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Analysis of dynamic mechanisms in building facades

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Abstract

Using the dynamic facades, the exterior of building is removed from the rigid state and in addition to adapting to the needs of users and the environment, it is possible to reduce energy consumption in the building. In this research, while introducing a dynamic facade in the building, the movement patterns of the elements that make up the facade were introduced. To analyze the characteristics of dynamic facades, specifications of 50 world-class dynamic projects with dynamic facades which were built in the last four decades in terms of type of use, the main purpose of dynamic application in facades, materials used and classification of facade movement mechanism, have been examined and the results were analyzed. The major objective of the dynamic facade design is light management and visual exploitation, and the most common application of this facade is in cultural and office buildings, according to the features of the examples. Photovoltaic cells, light-sensitive diaphragms, and solar panels are the most frequent materials and propulsion systems in most of the examples, with sliding and rotating motion being the most common pattern. Finally, the origami model designs and presents a dynamic facade example that may be employed in our country's hot and dry environment.

Keywords: Dynamic facades, facade function, movement mechanism, origami pattern

1. Introduction

The facade of building plays an important role in controlling the environmental conditions of interior spaces and is a barrier between inside and outside the building. In architectural design, the static facade, which is utilized in most structures today, is unable to fulfill fluctuating demands and environmental changes. The dynamic facade, which is an adjustable technology that uses moving connections, may vary the form and arrangement of the facade in response to the reactions it receives. This type of structure may improve the efficiency of a building aesthetically or functional. The facade of building, provides a boundary between architecture and urban spaces which has a fundamental impact on people's understanding of the built -in environment [1]. Some modern building facades interact more with weather, spatial functions, the internal environment, and people, and have evolved through time as complex evolved and adaptive systems [2]. Facade adaptation is done by various methods such as creating a responsive facade, two-shell facade and smartening facade materials. Many definitions of a building facade define it as the boundary between the indoor and outdoor environment that provides support, protection, aesthetics, and service distribution [3].

In general, the typology of movement in architecture can be divided into five types: (1) Movement of rigid architectural elements; (2) Displacement of transformable architectural elements; (3) Movement of soft and flexible architectural elements; (4) Movement of elastic architectural elements and (5) Pneumatic forms; Mechanical movements can be divided into rotation, transmission, and a combination of the two [4].

Despite the different classification of motion patterns in the dynamic facade, many of them have similar behaviors. Sheridan divides the various mechanisms of motion in the dynamic facade into five groups, which are: wave: sliding and rotating; square-tic: sliding and retracting; scissor net: contracting and expanding; balloon: inflate and deflate; triangular: expand and retract [5].

This research was done as one of the solutions to reduce energy consumption in buildings to introduce and analyze various dynamical mechanisms in the facade and evaluating the samples of the dynamic facade index and at the end, a suggested model of a moving facade is presented.

2. Analysis of sample of buildings with dynamic facades

To analyze and classify the features of dynamic facade, the characteristics of 50 samples of the most important projects implemented from 1987 to 2019 were reviewed. These studies are in four areas: (1) Use of buildings with dynamic facades; (2) Objectives

of using dynamic facades; (3) The type of materials used in the dynamic facades and (4) The frequency of the movement mechanism in the dynamic facades was done based on the Sheridan model and the results obtained from it was analyzed.

In Figure 1, the frequency distribution of various reasons for using dynamic views based on the designers' ideas is examined.

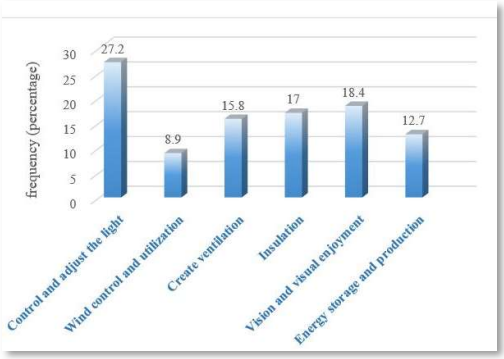


Figure 1. Comparison diagram of the objectives of using a dynamic facade in a building

It is observed that in 27.2% of cases, the main reason to use the dynamic facade is the management and regulation of sunlight; then, creating a landscape and visual use of the facade is 18.4% and the lowest share control and use the wind is 8.9%.

