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KINETIC FAÇADE AS A TOOL FOR ENERGY EFFICIENCY

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Abstract: **Buildings are generally affected by natural and climatic factors, and even human daily needs, and these factors are not static but dynamic, they change with time. As buildings are a major part of life, there is a need for buildings to adapt solemnly to the changing weather condition while retaining their energy efficiency and preferably attaining more energy as with without these parameters or improvements. One of the ways to make buildings to be adaptive to the current changes of the climatic conditions and human needs is to make the buildings facades dynamic as well, so as to adapt to the changing conditions, hence kinetic façade. The concept of kinetic façade consists of devices mostly that moves and change their forms by either internal computer control, sensory trigger or change due to climatic change conditions. This paper discovers the background of the kinetic façade and reveal on how kinetic facades function and how the retain the energy efficiency of their host buildings and in most cases add to the energy provision of the buildings.**

Keywords: **Kinetic Façade, Energy Efficiency, Kinetic Architecture, Sustainability, Climatic Factors, Building Façade.**

1. INTRODUCTION

A building envelope divides the outside from the protected inner environment, this barrier may exclude undesirable effects while passively or actively accepting beneficial ones. The enclosed building incorporates approximately 80% of an environmental response, creating a secure building that communicates with its environment (Etman et al, 2013). This plays an important role in enhancing energy efficiency and interior comfort for the inhabitants. Buildings are definitely affected by natural occurring elements such as weather, climate, wind, time and other human needs. All these elements and functions are not static, they are dynamic, therefor, there is need to improve buildings to adapt to such changes, thus, forming kinetic facades. The ability to adapt and travel was a major issue for humans. People used mobile and kinetic shelters in ancient times to safeguard their lives as well as provide food. The Bedouin tent has been used throughout history in Africa since it is adaptable to the climate of the desert and is a portable shelter. The African tent is a suspended tensile membrane from restraint poles (Kronenburg, 2013). A kinetic façade is one that shifts dynamically instead of being static or fixed, allowing motion to take place on the surface of a building. Architects have been trying to found a portable solution to the dynamic weather and human needs. They envisioned transformable buildings that could alter their physical layout, such as stadiums with mobile seats and retractable roofs, or versatile buildings with air-filled or rotating structures normally referred to as kinetic architecture (Bier & Knight, 2010). Kinetic design evolution has a rich history. In 1908, the initial Kinetic design was made with the passing of time. Then, transformable architecture emerged as a kinetic model. It took tens of years to merge kinetic method with computer science (Elmokadem et al, 2017). Kinetic facade therefor, is derived from the idea of kinetic architecture. A kinetic façade can be used to manage light, air, energy, and even send information. It is possible to program the moving elements of the façade to react to climatic or other environmental factors, time, rates and occupancy size, and so on to improve performance and efficiency. Kinetic facades can also be used for aesthetic purposes, to make a very strong impression, to generate interests, or as part of art exhibitions.

2. LITERATURE REVIEW

Historically, buildings are built on the basis of the preconditions of the external environment along with the available natural resources, creating convenient climate-related spaces, the word "house skin" referring to the external shell of the structure. By using the façade in this way, we can provide the ability of a building to react to or gain from external

climates, we mean the ability to accept or reject free energy from the environment, thus reducing the amount of artificial energy needed to achieve indoor comfort (Cherif & Fatiha, 2016). It is a challenge facing architects today to create efficient buildings. Latest developments in computer-aided design software and digital manufacturing, however, have allowed architects to discover new modes of design and new envelope techniques in an attempt to rectify architectural design problems (El-Sheikh & Gerber, 2011). Clearly, creative energy-efficient architecture can substantially reduce the total energy consumption of buildings (Sadineni et al, 2011). It is ideally important to design and create facades that are responsive and interactive to the environmental qualities. As part of the so-called intelligent façades, these façades are capable of changing their size, shape, orientation or openings to react automatically to environmental factors like humidity, temperature, wind, etc (Kensek, Hansanuwat, 2011). The entire idea of kinetic façades involves the use of geometric transition to generate a motion or movement in space. This motion or movement changes the physical appearance of the structure and material properties of the facades without affecting the structure of the building. There are many kinetic façade classifications, most generally based on façade transformation. Four geometric transformation systems can be used to move kinetic facades (Jewell, 2015).

- Rotation: The devices move around an axis.
- Scaling: It is the contraction and expansion of the devices/objects.
- Translation: The movement takes place in the direction of a vector
- Movement by material deformity: depends on changing properties of materials, such as weight and elasticity.

