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ARCHITECTURE INSPIRED BY THE BIOMIMCRY THROUGH A DOUBLE SKIN FACADE TO IMPROVE SUSTAINABILITY

Dr. TAREK IBRAHIM NASRELDIN

Associate Professor in Cairo University.

Dr. NASHWA YOUSSEF ABD ELHAFEZ

Associate Professor in the October High Institute for Engineering and Technology.

ENG. HANAA AHMED MOHAMED AHMED

Lecturer Assistant in Canadian International College.

Abstract

Humans have been surrounded by nature since their creation. Everything in the natural world is well-organized and harmonious. Nature is seen as a source of inspiration for humans in a variety of domains. Biomimicry is a new approach of seeing and appreciating nature that contributes to make the built environment resemble like living beings. The built environment is at the forefront of the discussion on how to reduce the environmental impact on the earth and its inhabitants and the exhaustion of the unrenewable resources. In the hot desert region, Double-Skin Façade (DSF) is a method that can achieve equilibrium between user demands and energy efficiency and thermal comfort. The purpose of this article was to investigate the effect of using a double skin façade instead of a single skin façade as the exterior of an office building in Egypt to improve building performance. Design builder software was used for modeling the existed case studies for cooling loads, energy efficiency and thermal comfort simulations. The effect of double skin façade introduction classified into three groups such as air cavity depth, shading devices and glazing types resulted in 8 modeled cases for examination. Each parameter is examined individually to be compared to the base case in each case study to determine its influence separately on the energy consumption performance. In all double skin façade types, results showed that all cases were successful and are better than the single skin façade. Shading devices added ameliorate the general building performance as well as the low e and reflective glass used as substitution of the existed tinted glass.

Keywords: Biomimicry, Double Skin Façade, Energy Efficiency, Thermal Comfort

1. Research Problem

In our days, there are few designs with an ecological goal for existing sustainably on earth, taking into consideration the environmental impact of their buildings on the environment surrounded and its resources. The simulation and imitation of nature is better than the desire to dominate it in order to begin an era based not on what we can extract from the nature ignoring the rights of the next generations, but on what we can learn and mimic it. Biomimicry is introduced to study and analyze the models of nature and imitates their designs for solving design problems.

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2. Research Goal

The research aim is to increase sustainability and decrease the environmental impacts of buildings on nature through studying the natural organism's behavior. The main goal is to create methodology for the development of the design inspired from nature. One of the goals of the research is to study and analyze the organisms of nature and imitates their form, structure, behavior and evolutions for solving design problems. Providing built environment similar to living organisms.

3. Research Hypothesis

Nature and its organisms are regarded as innovative, developed, and sustainable sources of inspiration for architects. The biomimicry ideas and concepts studied and drawn from nature will help to achieve unique and endless approaches and architectural solutions. By incorporating these ideas into the design process, the understanding of natural principles like evolution, optimization, and adaptability will help to improve architecture.

4. Introduction

The Nature with its huge toolbox is considered a great source of inspiration for engineers and scientists from various domains of interest. The natural organisms are characterized by their uniqueness and their ability of adaption to their environment. The evolution of Natural organisms takes place by meeting their need and discovering solutions for their problems that work. Today architects are looking for sustainable solutions to develop design processes and to decrease the environmental impacts of their buildings.

5. Theoretical Background

The biomimcry approach is considered nature as a teacher and guild to simulate and learn from it with its evolutions and experiences for billion years in addition to be a judge to evaluate our products introducing era where our thinking is shifted from resources exhaustion to natural instructions. It is a new discipline and science that studies nature's best principles and concepts and then imitates these designs and processes to solve human problems. The Biomimicry is the creation of innovative design solution and concepts by the simulation of various living organisms that they have evolved during the 3.8 billion years through learning from them and analyzing their way of acting.

In the biomimcry application, the design process is based on looking at nature, specifically organisms or ecosystems, to solve a particular human need or design problem. Converting these types of biomimetic strategies and principles considering as biological paradigm such as visual inspiration through form and behavioral and functional processes into design solutions is the lessons learned from nature.

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5.1 Biomimcry Approaches

The approaches in the biomimcry are classified into two groups.

5.1.1 Problem-Based Approach

In this approach, designers are required to define design problems, and then they look to the living world for solutions and treatments, they have to identify goals and parameters for the design taking into consideration what is required from the design. These goals and problems are corresponded and compared with organisms that solved the similar issues to learn from them.

5.1.2 Solution-Based Approach

The biological background and knowledge have an influence on the human designs, the benefits from the biological and ecological research and the biologists can be applied in the design process to solve problems and improve products. Looking to the natural organisms, act and adapt as they do then transform their way of behavior toward the whole ecosystem into solutions and treatments to humans problems

5.2 Biomimicry levels

There are three levels of biomimicry introduced as form, process and ecosystem (Biomimicry Guild, 2007). In the analysis of an organism or ecosystem, form and process are the characteristics that could be mimicked.

The first level is the organism level where the designer will study a specific natural organism such as a plant or animal, the level of mimicking refers to a part of it or the whole organism. It is a simulation for its external shape, form, color, material and texture. The second level concerns mimicking the behavior, reaction and adaption of an organism to the context surrounded in addition to the translation of their actions into solutions to the designs problems. The third level is the simulation of the whole ecosystems and the common principles that allow them to successfully work and evolve.

The biomimcry is characterized by the overlap between the different levels and dimensions, the whole ecosystem is mimicked as a whole system and in the same time the individual organisms inside this ecosystem are mimicked in the level of organism and its shape and form and the level or behavior and process.

5.3 Double skin façade

In building with high glazing skin, which is situated in high temperature areas, traditional facades confront several problems such as thermal comfort and natural ventilation. Double skin façade are applied in order to enhance the thermal energy performance of buildings facades distinguishing by high glazing fractions consisting of an offset of two layers of external and internal glazing combined into a curtain wall system in addition to a controllable shading system situated between the two glazing systems.

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The double skin facade has attracted a great attention due to its capability to diminish the solar heat gain according to the situation as well as its transparency and visibility characteristics, for the reason that it enables direct interaction with the surroundings and allows a considerable amount of sunlight to penetrate inside the building without glare.

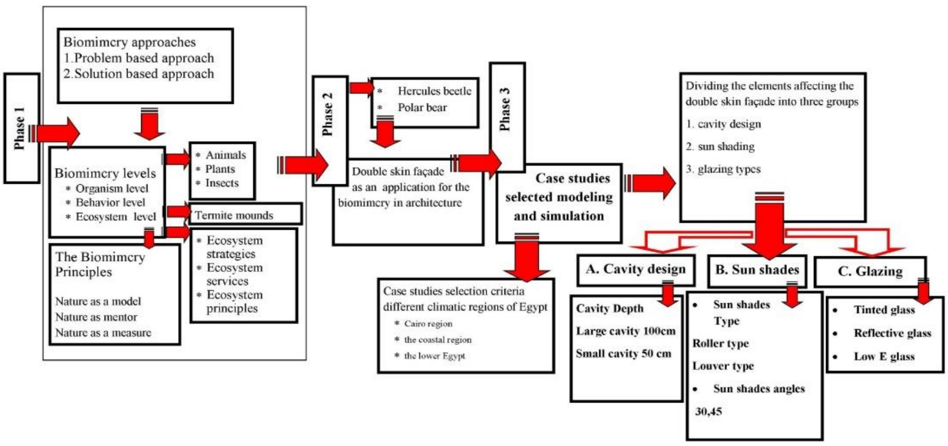
5.4 Methodology

The suitability of the double skin façade for Egypt's different climatic regions will be investigated through the use of its various parameters, which are classified into three groups: cavity depth, shading devices, and glazing types. The performance of the double skin façade will be assessed in terms of cooling loads, energy efficiency, and thermal comfort.

Three buildings in three distinct climatic areas, Cairo, costal region (Alexandria), and Upper Egypt (Aswan), are chosen to assess the double skin façade as a tool added to the elevation to improve building performance, energy efficiency, and thermal comfort for the people inside.

The three cases are simulated using Design Builder in order to evaluate the double skin façade performance with its different parameters to be compared with the single skin façade as the base case. In the simulation, each parameter was evaluated individually to study its effect on building energy performance to reach a set of guidelines for an efficient design of a double skin façade system in hot and humid climates.

