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Dynamic Facades
Environmental Control Systems for Sustainable Design

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Abstract - Façades are the most strategic and visible part of the building which leads to an improvement in appearance and environmental performances in buildings. Facades play a significant role in the quality of a building. It forms the barrier between the internal space and the outside climate. This means that the façade is the medium through which the interaction takes place between the activities, inside and outside. The image of a building, and therefore for the users, is reflected through the design of the façade.

In recent practices, architects and engineers are strategically designing and installing dynamic facades not only for their aesthetic values, but also for improving the buildings' energy performance. The high integration of these strategies for dynamic facades increases their durability and suitability, with current building demands, which targets for energy efficiency and thermal comfort level.

In the meantime, recent studies show that the majority of people spend up to 90% of their time indoors especially in hot climates. This trend has had a high impact on the requirements of the indoor environment, consequently turning the buildings into complex devices that ensure the wellbeing of the people who use them. Therefore, users are starting to look for new products for the façade design that comply with the requirements of energy. This poses an important question, is there anything to be done to this specific part of the building in order to positively influence the overall energy need of the building?

The paper will discuss the concept and the importance of dynamic facades according to their design and types, implementations, current challenges and climate impacts. It will highlight the history of these facades and the essential parameters which make the building sustainable through its facades. Moreover, the paper will analyze two examples of buildings with dynamic facades with automated control systems and its effect on the building environment. At the end, the paper tries to demonstrate if these facade systems and strategies could be applicable on the buildings in Egypt.
Finally, the paper aims at integrating the dynamic facades in buildings as an environmental control system to achieve a sustainable design to reach good energy performance in buildings.

Keywords - dynamic facades; sustaianble design; energy efficiency; environemtal control.

I. INTRODUCTION

In recent years, contemporary architecture has been deeply influenced by the urgent need for reducing harmful emissions of carbon dioxide in the atmosphere. The building sector constitutes in fact one of the most energy consuming sectors of the world economy. However, buildings are also potentials and powerful agents able to carry out with effectiveness and relatively rapid's time actions to minimize emissions, through the drastic reduction of their energy consumption. With regard to energy consumption, sustainable building is often directed at energy-efficient use of fossil fuels and the generation of renewable energy through technical appliances. These measures may be considered adjustments to a furthermore traditional way of building, ignoring the fact that the building itself can be innovated to an intelligent, responsive or even proactive device.
From this perception, the building is to be fire-tuned to its environments and interact intelligently with local characteristics such as: climate, type of soil and surroundings. This interaction is most logically performed by the building skin: the roof, the ground floor and the façade, where in changeable climates the use of building mass of the thermally subsoil is an effective means to smooth big temperature differences.

In this paper, the concept of dynamic facades will be explored. Also, the importance of active facades according to their design and types will be discussed. The paper will present the role of building facades particularly "dynamic facades" as an innovative solution that makes buildings sustainable to different conditions and responsive to different environmental needs. In addition, the paper analyzes two applications in different regions with different climates that deal with technological and environmental aspects in sustainable building skins and their role in fulfilling the environmental demands.

Finally, the paper ends up with a comparison between the two applications to reach different solutions to be applied on the Egyptian building facades which could control the surrounding environment and be sustainable.

II. THE BUILDING SKIN AS A SEPRATING AND A LINKING ELEMENT BETWEEN INSIDE AND OUSIDE

Despite changed cultural, economic, building technological and energetic parameters, the principal task of architecture is still to create a comfortable "shelter". In other words, the fundamental aim of a building is to protect people from the external climate conditions, such as intensive solar radiation, extreme temperatures, precipitation and wind. In construction, the building skin is the primary subsystem through which prevailing external conditions can be influenced and regulated to meet the comfort requirements of the user inside the building. Like the skin and clothing of humans, this raiment, too, fulfills the tasks demand of it by performing a number of functions made possible by means of the appropriate design and construction.

The building skin is the dominant system in all subsystems of a building-the load bearing structure, mechanical services and spatial framework-not only in terms of design, but also fulfill a multitude of vital functions and is a principal factor in the energy consumption of a building [1].