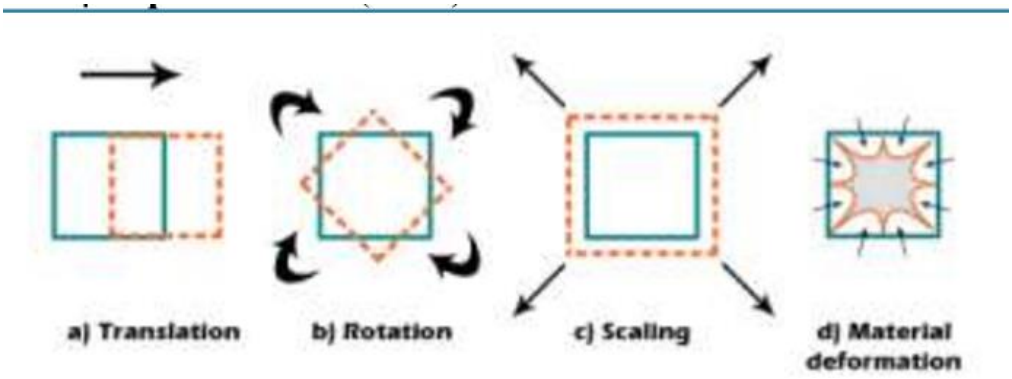

Figure: Kinetic Facade Geometric Transformation Systems (Moloney, 2011)

Michael Fox has divided kinetics control systems into six groups, based on the complexity level (Fox, 2000).

- Direct control: they are directly controlled outside the systems by an energy source.
- Indirect control: Movement of the devices depends on the feedback system of the sensors.
- Internal controls: Devices have no direct control or mechanism whatsoever like mechanical hinges.
- Responsive indirect control: Movement of devices depends on multiple feedbacks from the 1sensors
- Ubiquitous responsive indirect control: Devices has the powerful ability of predictions by using a system of controls with predictive algorithms.
- Heuristic indirect control responsive: Movement of devices depend on written algorithm networks with learning ability.

3. METHODOLOGY

The methodology of this paper is going to be based on review and analysis of some selected examples of buildings. After literature review of the stated topic, some examples of buildings with adaptive kinetic façade will be fully analysed and explained based on energy efficiency of the kinetic facades in the buildings. The effectiveness if the kinetic façade will be analysed based on how much energy it saves or generates to the building. This type of methodology is simple and straightforward in finding examples, fully studying them and making a full analysis based on the study done.

3.1. FINDINGS AND DISCUSSIONS

The 21st century is seen as the real starting point of kinetic architecture, because many kinetic buildings and facades have been designed and constructed in this century. Some examples of sustainable buildings with kinetic facades that are energy efficient are as follows.

i. Brisbane Airport Parking Garage, Queensland, Australia

The kinetic facade of Brisbane Airport Parking Garage was designed by the artist Ned Kahn in Australia. Constructed in 2011, the building's facade looked like a vertical water body and like calm waves. The façade is constructed with about 250,000 panels of aluminium that moves when the wind blows on them. The movement of the panels inside the structure gives the internal areas appealing daylight patterns (Delana, 2015). American artist Ned Kahn, worked with Hassell architecture, UAP and the Brisbane airport corporation to create an eight-story, five-thousand-square-meter kinetic façade for the airport's domestic terminal car park. As the wind triggers about 250,000 suspended aluminium boards, the entire exterior of the park appears to flow fluidly. The elevation should create a direct connection between the installation and its natural environment as it reacts to the ever-changing patterns of the air. Complex light patterns and shadows are projected onto the floors and walls inside the car park as daylight passes through the internal panelling network. It offers practical environmental benefits for the interior space of the property, such as shade and natural ventilation.

Figure: Brisbane Airport Parking Garage facade, Queensland, Australia

Source: (Brisbane Airport Kinetic Parking Garage Facade by Ned Kahn + UAP, 2012).

ii. Sharifi-ha House, Tehran, Iran.

Pivoting pods allow the owner of this Tehran house to adjust to the fluctuating temperatures of Iran by exposing rooms during the summer and turning rooms inward in winter. Designed by Tehran's Next Office studio, Sharifi-ha House houses three rooms which can be rotated 90 degrees to open views and balconies during the hot summers of the city and turns horizontally to keep the house cooler during the cold winters. The building's openness and closure refers to typical Iranian houses providing both a winter and a summer living room. This building is considered as the transition from two dimensional facades to three dimension. The three pods contain a first-story dining room, a second-story guest room and a third-story home office. Each has a side door that gives access to the terrace when it is turned open and access to the room when it is closed. Terraces were designed with folding balustrades that flip up or down as the pods rotate to accommodate the changing façade.

