INTRODUCING RESPONSIVE BUILDING FACADE IN EGYPT FOR ENERGY EFFICIENCY AND SUSTAINABILITY

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Abstract- Responsiveness is a distinctive characteristic that can offer a great opportunity when used in building facades while adding responsive units that allow or prevent the daylight into the spaces offering a chance to regulate sun light to minimize electric light dependency and benefiting from natural resources to reduce energy consumption seeking sustainable building design. Not ignoring the human comfort as a main aspect and the psychological and physiological impacts, inspiring from the mother nature the concepts of biomimicry can be apply all over the notion of responsive facades systems, whereas a lot of ideas have evolved mimicking on different scales to solve problems nature has experienced and solved a long time ago where as these solutions might minimize the human impact on the environment in the road of achieving the main goal which is a sustainable built environment. Exploring the ideas either implemented or not for responsive façade and finding a method to categorize them in accordance to motion type and complexity, might open the door for more innovation in this field helping more architects to get involved and contribute in finding a suitable strategy to implement responsive facade systems in Egypt.

Keywords— biomimicry, daylight, human comfort, kinetic façade, responsive façade

I. INTRODUCTION

A blessed geographical position prized by god should be totally exploited and in other words architects in Egypt should make use of the sunny weather of Egypt by benefiting from the daylight, while rationalizing the energy consumption for lighting and air conditioning. Since the 60s dynamic patterns has been used to generate responsive facades, where it offers a suitable solution to create a façade that responds to external stimuli; including environmental condition, social situation as well as the whole building context. This paper will explore the field of responsive architecture in the terms of the façade as a conjunction between the inside of the building and its context.

II. PROVIDING SOLUTIONS INSPIRED FROM NATURE

In nature a notable form of dynamic adaptation could be found in some flowers, where they perform a process known as nyctinasty, this process can be either in the form of the flowers closing by day and opening by night to protect the flower from harmful sunlight and prevent the loss of nutrient and water content, being closed by day they miss the chance of being pollinate by day active creatures, and depending on bats for example for pollination. [2]

The other form of adaptation can be found in the flowers opening by day and closing by night protecting itself from harmful insects and keeping the pollen grains from being lost preserving hem t other pollination in the next day. The flowers use a sort of a natural sensors to open or close by ether growing cells on the outer sides of the petals to push close the flower or by pumping water in and out of the cells. other forms of adaptation could be found in flowers in nature like flowers following the sun or changing shape, or even flowers that catch insects to feed on them. By the observation of such behavior, we conclude that flowers in nature responds to external stimuli such as light, temperature and in some cases humidity, to provide protection and to save their water content and energy.

Building skin is the barrier between the occupants of the building and the external context of the building, separating and indoor environment from the outdoor environment, where the outdoor has its effect on the indoor affecting the indoor qualities and the human comfort. [2]

The management of the building skin and controlling it to be responsive to real time changes in environmental conditions, enhancing the building performance toward energy consumption and taking advantage of external stimuli better than isolating the building.The relation between the indoor and the outdoor can be seen in making use of the day light avoiding over heating

Giving the building the ability to responds to the external stimuli not only stay as a rigid body, helping it to act as a living component with in the environment and achieving much sustainability by adding features that could help in energy conservation as well as making the most out of the available resources.

In an inspiration from nature where all living organisms are linked together in a hierarchy and the

organisms themselves are formed out of an array of cells that are also linked to each other.

Responsive facades are solving the problems faced static facades by providing the capabilities of acting more than one role at once from which static facades plays one in a time, such as; allowing solar heat in certain time but preventing it in other times, it also can prevent glare but allow day lighting and visual contact of occupants to the external environments.

The switching between each functionality in adaptation to different conditions gives the façade the ability to minimize compensation, maximizing human comfort as well as building performance from an environmental point of view.

While searching of the tool of evaluation, an analysis of examples has to be done to extract the main criteria through which the responsive façade could be evaluated and the suitable tools for simulation

III. MOTIVATION FOR RESPONSIVE FACADES IMPLEMENTATION

The search for a high- performance building skin has resulted in sophisticated components gathering advancements achieved in technology such as real-time environmental response, advanced materials, embedded microprocessors, sensors and actuators, requiring a new approach to the design process concerned with the performance of the building.

When monitoring the building- it's found that the forces outside the building are dynamic and not stable, as a consequence the building skin should be as interactive and dynamic to achieve energy efficiency.

The building envelopes are now provided with components that can perform dynamic functionalities like controlling daylighting, sound and air transition, heat transfer and natural ventilation. Being the most part of the building exposed to weather fluctuations, the building facades are considered an active ingredient in the process of saving energy and raising the energy efficiency of the building.

Research in the field of building envelope Is getting more intention in line with the advancements in the field of building science, also as a result of new technologies such as smart materials new design methodologies has emerged inspired from nature and the biological model adding new terminologies to the architecture language such as referring to the building facades or envelope as building skin.