III. CONCEPT OF DYNAMIC FACADES

The façade is a strategic element because it is the most visible part of the building. This leads to an improvement in environmental and appearance performances of a building. The façade also exchanges energy with the external environment, this increases energy performance. The façade protects structures and interiors of the building and this contributes to the extension of the life of the building [2].Thus, the building's façade should function as a mediator between the external and internal environments which can be entrusted with multiple vital functions that dictate the building's energy consumption and which determine the indoor environmental quality [3]. Dynamic facades are "facades with the ability to respond to their environment by either typological change of material properties that alter the overall form or local alteration by regulating their energy consumption to reflect the environmental conditions that surrounds it".

Traditionally, the design of a building's façade is "static", where the external environmental boundary conditions are designed to be constantly changing. As a result, traditional facades are not capable of adapting and responding to various changes that they are exposed to. According to a recently completed project of the International Agency – Energy Conservation in Buildings and Community Systems Programme, the development, application and the implementation of dynamic facades provide a necessary step towards creating improvements for energy efficiency within building environments. However, through the use of dynamic facades, the buildings have the ability to react to these conditions with improved energy efficiency in the building [2].Facades that respond to the environment are considered as part of the building's envelope in a primarily different way. Dynamic facades actively adapt to their behavior over time in response to changing environmental conditions and performance requirements. The term "dynamic" in architecture has been described as the ability of artificial and natural systems to adapt to varying environmental conditions. Also, this term is used to describe the interaction between external environmental conditions and the façade systems. Thus, environmental conditions can encompass a range of different elements such as daylight, wind and heat. However, the term "environmental conditions" are associated with solar radiation, daylight and heat [3].

IV. HISTORY OF DYNAMIC FACADES

Within the scope of the technologies of their time, traditional farmhouses had already made optimum use of energy-saving potentials. The heat generated by the livestock was used for heating the building, and straw and hay were not merely bedding and feed but provided insulation. Energy consumption caused by burning firewood was kept to a minimum. Windows had folding shutters that created a thermal buffer between the glass and the shutter at night, very much like a double-skin façade today. Double skin structures make up one of the most widely employed functional principles used to protect against exterior environmental influences through the façade envelope. Prior to the development of insulated glass, a second window was insulated to utilize the area between the two windows as a thermal buffer. The combination of two single glass panes generated higher insulation values and adapted to the prevailing weather conditions. During winter both windows remained closed, whereas during summer, the exterior windows opened to promote ventilation [4].

In modern times, glass has been used more frequently, however, this has increased the issue of excessive cool down in winter and overheating in summer.

As early as 1929, the integration of the building skin and the building mechanics was of vital importance in the goal to successfully translate and realize innovative façade concepts. Le Corbusier formulated a concept for a building envelope with positive impacts on the indoor climate in Precisions: On the Present State of Architecture and City Planning. He talked about the "Mur-rneutralisant": 'We have seen that these neutralizing walls are in glass, in stone, or in both. They are made up of two membranes with a space of few centimeters between them…A circuit in that narrow interval between membranes, hot air is pushed if in Moscow, cold air if at Dakar. The result: one has regulated in such a way that the inside face, the inside membrane, stays at a temperature of 18 degrees".

Le Corbusier's thoughts were never conveyed into a satisfactory result. His ideas were far ahead of his time. Today his "Mur-neutralisant" can be seen as the predecessor of the exhaust-air façade. This type of façade allows regulating the environment of the usable spaces individually independent on the exterior environment by employing a combination of a double-skin structure and an air-conditioning unit. Whereas Le Corbusier aimed to moderate the room adjacent to the façade with an artificial environment in the building envelope, modern environmental concepts used the gap between the façade layers to create a buffer. Thus, the façade space creates an intermediate environment between the interior and the exterior [4].

In other words, the regulation and the adaptability of skin were achieved with control system that is intelligently planned and easy to operate.

