Integrating Kinetic Material in High-Rise Office Buildings Facades

Aniket Bhadouriya[1], Dr. Parampreet Kaur[2]
[1]*Undergraduate Student, Amity University Chhattisgarh*
[2]*Head of the Institution, Amity University Chhattisgarh*

Abstract— Integrating kinetic materials into high-rise office building facades revolutionizes modern architecture by making structures dynamically responsive to environmental conditions. This dissertation investigates the use of movable elements in facades that adapt to changes in sunlight, temperature, and wind, optimizing natural light, reducing glare, and improving thermal performance. The research highlights the significant benefits and challenges of incorporating kinetic materials. The findings underscore the potential of kinetic facades to enhance energy efficiency, occupant comfort, and sustainability, offering a comprehensive framework for future architectural innovations.

Index Terms— Kinetic material, Day Lighting, Natural Lighting, Thermal Comfort, Sustainability

I. INTRODUCTION

Kinetic facades are transforming modern design by offering dynamic, responsive solutions to environmental concerns. These facades respond to variations in sunshine, temperature, and wind, improving energy efficiency and occupant comfort. Examples include the Al Bahar Towers in Abu Dhabi, The Edge in Amsterdam, and the Kolding Campus at South Denmark University, which highlight the technology's functional and aesthetic value. By using dynamic materials, these structures achieve considerable energy savings, better thermal comfort, and eye-catching visual appeal. As urban surroundings change, kinetic facades provide a viable route towards more sustainable and flexible architectural techniques that are consistent with modern sustainability aims.

II. LITERATURE STUDY

A. KINETIC FAÇADE

Dynamic building envelopes known as "kinetic facades" are capable of altering their physical characteristics or arrangement in reaction to external factors. Through its ability to adjust to temperature, wind, and sunshine, these facades are intended to increase a building's thermal comfort and energy efficiency. Sensors and actuators can be used to automatically or manually control the movement or alteration of the façade pieces. A variety of devices, including sliding screens, folding structures, and rotating panels, can be used into kinetic facades. primary goal of kinetic facades is to optimize the building's performance by reducing energy consumption for heating, cooling, and lighting while enhancing occupant comfort. (Khraisat, 2024)

Figure 1- Kinetic Façade
Source- https://alubuild.com/en/architecture-kinetic-facades/

B. THERMAL COMFORT

The mental state that conveys contentment with the surrounding thermal environment is known as thermal comfort. Air temperature, humidity, air movement, and radiant temperature are some of the variables that affect it. For the health and productivity of building inhabitants, thermal comfort must be achieved. By controlling the quantity of solar radiation that enters the building, kinetic facades help to improve thermal comfort by lowering heat gain in the summer and enabling passive solar heating in the winter (Khraisat, 2024)

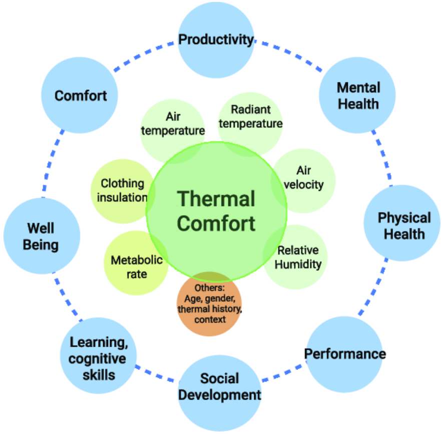

Figure 1- Components of Thermal Comfort
Source- https://alubuild.com/en/architecture-kinetic-facades/

C. SMART MATERIALS

Materials that may alter their characteristics in reaction to outside stimuli like light, pressure, temperature, or electric fields are known as smart materials. Adaptive building systems are among the many applications for these materials. Thermochromic and photochromic components are two prominent categories of smart materials utilized in kinetic facades (Khraisat, 2024)

