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Comparative analysis of static and dynamic double skin façade to Achieve indoor thermal comfort and daylighting

Case Study of Office Buildings In Arid Region

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Abstract

The envelope of the building has high impact in the indoor climate, In hot dry climate the building has indoor thermal discomfort. This enclosure can either passively or actively reject undesirable effects while allowing beneficial ones. Therefore, the aim of the paper is achieving thermal comfort and daylighting of the office building through the facades by a comparative analysis of static and dynamic double skin façade as an alternative for the single curtain walls to achieve indoor thermal comfort and daylighting. Curtain walls usually are seen as an attractive feature in the building, but it consumes a lot of energy because it is similar as the outdoor climate because it did not have anything to opaque the outdoor temperature and daylight. The study focuses on comparing between the double skin façades in the thermal comfort of the building and daylighting by simulation in design builder. The simulation process in this this research will be taken in different categories, the first one is simulating the indoor air temperature, the second one is in the measuring the daylighting inside the building. The expected result of this research after the comparative analysis is to find which is better in achieving the thermal comfort and daylighting with respect to the energy consumption in any office building and the efficiency of the workers in the daylighting.

Keywords: Double skin façade; Static; Dynamic; Indoor thermal comfort; Energy Consumption; Daylighting; Office Buildings.

1 Introduction

Choosing an appropriate architectural envelope is a critical issue in architectural design to improve the indoor environment. Natural lighting is very important for health and productivity and curtain walls is the best way to get indoor daylighting but with managed quantity. The dynamic double skin façade with curtain walls can control the indoor daylighting but the static double skin façade can also control but with limited values because it is a static facade. In this research there is comparative analysis between both of them according to the indoor thermal comfort and daylighting and which of them is better in achieving indoor thermal comfort and daylighting in office buildings.

2 Literature Review

1.High Performance Façade (HPF)

High performance facades are outside enclosures that use as little energy as possible to create a comfortable interior climate that enhances occupants' productivity and well-being. (Aksamija, 2015). High performance building façades can be created using a variety of design techniques, like:

- Adapting building orientation, geometry, and massing to the location of the sun.
- Solar shading to reduce cooling needs and increase comfort levels.
- Reduce cooling loads and enhance air quality with natural ventilation.
- To reduce the amount of electricity used for lighting, cooling, and heating devices, external wall insulation should be optimized, and daylighting should be increased. Refer to figure 2 for a variety of configurations

that have been suggested to implement the HPF concept. The ensuing bullet points provide an overview of each category.

Fig. 1: High performance façade configurations.

1.1.Polyvalent wall

A 30 cm thick wall for all seasons consists of thin layers that reflect, absorb, filter, and transfer external energy (see figure 3). Moreover, it can:(Waseef et al., 2017)

- Its opacity as an electrochemical window to be changed.
- Produce electricity similarly to photovoltaics.
- As with thermoelectric heat pumps, achieve a pleasant temperature.
- Enter the space's ventilation.

Fig. 2: Capricorn house.

1.2.Static Double-skin Façade (DSF)

It got 2 skin layers & the inner one normally fully or partially window glazed, and the outer skin is typically glazed (Poirazis, 2004). Figure 4 illustrates how an adjustable shade mechanism for greater temperature management is typically present in the air cavity which is 20 cm or more and it separates the two layers (Ahmed, Abdel-Rahman, Ali, & Suzuki, 2016). According to the ventilation method, DSFs can be divided into four categories: buffer systems, air extracted systems, double face systems, and double layer hybrid facade systems (Elghazi,-Wagdy, Mohamed & Hassan, 2014).

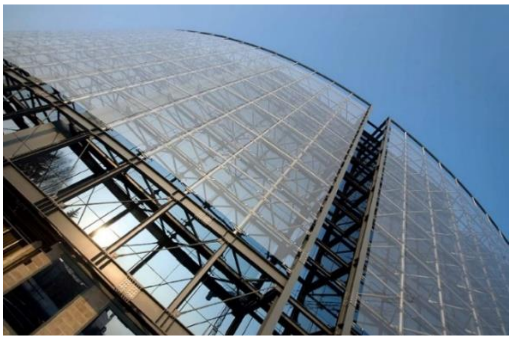


Fig.3: milan Mediaset's Headquarters

1.3. Intelligent Façade

Intelligent façades is a group of structural components in the building's outer, weather-protective cover that may change or react to environmental changes and maintain thermal comfort with the min. amount of energy used in any building layout (Wigginton & Harris, 2013). Weather, context, and occupants are three essential elements that the intelligent façade must be responsive to (Ghaffarian-Hoseini, Berardi, & Makaremi, 2012).

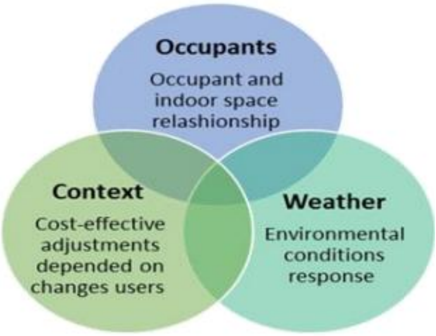


Fig.4: key parameters of Intelligent façade

2.Dynamic double skin-façade

Described as a facade that responds and adjusts to changes in the external environment & can be used to enhance the thermal heat performance & daylight quality in interior areas (see figure 6). This adaptability depends on movements that alter the façade of the building's physical structure or material qualities without impairing its overall structural integrity (Sharaidin, 2014).

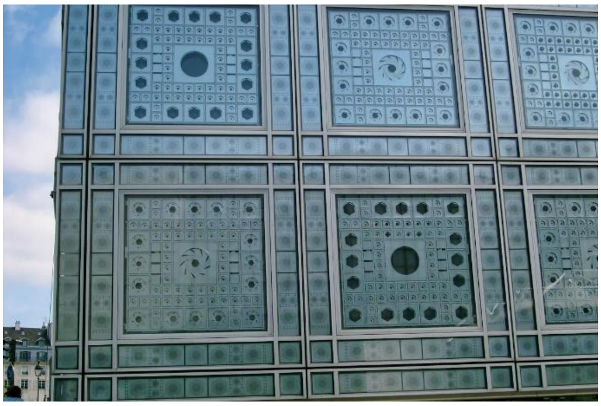


Fig.5: Arab world institute

According to what was previously stated, dynamic double skin facades also contain environmental adaption. Additionally, one of its forms of application is to use the double skin façade concept (as discussed in the coming points). As a result, in addition to the various HPF variants that will be shown in the tables below, Dynamic double skin façades also feature other HPF combinations. Dynamic double skin façade is reliant on cutting-edge tools and methods. Refer to figure 5 for details. According to Maia and Meyboom (2015), it has four primary parts:

- Sensors that take note of environmental factors.
- A logical unit analyses the input and formulates an answer.
- Actuators that are responsive to their surroundings.
- A management system that uses wired and wireless connectivity to communicate information between all parts.

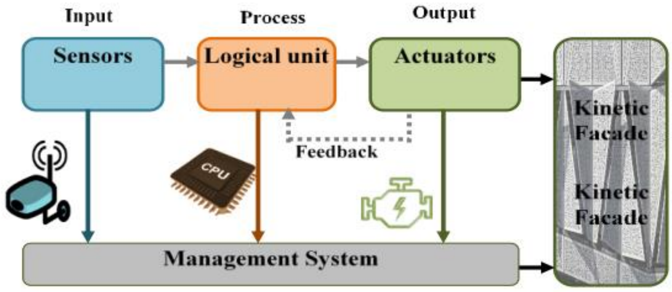


Fig. 6: Dynamic façade idea

Classification of dynamic façade

In 2011, Moloney developed his dynamic double skin Facades categorization, which was based on categorizing the façades in accordance with these types of geometric modifications that the façade of the building underwent (Moloney,-2011). from then, specialists have modified Moloney's classification. However, this classification only put in consideration the motion of the façade units from a form perspective, not putting in consideration other types of dynamics that have developed more recently in recent years. Additionally, this classification was a little too broad because these changes can include other subclassifications. The research therefore suggests a new classification for dynamic double skin facades depending on the type of transformation employed, the aim of using, and the motion after evaluating recent instances of dynamic facades.

As a result, the research suggests that Kinetic Façades can be divided into two major categories:

• Façade Form.