V. THE RELATIONSHIP BETWEEN INDOOR THERMAL COMFORT AND BUILDING FACADE

In general, facades are designed to respond to many scenarios and perform functions that can be contradictory to each other: daylighting versus energy efficiency, ventilation versus views and energy generation. Since a wide range of environmental parameters can affect the quality of indoor spaces and user's satisfaction. Numerous studies have been conducted by researchers and architects in order to establish design strategies to create acceptable indoor environments in accordance with the behavior of users and locality of the buildings. Hence, in view of the indoor environmental quality, most of the researchers concentrate on the thermal aspects of environments and the condition of human thermal comfort inside the building.

Facades are the main constitute of the building envelope and a boundary between external and internal environments, considerably impact the environmental conditions of indoor spaces, the thermal performance of buildings and subsequently the user's satisfaction. Hence, thermal comfort conditions depend not only on the external environmental factors (i.e. air temperature, air movement, solar radiation) but also mainly on the architectural parameters and design elements such as the position and orientation of building, façade materials, shading devices, type and location of windows and roof shapes. Thence, design and selection of facades during the design process of building should be considered as one of the major tasks in order to support the quality of visual and thermal sensations in indoor environments [5].

VI. PARAMETERS FOR DESIGNING DYNAMIC FAÇADE

The concept of dynamic facades is not new, however, it is only during the last few years that architects and engineers have started to trust these systems and use them in building. Facades focus on feasibility systems for developing the quality and economy of this technology to be sustainable in the future [6].There are several parameters that should be included when designing building facades. Each has the potential to define the character and affect the overall perception of a building.

- Sun ccontrol

Thermal and visual comforts are dependent on controlling the light entering a building through its façade. The amount of light admitted to a building correlates directly with an increase in interior temperatures, affecting the comfort level of the users within. Blinds can provide a simple way to restrict sunlight subtly without affecting the overall appearance of the building. Alternatively, shading elements can be highlighted by integrating the solar strategy into the façade.

- Natural ventilation

The building skin plays an important role in terms of the natural air exchange in buildings. Ventilation strategies can also give a strong character to the elements of a façade. They can be simple, small, repetitive louvers that allow for localized air circulation, or involved mechanical systems that direct fresh air throughout the building.

- Daylighting

The use of natural daylight is important, both in terms of the comfort and contentment of the users and with regard to reducing the requirements for artificial light. Daylight systems can be achieved mainly through passive measures. A simple movable light shelf can bounce light deep into the space, illuminating the interior by taking advantage of the reflectivity of the ceiling. Daylight levels are known to affect the mental health of the users.

- Connection to outdoors

Connection to the outdoors is another sustainability feature that is physiological in nature, like daylighting. This could be achieved by applying glass protected by a vegetated screen that serves as a visual connection to the outdoors. Sometimes, the walls can open, connecting the interior of the building directly with the outdoors. The aim is to blur the boundary between the interior and exterior space, enhancing the feeling of building in nature.

- Thermal insulation

Thermal insulation systems employ materials and components capable of reducing heat loss through transmittance, convection or radiation. The invisible insulation in walls has a huge potential to impact the thermal performance of a building. A particular insulation's make up and placement within the layering of the building skin can have large consequences that are observable in the thermal performance and aesthetics of the building skin [7].

- Moisture control

Bitumen, a natural substance consisting mainly of hydrocarbons, is frequently used to create moisture barriers in buildings. It is often thought of the outer most skin as the water barrier, but more frequently it is as a rainscreen. There are two kinds of moisture to contend with when trying to keep the building dry: rain and condensation. When large temperature differentials occur between the interior space and the exterior, condensation forms on the colder surface. Protection is necessary to prevent this moisture from seeping into the building. The rainscreen and moisture barrier work together to prevent the unwanted rain and condensation from entering the building.

- Structural efficiency

It is important to integrate structure into the building skin. High-rise construction is primarily concerned with carrying lateral loads, so the diagonal lateral bracing of the building often called the “Gherkin” is expressed as part of the skin, helping to define the character of the building.