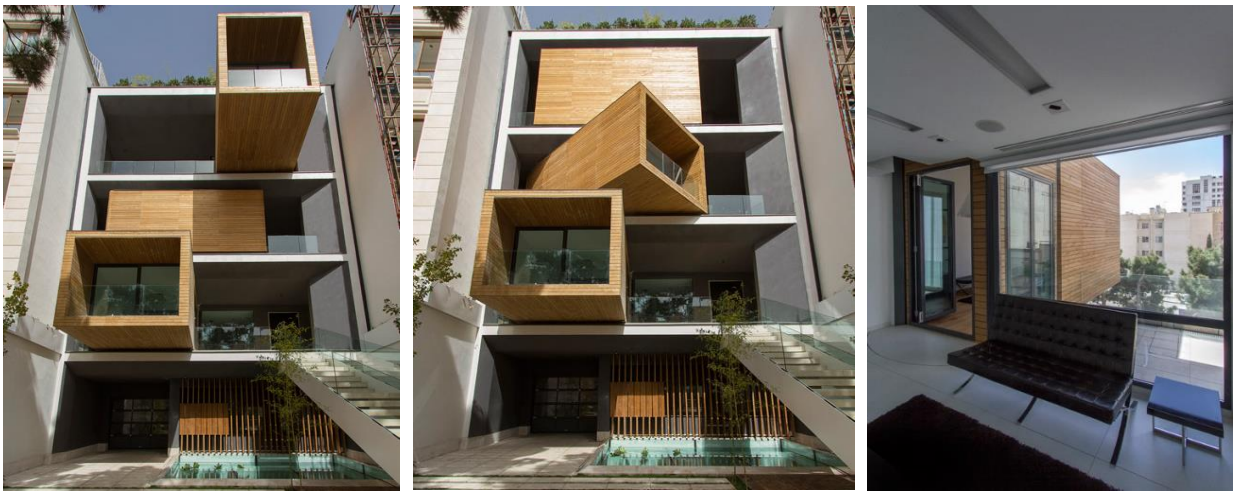

Figure: Sharifi-ha House facade, Tehran, Iran.

Source: (Tebbutt, 2014)

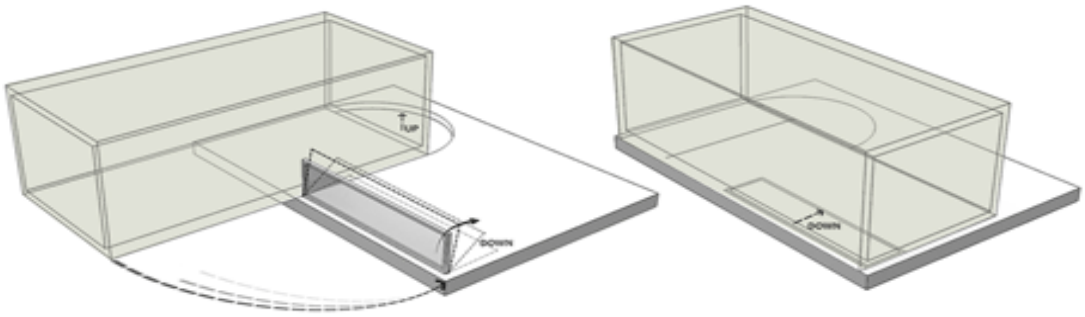

Figure: Sharifi-ha House facade technique

Source: (Tebbutt, 2014)

iii. Foster and Heatherwick Fosun Art Centre, Shanghai, China.

The three-story theatre building, influenced by traditional Chinese theatres, features a bronze tubes/pipes curtain-like façade. Such tubes hang in three layers, making front doors and balconies semi-transparent displays. When the project was first revealed, the architects introduced the façade as "a moving curtain that adapts to the building's evolving use and reveals the balcony stage and views of Pudong." The curtain of three layers stretches out into three wings. The plane consists of long lines and long vertical lines of rhythm. Composition, each line's anti-collision points are connected to the curtain's beautiful curve. Such elements are shaped in order to form the marked points, like singing music, undulating waves, flowing art and endless circulation. The art centre's versatility and the riverside's personality. The mixed use arts and cultural creation centre features a bronze pipe curtain façade that resembles giant bamboo pieces. Such tubes are hanging in three layers, forming a curtain that travels horizontally around the building's exterior, shifting its form (Keegan, 2019).

