Optimization of daylighting and energy performance in hot - arid climate

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Optimization of daylighting and energy performance in hot - arid climate

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Abstract. The daylighting performance, besides the thermal comfort of the buildings is extraordinarily needed to be determined at the early phases of design. In addition, the building envelope is playing a vital mediator between the building and other the surrounding conditions whether perceptible as climate change or intangible like cultural heritage identity. So that, studying responsive architecture for sustainable buildings by developing the daylighting performance, and reducing the energy consumption of the buildings are important scopes for getting rid of Carbon dioxide (**CO_2**) emissions to adapt and mitigate climate change and occupants' satisfaction.

Currently, the hot-desert countries are carrying out the design strategies based on the fully glazed office buildings as in the United Arab Emirates (**UAE**), which is called '**the International Style**', was established for another climate. This causes an inefficient building performance coupled with identity crises. Furthermore, the artificial lighting and thermal comfort are two of the primary energy demands in the office buildings. In terms of both productivity and human comfort, the occupants ' satisfaction with their surrounding workplace is vital. So that, any strategy aims at decreasing exaggerated solar radiations and improving availability of daylight is deemed a sustainable strategy for design. Furthermore, there are limited performance evaluation tools offered to architects at the early phases of design. In this light, the state-of-the-art " **Digital Age** " has applied smarter and more interactive " building envelopes " to ensure environmental control and comfort. So that, this paper focuses on this problem in Hot - Arid countries.

1. Introduction

The current concerns about environmental, and performance necessities are increasing to be met efficiently, so the architectural design has turned into a complex mission [1]. Furthermore, the building sector consumes exaggerate energy more than the other sectors [2]. So that, the shape of the building, along with the building performance becomes the ground-breaking powers, which are dictated by the surrounding conditions of the building for either variations in climate or cultural character of a region [3]. Therefore, the building envelope plays a vital role as an adaptive element which is used to achieve energy saving and human thermal comfort [4]. Thus, designing a responsive building interacts with changeable surrounding conditions is the noteworthy inspiration in this research by utilizing computer-aided design (**CAD**) tools and techniques, that has magnificent possibilities to ease understanding the association between performance, and form to rescue the entire environment.

2. Architecture problems in the 20th century

During the 20th century indoor comfort requires are met by Heating, Ventilation, And Air Conditioning (**HVAC)** systems and artificial lighting [5] simultaneously connected with improvement in construction and materials to innovate a new style of architecture, **'the international Style'**, that is distinguished by the completely glazed buildings [6]. This style acquired one bound together strategy, particularly contemporary commercial buildings in New York, London, or even in the (**UAE**) appears the same, which ignores the distinction in surrounding climatic conditions or social character's identity as **Figure 1**. These buildings depend primarily on mechanical devices for ensuring the necessary conditions for internal human comfort and massive inputs of energy due to the glazing 's poor thermal performance and its selective property in terms of the permeability of radiation (**greenhouse effect**). In this case, the indispensable role of the building envelope as a climatic moderator could not be achieved, which causes numerous worries like increasing $\mathbf{CO_2}$ emissions, growing energy consumption, health and comfort problems, and so on.

Figure 1. Contemporary office buildings in different climate and culture conditions

The glazed transparent component plays the most important role in the envelope of each building. It offers natural lighting to the occupants that enhances their comfort and the sense of wellness. [7] In the meantime, the fully glazed building envelope in hot-arid climates is normally less thermal and does not allow efficient solar and thermal control [8]. Particularly, in hot-arid countries with extreme daylight levels, sunlight often penetrates the interior of the building too much. These buildings are mainly dependent on artificial light during daytime with the presentence of outdoor daylight because they have not any daylight optimization design strategy. The advantages of natural light are completely eliminated by glare and solar radiation. So that, the occupants prevent the excessive solar radiation by using internal curtains or blinds to maintain thermal and visual comfort. These also absorb the transmitted solar energy and generates heat, simultaneously with continuous operation for electrical devices which are considered another source of heat. Lighting in office buildings accounts for almost 50 % of the world's energy needs [9]. Thus, the appropriate usage of daylight, along with artificial high - performance lighting and the right choice of glazing size and its characteristic can reduce energy consumption at least from **30%** to **50%** [9].

After the energy crisis in **1973**, this problem is starting to be reconsidered all over the world. In particular, energy consumption in the building industry presents a significant amount of the overall consumption of energy around **40 %** of the energy consumption worldwide, and the building industry should therefore play a vital role in the conservation of energy and environmental protection [10].

3. The role of Responsive Building Envelope

Recently, responsive envelopes are an essential target in Europe's **2020** goals [11]. Therefore, the **RBE** plays a vital role in adapting to climate change by providing the most comfortable and environmentally friendly indoor quality, which is considered to be the biggest energy use challenge. They can work as a decent moderator for whole building design to achieve the optimal use of sustainable power source and enhanced thermal comfort of buildings as **Figure 2**. Thus, architects can save energy and create a healthy

environment through well-organized daylight design methods for buildings, but an adjustment must be made to avoid excessive daylight gains or visual glare. [12].