Figure 1. Methodology chart



Source: researcher

The case studies description

Cairo's first climatic area was represented by the capital office building as the first case study. The National Bank of Egypt tower in Asswan represents the Upper Egypt climatic area in the second case. The coastal region, represented by the Alexa tower in Alexandria, is the third climatic area.

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In the first case, the capital office building consists of 6 floors with dimensions of 30 m x 20 m. In the second case, the National Bank of Egypt office building consists of 4 floors with dimensions of 15 m x 15 m. In the third case, The Alexa tower office building consists of 8 typical floors with dimensions of 20 m x 16 m. generally, the office building contains separate offices, meeting room, work stations, toilets and vertical circulations (stairs and elevators).

5.5 Double Skin Façade Simulation and Results

5.5.1 1st case

Capital Office Building

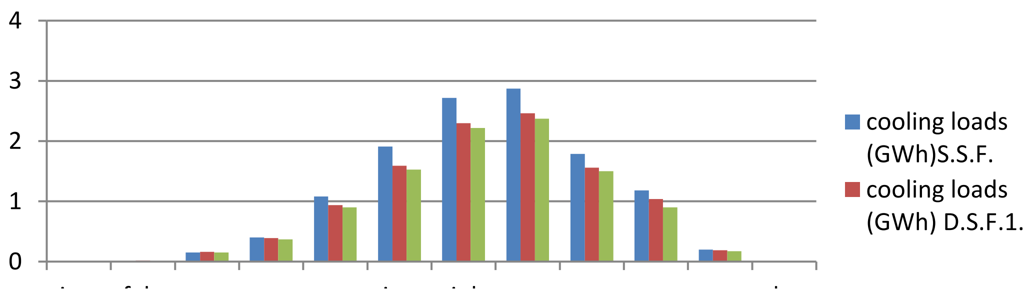
A. Group 1, Cavity Depth

The depth of air cavity applied in the double skin façade system among the three cases is classified as small air cavity and large one for a fixed corridor shape. The office buildings are simulated with their air cavity in each case study in the two cavities cases to be compared to each other in addition to be compared also to the single skin façade in order to evaluate the effect of air cavity depth of the double skin façade system introduced. The simulation outcomes concern the cooling loads monthly and annually, energy efficiency and thermal comfort the two double skin facades alternative with different air cavity depth are simulated through two varied thickness, small (50 cm) D.S.F.1 and large (100 cm) D.S.F.2. The two alternatives will be compared to each other besides to the single skin façade base case as followed in the next charts.

Table 1. Monthly cooling loads (gwh) for varied cavity depths

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
cooling loads (GWh) S.S.F.	0	0	0.15	0.4	1.08	1.91	2.72	2.87	1.79	1.18	0.2	0
Cooling loads (GWh) D.S.F.1.	0	0.02	0.16	0.39	0.94	1.59	2.3	2.46	1.56	1.04	0.19	0
Cooling loads (GWh) D.S.F.2.	0	0.01	0.15	0.37	0.9	1.53	2.22	2.37	1.5	0.9	0.17	0.01

Figure 2. Monthly cooling loads for office building with varied cavity depths



Source: researcher

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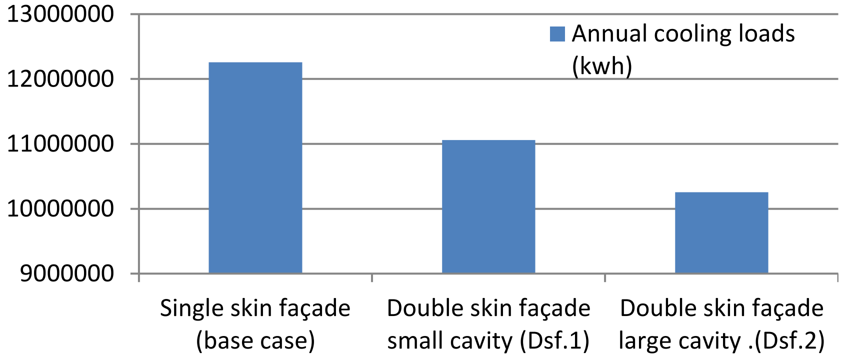
This chart is a comparison between the single skin façade and the two alternatives of double skin facades with various cavity depths in order to evaluate their performance concerning the monthly cooling loads. Obviously, the cooling loads are decreased in case of application of the two alternatives of double skin facades in respect with the single skin façade base case (S.S.F.). In addition to the cooling loads required is less in case of large cavity (D.S.F.2) than in case of small cavity (D.S.F.1).

Table 2. Annual cooling loads (gwh) for varied cavity depths

Skin type	Cavity width	Cooling loads
Single skin façade (base case) S.s.f.	none	12258705 kwh
Double skin façade small cavity (Dsf.1)	50cm	11058250 kwh
Double skin façade large cavity .(Dsf.2)	100cm	10256360 kwh

The annual loads for cooling required for the three alternatives studied are indicated in the bar chart, the single skin façade base case (S.S.F) and two alternatives for double skin façade (D.S.F.1, D.S.F.2) the simulation and analysis demonstrates that the minimum annual loads are needed in case of double skin façade with large cavity while for the double skin façade with small cavity are higher and the maximum are in case of single skin façade base case.

Figure 3. Annual cooling loads for office building with varied cavity depths



Source: researcher

The operative temperature is decreased and consequently the thermal comfort for the occupants inside enhances in the D.S.F.2 more than D.S.F.1. The analysis indicates that the introduction of double skin façade system instead of single skin façade decrease the temperature inside in the summer time in addition to the application of large cavity is better than use small one.

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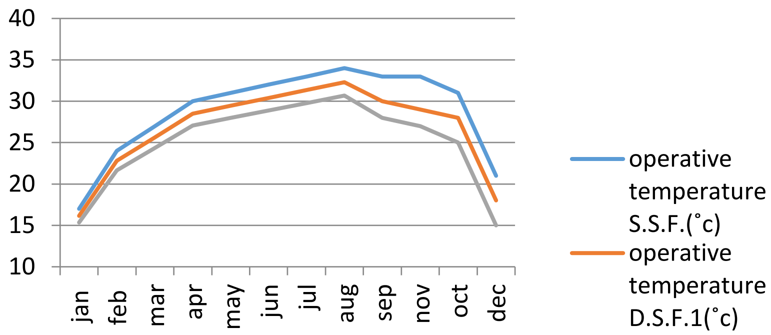
Figure 4. Operative temperature for office building with varied cavity depths



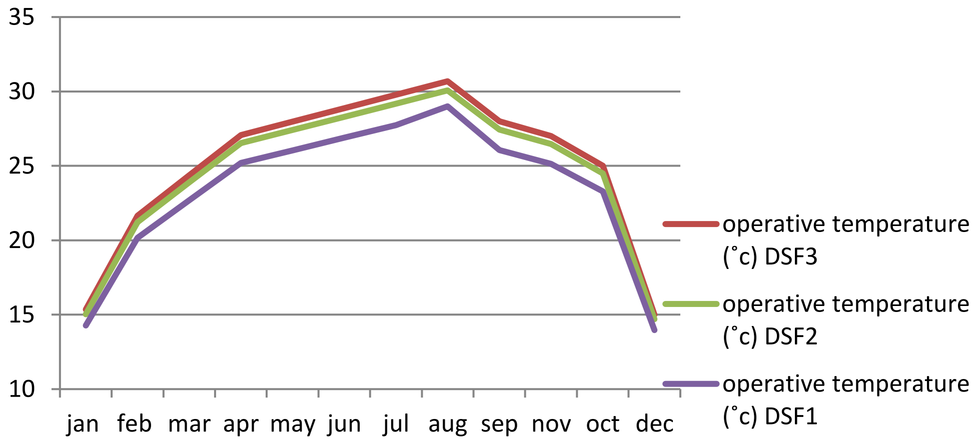
Source: researcher

B. Group 2 Shading Devices

The shading devices are introduced in the air cavity between the glass layers in the double skin façade systems in order to reduce the heat gain transferred into the indoor by employing shade devices. The louver shades type will be tested with its varied inclination angles as well as to the roller shades type to be compared to each other additionally to the base case where single skin façade is applied.

In the scenario of deploying shade devices, the operative temperature is reduced, and as a consequence, the thermal comfort for the occupants inside the office building improves. Generally, the building performance will enhance. . The analysis indicates that the introduction of roller shades (DSF 1) is better than louver shades (DSF 2, DSF 3). The 45 slatted inclination angle louver application (DFS 2) is effective than the 30 slatted inclination angle louver (DSF 3).