Thermochromic materials change their color or transparency in response to temperature changes. In the context of kinetic facades, thermochromic elements can be used to control the amount of solar radiation entering the building. For example, a thermochromic window can become opaque when the temperature rises, reducing heat gain and glare, and become transparent when the temperature drops, allowing more natural light and heat into the building (Khraisat, 2024)

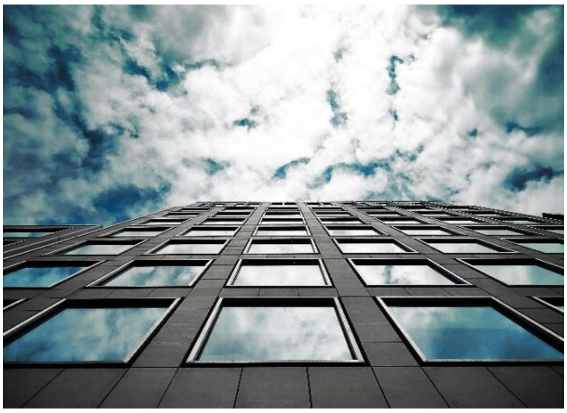

Figure 3- Photochromatic Glass as a Smart Material
Source- Brown High-rise Building Under Sky Full of White Clouds

When light intensity varies, photochromic materials alter their color or transparency. By using these materials, kinetic facades can modify the quantity of natural light that enters the building. For example, photochromic windows may darken under direct sunlight to reduce heat intake and glare, and they can revert to their clear condition when the light intensity drops.

D. ADAPTIVE SHADING

Adaptive shading systems are designed to dynamically adjust the shading provided to a building's interior based on environmental conditions. These systems can include movable louvers, blinds, or screens that respond to sunlight, temperature, and wind. Adaptive shading helps control solar heat gain, reduce glare, and enhance daylighting, contributing to energy efficiency and thermal comfort. Kinetic facades often incorporate adaptive shading elements to optimize the building's performance and occupant comfort (Khraisat, 2024)

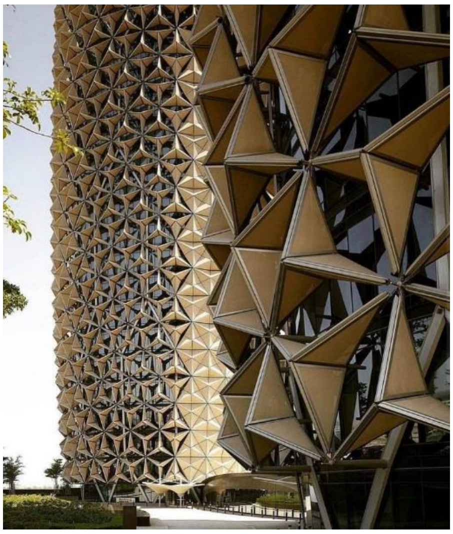

Figure 4- Shading Device
Source- Pinterest

- Al Bahar Towers – Abu Dhabi, UAE

Owner: Abu Dhabi Investment Council (ADIC)

Completion: June 2012

Location: Abu Dhabi, United Arab Emirates

Building Type: Office Towers

Total Built-up Area: 56,000 m²

Building Name: Al Bahar Towers

Vicinity Type: Urban, near the junction of Al Saada and Al Salam Streets

Figure 2- Al Bahar Towers
Source- https://tandctech.com/en/projects/projects/al-bahr-towers-

The Al Bahar Towers in Abu Dhabi exemplify cutting-edge architectural design with their innovative kinetic façade. Completed in 2012, these twin office towers feature a dynamic shading system inspired by traditional Islamic "mashrabiya." This façade comprises over 1,000 individual elements that respond to the sun's movement, reducing solar heat gain and glare while maximizing natural light. This approach not only enhances energy efficiency but also adds a unique aesthetic quality. The Al Bahar Towers seamlessly blend cultural heritage with modern technology, setting a new standard for sustainable high-rise buildings and showcasing the potential of kinetic facades in contemporary architecture.

