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Abstract

The building envelope plays a crucial role in saving or consuming energy, depending on the type of the envelope and design. Architects and engineers need to consider many issues when working with envelope designs, including environmental issues, aesthetic appearance, occupant comfort, and view; these aspects make the envelope a multifunctional component, thus the integration approach is the optimal method to address envelope design. In the last decade we have witnessed the inclusion of the kinetic envelope in many typologies of buildings. Many scholars believe the kinetic envelope improves the environmental performance of the building. The purpose of this paper is to review the current practice and development of the kinetic envelope and to investigate its role in the improvement of energy performance in buildings.

Keywords: Kinetic envelopes; Green architecture; Facades; Energy performance; Responsive architecture; Shading device

Introduction

ere has been an interest in interactive, responsive, and intelligent architecture, particularly in the 1960s and 1970s [1-3]. e new paradigm shi in architecture coincides with advancements in computer science, cybernetics, and building technology that have altered the architecture from a static form to a more kinetic and dynamic form. e origin of the word kinetic is Greek, pertaining to, or caused by motion [4], thus the main aspect is the motion and integration within the context of the surrounding environment or occupant. e Children's Museum of Pittsburgh is a hands-on interactive children's museum in Pittsburgh, Pennsylvania. It is in the Allegheny Center neighborhood in Pittsburgh's North side (Figure 1).

Fraser states: how can architecture become part of an increasingly responsive and changing social environment characterized by digital technology, global nomadism and ubiquitous consumption? Is it possible for buiarchitecture in which building components, or whole buildings, have the capability to adapt to change through kinetics into reversible, deformable, incremental, and mobile modes.

Cedric Price asks, "What if a building or space could be constantly generated or regenerated?" [6]. He argues for the new role of architecture a er the failure of modern architecture in the 1960s. Price is considered one of the earliest architects to bring this discourse into architecture when he designed the Fun Palace in 1961. He was in uenced by the work of Gordon Pask and his theory of conversation. During the same time period seminal works paved the way for the kinetic concept of architecture, such as Yona Friedman's "Mobile Architecture Manifesto" (1956), and the beginning of the Archigram and the great design of the Plug-in city in 1967, and the seminal book e Architecture Machine by Nicholas Negroponte, published in 1970.

Figure 1: Pittsburgh children museum.

Figure 2: Fun palace-Cedric price.

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Why We Need a Kinetic Façade?

e architecture from the last decade has changed to transformable, dynamic, interactive objects to achieve numerous goals, including environmental considerations, human considerations, social interaction, and sense of place. Micheal Fox states, " e primary goal of intelligent kinetic systems should be to act as a moderator responding to changes between human needs and environmental conditions [7,8]." at will help to achieve many goals, toward a high e cient building, because the building will be more exible to adapt its envelop for the external weather, which mainly considered in a sun glare and a direct heat gain, that will exempli ed in the case studies in this paper. e façade is the most important protection structure from the harsh weather, in the outer environment, thus the advanced of this system

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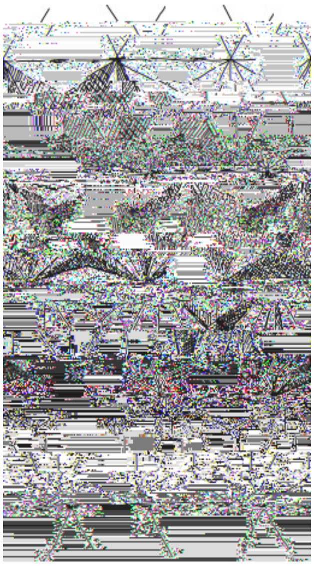

Figure 4: Sketch for the envelope idea.

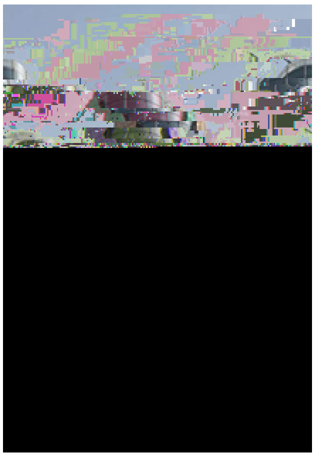

Figure 5: Al Bahar Towers.

Project description

Council House 2 (CH2) is an o ce building in Melbourne, Australia that features a kinetic façade with a great sustainability approach. e building comprises numerous sustainable strategies, including wind turbines on the roof, chilled ceiling, double skin façade, and timber shutters that work as a kinetic device to protect occupants from direct sun by tracking the sun's path in summer and providing full shading for the indoor environment. e building is the rst o ce building to get six Green Star rating (GBC of Australia) [17]. e kinetic façade (operable timber shutters) improves the building's performance, and based on a post-occupancy report [18] the sta productivity increased by 10.9%. In addition, 80% of the occupants appreciate the building's indoor environment. Improvement of occupant well-being was an important goal in the achievement of sustainability, in addition to energy saving and reducing the environmental impact [19] (Figure 8).

Council House 2 (also known as CH2), is an o ce building located at 240 Little Collins Street in the CBD, in Melbourne, Australia. It is occupied by the City of Melbourne council, and in April 2005, became the rst purpose-built o ce building in Australia to achieve a maximum Six Green Star rating, certi ed by the Green Building Council of Australia. CH2 o cially opened in August 2006.