• Façade function. Under each broad categorization, the paper also adresses sub- and secondary classification, with each one presented through the figure, a proposed project, and an application.

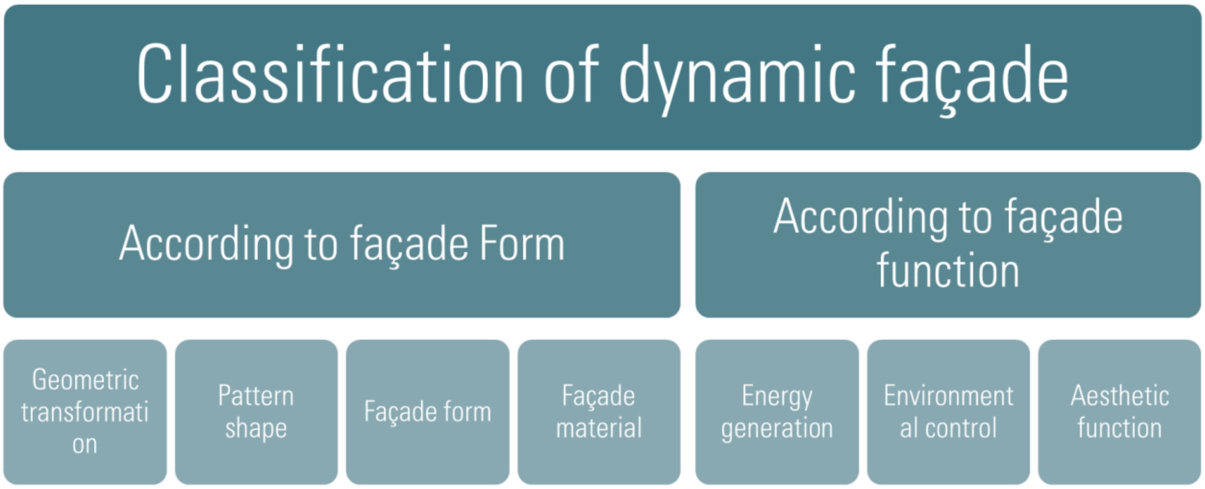


Fig. 7: Moloney dynamic double skin façade classification (Moloney, 2011)

2.1 According to façade form

1. Geometric transformations

Four major factors—geometry transformed, pattern shape, form of skin, and material of the facade—can be grouped together to impact how Kinetic façades are configured. Figure 9 illustrates the fundamental geometric transformations, which include rotation ,translation , scaling, and material deformation , the combination of 2 or more can result to a lot of hybrid kinetic systems .(Sharaidin-,2014).

Fig. 9: Transitions in geometry for kinetic facades

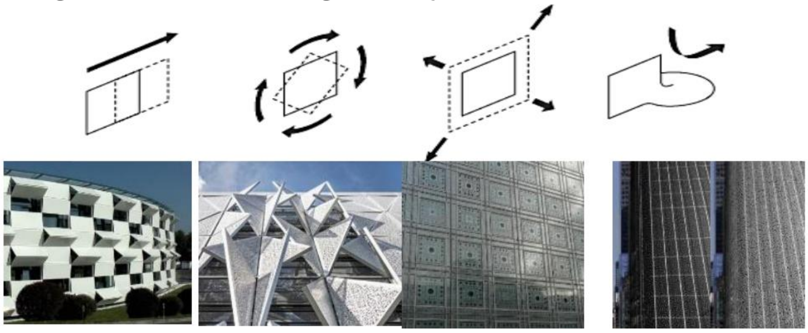
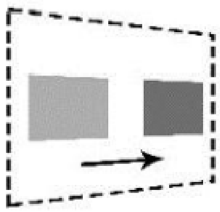
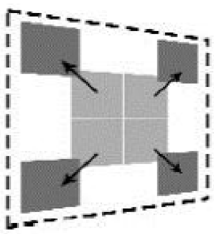
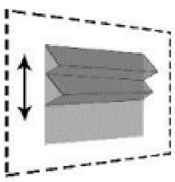
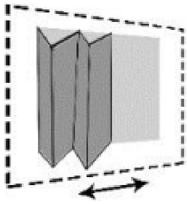
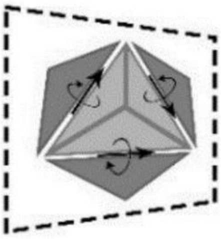
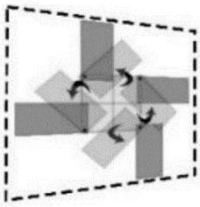
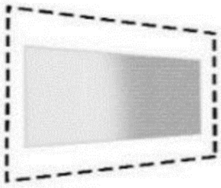
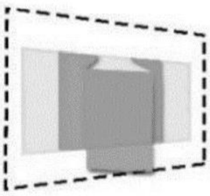
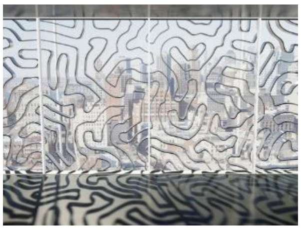


table (2) explains the expected categorization for pattern shape, form of skin, and material of façade while table (1) shows the proposed classification with its subcategories for the four geometric changing forms mentioned above.

Table no 1: . Classification of layouts for dynamic facades based on their geometric transitions.

The type of motion			Sketch	Applied Facade	
				Figure	Concept
Transition	Sliding	Sliding one axis		 Situla complex façade	The sliding modules covering the façade create both dynamic skin and privacy for users.
		Sliding Multi axis		 Tessellate Metal Surfaces facade	There are multiple metal panels that slide one in front of the other.
	Folding	Vertical		 Kiefer Technic Showroom	The users can regulate the exterior environmental conditions thanks to the vertical facades.

		Horizontal		 Lab building, Graz University of Technology	The south elevation is covered with perforated white aluminium slates to manage daylighting and shield the interior atmosphere from glare.
The type of motion			Sketch	Applied Facade	
				Figure	Concept
Transition	Rotation in Multi Axis			 El bahr Towers	All of the facades, with the exception of the north façade, are covered in PTFE panels, allowing for daylighting control and a 50% reduction in solar heat gain.
Scaling	Scaling based on 2D Rotation			 Arab World Institute	Each panel on the south façade is covered in 73 diaphragms, however there are only 57 kinetic ones.
Material deformation	Deformation in visual properties			 Electro-active display system by SOM	The façade is made of thin film electrochromic and insulated glass.
	Deformation in physical properties			 Homeostatic Building	Twirling ribbons on the facade expand as the temperature rises and contract as it descends.

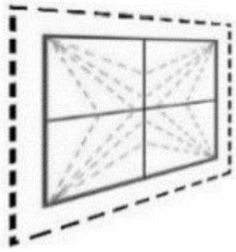
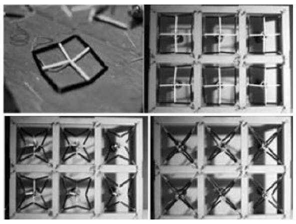
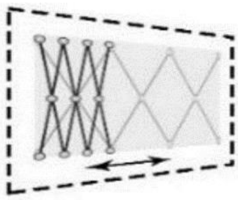
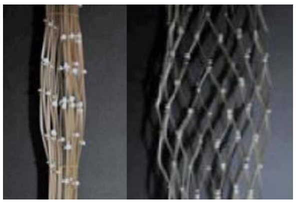
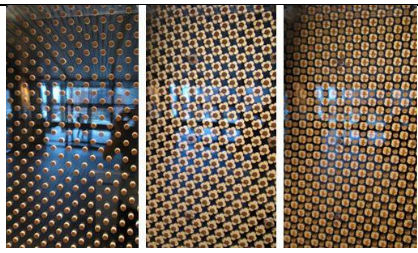
Hybrid systems	Square-tic: Sliding and Retracting	 Square-tic elevation unit	 Unit sample of Square-tic elevation	The mechanism takes the shape of a square when it is open and a star when it is closed when using a rubber.
Hybrid systems	Scissors: Contracting and expanding		 Physical prototype of Scissornet	Stretchable, expandable materials were used to create the scissor net façade.