Figure: Foster and Heatherwick Fosun Art Centre, Shanghai, China.

Source: (Frearson, 2017)

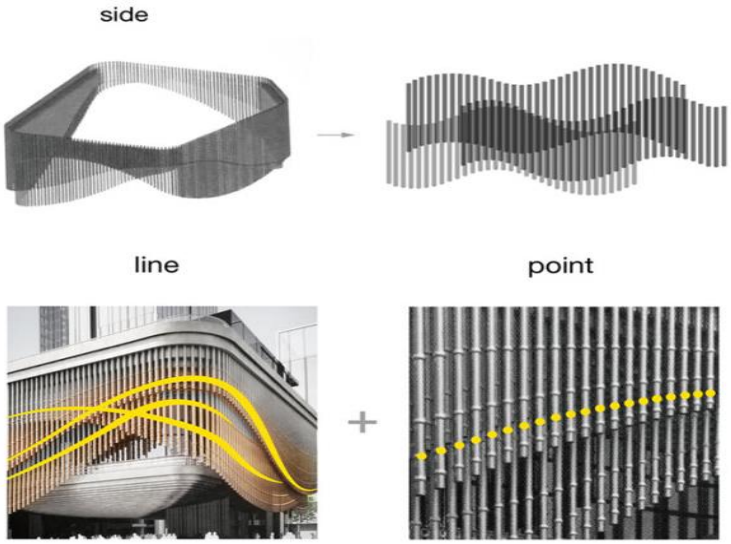

Figure: Foster and Heatherwick Fosun Art Centre façade technique

Source: (Frearson, 2017)

iv. Penumbra - A Kinetic Daylighting and Shading System

Student in architecture Tyler Short has created an effective alternative window shades-mechanical vents that switch in three dimensions to respond to daylight at different times of the day. The conceptual Penumbra shading scheme, like vertical indoor blinds will hang right and left in front of the windows to conform to the sun's east and west orientations. But it could also fold up against the high afternoon sun to create a horizontal shade. This design was intended to provide a dynamic and mechanical solution to a problem that is otherwise almost impossible to solve with rigid architectural components. Building façade shading for high afternoon sun and low evening sun conditions. The student designer expresses that the method used was a system of vertical shading devices, which can rotate independently to optimize solar protection, and that when the sun hits an angle where vertical shading devices are ineffective, rotate fully upwards to serve as a horizontal shading component and a light shelf. He also added that the system could be powered by either computer or hand.

Figure: Penumbra

Source: (Frearson, 2014)

v. Kiefer Technic Showroom, Gleichenberg, Austria.

The Kiefer Technic Showroom is an office building and a hybrid exhibition room that moves according to the general weather conditions and it is situated in Bad Gleichenberg, Austria. It is a specific example of modern dynamic architecture with an external frame of 112 tiles moving and folding into commanding columns. The Kiefer Technic building façade is expanding and contracting to regulate the amount of sunlight allowed inside. Through maintaining a

constantly moving barrier against external heat, this reactive model minimizes the need for air conditioning. The was designed by Graz based architectural firm called Giselbrecht & Partners, and it was completed in 2007. Architect Ernst Giselbrecht clarified the change in modern architecture that allowed the building's exterior to be viewed as a whole, rather than accommodating graded parts of the building. The skeletal frame of Kiefer Technic Showroom encompasses of steel-encased columns, solid brick faces, and bolstered cement ceilings. The moving façade is controlled by 56 engines that trigger perforated aluminium folding panels and automated shutters. The structure shows a slowly changing front as the day progresses and the rays of the sun change. It transforms into a complex sculpture that regulates its own internal climate. The shutters can alternatively be operated on human commands.

Figure: Kiefer Technic Showroom, Gleichenberg, Austria.

Source: (Ernst Giselbrecht + Partner, 2010)

4. CONCLUSION

Climate change is inevitable and cannot be altered, buildings can be. As such, the invent and adaption of the kinetic façade technique is one of the best improvements done with technology in the architectural world. These kinetic facades are used to effectively maximize energy in buildings and adapt fully to the climate conditional change providing maximum comfort to the inhabitants with the change in time. In conclusion, kinetic façade is a perfect tool for energy efficiency again climatic unhindered change and dynamic human needs. Good urban design is becoming an increasingly complex challenge due to an increasing demand to meet more stringent ecological, social and economic performance requirements. The building needs to be responsive to the climate context, and since the building envelope is the boundary between the external atmosphere and the interior, the layout of the envelope becomes a key factor in the development of sustainable and energy-efficient buildings.

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