The introducing of the term skin is not only a symbolic likening; the building envelope is considered a live film not only separating the outside of the building from the inside but also as a medium for energy, material and information exchange, acting as an essential part of the building functionalities and could be connected to the other components of the building like the sensors actuators, and command wires from the building management system. [7]

This new approach of design has leaded to viewing the building envelope as a behavioral element not only a physical robust element, in which a new channel has been established between other branches of engineering including mechanical and electrical in an interdisciplinary process; blurring the boundaries between these disciplines , and causing a sort of confusion that appears in the field of architecture as in terms like smart, intelligent, interactive, responsive or adaptive, a sort of a comparison has been made starting with the term smart, which has been frequently used to describe materials and surfaces, when they include ubiquitous technologies assisting interactivity through internal physical property changes or through external energy exchanges. [1]

IV. THE MAIN CONCEPT FOR A RESPONSIVE FACADE

The idea of responsive facade is built upon multiple small units manipulated in a form of arrays or patterns acting as shading devices attached on the façade enabling and disabling the daylight to the indoor spaces, offering an infinite number of possibilities and solutions creating the optimum situation offering an efficient daylighting to different parts of the building according to the needs of the spaces.

The units are arranged in a way that enable their transformation in the form of rotation or translation or scaling according to actuators attached and manipulated by sensors regarding the daylighting for an indoor space, introducing parametric design tools in addition to the sensors and microcontrollers being inexpensive has contributed in offering the ability of implementation of an autonomous system where each unit of the array, acts individually and adding a decentralized action, depending on each unit to perform on her own according to the data it receives from their own sensor according to their unique position and to data received from communication with other units [3]

V. ROLE OF ADVANCEMENTS IN COMPUTER PROGRAMMING IN RESPONSIVE STRATEGIES

The notion of the evolutionary solvers and genetic algorithms was referenced to the sixties of the last century , when Lawrence J. Fogel published the landmark paper "On the Organization of Intellect" an then appeared more than once, until 1986 the evolutionary programing was not popular beyond the programmers community, when Richard Dawkins' book "The Blind Watchmaker" was published, helped

by the availability of personal computers to be applied in personal project away from the governmental funds. Being a programming tool made by a programmer for other programmers it was a great advancement to provide a tool for non- programmers in the form of a generic platform to apply evolutionary algorithms in problem solving

Evolutionary algorithms application is considered to have some drawbacks one of them s that they provide a number of generations but not guaranteeing a solution as well as the other disadvantage which is the time consumed in calculations and generating solution depending on the number of inputs and variables which should be considered. The process starts by identification of variables where each one is called a gene and a group of them is called a genome, according to a fitness function which is the targeted product of the algorithmic solver and according to it the fittest offspring are chosen to mate and produce the next generation from which the fittest are chosen and so on until the best is selected.

VI. UNDERSTANDING THE RELATION BETWEEN THE FAÇADE AND THE CONTEXT

Controlling the amount of illumination transmitted to the inside of the building, by optimization of responsive units acting on the façade in terms of specific variables such as the shape of the unit that the pattern consists of described as the number of sides of the shape, size of the unit, and the type of motion whether it's a rotation or translation, typically a type of response is ignored which is the scaling, that's because the unit scale is previously determined.

VII. EXPLORING VARIOUS ACHIEVEMENTS FOR RESPONSIVE FACADE SYSTEMS

Architects all over the world have been exploring the ideas of integrating responsive façade systems either for the aesthetic value or for environmental needs and functional purposes

A. Horizontal and Vertical Rotating Shading Units

Louvers are the most familiar element to be motorized and controlled either manually or automatically through computerized systems to manipulate day light inside interior spaces. A part of the implementation of net zero houses can be achieved by integrating the distributed responsive system of skins, as offered by the north house responsive envelope which is design to suit the near northern climates (42-55 latitude) where heating is needed and the daylight time is short where the is a great need to maximize the daylight inside the interior spaces.

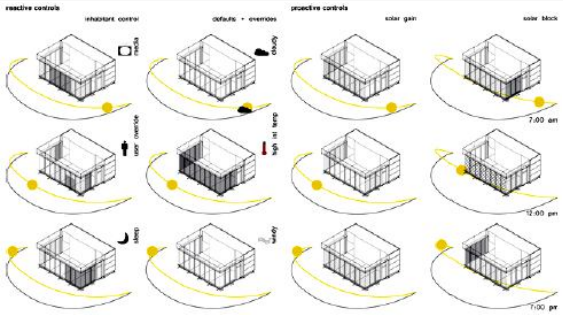


Fig. 1 Exterior shade configuration scenarios based on relative exterior environmental conditions, and related responsive envelope reactions. Source: by Perkins and Will research journal

Designed with a window wall ratio of 75 percent, north house is taking advantage of advancements in fields of glazing and shading systems, directing a highly glaze façade toward the south as living spaces and services with minimal glazing directed to the north, minimizing heat loss and maximizing daylight harvesting. [6]



Fig. 2 Components of Distributed Responsive System of Skins, detail for automated two stage exterior shades. Source: by Perkins and Will research journal

A drawback of the glazing is high luminance offered by solar radiation affecting human comfort as well as the heating and cooling of the space requiring a control unit monitoring the weather conditions outside and controlling the horizontal shades.