Table 2.: Categorization of dynamic facade configuration based on material, pattern shape, and skin type.(Waseef et al., 2017)

Façade Configuration		Description	photos	
Façade Form	Single skin façade	A single skin kinetic façade is made of kinetic adaptable appearance glass that may change shape, such as electrochromic and photochromic glass, and an adaptive fitting system.	 Adaptive fritting system	
	Double skin façade	In terms of ventilation, sun heat regulation, and daylighting augmentation, double skin facades are typically more successful than single skin facades (Crisinel, 2007). It can reduce the amount of energy consumed for mechanical ventilation	Internal kinetic skin	

		by 50%. (Watts, 2016). Additionally, kinematic skin may be an exterior or interior layer (Kolarevic and Parlac, ,2015). The appropriate form to choose will depend on the scale, material being utilised, actuation technique, and maintenance plan (Kanaani & Kopec, 2015).	External kinetic skin	
Pattern Shape		Depending on the unit shape— square, rectangle, diamond, circle , hexagon, or triangle—these dynamic facades have different patterns.		 Various Pattern Shapes

Façade Material

Low weight and thin panels are essential for creating such kinetic façades (Jeska, 2007). Additionally, the facade's intended use dictates the material's characteristics (Pacheco,Torgal,Buratti, Kalaiselvam, Granqvist, & Ivanov, 2016). sandblasted glass Stainless steel, , aluminum, PTFE (polytetrafluoroethylene), and bamboo are some of the materials used.

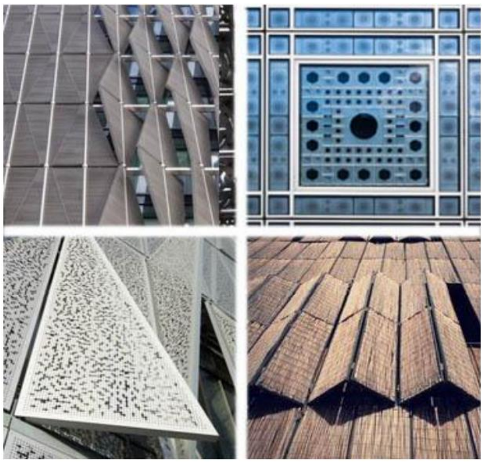


Fig. 10: envelope materials

2.2. considering the function of façade

The 3 main purposes of dynamic facades are environmental management, producing energy, and aesthetics (Sharaidin & Salim, 2012). This classification is introduced in table 3 along with the subcategories that are suggested for each kinetic façade function.

Aesthetic Function

Description: You may make art by using kinetic facades. To create a responsive exterior, it may depend on wind or human movement.

Fig. 11: Mega Faces platform

Concept: MegaFaces platform's stretchy façade may morph in 3D to replicate visitors' faces using a 3D scanning system.

Energy Generation

Building integrated photovoltaic (BIPV) systems typically move in a sliding or rotating motion to track the sun's radiation to the fullest.

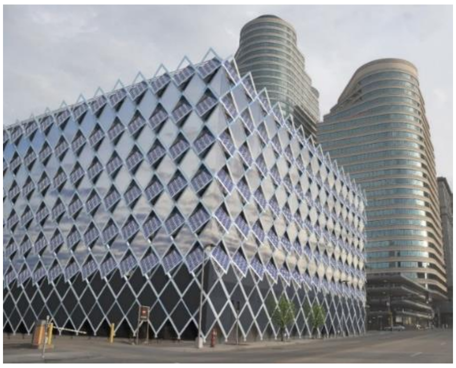


Fig.12: Adaptive solar skin

Concept: The façade has two layers and rotates to follow the path of the sun. The panels also serve as shelves that block the sun.

Environmental Control

Thermal solar techniques can be incorporated into building envelope as covering materials or even as sun screening equipment (Probst and Roecker, 2011).

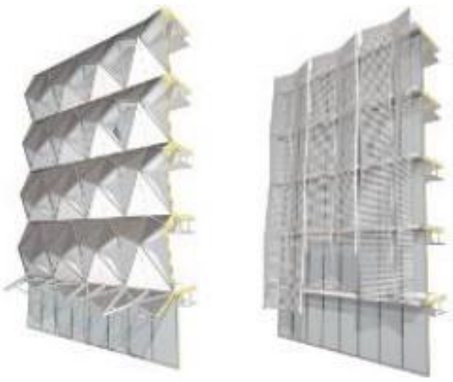


Fig. 13: thermal vail and Umbrella systems

Concept: These systems create adaptable facades using thermal solar technologies as evacuated Tube, flat plate, and roll bond collectors. (Blough, 2015)
Hybrid Systems description: Using a hybrid system entails utilizing many renewable energy sources. similar to BIPV/T (photovoltaic/thermal) systems.

Fig.14: Integrated Concentrating Solar Façade (ICSF)

ICEF system works in 3 steps:

1. Sun orientation tracking.
2. The PVC centre of each receptor with light concentrated there.
3. Thermal energy capture.

Daylighting Control description: regulating the amount, quality, and dispersion of interior lighting. This type relies on two primary methods: mechanically propelled devices and intelligent materials.

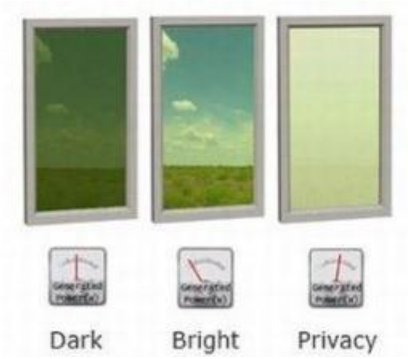


Fig. 15: SEG three conditions

Concept: By adding an external voltage to the coating, Smart Energy Glass (SEG) modifies its optical characteristics. It comprises of two layers of glass sandwiched together with a polymer covering.
Heat Gain Control description: The purpose of solar heating regulation using dynamic façades is to increase solar heating in interior spaces while rejecting solar gain in the summer.

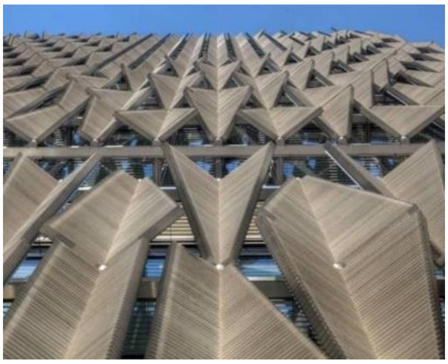


Fig.16 : The Q1 Headquarters

Concept: A managing system that regulates heat gain, cross ventilation, & daylighting protects the façade with vertical louvres that decreases solar heat gain in the building.
Ventilation Control description: Applying the double skin façade concept is a common method of controlling ventilation in façade design, allowing for greater airflow through the cavity. (Barbosa, Ip, & Southall, -2015).

Fig. 17: Federal Building south façade

Concept: makes the building responsive to wind speed and direction, southern face is covered with DSF panels which flips to a ninety-degree angle to inlets air inside. (Wang et al., 2012).
Noise Control description: By utilising Sound Absorbing shade devices, kinetic facades provide a fantastic possibility for a better acoustic design of facades. (Gu et al.,. 2014;, Zuccherini et al., 2015)

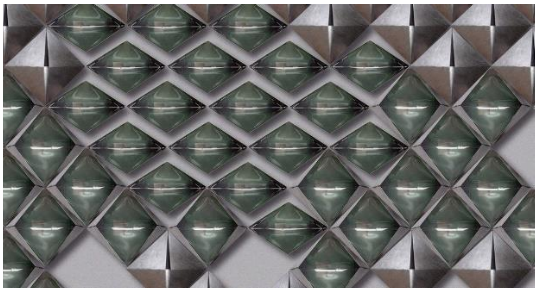


Fig.18: Noise Control

Concept: A glass-reinforced plastic inner panel and an aluminum exterior panel make up the Sonomorph unit. With the necessary hardware and sensors, the modules are fastened to a web of steel wires. (Elkhayat, 2014; Brownell, 2010).
Humidity Control description: Either actively controlling façade patterns with humidity sensors or passively controlling façade patterns with humidity-reactive materials such as timber (Lopez, ..Rubio, Martín, ,Croxford, and Jackson,- 2015).