Figure 5. Operative temperature for office building with varied shading devices



Source: researcher

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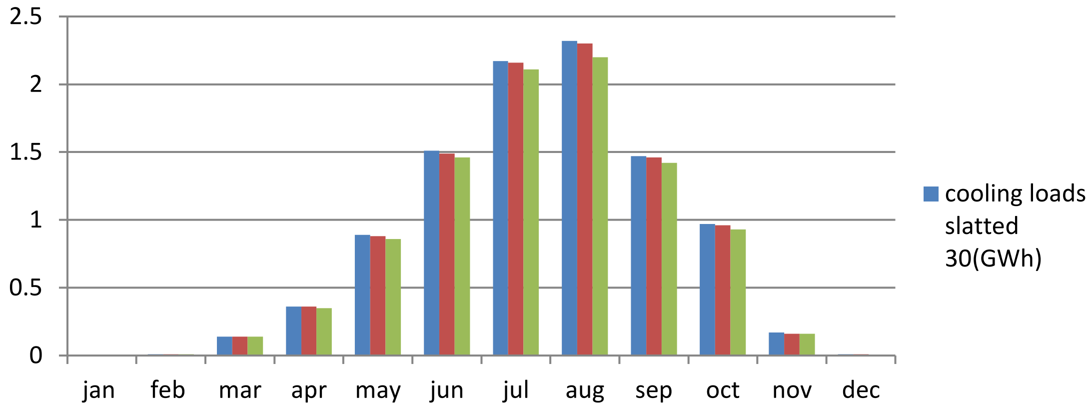
Figure 6. Monthly cooling loads for office building with varied shading devices



Source: researcher

The cooling loads distributed in the chart illustrates that the less cooling loads required are in the case of application of the roller type shading device and then the louver type with 45 slatted inclination angle and finally the louver type with 30 slatted inclination angle. In case of introducing roller or louver shading devices to the double skin façade to take place in the middle of air cavity of 100 cm depth, the cooling loads and energy consumption will decrease. The thermal comfort will improve as well as operative and radiant temperature will decrease in summer period.

Table 3. Annual cooling loads (gwh) for varied shading devices

Skin type	Shading devices type	Inclination angle	Cooling loads (kwh)
DSF 1	Roller type	-	9694489.67
DSF 2	Louver type	45	9933291.01
DSF 3	Louver type	30	10022096.02
DSF 4	No shading devices added	-	10218794.84
S.S.F.	Base case		12258705.79

The annual cooling required in the chart illustrates that the less cooling loads required are in the case of application of the roller type shading device and then the louver type with 45 slatted inclination angle and finally the louver type with 30 slatted inclination angle compared with the case where no shading devices are added and as well as the single skin facade base case.

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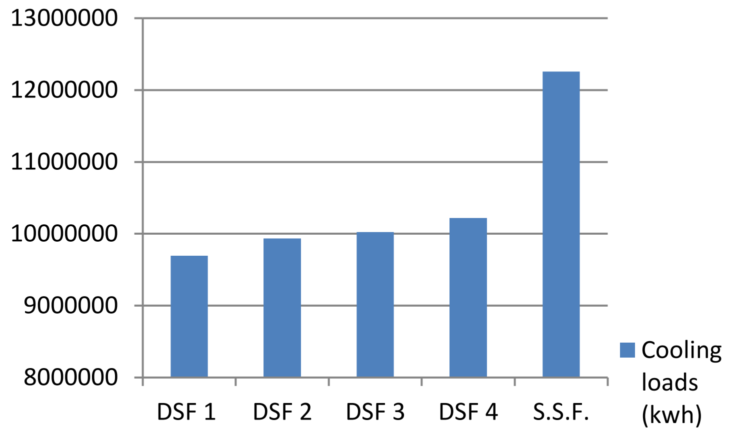
Figure 7. Annual cooling loads for office building with varied shading devices

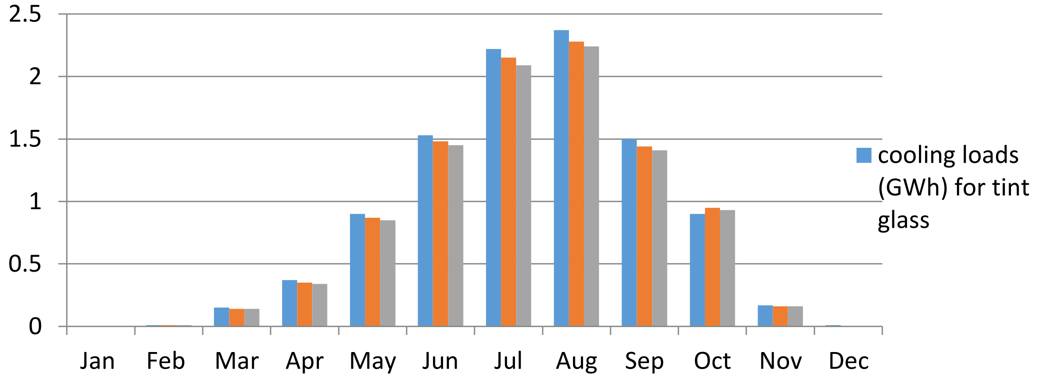


Source: researcher

C. Group 3 glazing types

Three different types of glass are used in the double skin façade such as tint glass, reflective glass and low e glass. The double skin façade system in three alternatives consists of dual single glass layers of 6 mm thickness and in the middle large air cavity of 100 cm. The internal glass layer is a constant clear glass of 6mm thickness and on the other hand the external one is considered as the three alternatives. The results will be evaluated and analyzed to assess the impact of the modification of different glazing types.

Figure 8. Monthly cooling loads for office building with varied glazing types



Source: researcher

The cooling loads distributed in the chart illustrates that the less cooling loads required are in the case of application of the low e glass type and then the reflective glass type and finally the tint glass type with no shading devices added in addition to apply the same air cavity thickness and the glass type for the internal glass layer. In the case of apply different types of glass such as low e and reflective glass to be compared with the tinted glass, the operative temperature is

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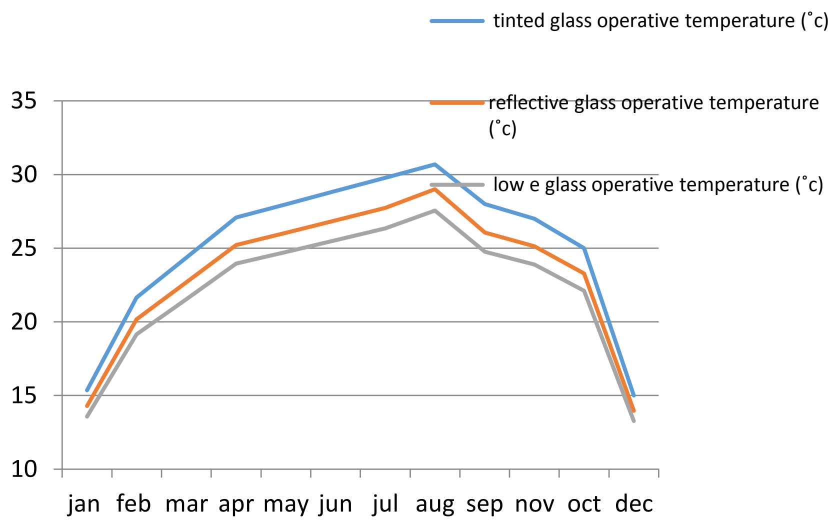
reduced, and as a consequence, the thermal comfort for the occupants inside the office building improves. The analysis indicates that the application of low e glass as the external glass layer for the double skin façade system is better than reflective glass due to the decrease of the operative temperature. The reflective glass application is effective than the tinted glass.

Figure 9. Operative temperature for office building with varied glazing types



Source: researcher

In case of introducing reflective or low e glass types to the double skin façade to take place instead of the tint glass in the external layer, the cooling loads and energy consumption will decrease. The thermal comfort will improve as well as operative and radiant temperature will decrease in summer period. Generally, the building performance will enhance.