Fig. 3 glass slat lying in front of a three-meter-high glazed curved wall for the new exchange Senlau in Zurich. Source: http://www.colt-info.de/

The new exchange Senlau in Zurich is provided by a sun tracking device used in aiding the glass slate to rotate with a step of a five degrees to provide optimum

shaded and protection from direct sun rays, as well as responding to various weather conditions like wind and rain. The new extension was designed to reveal the dynamic performance of employees inside the spaces exposing the interior space to a vast amount of solar radiation increasing the thermal loads, that required a soluion which was a matching dynamic vertical shades.

B. Two Dimensional Translating Unit

There are several examples for automated systems that consists of two dimensional units sliding in a translation motion to allow or stop the daylighting into the space providing different patterns adding an aesthetic value as well as the environmental consideration, such as "Arab world institute" and work by chuck hobberman "the adaptive fritting "



Fig. 4 adaptive fritting at The AHHAA Science Centre designed by Chuck Hoberman. Source: http://www.hoberman.com/

Adaptive Fritting is a result of dynamic layers of fritted glass that slides to get aligned or diverged to provide different grades of opacity and transparency providing privacy and allowing to control visual contact and daylight interring the space.

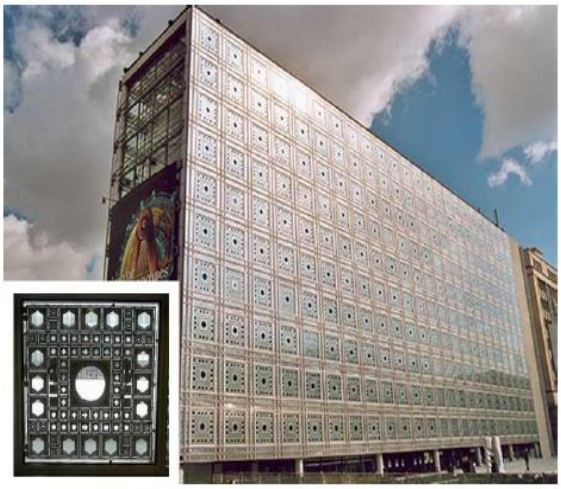


Fig. 5 Arab World Institute, Paris, France, 1989, by jean Nouvel. Source: flexible, architecture that responds to change, Robert Kronenburg

As considered at the time of construction, the south façade for the Arab world institute is a contemporary translation to the traditional Arabic sun shades but in a dynamic way with shifting small units in an aperture style are providing different patterns of daylight and shades to the interior of the building. [4]

C. Contracting and Expanding Units

Considered a three dimensional motion a for dynamic units, research was carried out on more than one idea, one of the implemented ideas is the units used in the El-Bahr tower in the United Arab Emirates

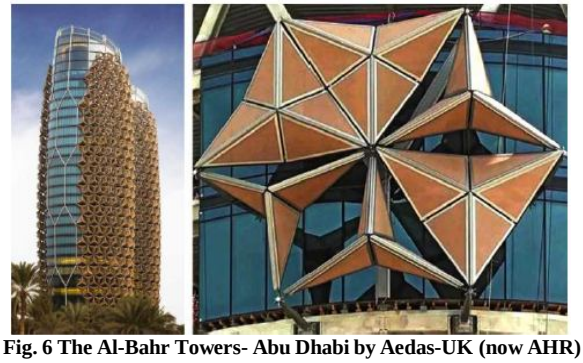


Fig. 6 The Al-Bahr Towers- Abu Dhabi by Aedas-UK (now AHR) in Collaboration with Arup. Source: Karanouh, Abdulmajid

Digitally generated and designed inspired from the vernacular architecture in UAE, the dynamic sun shades are offering a unique identity to the AL- Bahr towers, and respecting the external environment by tracking the sun to control the opening and closing of a complex dynamic origamic 1048 units. [5]

VIII. CHALLENGES FACING THE IMPLEMENTATION OF RESPONSIVE ARCHITECTURE IN EGYPT

Egypt is considered a developing country where a lot of challenges would face the implementation of such an initiative these could be summarized in the following points:

- The majority of construction is not handed to professional architectural firms.
- The high price of technology implementation makes it harder to spread such an initiative.
- The weather conditions requiring high maintenance cost
- The unavailability of diversity in construction materials add limitations on the implementation process.
- The lack of trained workers and engineers in such a field.

CONCLUSION

The benefits of Implementing the responsive façade systems are sufficient to overcome the challenges

facing It, as a training could be provided to workers and architects, the availability of the daylight and Its quality motivates to harvest and Integrate the systems in design, examples explored all over the world has proved that locations with less daylight and solar radiation has benefited from responsive systems and saved energy to achieve sustainability.

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