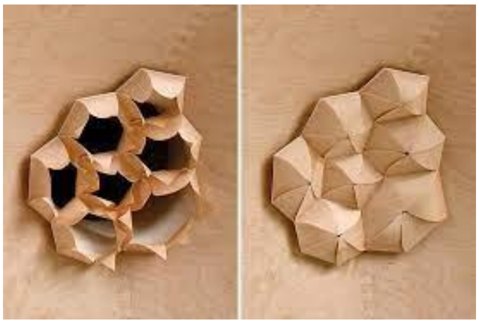


Fig.19: The hygro-skin pavilion skin

Concept: Using the elastic qualities of plywood sheets, building envelope responds to humidity between 30 and 90 % to control opening & closing the elements of envelope. (Menges, 2015).

2.3. Advantages and disadvantages:

Advantages:

- Sunlight Controller.
- acts with different climates in different direction on building.
- Cleaning air flow from pollution.
- control of energy in smart way

Disadvantages:

- high cost of maintenance & Construction.
- Complexity in design
- Using high cost Materials

3.Double Skin Façade (DFS)

A classic single-skin façade that got a 2nd layer, or efficient glazed façade, added to it on the outside is referred to as a "double-skin façade." Since each of these layers is frequently referred to as a skin, the term "Double-skin Façade" came to be. A cavity that is naturally vented, sealed, or capable of self-regulating is also present between each skin, and its width can vary from a few centimetres for the smallest to a few meters for the largest accessible cavities. The glazing could cover the whole building or simply a section of it. The inside layer of glass, which is often insulative, is used to create a curtain wall or a standard structural wall. this additional layer, is typically single glass.

3.1.Double skin façade structure:

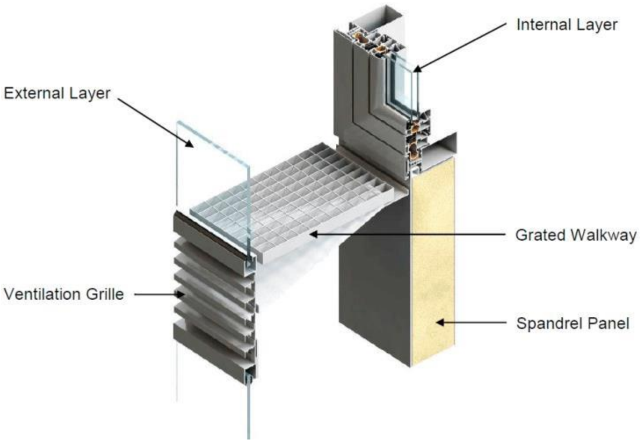


Fig.20: Double Skin façade structure

Exterior Glazing: Typically, it has a single toughened glazing. The entire outer façade may be made of glass. In especially noisy settings, like airports or densely populated cities, this extra shell lowers sound levels (A. De Gracia, 2013).

•**Interior glazing:** Double glazed unit with insulation (clear, low E coating, solar control glazing,etc. can be used). This layer is typically not entirely glazed. Even in the case of tall structures that are susceptible to wind pressures, the inner window can be opened by the user. This might enable the offices' natural ventilation.

•**Air cavity**: (also known as an air corridor or intermediate space) is mechanically or naturally ventilated and is located between the skins. The method for ventilating the air cavity may change throughout time. Its breadth, which can range from 20 cm to several meters (A. De Gracia, 2013), affects how the façade is maintained. The pressure of wind effect on the building's envelope, the stack effect, and the discharge coefficient of the apertures all affect how much air moves between the environment and the cavity. These vents can be opened manually or automatically, or they can be left open continuously (passive systems) (active system). Active systems are exceedingly complex, which makes them expensive to build and maintain.

3.2.Double Skin Façades Types:

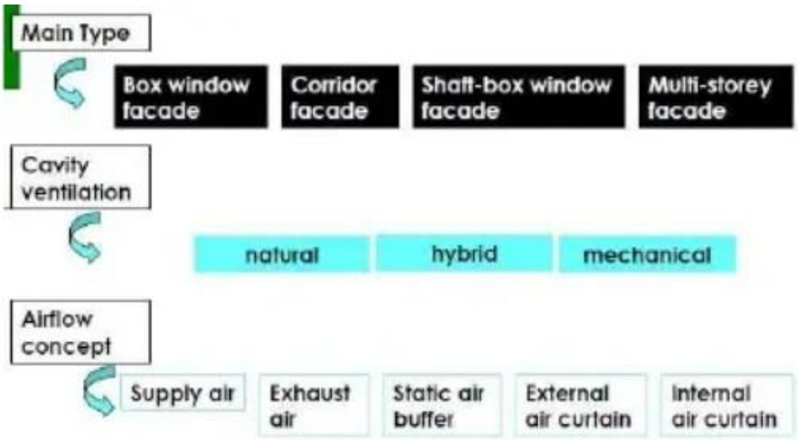


Fig.21: Types of double skin façade

A. Box window type

In this instance, vertical and horizontal partitioning splits the façade into separate, more manageable boxes.

- One of the earliest types of double-skin façade configuration is the box façade.
- It is made up of modular single-story box units with a double-skin façade that are divided either by the structural bay widths or by individual rooms (Boake, T. August 2013).
- There are apertures in the outside single-glazed skin that let in fresh air and let out stale air. As a result, the internal rooms and the intermediate area can both be naturally ventilated.
- The Box Façade arrangement is most frequently employed when there are unique requirements for the propagation of sound between adjacent rooms and when consideration is given owing to high external noise levels.

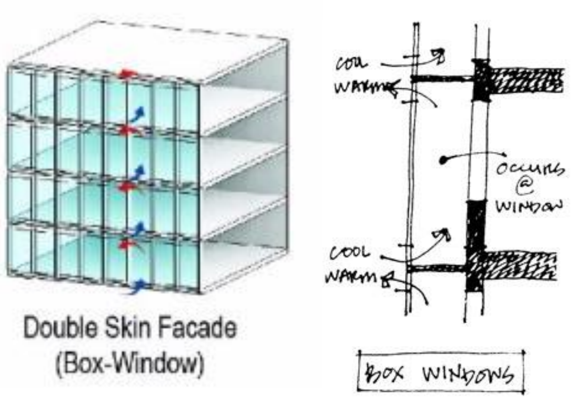


Fig.22: Typical Box window type section

B. Shaft box type

- In this instance, the façade has a set of box window components. Vertical shafts inside the elevation connect these parts. An enhanced stack effect is guaranteed by these shafts..
- A Double-Skin Façade with a Multi-Storey Cavity and one with a Single-Storey Cavity combine to form the Shaft-Box Façade, a singular variant on the Box Façade layout.
- Due to the greater stack effect, the shaft's vertical height generates high uplift pressures that pull the air from the box façade elements up to the shaft's top, where it is expelled.
- In low-rise buildings, the Shaft-Box Façade configuration is frequently utilized.

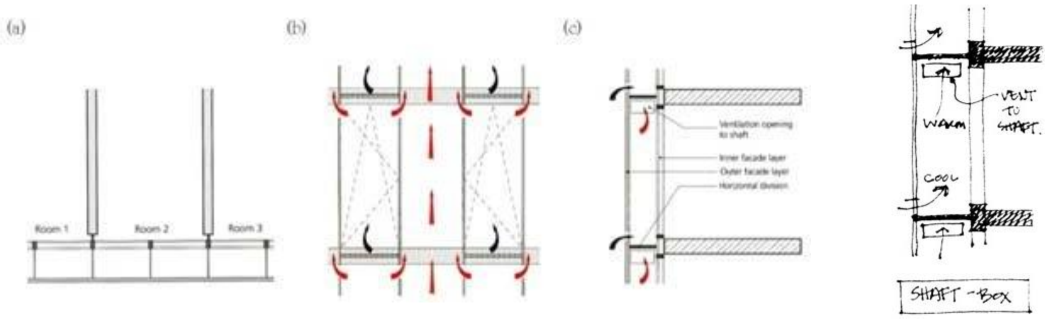


Fig. 23: Shaft box type (a) plan, (b) section and (c) elevation

C. Corridor façade

For reasons of ventilation, fire safety, or acoustics, horizontal partitioning is implemented.

- It doesn't have any vertical divisions other than those that are necessary for structural, acoustic, or fire safety reasons at the building's corner or elsewhere.
- To stop stale air moving from one level from entering the empty area of the level directly above, the outside single glazed skin has holes that are typically spaced apart from bay to bay.
- When it comes to high-rise structures, a corridor façade configuration is often used.