By examining the studied samples based on the movement mechanism of the facade according to the Sheridan pattern which can be seen in Figure 2, the sliding and rotating system with 32% is the most used in the movement patterns of the facade, followed by the square-tic: sliding and retracting system with 26% in the second place. Some forms of dynamic facades are referred to as "other" since they are not included in this categorization. This category includes media facades that display more movement visually by lighting in appearance, as well as intelligent or memory materials that have dynamics inside the material and, lastly, a general impact that may be observed in the building's facade and inner areas.

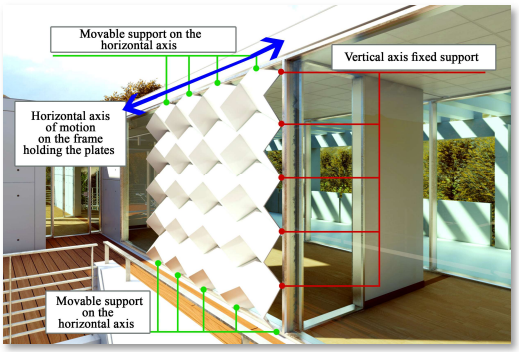
Figure 2. Frequency diagram of the movement mechanism in the dynamic view based on the Sheridan pattern

3. Design a dynamic facade model

The design the sample is based on the origami pattern and moving plates. This pattern is inspired by the design of Miura and his colleague Sakamaki and is known as the Miura- Auery model [6]; The structure of this pattern consists of two parallel symmetrical plates that a simple movement within the structure causes movement in the other members, and by creating a low compressive force in one corner, the plate is bent in diameter and the set of plates can be easily opened and closed.

Figure 3 is a simulation of a model designed for a part of a building facade, and shows a simulated panel consisting of an origami plate and a retaining frame, which can be opened and closed by moving the plate inside a fixed frame. The comfort of building occupants is offered in this model by preventing bright light from entering the structure and producing shadows. A study of indigenous architectural experiences in historic homes in Iran's core towns, such as Kashan, Yazd, and Isfahan, reveals that the usage of the Orusi lattice window structure for shade and direct light control was popular. Therefore, to shade the interior of the building with new technology, this structure can create a similar function; the proposed structure has more features than traditional cases, such as the possibility of automatic and integrated control of the facade, low weight and higher deformation speed.

These panels can be installed on the exterior stand-alone or using frames and meshes as shells. The set of moveable plates is installed in separate frames on the facade and allows for the horizontal movement of the origami shell; the movable stiff plates are joined by hinged parts.



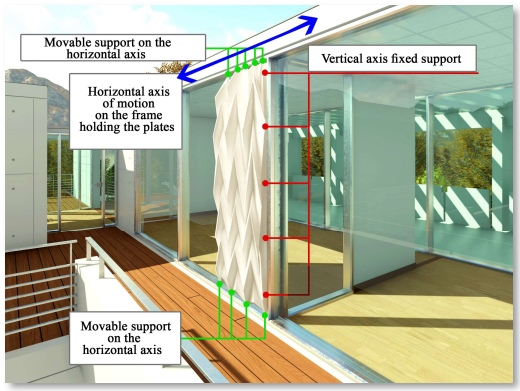


Figure 3. Simulation of using an origami model on a building facade in both closed and open modes

The facade's movement and dynamism may be controlled vertically, horizontally, and angularly using different electrical or light-sensitive stimuli; the facade's movement mechanism in this design is based on the scissor net movement pattern: contracting and expanding of the Sheridan. The simulated model of the building facade is shown in Figure 4; this moving facade pattern can move in both horizontal and vertical directions and makes it possible to control the amount of light entering the building. Moreover, if the transparent panels are replaced instead of part of these panels, it will be possible for different amounts of light to pass through different parts.

Figure 4. Replica for modeling dynamic facades using an origami pattern

4. Conclusions

Responding to climate change and the different needs of users, proper use of renewable energy and reducing environmental pollution are the most important advantages of dynamic facades over traditional facades. Despite the significant expenses of planning, installing, and maintaining dynamic facades, the benefits they provide are compelling enough to justify their inclusion in a structure. Buildings with cultural and administrative applications have been the most often employed of this sort of facade, according to the requirements of 50 worldwide index examples of dynamic facades executed during the last four decades.

By examining the research on the origami pattern, a dynamic exponential design is presented in this research which uses folded plates to create a flexible coating surface and its driving force can be considered by electric motors under the command of sun - sensitive sensors. This cover as an additional part of the facade, especially for areas with intense sunshine, can create thermal comfort, cold and visual beauty.

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