Table 3. Annual cooling loads (gwh) for varied glazing types

Skin Type	Glass Type	Cooling Loads (Kwh)
DSF 1	6mm thickness Low e glass	9623045.06
DSF 2	6mm thickness Reflective glass	9923898.14
DSF 3	6mm thickness Tint glass	10218794.84
S.S.F.	6mm thickness Base case	12258705.79

The annual cooling required in the chart illustrates that the less cooling loads required are in the case of application of the low e glass type and then the reflective glass type compared with the case where tint glass type are applied in the double skin facade and as well as the base case where the single skin façade is applied.

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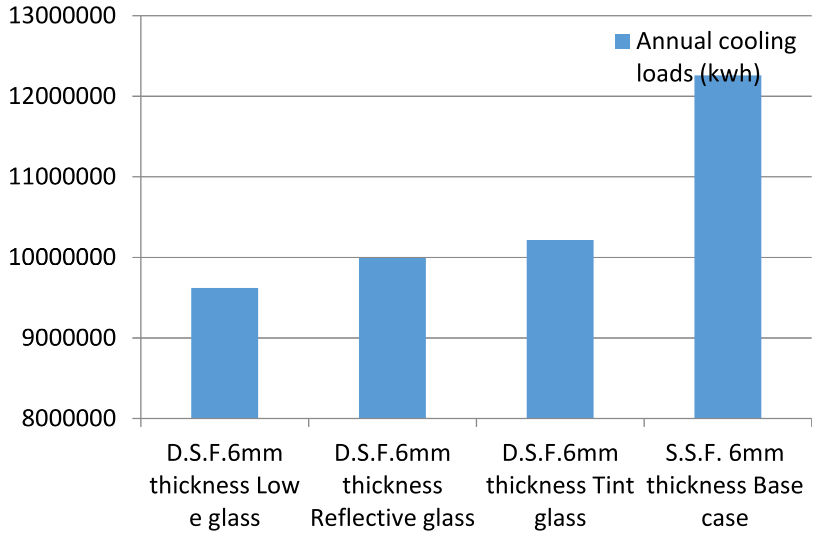
Figure 10. Annual cooling loads for office building with varied glazing types



Source: researcher

5.5.2 The 2nd case

The National Bank of Egypt Office Building

A. Group1, Air cavity Depth

Through the comparison between the two alternatives for the application of double skin facades, the parameter measured is the cavity depth through two varied thickness, small (50 cm) and large(100 cm). The two alternatives will be compared to each other besides to the base case chosen with single skin façade as followed in the next charts.

Table 4. Monthly cooling loads (gwh) for varied cavity depths

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
S.s.f. (base case) cooling loads (GWh)	0	0	0.37	1.43	2.66	3.38	3.92	4.35	2.75	1.75	0.35	0
D.s.f. (small cavity) cooling loads (GWh)	0	0.02	0.35	1.14	2.02	2.51	2.9	3.18	2.09	1.37	0.34	0
D.s.f. (large cavity) cooling loads (GWh)	0	0	0.3	1.08	1.95	2.43	2.8	3.09	2.01	1.3	0.3	0

Obviously, the cooling loads are decreased in case of application of the two alternatives of double skin facades in respect with the single skin façade base case (S.S.F.). In addition to the cooling loads required are less in case of large cavity (D.S.F.2) than in case of small cavity (D.S.F.1).

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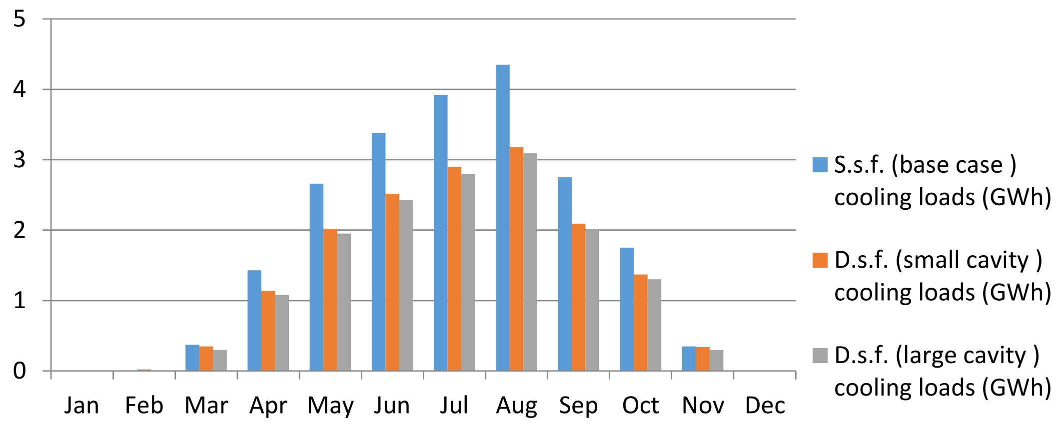
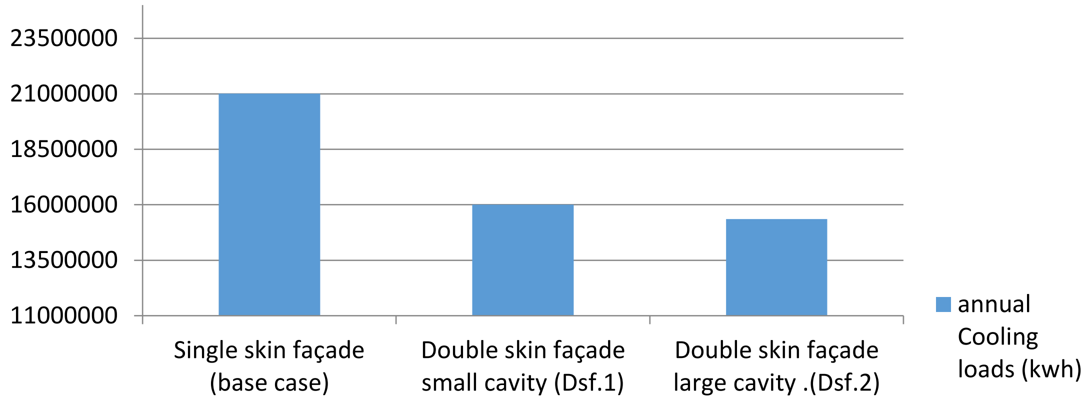
Figure 11. Monthly cooling loads for office building with varied cavity depths



Source: researcher

Figure 12. Annual cooling loads for office building with varied cavity depths



Source: researcher

For this chart, it indicates the annual loads of cooling required for the three alternatives studied, the single skin façade base case (S.S.F) and two alternatives for double skin façade (D.S.F.1, D.S.F.2) the simulation and analysis demonstrates that the minimum annual loads are needed in case of double skin façade with large cavity while for the double skin façade with small cavity are higher and the maximum are in case of single skin façade base case.

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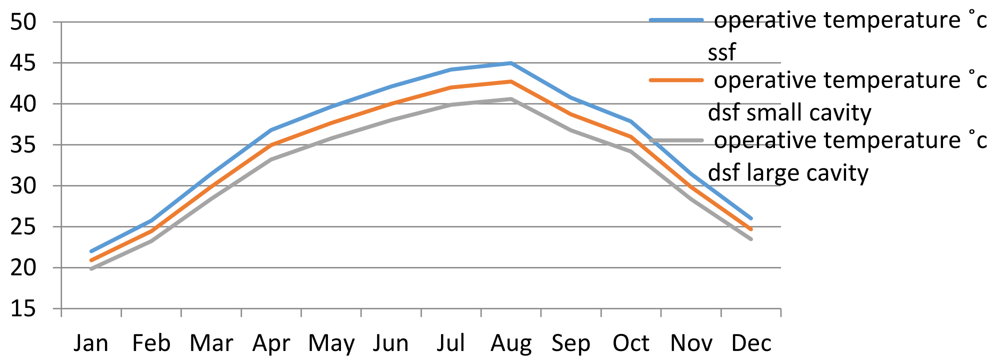
Table 5. Annual cooling loads (gwh) for varied cavity depths

Skin type	Cavity width	Cooling loads
Single skin façade (base case) S.s.f.	none	21007852 kwh
Double skin façade small cavity (Dsf.1)	50cm	15999651 kwh
Double skin façade large cavity .(Dsf.2)	100cm	15354349 kwh

The reduction in the operative temperature and consequently the thermal comfort for the occupants inside enhances in the case of large cavity double skin facade system more than small air cavity double skin façade system is clear. The introduction of double skin façade system instead of single skin façade decrease the temperature