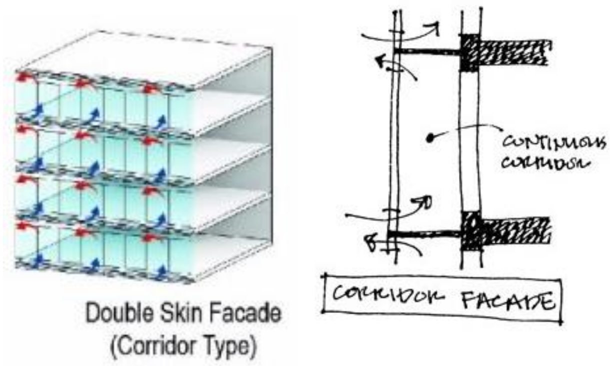


Fig.24: Corridor façade type section.

D. Multi-level Double Skin Façade

None of horizontal or vertical partition separates the two envelopes in this case. wide holes near the building's floor and roof enable the air ventilation of cavity.

- Large holes near the building's floor and roof enable the ventilation of air cavity.
- High external noise levels and acoustic insulation is a major design need, a multi-storey façade configuration is best suited.

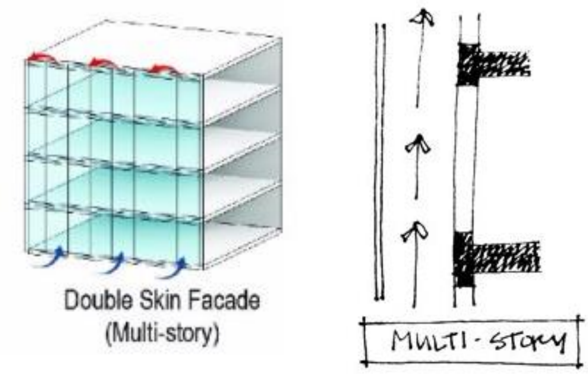


Fig.25: Multi storey Façade type section.

3.3. positives & negatives of double skin façade:

DSF as a sustainable technique entails both benefits and drawbacks. Therefore, it is crucial to ensure that it is appropriate for the proposed building and the specific location for a successful implementation (i.e. climate).

Positives of DSF: A well-implemented DSF can provide numerous advantages, like:

- In winter, supplying a thermal buffer zone and heating air.
- Safeguarding the built-in shading components.
- Lowering summer cooling demands and outdoor noise.
- Natural ventilation and nighttime cooling may be possible. air filtration for ventilation.
- Presenting a beautiful, contemporary, and appealing architectural appearance.
- High transparency demonstrating the openness of users and internal workings.

Importantly, correct DSF use would significantly improve inside daylighting, saving energy for artificial lights. Additionally, it is anticipated that the installation of such systems will improve occupant psychology, behavior, and productivity because they offer direct and comfortable visual consistency to external areas.

Disadvantages of DSF: On the other side, the application of DSF may have a number of unfavorable effects that are brought on by either poor design or ineffective operation. These typical drawbacks are:

- The potential for summertime overheating.
- The worsening of the inner acoustics.
- High quantities of wetness could be possible.
- Increasing the danger of a fire spreading.
- Problems with maintenance and cleaning.

In addition, there are still some other factors that prevent the application from being widely used. These include waste-areas of space (perimeters), the necessity for careful technical planning, and high capital costs with additional operating costs.

2.3.3.The five main Ventilation systems for DSF :

The ventilation technique depends on direction and the destination of the air moving in the ventilated space. One must choose bet. 5 main ventilation techniques.

1. **Outdoor Air Curtain:** In this ventilation technique, the air entering the cavity moved from the outside and is immediately reflected to the outside. (Boake T. , August 2013)

2. **Indoor air curtain:** The air moves from inside the space & returns to the interior of the room or through the air system. (Boake, T. M.)
3. **Air supply:** The facade ventilation is made from outdoor air. This air then moves to the interior of the space or into the ventilation system.
4. **Air exhaust:** The air moves from the room interior and is evacuated towards the outside. The façade ventilation makes it possible to expell the air from the building. (X. Loncour, A.Deneyer, M. Blasco, P. Wouters., 2004)
5. **Buffer zone:** This ventilation mode is effective as each of the skins of the double skin facade is made airtight. The cavity also provides a buffer zone between the inside and the outside, with no ventilation of the cavity being possible. (Saelens, 2002)

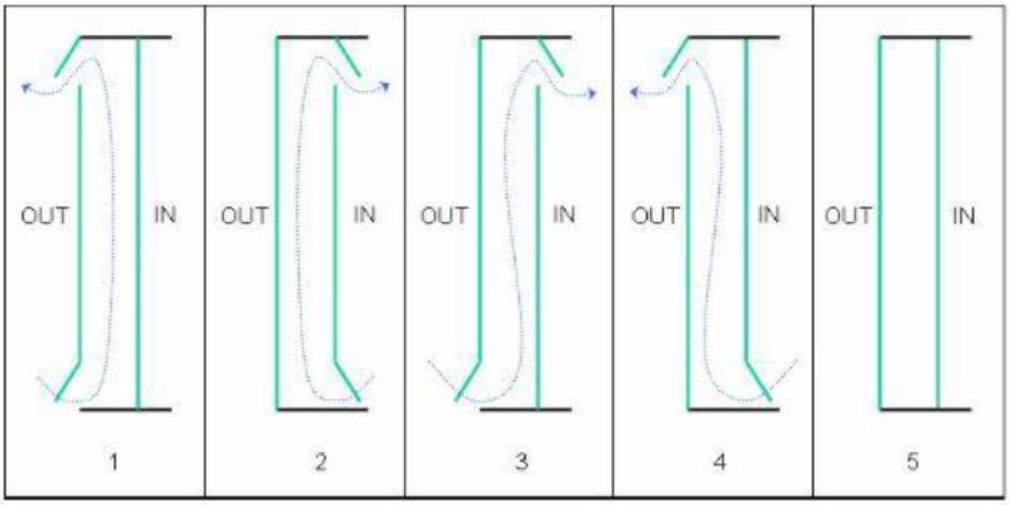


Fig. 26: The 5 Ventilation modes for DSF.

3.4.DSF Energy Performance:

A sizeable portion of the world's energy usage is accounted for by the construction industry. The negative repercussions of increasing energy consumption, such as resource depletion, The building industry was forced to look for innovative technologies that would reduce energy consumption while maximizing the use of natural resources by fossil fuel reserves and other natural resources. European nations that care about the environment and the environment have taken into account the well-being of their citizens when researching cutting-edge technologies.

Double-skin façades became a promising invention for all concerns due to the fact that they provide a comfortable & healthy for the users and employ natural resources thus consuming less energy. The analysis of the energy usage and performance of double-skin façades is still preliminary. However, a double-skin façade outperforms a normal double glass unit wall and offers some energy savings, especially on the heating side cycle, according to thermal performance data that has been done thus far.

4.Thermal Comfort:

4.1.Definition

One of the main factors in a building's design is thermal comfort since it affects how people experience the interior space. On the other hand, how people behave inside a building may directly affect how much energy they use. The risk of overheating is another crucial aspect of thermal comfort. Knowing the precise temperature at which overheating occurs is challenging since it depends on factors including metabolic rate, uncertainty in the body's mass, blood flow, and fitness. 11 Thermal comfort is a subjective situation (Arntsen & Hrynyszyn, 2021, p. 2).

The effectiveness of DSFs in the winter and summer is covered in this section.

A. The external additional skin improves insulation during the winter, and the results are better if the intermediate cavity is closed (totally or partially) during the heating season. Because of the slower air flow and higher temperature inside the cavity, there is a reduction in heat loss because less heat is transferred to the glass's surface. This keeps the interior of the internal window pane at a greater temperature.

B. When radiation enters a building in the summer, is absorbed by the structure's material and re-radiated as long-wave infrared energy, which does not travel through the glass. As a result, convection will be used to heat the air inside the hollow. Conduction allows the hot air flow in the cavity to move through the glazing between the interior and exterior of the room. The stack effect improves as the cavity warms up, and the blinds that are positioned in between the two skins lessen solar heat intake.