- Material choices

Materials can give a very distinctive character to a building. Although they are often overlooked by professionals early in the design process, materials are seminal because their texture and appearance define the experience of the building. Materials also play a primary technological role and have a tremendous effect on the comfort of the building.

- Possibility of energy generation

There is also the possibility for a building's skin to become an energy source. Photovoltaics or flexible solar thin films can be integrated into facades to simultaneously generate power and shade a building [7]. To advance the issue of the building skin with a view to creating truly sustainable and enduring architecture, planning must be goal-oriented, responsible and sensible. Also, a high degree of technical and creative ability is essential. The enormous potential of the building skin must be realized from structural, functional, aesthetic and ecological perspectives to promote advances in the development of architecture that is oriented towards sustainable future [1]

VII. TYPES OF DYNAMIC FACADES

The environment is the key factor that impacts the design of facades, the amount of layering and the material choice, all is dependent on these external forces. So, there are several types of dynamic facades which could be put in category according to the previous parameters.

A. User Control Dynamic Façade

The user control system is an automated system that provides solutions for some time to convey the actuated and responsive reactions to passive processes. Applying such a technology to a building's façade and integrate it with intelligent features will develop an adaptive system that will transmit a higher level of performance while reducing the negative impact of the environmental conditions and the consumption of resources. As a consequence, designing any façade system should take advantage of all the surrounding conditions and resources to develop intelligent techniques that observe occupants' behavior and thus control the façade and achieve a performative envelope that enhances energy efficiency, adaptivity and aesthetics.In general, dynamic and adaptive façade implies that the intelligent objects and components will be featured with enhanced abilities to communicate and interact with environmental conditions and user behavior and respond to changes in external climatic circumstances. Therefore, the situational information can provide the users with complete control through applications to accomplish its process and adjust its functions [8].The following example illustrates this type of dynamic façade. Kiefer Technic Showroom designed by Ernst Giselbrecht + Partner (2007) located in Steiermark, Austria. It is an office building and an exhibition space with a dynamic façade "Fig.1". In this building, the façade changes continuously, each day, each hour which shows a new "face" that turns into a dynamic sculpture. It changes according to the outdoor conditions to optimize internal climate while allowing users to personalize their own spaces with user controls. The façade exterior insulation and finishing system (EIFS) in white plaster operates automatically and can be controlled by users. The façade shading not only can give the flexibility in controlling the outdoor conditions, but also can lend variable forms to the façade design [9].

Fig .1. The dynamic façade of Kiefer Technic Showroom

B. Light Control Dynamic Façade

In this type of façade, automated shading and daylighting control systems are integrated and operate appropriately for all environmental conditions. A notable example is the Arab Institute in Paris designed by Jean Nouvel in 1988. The façade of the building showed continuous considerations for the surface that can actively respond to changes in environmental conditions "Fig.2 and 3". The south of the facades is composed of a 20x10 grid square bays that consist of a central circular shutter that was set within a small grid of shutters – the design was adopted from the geometry of traditional Arab screens. These screens operate like a series of camera lenses, shrinking and widening in response to sensors to control the penetration of sunlight into the building.

Fig .2. The façade of Arab Institute (Paris)

Fig .3. The dynamic circular shutter adopted from the traditional mashrabiya

A similar pattern of design was adopted by AEDAS in Abu Dhabi in Al Bahr Towers (2012). The building consists of a membrane clad dynamic façade with a similar hexagonal pattern in the construction of the active surfaces "Fig.4 and 5". The design of the dynamic "mashrabiya" adopted a similar concept by Nouval to create a responsive façade. The dynamic mashrabiya includes 1,049 units for the west and east side of the building, which claims to be the world's largest, computerized façade built today for 150 metres high towers. The facades create a folding and unfolding movement, which adapts to the sun and the changing environmental conditions [4].This system is predicted to reduce the solar energy entering the building by 20%. Also, it is claimed that the design has resulted in 40% saving in carbon dioxide emissions.