Figure 13. Operative temperature for office building with varied cavity depths

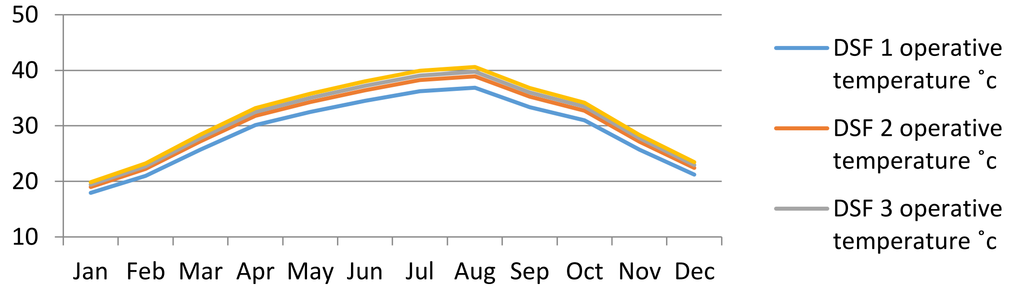


Source: researcher

B. Group 2. Shading devices

In the situation of installing shade devices, the operative temperature is reduced, and as a result, the thermal comfort for the occupants inside the office building improves. The analysis indicates that the introduction of roller shades (DSF 1) is better than louver shades (DSF 2, DSF 3). The 45 slatted inclination angle louver application (DFS 2) is effective than the 30 slatted inclination angle louver (DSF 3).

Figure 14. Operative temperature for office building with varied shading devices



Source: researcher

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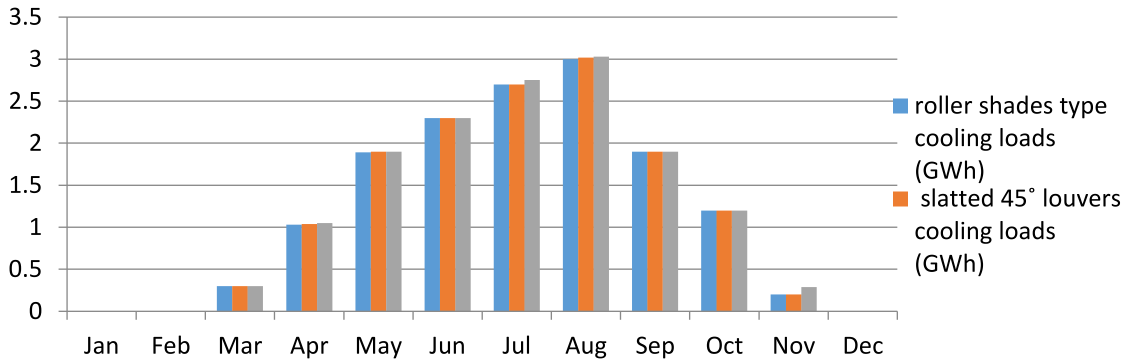
Figure 15. Monthly cooling loads for office building with varied shading devices



Source: researcher

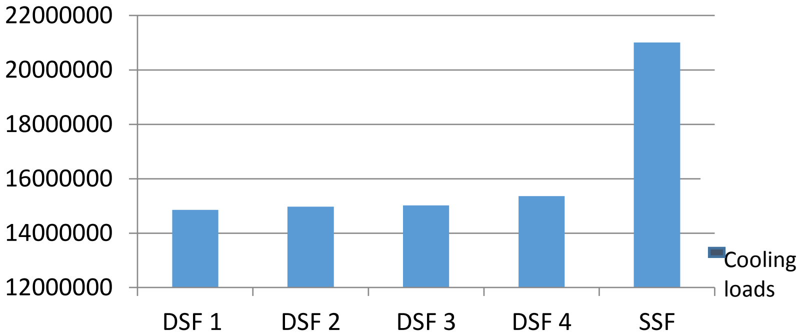
The cooling distributed in the chart illustrates that the less cooling loads required are in the case of application of the roller type shading device and then the louver type with 45 slatted inclination angle and finally the louver type with 30 slatted inclination angle

Table 6. Annual cooling loads (gwh) for varied shading devices

Skin type	Shading devices type	Inclination angle	Cooling loads (kwh)
DSF 1	Roller type	-	14859009
DSF 2	Louver type	45	14971068
DSF 3	Louver type	30	15022793
DSF 4	No shading devices added	-	15354349
S.S.F.	Base case		21007852

The annual cooling required in the chart illustrates that the less cooling loads required are in the case of application of the roller type shading device and then the louver type with 45 slatted inclination angle and finally the louver type with 30 slatted inclination angle compared with the case where no shading devices are added and as well as the base case.

Figure 16. Annual cooling loads for office building with varied shading devices



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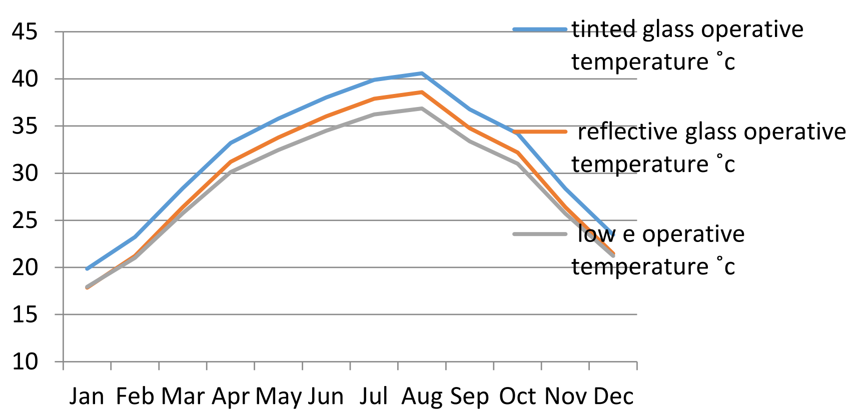
C. Group 3. Glazing types

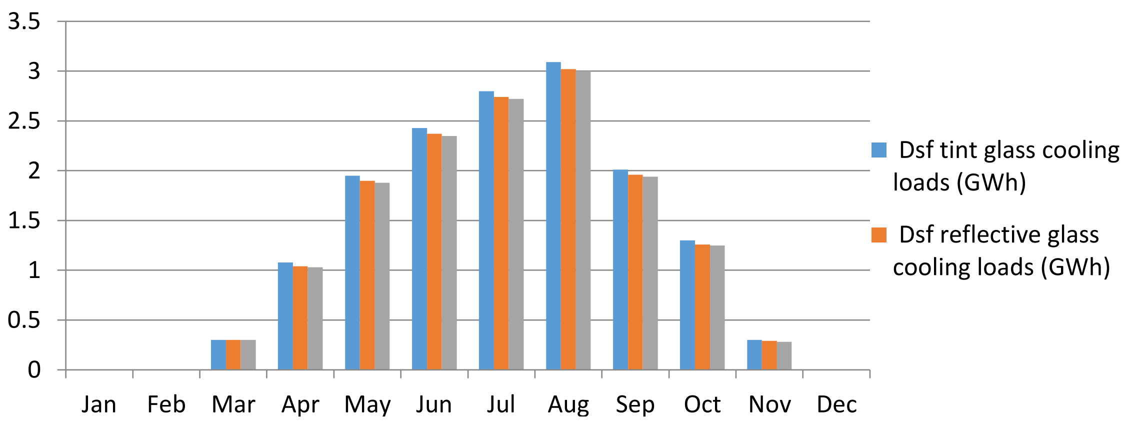
When alternative varieties of glass are used instead of tinted glass, such as low-e and reflecting glass, the operating temperature is decreased, which enhances the thermal comfort of the building's occupants. Due to the reduction in operating temperature, the analysis shows that low e glass is preferable to reflective glass when used as the exterior glass layer for a double skin façade system. The use of reflecting glass is more efficient than tinted glass

Figure 17. Operative temperature for office building with varied glazing types



Source: researcher

Figure 18. Monthly cooling loads for office building with varied glazing types



Source: researcher

The cooling distributed in the chart illustrates that the less cooling loads required are in the case of application of the low e glass type and then the reflective glass type and finally the tint glass type with no shading devices added in addition to apply the same air cavity thickness and the glass type for the internal glass layer.