Performance features

e building achieved remarkable results in environmental

Figure 6: Parametric Mashrabiya Model.

amount of energy savings, particularly for tall buildings. e World Trade Center in Bahrain, which is classi ed as the same region type, achieved a 14% reduction in energy by introducing wind turbines [15]. How this goal was achievable? Moreover what the main role for kinetic façade to create a great environmental performance for this project . e main aspect of the Al Bahar Towers is the reinvention of the traditional Mashrabiya. With advanced technology, the mechanism of the triangular shading panels is based on a linear actuator's response to the sun's movement to provide solar and glare protection, and maintain privacy. Antony Wood states, "Many believe that the façade is the real battleground in the ght for better building sustainability [16]. Al Bahar could thus be considered the advanced guard in that ghts [17]." To summarize, this kinetic façade system reduces solar gain, improves indoor lighting, increases occupant comfort, and reduces energy consumption by 50% and CO_2 emissions by 1,750 tonnes per year (Figures 5-7).

Case Study 2

Case study 2 was explained at Table 2.

Figure 7: Thye Mashrabia system of operation.

Location	Melbourne	Building Uses	Offce
Status	complete	Structural Style	
Construction Start	2004	Architectural Style	Green Architecture
Construction End	2006	Materials	Concrete
Floors	10	Heights	388 meter
Floors Area	12,536 m²	Elevator Count	-

Table 2: Case study 2.

performance, with an 85% reduction in electricity consumption, lower emissions at just 13%. e façade was creatively designed with a unique solution for each direction of the building envelope; all of which combine to provide 80% of the occupants with a view. e kinetic system applied to the western façade exceeds 95% of shading during the day and provides natural ventilation at night by automatically opening the windows and allowing the night air to cool the building. e mechanism of the western façade works on an automatic actuation system to track the sun's position and provide shading in the a ernoon (Figures 8-10).

Case Study 3

Case study 3 was explained at Table 3.

Project description

e Q1 Headquarters Building, outside of Essen, Germany is another example of a well-designed façade that consists of an advanced kinetic system to achieve a high level in German sustainability standards. e main character of the building is the sun shading system, which works with the sun's path, and creates a unique identity for the building. e designer, Jürgen Ste ens says, "When you look at the building in the evening when the sun is going down,it is absolutely amazing to see what the stainless steel does with this red light." e complex façade system made it possible to reduce the HVAC load on the building by maximizing the amount of natural air ventilation and by minimizing glare and direct heating gain (Figures 11 and 12).

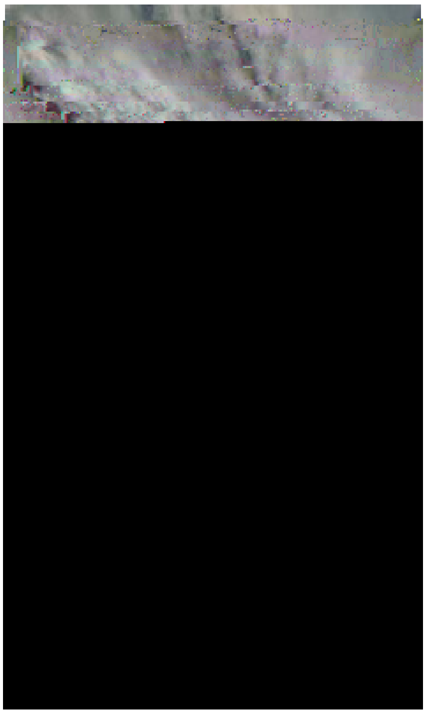

Figure 8:

Location	Essen-Germany	Building Uses	**Offce**
Status	complete	Structural Style	
Construction		Architectural	Green
Start	2004	Style	Architecture
Construction End	2010	Materials	Concrete
Floors	10	Heights	50 meter
Floors Area	170,000 m²	Elevator Count	-

Table 3: Case study 3.

Performance features

e building consumes less energy compared to a typical o ce building. e sustainable strategies used to accomplish reduction, including the kinetic façade, allow the building to consume less than 150 kWh/sq.m./year.

e outer skin of the façade works as a sun-shading system, consisting of approximately 400,000 metal “feathers” in three di erent shapes - triangular, square, and trapezoid. All these element automats, with assistance from 1,280 electric motors, work to open the whole sun screen for natural light or to close it completely to protect building occupants from glare and heat gain. Another important aspect for the kinetic façade is the ability to move in windy weather up to a speed of 70 km/hour (Figure 13).

Conclusion

is paper focuses on the environmental performance of kinetic façades in buildings by reviewing current practices. e process involved an investigation of literature studies that conducted research to evaluate the performance of kinetic façade systems from numerous perspectives.

e kinetic façade proves to be an e ective approach to designing a building envelope, as shown by gures of reduced energy consumption, making the kinetic façade an optimal method to address harsh climates, particularly in the case of sun shading, and to provide convenient natural lighting and fresh air.

e case studies examined in this paper are evidence of the proliferation of this type of system. In addition, the results in energy saving is considerable.

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