Fig .4. Al Bahr dynamic facades

Fig .5. The folding and unfolding movement of the facade

C. Energy Control Dynamic Façade

Another application for dynamic facades is saving energy in buildings and controlling energy performance in buildings. Energy conscious facades is where the envelope has construction functions such as strength and rigidity, stability and durability, control of heat, air and moisture vapor flows, control of liquid water movement cost-effectiveness and fire resistance. The envelope is responsible for the building energy performance [10].

This is illustrated in Henning Larsen's University Building in Kolding, Denmark that moves in response to changing heat and light "Fig. 6". The daylight changes and varies during the course of the day and year. Thus, Kolding Campus is fitted with dynamic solar shading, which adjusts to the specific climate conditions and user patterns and provides optimal daylight and a comfortable indoor climate spaces along the façade. The solar shading systems consist of approximately 1,600 triangular shutters of perforated steel. They are mounted on the façade in a way which allows them to adjust to the changing daylight and the desired inflow of light. When the shutters are closed, they lie flat along the façade, while they produce from the façade when half-open of entirely open and provide the building with a very expressive appearance. The solar shading system is fitted with sensors which continuously measure light and heat levels and regulate the shutters mechanically by means of a small motor [11].

Fig .6. The dynamic patterns in the façade of Henning Larsen's University Building

D. Wind Responsive Dynamic Façade

Wind as a natural element itself is strong enough to provide a dynamic pattern of motion without wasting any energy. Brisbine domestic Terminal Carpark in Australia (2011) has installed 250,000 aluminum plates to create this wind-powered façade. The car park's entire eastern side appeared to ripple fluidity as the wind activates 250,000 suspended aluminum panels. As it responds to the ever-changing patterns of the wind, the façade created a direct interface between the built and the natural environments. The façade itself constantly stays in moving motion as the wind blows.

E. Façades Designed to Manage Water

A fundamental role for high-performance buildings is the management of water. It is imperative that roofs and facades effectively manage rainfall through material selection and articulated detailing from top to bottom. Rainscreens are innovative solution to manage rain and vapor migration. As buildings embrace a greater set of sustainability challenges, they also need to collect rainwater. There is a decline in sources of fresh water and increase of storm runoff challenges. The importance of designing building to catch and store water is of growing importance.

VIII. APPLICATIONS ON DYNAMIC FACADES

A. Masdar Institute for Science and Technology (Abu Dahabi, United Arab Emirates)

Masdar Institute for Science and Technology (2007-2010) is located in Masdar City under the supervision of Masdar Initiative. It is designed by Foster + Partners "Fig. 7". Abu Dhabi's climate is considered to be subtropical climate, with temperatures that very from warm in winter months to hot in summer with sunny blue skies prevail throughout the year and rainfall is infrequent which affect the building architecture design to fulfill the environmental and climatic conditions.

Fig .7. Masdar Institute for Science and Technology (Abu Dhabi-U.A.E)

- Sun control

Windows that are not already shaded by adjacent buildings have louvers vertical to block morning and afternoon and horizontal to block mid-day sun-set to prevent direct sunlight from shining into the building.

- Natural ventilation

There is a contemporary re-interpretation of the traditional Arabic wind tower which brings cooling breezes to the courtyard. Rising 45 meters above the podium, this modern interpretation will be a landmark for Masdar city. Sensors at the top of the steel structure operate high level louvers to open in the direction of the prevailing winds and to close in other directions to divert wind down the tower. A PTFE (non-stick brand Teflon) membrane carry the wind downward while mist generators at the top add additional cooling to the air. Combinations of evaporative cooling and air movement techniques help to moderate perceived air temperatures, thereby improving users' comfort.

- Moisture control

Behind the foil is a highly insulating and highlysealed panel. Aside from the rest of the façade, are highly sealed, insulated and wrapped 90% windows, recycled aluminum sheeting and rose-red color.

- Material

Facades at Masdar city incorporate a variety of technologies and materials to address sustainable building. Laboratory buildings are characterized by air-filled ETFE cushions (30 cm thick) that ensure almost no solar gain on the structure and limit the heat re-radiated to the street. A reflective foil-clad inner layer behind the cushions send light to the pedestrian street below.