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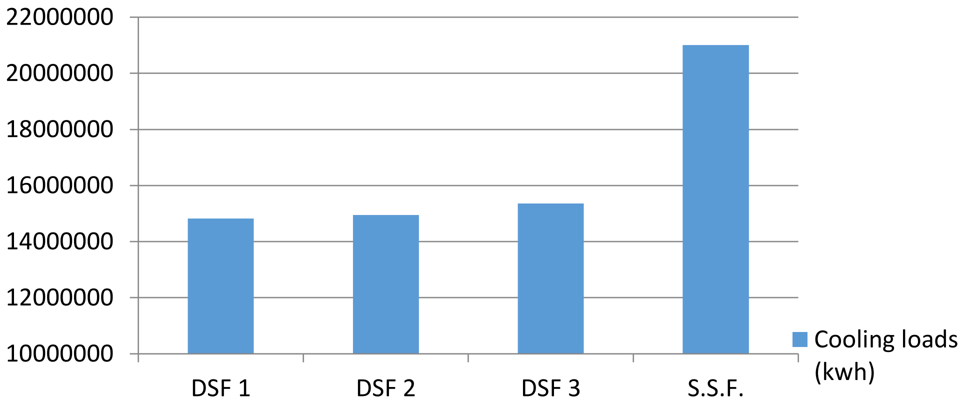
In case of introducing reflective or low e glass types to the double skin façade to take place instead of the tint glass in the external layer, the cooling loads and energy consumption will decrease. The thermal comfort will improve as well as operative and radiant temperature will decrease in summer period. Generally, the building performance will enhance.

Table 7. Annual cooling loads (gwh) for varied glazing types

Skin type	glass type	Cooling loads (kwh)
DSF 1	6mm thickness Low e glass	14821448
DSF 2	6mm thickness Reflective glass	14945254
DSF 3	6mm thickness Tint glass	15354349
S.S.F.	6mm thickness tint glass Base case	21007852

The annual cooling required in the chart illustrates that the less cooling loads required are in the case of application of the low e glass type and then the reflective glass type compared with the case where tint glass type are applied in the double skin facade and as well as the base case where the single skin façade is applied.

Figure 19. Annual cooling loads for office building with varied glazing types



Source: researcher

5.5.3 The 3rd case

Alex tower office building

A. Group 1. Air Cavity Depth

The parameter examined in the comparison of the two alternatives for applying double skin facades is the cavity depth across two different thicknesses, small (50 cm) and big (100 cm). The two double skin façade alternatives will be compared to each other as well to the base case with single skin façade as followed in the next charts.

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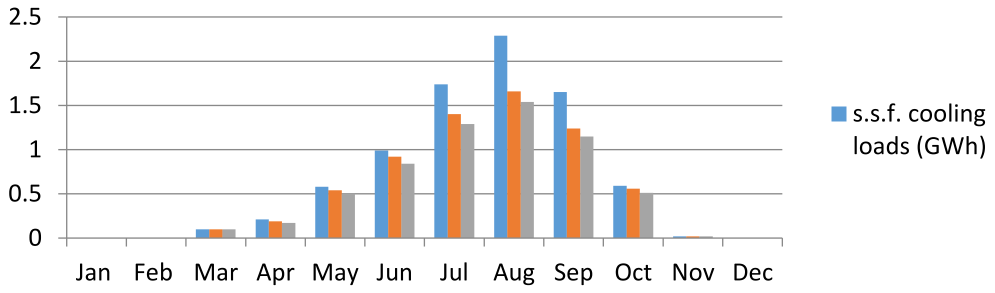
Table 8. Monthly cooling loads (gwh) for varied cavity depths

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
S.s.f. (base case) cooling loads (GWh)	0	0	0.1	0.21	0.58	0.99	1.74	2.29	1.65	0.49	0.02	0
D.s.f. (small cavity) cooling loads (GWh)	0	0	0.1	0.20	0.54	0.92	1.4	1.66	1.24	0.56	0.09	0
D.s.f. (large cavity) cooling loads (GWh)	0	0	0.1	0.1	0.5	0.84	1.29	1.54	1.15	0.51	0.08	0.02

Figure 20. Monthly cooling loads for office building with varied cavity depths

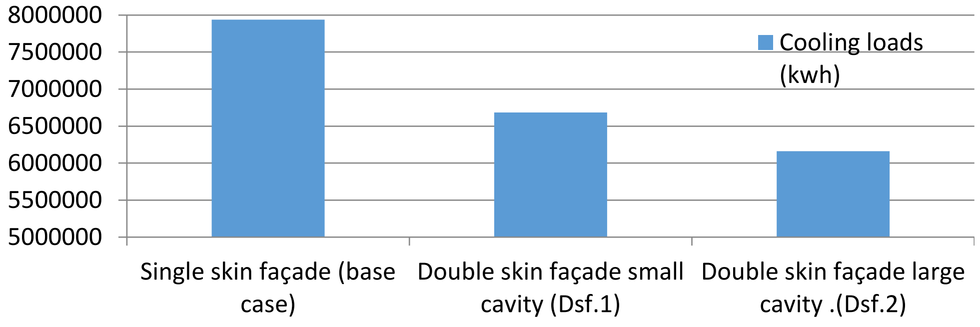


Source: researcher

The graph compares the performance of the single skin façade to the two options of double skin facades with cavity depth parameters in terms of cooling loads. Obviously, the cooling loads are reduced when the two double skin facade options are used instead of the single skin façade base case (S.S.F.). Furthermore, the cooling loads required are lower in the case of a large cavity (D.S.F.2) than in the case of a small cavity (D.S.F.1).

The annual cooling loads required for the three alternatives evaluated, the single skin façade base case (S.S.F.) and two alternatives for double skin façade, are shown in this chart (D.S.F.1,D.S.F.2). the simulation results demonstrate that the minimum annual loads are needed in case of double skin façade with large cavity while for the double skin façade with small cavity are higher and the maximum are in case of single skin façade base case.

Figure 21. Annual cooling loads for office building with varied cavity depths



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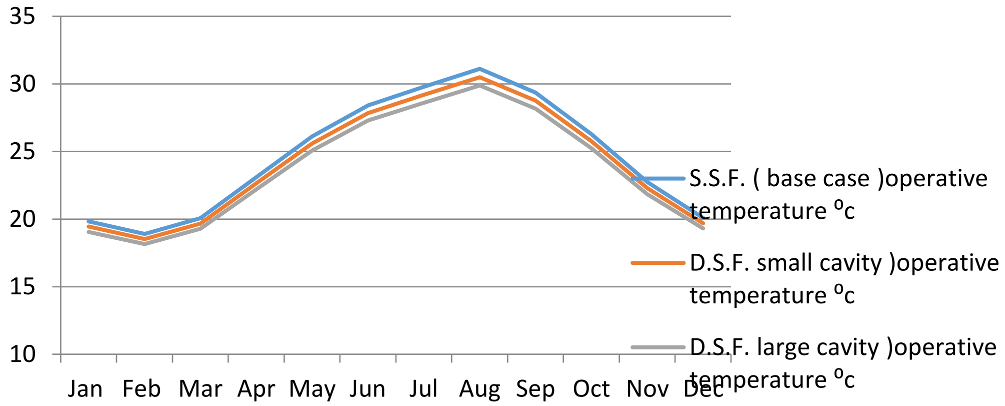
Source: researcher

Table 9. Annual cooling loads (gwh) for varied cavity depths

Skin type	Cavity width	Cooling loads
Single skin façade (base case) S.s.f.	none	7937514.36 kwh
Double skin façade small cavity (Dsf.1)	50cm	6682528.00 kwh
Double skin façade large cavity .(Dsf.2)	100cm	6158973.54 kwh

The thermal comfort for the occupants improves in the case of large cavity double skin facade system more than small air cavity due to the obvious decrease in operating temperature. The analysis indicates that the introduction of double skin façade system instead of single skin façade decrease the temperature inside