The screen, which is mounted on a separate frame two meters beyond the building's façade, functions as a curtain wall. To lessen solar gain and glare, fibreglass is applied to each triangle, and it is designed to react to the sun's movement. All of the screens will go out in the evening. "They will all fold and close at night, allowing you to view more of the façade. The mashrabiya east of the building will all start to close as the sun rises in the morning, and the entire vertical strip of mashrabiya will move with the sun as it round the structure.

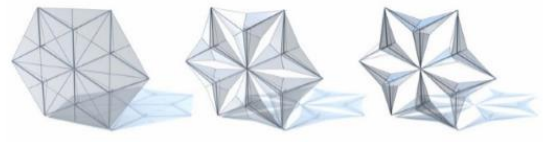

Figure 3- Responsive Façade
Source- www.Archdaily.com

Such a screen is predicted to cut solar gain by over 50% and lessen the demand for energy-intensive air conditioning in the structure. Additionally, the architects were able to choose more carefully how the glass was treated because of the shade's capacity to filter light. Because of the screen, we can use more naturally colored glass, which lets in more light and improves vistas while reducing the need for artificial light.

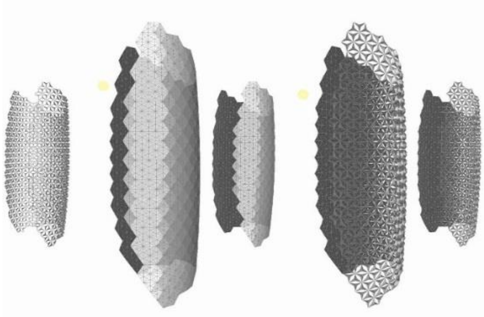

Figure 7- Exoskeleton of Al bahar Tower
Source- www.Archdaily.com

In conclusion, The Al Bahar Towers in Abu Dhabi showcase the remarkable potential of kinetic facades in contemporary architecture. Their innovative design, inspired by traditional Islamic "mashrabiya," integrates over 1,000 dynamic shading elements that adapt to the sun's movement. This system enhances energy efficiency by reducing solar heat gain and glare while maximizing natural light. The towers represent a harmonious blend of cultural heritage and modern technology, setting a new standard for sustainable high-rise buildings. The Al Bahar Towers exemplify how kinetic facades can create environmentally responsive and visually striking structures, highlighting the future direction of sustainable architectural design.

- The Deloitte Amsterdam Headquarters (The Edge) – Amsterdam, Netherlands

Owner: Deloitte Netherlands

Completion: 2014

Location: Amsterdam, Netherlands

Building Type: Office Building

Total Built-up Area: 51,000 m²

Building Name: The Edge

Vicinity Type: Urban, located in the Zuidas business district

Figure 8- Deloitte Amsterdam Headquarters
Source- Ecolution Consulting

With its dynamic façade, Deloitte's Amsterdam headquarters, The Edge, is a shining example of sustainable and avant-garde architectural design. This cutting-edge office complex was finished in 2014 and is situated in Amsterdam's Zuidas business sector. Advanced technology is incorporated into The Edge's dynamic façade to maximise energy efficiency and improve occupant comfort. In order to minimise solar heat gain, minimise glare, and maximise natural illumination, these dynamic features adapt to ambient factors including temperature and sunshine. The Edge lowers the building's overall energy consumption while simultaneously achieving greater thermal performance through the integration of smart materials and adjustable shading devices. This method is a prime example of how kinetic facades may convert conventional office buildings into livable, adaptable structures that support contemporary sustainability objectives.

BUILDING ORIENTATION

The Edge was designed from the ground up to benefit from both the most recent technological advancements and its immediate surroundings; the Edge's orientation alone offers significant advantages. It has been fashioned and built to maximise the sun's benefits all year round. The windows are one example; properly integrated, they maximise the amount of daylight that enters the workspace. Additionally, the building's south-facing exterior features a 6000 m2 solar array that helps block solar radiation while simultaneously meeting all of its energy requirements.