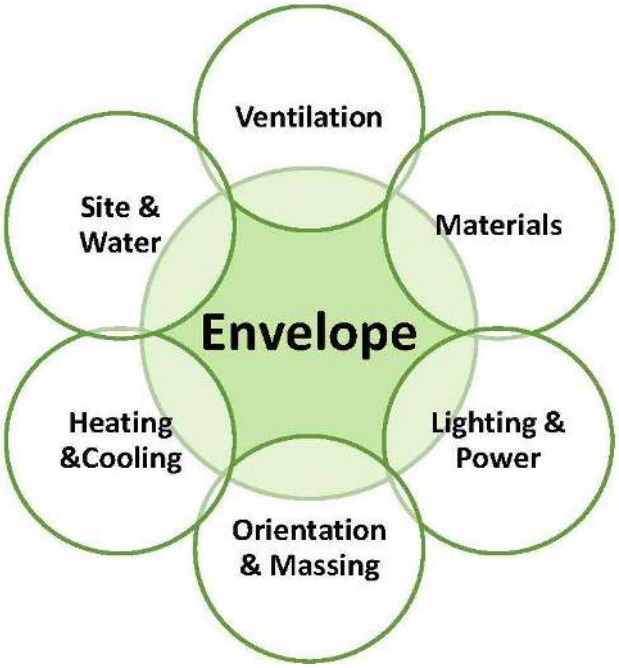

Figure 2. The role of Responsive Building Envelope (**RBE**) in interdependent building considerations of whole building design. [21]

In the past, conventional buildings in hot-arid climate have developed a number of passive design solutions, such as various shading systems, such as sunscreen well-known "**mashrabiya**", louvre or overhangs [13]. However, these methods were intended to provide fixed passive solutions to protect occupants from an externally changing environment [14].
Otherwise, the current responsive buildings with high performance have been developed with sophisticated compositions to adapt to environmental change. This trend in architectural design has mainly changed the way in which architects deal with building design based on the importance of performance and adaptive envelopes [15]. It helps achieve energy efficiency, well-daylight building and human thermal comfort by using intelligent responsive materials and by integrating various dynamic building envelope components as façade shading devices [16]. Besides, the use of adaptive components and materials as an effective regulator for the energy exchange between building skin, surrounding conditions and the priorities of the inhabitants [17]. However, less attention is paid to architectural aesthetics, the social and local legacy or to cultural characteristics.
However, the newest Middle East and North Africa (**MENA)** buildings like in the (**UAE**) are currently dominated by the international style with large glass facades and a limited number of light control components.

4. Methodology for Buildings In MENA

In this light, this paper aims to force the thinking of designers to establish a new methodology for buildings in the Middle East and North Africa (**MENA)**, especially in the (UAE), which can improve the overall performance of the building by taking into account the tangible and intangible forces that interact with it. This methodology can be achieved by utilizing regional responsive approaches for vernacular architecture as a source of inspiration integrated with avant-garde computational tools and design thinking during the conceptual design to overcome the critical architectural problems in order to create RBE that interacts with variable performance requirements and various external conditions. The

study encourages designers to explore strategies and technical guidelines for energy efficient envelopes in MENA, in particular the (UAE), based on scientific principles and the use of daylight monitoring requirements to innovate creative design solutions to reduce energy requirements.

On the other hand, the envelope of the building should never be left to the concept of energy efficiency, as ironically stated by Daryanani [18]:

" If energy preservation was the sole standard for a commercial building's success, the ultimate energy-conscious design would be a windowless underground building " [18]

The building envelopes, in particular the transparent façade components, play a crucial role in the energy performance and visual requirements of the buildings [19]. Therefore, Energy design-efficient building envelopes presuppose a precise comprehension and assessment of the climate conditions. Passive solutions, efficient thermal insulation, required light transmission with the visual transparency and low solar heat gains should be provided to minimize the building's cooling / heating and lighting charges , in order to save energy, and the occupants ' thermal and visual comfort [20].

Therefore, the responsive building should achieve many functions as the following:

Provision of outdoor views
Provision of views to the outside
External force resistance
Use of daylighting strategies to reduce the use of artificial lighting
Protection against solar thermal gain

5. Conclusion

This paper focuses on Problem Definition Over the last decade, regional climate and heritage neglect, particularly in the (UAE); has been a major weakness in this architectural field with the application of the international style in many MENA buildings. At the same time, the buildings with completely glazed façade in the (UAE) experience insufficient daylight during working hours, inadequate daylight distribution and a significant risk of glare. This leads to the exaggerated use of energy in countries already suffering from energy shortages, such as in MENA, by relying heavily on technical solutions to provide the necessary internal thermal comfort conditions. Energy saving is therefore an urgent goal for the government of the (UAE).

So that, this recommends the integration into a building envelope of more designed responsive capabilities, through recalling the conventional pattern of vernacular architecture combined with optimized daylight strategies (to be an inspiration) in design (RRBE) using generative algorithms of computational design and building performance analysis (BPS) tools. This constructive building is estimated to be able to modify its performance, according to different performance demands and external conditions, with the least use of an artificial lighting, in order to maximize the performance of the entire building in terms of the environmental, cultural, economic and social aspects.

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