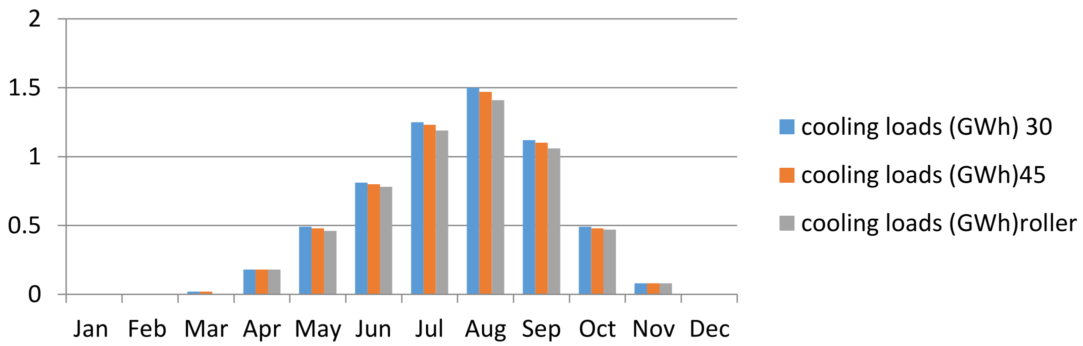
Figure 22. Operative temperature for office building with varied cavity depths



Source: researcher

B. Group 2. The shading devices

Figure 23. Annual cooling loads for office building with varied shading devices



Source: researcher

The shading devices added to the double skin facade system generally decrease the cooling loads. The cooling loads distributed in the chart illustrates that the less cooling loads required

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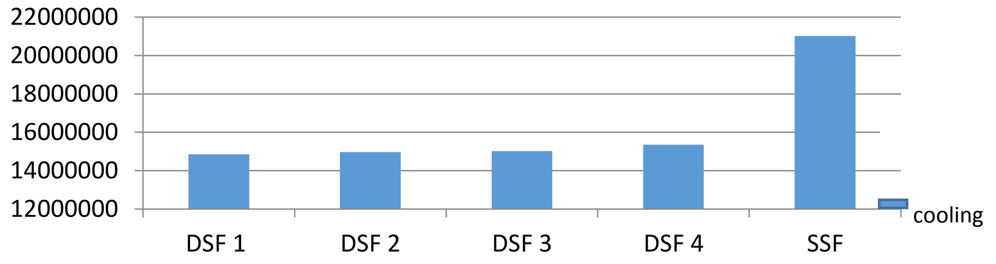
are in the case of application of the roller type shading device and then the louver type with 45 slatted inclination angle and finally the louver type with 30 slatted inclination angle.

Table 10. Annual cooling loads (gwh) for varied shading devices

Skin type	Shading devices type	Inclination angle	Cooling loads (kwh)
DSF 1	Roller type	-	5664833.42
DSF 2	Louver type	45	5860696.09
DSF 3	Louver type	30	5966526.21
DSF 4	No shading devices added	-	6158973.54
S.S.F.	Base case		7937514.36

By comparing the alternatives, The annual cooling loads demanded is the least cooling loads in the case of application of the roller type shading device and then the louver type with 45 slatted inclination angle and finally the louver type with 30 slatted inclination angle compared with the case where no shading devices are added and as well as the base case.

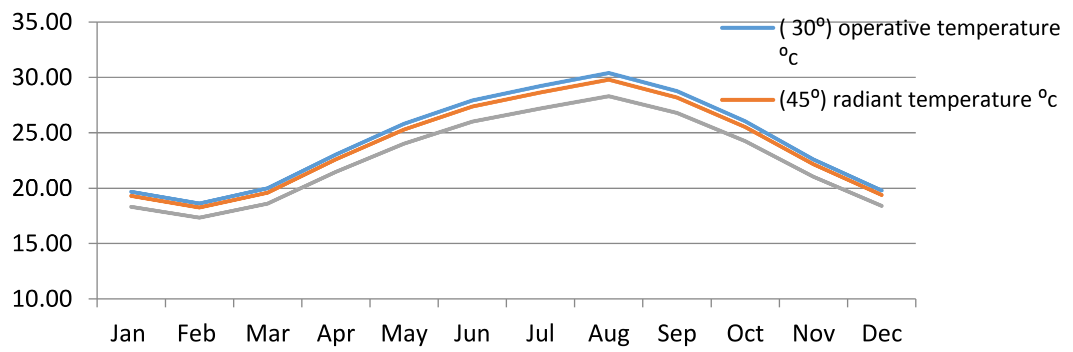
Figure 24. Monthly cooling loads for office building with varied shading devices



Source: researcher

The reduction in operating temperature is obvious, and as a result, thermal comfort for the occupants is greater in the case of roller sunshades than in the case of louver sunshades. According to the investigation, the introduction of louver sunshade type with 45 degree inclination is better than its instance with 30 degree, and the roller type is the best.

Figure 25. Operative temperature for office building with varied shading devices



Source: researcher

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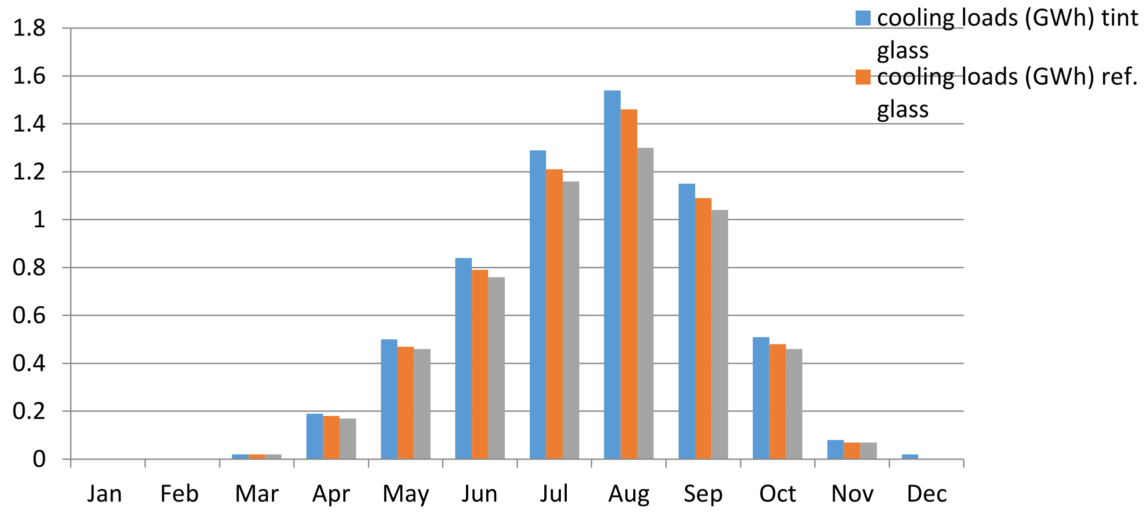
C. Group 3. The glazing types

The cooling distribution in the graph demonstrate that the less cooling loads demanded are in the scenario of applying the low e glass type, then the reflective glass type, and finally the tint glass type with no shading devices added in addition to applying the same air cavity thickness and glass type for the internal glass layer

Figure 26. Monthly cooling loads for office building with varied glazing types



Source: researcher

Table 11. Annual cooling loads (gwh) for varied glazing types

Skin type	glass type	Cooling loads (kwh)
DSF 1	6mm thickness Low e glass	5566141.39
DSF 2	6mm thickness Reflective glass	5784134.99
DSF 3	6mm thickness Tint glass	6158973.54
S.S.F.	6mm thickness tint glass Base case	7937514.36

The annually cooling loads demanded in the graph illustrate that the low e glass type (DSF 1) and subsequently the reflective glass type (DSF 2) require smaller cooling loads than the tint glass type (DSF 3) in the double skin facade and the base case scenario when the single skin façade (SSF) is applied.