Figure 9- Building Orientation
Source- https://archinspires.com/2024/08/12/case-study-sustainable-features-of-the-edge-in-amsterdam/

USAGE OF SUNLIGHT

The Edge's efficient use of sunlight is perhaps one of the main features that contribute to its high level of sustainability. The Edge's southern wall has a visually arresting chequerboard pattern of windows and solar panels. Even in intense sunshine, deeply recessed windows reduce the need for blinds, and thick load-bearing concrete helps control the building's temperature. Solar panels are also installed on the roof. The Edge uses 70% less electricity than a normal office block as a consequence. The Edge was only able to boast that it produced more energy than it consumed when OVG installed solar panels on the roofs of surrounding university buildings.

Figure 40- Smart Façade
Source- hermanstechnisolar.com

In Conclusion, The Edge, the Amsterdam headquarters of Deloitte, is a prime example of how dynamic facades in contemporary design can revolutionise a space. This dynamic façade system optimises energy efficiency and improves occupant comfort by responding to environmental conditions via the integration of smart materials and innovative technologies. The kinetic façade's adaptive characteristics lower energy usage, glare, and solar heat gain, resulting in a high-performing and sustainable office space. The Edge, which demonstrates the usefulness and visual attractiveness of kinetic facades in high-rise office buildings, establishes a standard for environmentally sustainable. (Patil, 2021)

- THE SOUTH DENMARK UNIVERSITY'S KOLDING CAMPUS

Owner: University of Southern Denmark

Completion: 2014

Location: Kolding, Denmark

Building Type: Educational Institution

Total Built-up Area: 137,000 m²

Building Name: Kolding campus

Vicinity Type: Urban, located in the Grønborg grounds near the harbor and Kolding River

Figure 11- Kolding Campus, South Denmark University
Source- https://archello.com/project/kolding-campus

The South Denmark University's Kolding Campus provides courses in languages, design, culture, and communications. It is situated adjacent to the Kolding River and in the centre of Kolding city. This campus was constructed by the Copenhagen-based Henning Larsen Architects and finished in 2014. The University's five-story structure features a recognisable triangle layout. The goal of the university campus design is to provide dynamic study areas that differ from traditional classroom settings.

I moved to foster a sense of togetherness and community among the building's students, instructors, and researchers. Therefore, a range of spaces are formed when the triangle form repeats itself in different patterns on all levels. These spaces include semi-open circular rooms for group study, formal and informal group spaces, and individual study spaces. A five-story atrium is created by the triangles in the design cutting into the floor slabs. As it climbs towards a triangle skylight, this 3 creates the illusion that the inner space bends (Patil, 2021)

KINETIC FAÇADE FEATURES

The facades in the Kolding Campus are covered with kinetic vertical shading devices made of 1600 perforated Aluminum panels that also act as shutters. When not in use, these shutters lie flat along the façade. When opened, they protrude from the façade at certain angles depending upon the need of daylight and heat in the building. These panels are mounted on a galvanized steel frame that projects outwards to a distance of 600mm from the building. This 600 mm gap is also used as a maintenance service corridor for the kinetic façade. The double-skin composition comprising of the steel frame and panels also provides flexibility for the future addition of pipes and ducts without affecting the landmark appearance of the building (Asefi, 2019, p. 171)

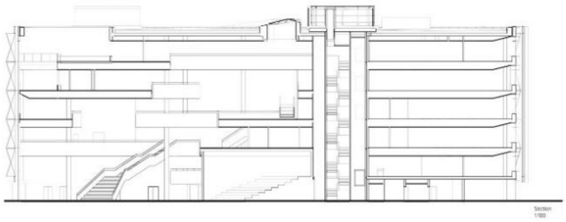

Figure 5- Section of the building
Source- www.Archdaily.com

DESIGN OF SHUTTERS.