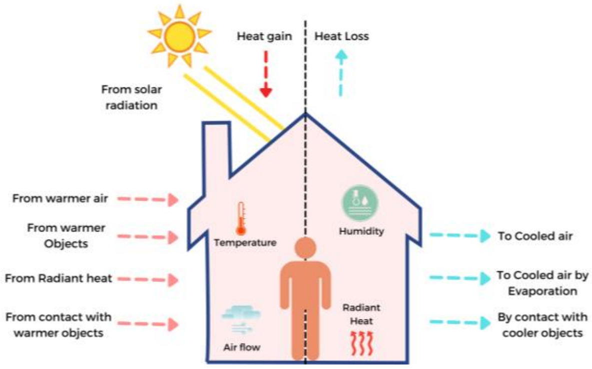


Fig.28: Thermal Comfort.

Figure 28 displays the effect of solar radiation, conduction, and convection on the airflow through the DSF cavity and the effect of various parameters on heat transfer through the building's skin. With a DSF system, min heat is transmitted from the outer to the inside, requiring minimal energy to cool the area.

4.2. Factors affecting thermal comfort

The six fundamental elements of interior thermal comfort

Fig.29: The six factors that affects the indoor thermal comfort

1. **Environmental factors:**

   1-Humidity: increase in humidity level at work indicates that there is a lot of vapour in the atmosphere. This stops sweat from the skin from evaporating, which is how we primarily cool off. (Abokhamis Mousavi et al., 2015)

2-**Air Temperature:** The temperature of the air surrounding a body is known as air temperature, and it is typically expressed in Celsius degree.

3-**Radiant temperature:** Radiant temperature or thermal radiation refers to the warmth that comes from a heated source

4-**Air Velocity:** Thermal comfort is totally affected by how easily air is moving over an employee. People may experience problems in a place with artificially heated air. A fan can help us feel cooler even though the ambient temperature is not decreased because circulating air in a warm or humid office can accelerate heat loss through convection.(Abokhamis Mousavi et al., 2015)

On the other hand, tiny air movements can be perceived as a draught in an office that is cold or cool.

2. **Personal Factors:**

1-**Clothing Insulation:** A significant source of thermal discomfort is wearing either too many or too few clothes for the weather. Even if the surrounding temperature is not felt as being overly warm, which can lead to heat discomfort .(Abokhamis Mousavi et al., 2015)

2-**Metabolic heat (Activity):** more heat is produced at work if you are physically active. worrkers who perform physical labour must expend more heat in order to avoid being overheated.(Abokhamis Mousavi et al., 2015)

4.3.Aims of thermal comfort

Research indicates that there are numerous goals for thermal comfort.

1-The contentment of humans is impacted by thermal comfort.

2-Consumption of energy is being limited.

3- Air quality is getting better.

4- Reductions in carbon dioxide emissions lessen environmental damage.

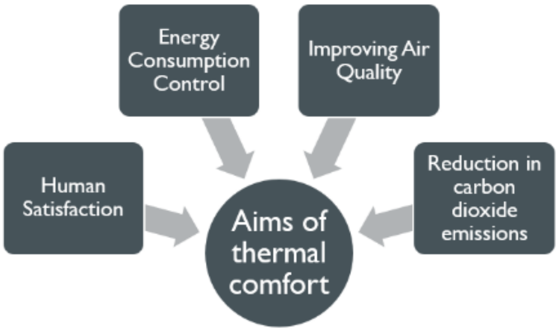


Fig.30: Aims of Thermal Comfort

5. Daylighting:

5.1. Definitions of daylighting

"Daylight is a balanced mixture between diffused daylight and direct solar" (Volla & Seinre, 2012). A common area of interest in many professions is daylighting. Due to the fact that many professions concentrate on various daylighting-related topics, this issue strengthens daylighting design. The table provides examples of daylighting definitions based on the area of interest.(Bahaa El-Dabaa, 2016) A multidisciplinary team that designs everything from the building's orientation to the fenestrations to the lighting control systems is required for an appropriate use of daylighting in buildings. "Although daylight, like other environmental factors, must be controlled, it is challenging because its characteristics change from day to day or even during the day" (Khoshroonejad, 2010).

5.2.Role of Daylighting

Regarding the use of space, energy efficiency, and human health, daylight serves three primary functions. First, **the function of space**: Light is integral to architecture, making form, texture, and color visible, and helping to create environments that are functional and comfortable (Bahaa El-Dabaa, 2016). Second, **energy efficiency**: Daylighting is advocated for its ability to reduce energy consumption, especially in large buildings that typically use significant electricity for lighting. While advances in electric lighting technology have reduced energy consumption, buildings still rely heavily on artificial lighting. Daylighting can also help reduce heating and cooling loads, making it an important aspect of energy-saving strategies. However, its value is not only in energy efficiency but also in its health benefits (Bahaa El-Dabaa, 2016). Lastly, **human productivity and health**: Natural daylighting improves health and well-being by providing dynamic lighting conditions that create a joyful environment and offering views of the outside world, contributing to increased productivity and a more positive atmosphere for building occupants.

6.Simulation

After studying the double skin facade types there is a simulation process evaluating the performance of different façade configurations for an office building in Cairo, Egypt. The base case consists of a single skin curtain wall façade, and two types of double skin façades—static and dynamic—are applied to investigate their impact on indoor conditions. The Cairo Business Plaza, located in the Fifth Settlement, consists of two seven-story buildings, each with office spaces around a central core. The simulation specifically targets a training room on the mid-floor with dimensions 10x6m and a height of 4 meters, which has a glazing curtain wall façade with non-operable windows. This model is then analyzed to determine how different façade configurations impact indoor air temperature, daylighting, and energy consumption.
The simulation process includes several key stages: installing the weather data for Cairo, constructing the model, applying different façade types (single skin, static double skin, and dynamic double skin), and then running simulations to measure energy consumption, indoor temperatures, and daylighting. The activity schedule for the building is configured to reflect typical office hours (9 am to 6 pm, Sunday to Thursday) for accurate energy consumption data.

(Figure 46: Cairo Business plaza)

For the façade configurations:

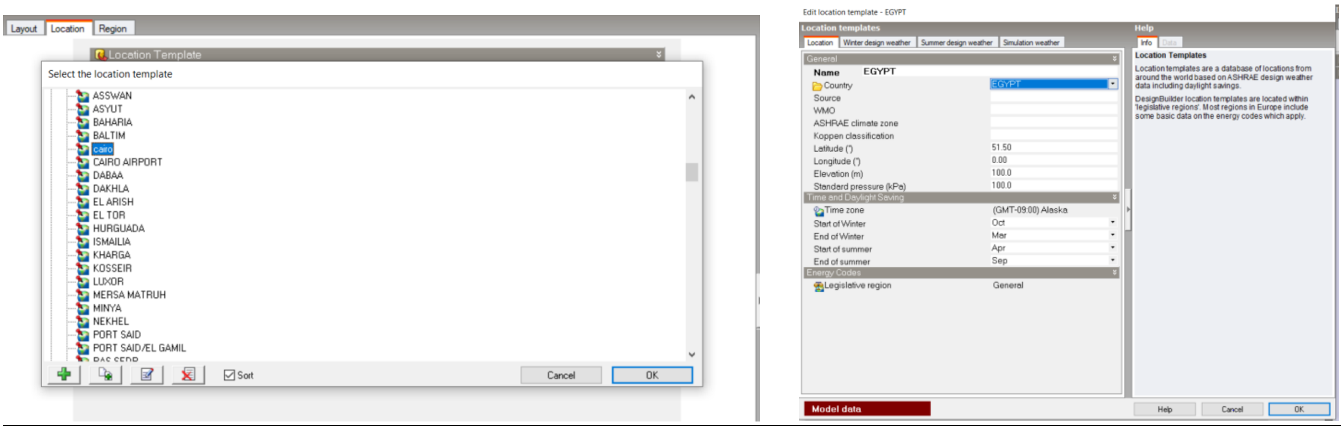
- **Base Case:** The office building is modeled with a single skin curtain wall façade.
- **Static Double Skin Façade:** This model is a modification of the base case, where a static double skin façade is applied to the building. This façade consists of two layers with a fixed gap, aiming to reduce heat gain and improve insulation.

- **Dynamic Double Skin Façade:** This model simulates the effect of adjustable louvers at different angles (15°, 30°, and 60°) to create a dynamic double skin façade, which can adjust based on sunlight and temperature conditions.

6.1.Simulation steps

- The simulation process consists mainly of the following stages:
- Install Cairo, Egypt weather file data.
- Model construction.
- Application of different types of façade on each model.
- Simulation of each type in the same climatic region.
- Measuring energy consumption of each case.
- Comparing the base case with static double skin to dynamic double skin case.
- Gathering information into a detailed comparison to examine the differences.