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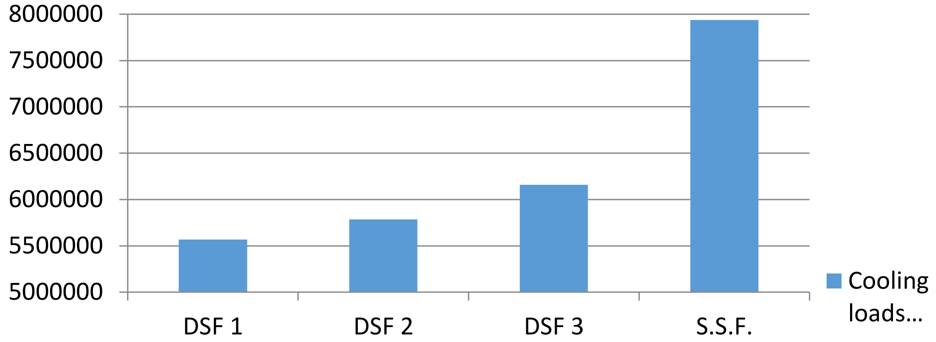
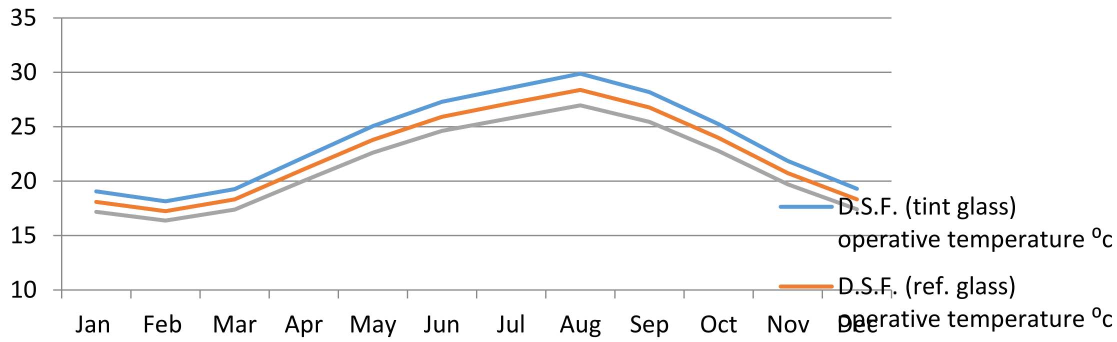
Figure 27. Annual cooling loads for office building with varied glazing types



Source: researcher

The graph above demonstrates that the installation of low-e glass reduces the operative temperature and, as a result, increases the thermal comfort of the interior occupants than apply the reflective glass. Using low-e and reflecting glass in place of tinted glass in the double-skin façade system will result in a reduction in summertime temperature.

Figure 28. Operative temperature for office building with varied glazing types



Source: researcher

6. Discussion and Findings

Three cases of study were selected to assess the extent of the appropriateness of the double skin façade for use as a substitute of Single skin façade in exteriors for administrative buildings in Egypt in three different climatic regions. And the study was done on the basis of three groups to study the vocabulary of the double skin facade. The three groups are classified as air cavity depth, shading devices and glazing types. The study is accomplished on cooling loads, energy efficiency, and thermal comfort to assess the general building performance. It was found in the first group the air cavity depth, where the study was based on two alternatives for air cavity depth, the first one of which is the small depth of air cavity 50 cm and the second is the large depth of air 100 cm that the double skin façade is better than the single skin facade in both cases.

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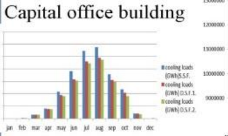
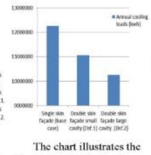
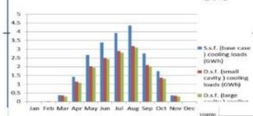
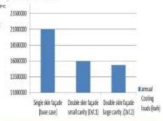
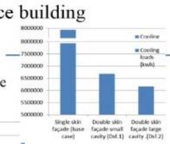
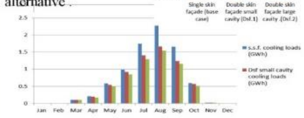
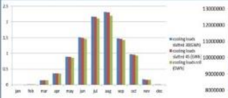
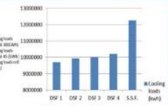
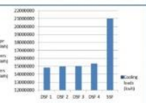
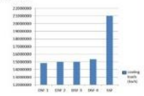
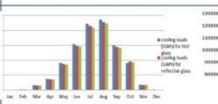
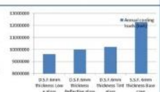
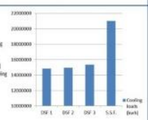
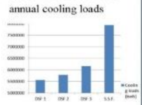
The large cavity double skin facade is better than the small cavity double skin facade. It is clear that the monthly and annual cooling loads have decreased, and also the efficiency of energy consumption has improved and the thermal comfort increased inside the building and the general performance of the building enhance. In the second group which is concerning the shading devices, the outcomes are insisting that the addition of shading devices in the double skin façade system in case of comparison to the single skin façade base case enhance the building performance decreasing the annual and monthly cooling loads and increasing the energy efficiency and the thermal comfort for users inside. The shading devices added are divided into two groups louver shades with two slatted inclination angle 30° and 45° and roller shades. The roller shades are better than the louver shades in use and concerning the inclination angles of slates the 45° is better than 30°.

The third group regarding the glazing types, the reflective glass and low e glass are tested in comparison to tinted glass. The double skin façade is tested in three cases tinted, reflective and low e in double skin façade cases to be compared to each other as well as to the single skin façade base case. The low e glass is the best and the reflective glass is better than the tinted glass and the double skin façade in all cases are better than the single skin façade. The glazing types substitution ameliorate the outcomes for the cooling loads, energy efficiency and thermal comfort.

Table 12. The three cases comparison

	1st case Capital office building	2nd case The National Bank of Egypt office build-	3rd case Alexa tower office building
Group1 Cavity depth Three alternatives are in comparison 1. Base case single skin façade SSF 2. Small cavity double skin façade DSF1 3. Large cavity double skin façade DSF2	 The chart illustrates the monthly cooling loads  The chart illustrates the annual cooling loads The double skin façade is more recommended compared by the single skin façade. The large cavity double skin façade is better than the small cavity in cooling loads consumption	 The chart illustrates the monthly cooling loads It is illustrated that the double skin façade in efficient than the single skin façade  The chart illustrates the annual cooling loads	The chart illustrates the annual cooling loads  The large cavity double skin façade is the best alternative .  The chart illustrates the monthly cooling loads
Group 2 Shading devices Five alternatives are in comparison 1. Base case single skin façade SSF 2. roller shade type DSF1 3. 45 louver type DSF2 4. 30 louver type DSF 3 5. Large cavity DSF 4	 The chart illustrates the monthly cooling loads  The chart illustrates the annual cooling loads The roller shades are preferable more than louver type.	 The chart illustrates the monthly cooling loads  The chart illustrates the annual cooling loads The addition of shades enhances the building performance. The roller shades are preferable more than louver type.	 The chart illustrates the monthly cooling loads The addition of shades highly improve the cooling consumption  The chart illustrates the annual cooling loads
Group3 Glazing Types Four alternatives are in comparison 1. Base case single skin façade SSF 2. low e glass DSF1 3. reflective glass DSF2 4. tinted glass DSF 3	 The chart illustrates the monthly cooling loads  The chart illustrates the annual cooling loads The low e glass cause decreasing in cooling consumption comparing by the reflective glass .	 The chart illustrates the monthly cooling loads  The chart illustrates the annual cooling loads The low e glass is the best alternative	 The chart illustrates the monthly cooling loads The chart illustrates the annual cooling loads  The low e glass is the best alternative
Conclusion	1. the double skin façade introduced is better than the single skin faced in all cases 2. the large cavity double skin façade is highly recommended in comparison to the small cavity 3. the roller sun shades type is efficient than the louver type 4. the angle of inclination of 45 is preferable than 30 in case of louver sun shades 5. the low e glass decrease the cooling consumption by comparison to reflective and tinted glass		

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7. Conclusion

Generally the double skin façade with its various features applied in the three case studies in three different climate regions in Egypt is considered as a successful tool as all the outcomes emphasis the reduction of the monthly and annually cooling loads, energy efficiency and thermal comfort presented by the operative temperature inside the office building. Consequently the double skin façade introduced in the exterior enhance the general building performance as well as confront the difficulties caused by the usage of glass curtain wall in hot regions giving the user the opportunity to take advantages of the curtain wall in interact with the surrounding environment as well as use sun rays in natural lighting.

8. Recommendation

The biomimcry approach is strongly suggested for use in the field of architecture in order to take cues from nature regarding how to solve problems and adapt to the surrounding environment in a sustainable way rather than depleting natural resources and taking into account the rights of future generations.

A double skin façade system is preferred over a single skin façade for office buildings in hot climates as an environmental treatment for glazed exteriors.

The double skin façade with a large 100 cm cavity is preferable than small one with a 50 cm cavity. In the case of roller and louver sunshades, the shading devices introduced improve the building performance. The roller sun shade is significant than the louver sunshade due to a reduction in the annual and monthly cooling loads

The use of low-e glass is strongly recommended due to its impact on cooling loads and thermal comfort. Reflecting glass is preferable over tinted glass due to less internal heat gain and solar rays penetration,

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