The Aluminum shutters are made of approximately 4,500 m2 of perforated aluminum sheets. The perforations in the façade are additionally designed and adapted to an opening angle of approximately 30%. Engineers and Architects have conducted analysis and calculations to establish this as the optimal opening angle in relation to the amount of light and energy let in and out of the building while at the same time providing users with optimal views to the outside urban space (McManus, Kolding Campus University of Southern Denmark, 2020)

Figure 6- Shutter Design
Source- https://arcdog.com/portfolio/sdu-university-of-southern-denmark-campus-kolding/

In conclusion, the creative incorporation of adaptable shading technologies in contemporary design is best demonstrated by the dynamic facade of South Denmark University's Kolding Campus. This structure, which was finished in 2014, has more than 1,600 perforated aluminium panels that react dynamically to variations in heat and lighting. By adjusting to maximise natural light and preserve thermal comfort, these panels drastically save energy usage. In addition to improving the building's sustainability, the facade's design produces an eye-catching and useful outside. This concept establishes a standard for next sustainable architecture projects by showcasing the potential of dynamic facades to enhance building performance.

IV. CONCLUSION

The analysis of kinetic facades in buildings like the Al Bahar Towers, The Edge, and the Kolding Campus highlights their transformative impact on modern architecture. These dynamic facades respond to environmental changes, improving energy efficiency, thermal comfort, and aesthetic appeal. Al Bahar Towers blends traditional design with modern technology, The Edge optimizes natural light and thermal performance, and the Kolding Campus achieves energy efficiency with its adaptive shading system. Collectively, these examples underscore the significant benefits of kinetic materials, promoting sustainable and responsive architectural practices that align with contemporary sustainability goals.

V. ACKNOWLEDGEMENT

I want to express my sincere thanks to Dr. Parampreet Kaur, my research guide, for all of her help and support during this study. I sincerely appreciate the help and resources provided by the Amity University Chhattisgarh professors and staff. I am grateful to my classmates and coworkers for their support and helpful criticism. We are especially grateful to the experts and professionals who contributed their knowledge and perspectives. Finally, I want to express my sincere gratitude to my family and friends for their patience and constant support during this trip. Their confidence in me is demonstrated by this achievement.

VI. REFERENCES

[1] Khraisat, D. (2024). Application of Kinetic Facades and Its Impact on Daylighting Performance : A systematic litertaure review . malaysia : http://www.hrpub.org.

[2] Patil, R. S. (2021). Analysis and Review of the Kinetic Façades in Kolding Campus, South Denmark University. Springer Nature Link , 265–274.

[3] Aksamija, A. (2013). "Sustainable Facade Design for Tall Buildings". Journal of Green Building, 8(1), 108-125.

[4] Davies, C. (2012). "Adaptive Envelopes: New Possibilities for Daylight, Ventilation and Cooling". Architectural Design, 82(1), 66-71.

[5] ArchDaily. (2012). "Al Bahar Towers / Aedas". Retrieved from https://www.archdaily.com

[6] Miller, N. (2015). "The World’s Most Sustainable Office Building". Bloomberg. Retrieved from https://www.bloomberg.com

[7] Bos, E. (2016). "The Edge: A Benchmark for Sustainable Building Design". Journal of Sustainable Architecture, 10(2), 55-63.

[8] Andersson, J. (2015). "Kolding Campus: A Case Study in Dynamic Facade Systems". Journal of Architectural Innovation, 12(3), 22-29.

[9] Thomsen, K. (2014). "Energy-Efficient Design in Educational Buildings". Building and Environment, 78, 97-108

[10] Kroner, W. M., Stark-Martin, J. A., & Willemain, T. R. (1992). "Using Advanced Office Technology to Increase Productivity: The Influence of Environmental Factors". Journal of Facilities Management, 10(1), 55-60.

[11] Raja, I. A., Nicol, J. F., McCartney, K. J., & Humphreys, M. A. (2001). "Thermal Comfort: Use of Controls in Naturally Ventilated Buildings". Energy and Buildings, 33(3), 235-244.

[12] Sabry, A., & Omar, A. (2016). "Kinetic Facades: An Environmental Performance Assessment". Procedia Environmental Sciences, 34, 73-85.