- Energy generation

There are over 5,000 square meter roof dynamic photovoltaic panels which provide power and further protection from the direct sun. The photovoltaic array above the building helps to provide 30% of the electrical load of the city [12].

B. Pearl River Tower (Guangzhou, China)

Pearl River Tower is located in Guangzhou, China. It was constructed under the supervision of CNTC Guangzhou Tobacco Company. It was designed and constructed by Skidmore Owings & Merill with partner Adrian Smith and Gordon Gill during the period 2006 – 2010 and it had been awarded in 2008 for Green, Carbon Lowering and Environmental Category: Gold Award "Fig. 8".Guangzhou is in south eastern China which is characterized by its hot humid, heavy rain climate with predictable prevailing north, south and south west winds. Summer season is long, wet, hot and humid, where winter is mild, dry and free of snow with average mean temperature. These climatic conditions played an immense role in terms of different design and sustainability integrated either on the building scale or façade scale.

Fig .7. The dynamic façade of Pearl River Tower (China)

- Sun control

Pearl River Tower integrates various technologies in building skin design as follows:
Double glazed wall system:
The north and south façade are double layer curtain wall system which offers insulation that reduces heat gain and leads to less demand on HVAC systems.

Exterior glazing material:
Exterior glazing is insulated, tempered glass with low-coating. The inner layer is operable clear glass on the building south face where low-emittance glass is coated with microscopically thin, virtually invisible metal layer that reduces thermal conductivity.
Triple glazed façade:

East and west facades are associated with external shades and automated blinds within the facades cavity. A photovoltaic system is integrated into the building's external shading system and glass outer skin.

- Ventilation

The most innovative of Pearl River's element are the vertical axis integrated wind turbines that are used for catching the prevailing winds from the south and the notrth with minimum loss.

- Shading

As all the facades of Pearl River Tower are double glazed facades, then shading blinds are placed within their cavities where motorized venetian blinds is in the east and west double façade. The blind position is determined by a photocell that tracks the sun position to ensure occupancy comfort from both solar gains and glare.

- Energy generation

There are photovoltaic panels which are integrated into the facades to transform the sun's energy to usable AC current where the use of PV cells could be productive if it is used on certain portions on the building envelope.

Also, Pearl River Tower is planned to utilize hydrogen fuel cells in the building façade to store excess generated energy and convert gas into electricity with more than 50% energy efficiency which could be used as power energy for cooling and ventilation [10].

Table 1. Comparison between the parameters of the two applications

Parameter	Applications	
	MIST (Masdar City, U.A.E.)	Pearl River Tower (Guangzhou, China
1. Sun control	Vertical louvers to prevent direct sunlight	Facades are associated with external shades and interior automated blinds
2. Natural ventilation	Re-interpreation of the traditional Arabic wind tower	Consists of a double glazed façade with integral spandrel panels and cavity space for air cooling
3. Daylighting	N/A	Integrated glass façade to provide visual transmissions, enhancing daylight and reduce artificial lighting
4. Connection to outdoors	N/A	N/A
5. Thermal insulation	N/A	N/A
6. Moisture control	High insulated panels	N/A
7. Structural efficiency	N/A	N/A
8. Material choices	air-filled ETFE cushions with reflective fiol cladding	N/A
9. Energy genration	Energy is 60% less using photvoltaic panels	Energy is 44% less using photvoltaic cells and hydrogen fuel cells

IX. TRANSFORMING TRADITIONAL FACADES INTO DYNAMIC FACADES IN EGYPT

So, the question now, after studying the parameters of dynamic facades, could these facades be applied in buildings in the Egyptian context?

The answer is yes, however there are some criteria concerning the climate of the region, the materials used and the availability of technologies. Also, design of facades should take the surrounding environment of the country, the sun path, wind and humidity and the use of energy consumed in consideration.