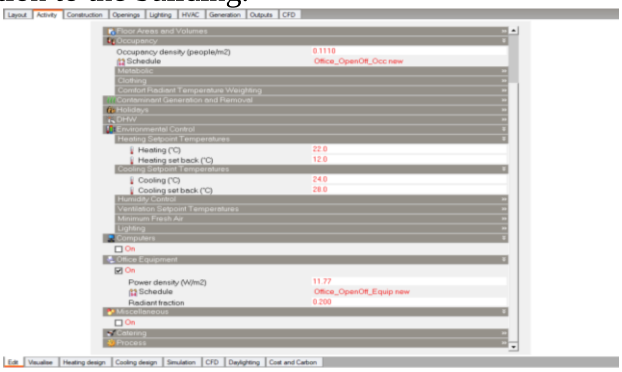
1.Install weather file data and choosing climate weather :



(Figure 47: Installing weather file data & choosing climate location)

Activity configuration:

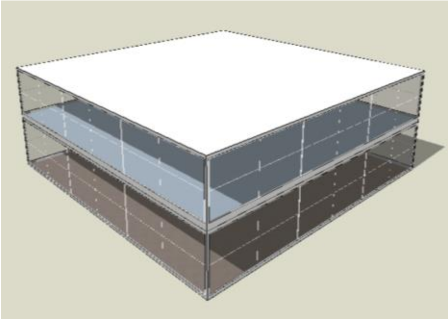
Setting a schedule with the working days and hours starting Sunday ends Thursday from 9 am to 6 pm. To get specific energy consumption to the building.



(Figure 48: Activity Configuration)

4.3.1.Base Case:

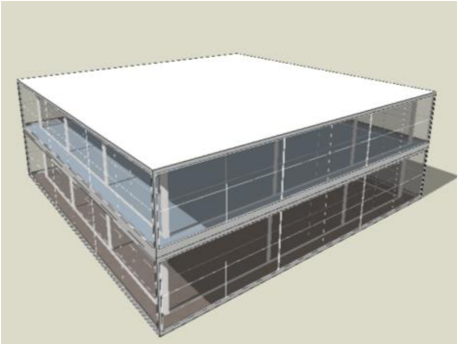
Setting the model as a base case as the cairo bussiness plaza with single cutain wall facade



(Figure 50: Base Case Model)

4.3.2.First case: Static Double skin façade

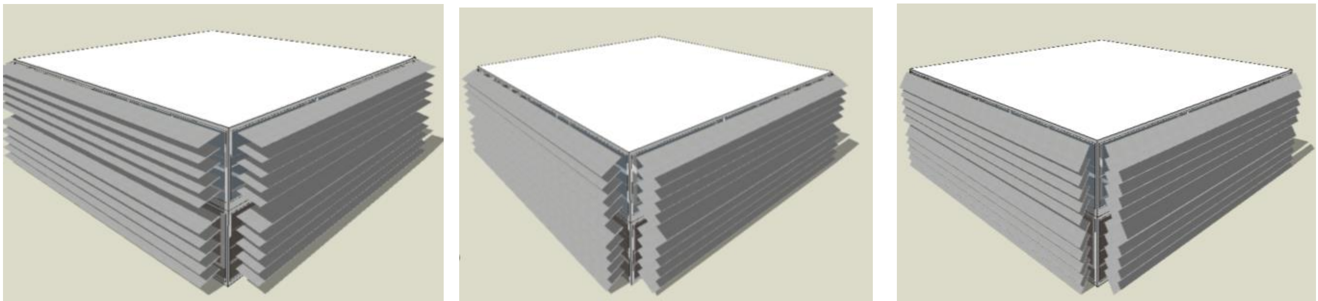
Setting a double skin façade model modified from the base case to compare them together.



(Figure 51: Static Double skin façade Model)

4.3.3.Second case: Dynamic Double skin façade(at 15 Degree)

To get the affect of the dynamic double skin façade effect ,set the louvers in different angles as if it is a dynamic façade and get the average calculations between them.



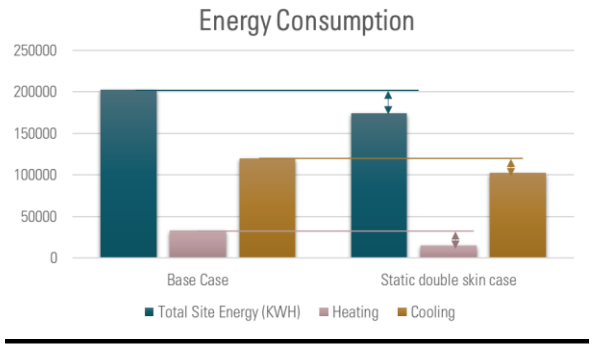
(Figure 52: 15 ,30 and 60 Degree Louver model)

The simulation then compares the performance of these three façade types in terms of energy efficiency, temperature regulation, and daylighting during the hot summer months (June, July, and August).

5.2.Results and findings

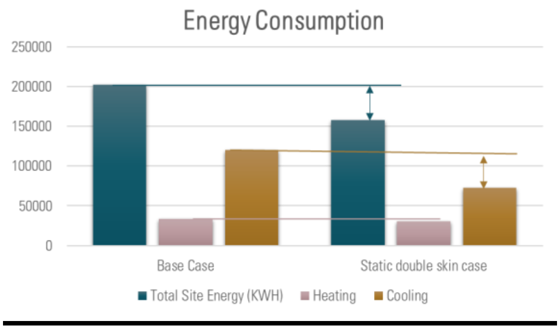
The annual energy consumption of each Double-Skin Façade type configuration studied within the administrative building, for the purpose of identifying which Double-Skin Façade succeed in achieving the highest degree of efficiency related to energy consumption ,better in achieving thermal comfort and better daylighting.

5.3.Energy consumption



(Figure 55: Graph of energy consumption at first case)

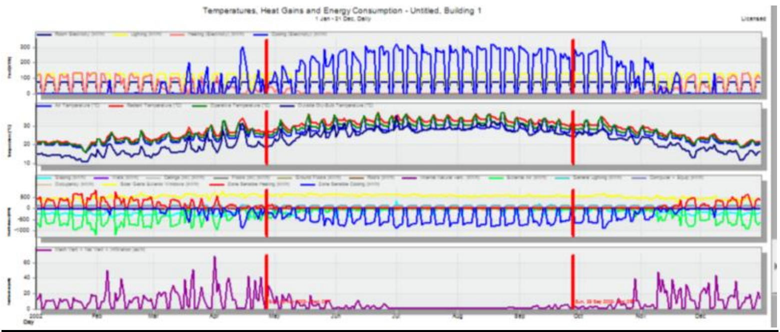
The energy consumed in the static double skin façade with respect to the base case
The Static double skin façade decreased the energy consumption of the office building by 13.92%



(Figure 56: Graph of energy consumption at Second case)

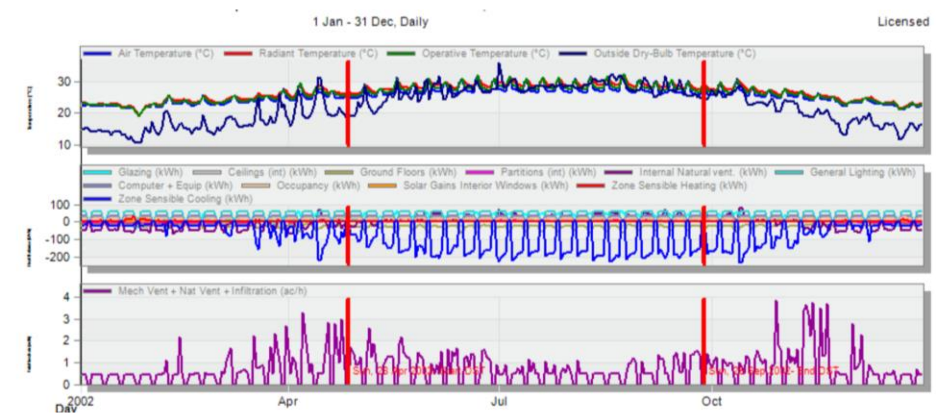
The energy consumed in the Dynamic double skin façade with respect to the base case
The Dynamic double skin façade decreased the energy consumption of the office building by 22.1%.
So the dynamic façade consume more energy than the static double skin façade by difference 8.18%.

