an SSF building, it is recommended to keep the cavity width between the two walls larger and the window opening ratio on the facade to be less than 30% if there is no shading device.

When designing DSF systems, each design decision should be considered separately, and the characteristics of the site where the building will be built should be considered. In this context, it is planned to carry out a comprehensive new study by analyzing lighting consumption and daylight analyses of the building to improve the results of the study and to consider the effect of window opening ratios on the façade of the building and the shading rate due to the cavity between two facades of DSF. It is thought that this study will create new perspectives on the applicability of DSF systems in line with various design decisions by addressing and helping mitigate the reasons why they are not preferred in hot climate regions.

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