This can be achieved through the delicate traditional mashrabiya which has offered effective protection against intense sunlight in Egypt for several centuries. However, nowadays this traditional Islamic window element, with its characteristic lattice-work, is used to cover entire buildings as an oriental ornament providing local identity and a sun-shading device for cooling.

In fact, designers have transformed this vernacular wooden structure into high-tech responsive daylight system according to the external conditions.

The ancient mashrabiya merges cultural, visual and technical aspects. Therefore, this window screen is often found towards the street to enable discretion and allow cool air to pass through the façade. Several newer buildings in Egypt have transformed the oriental window technique into dynamic facades to reduce the cooling loads for the interior.

Also, the malqaf is another façade element which could be used in a dynamic way. It is a suitable source for natural ventilation in buildings especially in hot arid regions. It is a device or a shaft rising high above the building where it is cooler and stronger and the wind channels down into the interior of the building.

The malqaf could be adapted to move dynamically according to the direction of the prevailing winds of the city/country which creates air movement and consequently natural ventilation . The following table (Table 2) proposes some ways for improving the façade systems in Egypt. These recommended ways could increase comfort and reduce energy consumption and improve daylighting inside buildings.

Table 1. Recommended ways for improving façade systems in Egypt

Design	Materials	Systems	Performance
- Automation - Daylighting - Design for adaptability - Design for intelligence - Design tools - Modular coordination - Natural ventilation	- Advanced materials - Advanced insulation - Air/Vapor barriers - Intelligent materials - Resource-efficient materials	- Advanced foundations - Double envelope - Intelligent envelope sysstems - energy services - rainscreen	- Modeling - Monitoring - Testing - Rating criteria

X. CONCLUSION

The paper has situated the main objectives for an efficient sustainable building façade taking into account the environmental sustainability aspect, where it has introduced the main parameters for developing building façade concept. Also, it has focused on the different façade techniques in terms of natural ventilation, shading techniques and energy conservation and its role in enhancing the internal environment.

According to the applications and examples reported in this paper, building facades play an immense role in building energy efficiency and building energy performance where:

- Dynamic facades are more widely used to permit natural light, it is considered also an efficient innovative ventilation system if properly designed.
- The most advantageous shading schemes have proved to be external shading device and movable overhangs installed on building façade, considering also other benefits of external shading as it could be suggested as a very effective design solution against overheating.
- The most effective shading system is the adjustable exterior shading louvers, where it is considered to be the most effective shading devices as it has a variety of colors and materials.

XI. RECOMMNEDATIONS

In this section, some recommendations about the appliance of sustainable building façades technologies in Egypt will be presented taking into account the environmental, economic and climatic conditions. Egypt lies within the North African desert, this geographical location gives the Egyptian climate some characteristics which affect the design of nay building especially the facades. The Egyptian climate is arid and characterized by hot dry summers, moderate winters and very little rain fall which will encourage designers to design dynamic facades which will be able to provide natural ventilation, shading and reduce energy consumption. There are some recommendations for architects and governments in order to enhance the application of sustainable dynamic facades strategies.

A. *Responsibilites for Architects:*

Designers should consider important issues for efficient dynamic facades. These issues affect the technologies applied into building façade taking into account its costs and how appropriate it is for building requirements and thus, energy saving. So designers should:

- Properly select site for the building, as the design features change with site climatic characteristics.
- Properly decide the best façade technology that serves the target of the building.
- Choose appropriate ventilation strategies that are suitable for the building usage.
- Architects must carefully study the complex issue of material and energy exchange, moreover they must know how to apply the information just thus gained to planning and construction and consult specialized engineers.
- Be updated to all computer modeling that can lead the designer to exact performance of the chosen perfect façade strategies.

B. Responsibilites for Governments:

Governments own and maintain a wide range of buildings and facilities where there are a variety of tools that could help the government develop and operate building resources for applying efficient passive cooling strategies in a sustainable manner:

- It could create community boards and commissions to study local sustainable issues and provide economic motivation for sustainable design building development.
- It should permit training and education programs that focus attention on building sustainable development.
- New government buildings should in corporate and promote energy efficient facades that harmonize with the Egyptian climate.

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