5.4.Temperature



(Figure 57 :Simulation of the Base case)

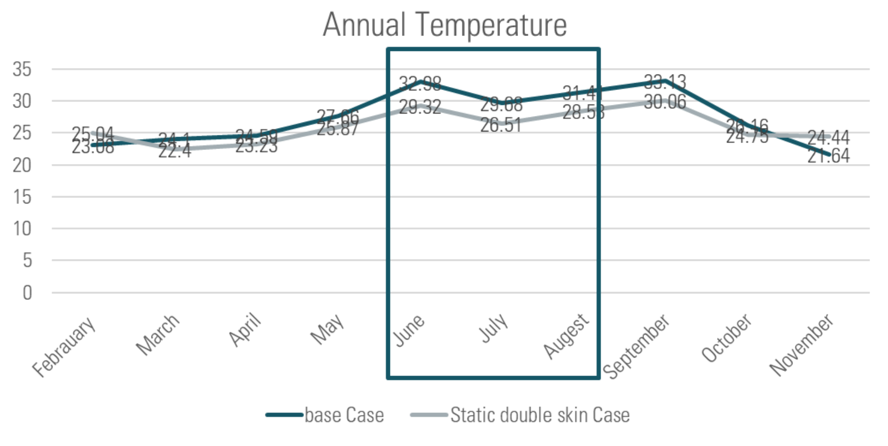
- The annual temperature of the office building in the base case (single skin façade)



(Figure 58 :Simulation of the first case)

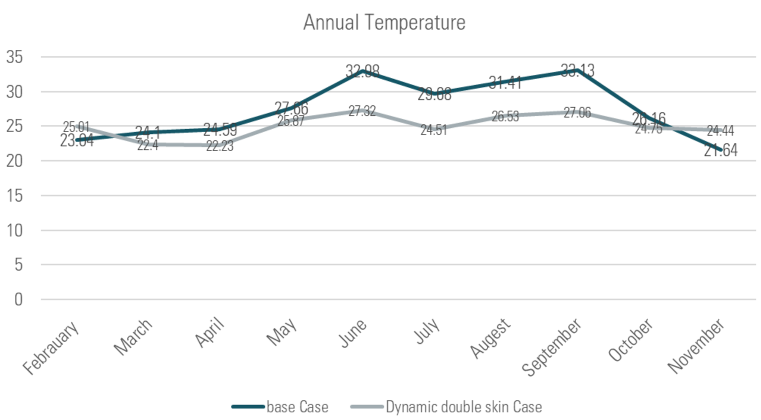
The annual temperature of the office building in the first case (static double skin façade case)

As in the second case the temperature is calculated in the three stages by taking the average temperature in the three cases to get the annual temperature of dynamic double skin façade of the office building on design builder.



(Figure 59: graph of the difference in temperature between base case and first case(developed by the author))

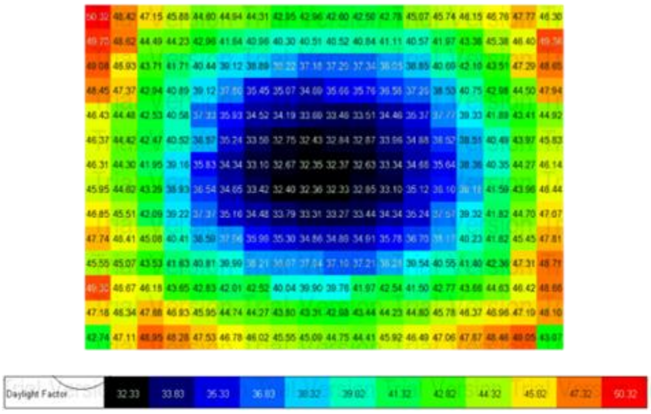
The difference between temperature between the static double skin façade and base case



(Figure 60: graph of the difference in temperature between base case and second case (developed by the author))

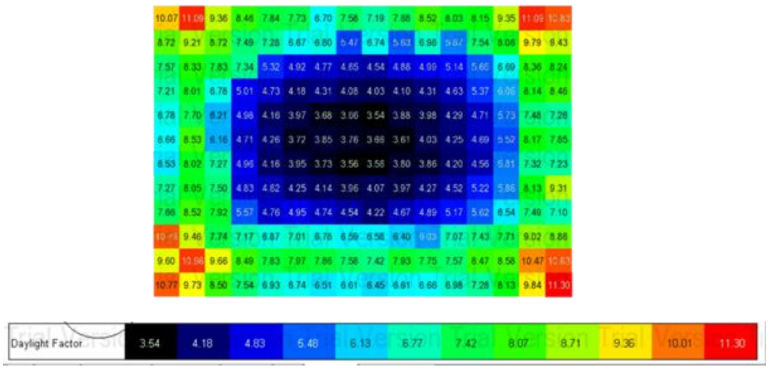
The difference between temperature between the Dynamic double skin façade and base case

5.5.Daylighting



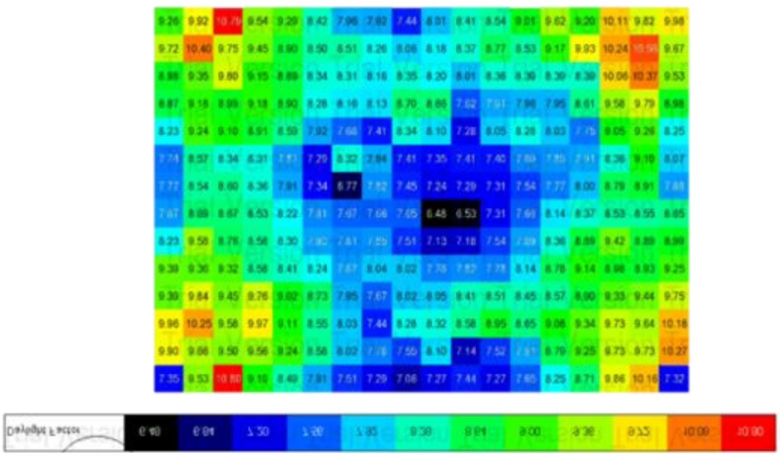
(Figure 61 :Illuminance graph of the base case using design builder (developed by author))

The effect of the daylighting in the base case of the office building.



(Figure 62:Illuminance graph of the first case using design builder (developed by author))

The effect of the daylighting in the Static Double skin facade case of the office building.



(Figure 63:Illuminance graph of the second case using design builder (developed by author))

The effect of the daylighting in the Static Double skin facade case of the office build

The results reveal that the **static double skin façade** reduced energy consumption by 13.92%, while the **dynamic double skin façade** led to a more significant reduction of 22.1%, although it consumed slightly more energy compared to the static system (8.18% higher energy consumption).

Temperature simulations showed a noticeable difference between the façade types, with the static and dynamic double skin façades helping to lower the indoor temperatures compared to the base case, thus improving thermal comfort. The dynamic façade, with adjustable louvers, was particularly effective in optimizing temperature control based on seasonal or diurnal variations in sunlight.

Daylighting analysis, which was also part of the simulation, demonstrated how each façade configuration affected the natural light levels within the building. The static and dynamic double skin façades improved daylighting compared to the base case by reducing glare and allowing more controlled light penetration, contributing to a more comfortable working environment.

Overall, the chapter provides a comprehensive evaluation of the potential benefits and trade-offs between the static and dynamic double skin façades, highlighting the dynamic option's superior energy-saving capabilities, despite its slightly higher energy consumption. The findings suggest that double skin façades—especially dynamic ones—could significantly enhance building performance in terms of energy efficiency, indoor comfort, and daylighting.

Conclusions

The research concluded that double skin façades (DSF), both static and dynamic, significantly enhance thermal comfort, daylighting, and energy efficiency in office buildings. Simulation results using DesignBuilder software demonstrated that dynamic DSFs are more efficient, offering better temperature control and improved daylight distribution compared to static systems. Although DSFs are more expensive initially than single-glass façades, their long-term cost-effectiveness is evident due to their durability, lower maintenance costs, and substantial energy savings. DSFs contribute to more comfortable and environmentally friendly work environments by optimizing insulation and natural lighting, making them a valuable solution for regions like Egypt, where rising electricity demand makes energy-efficient technologies like kinetic façades essential for reducing energy consumption and achieving thermal comfort.

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