IEREK PRESS Academic Research Community

http://www.press.ierek.com

ARChive

CrossMark

ISSN (Print: 2537-0154, online: 2537-0162)

International Journal on:

The Academic Research Community Publication

DOI: 10.21625/archive.v2i3.347

Kinetic Architecture & Renewable Energy

Azza Gamal Haggag[1]

[1]*Modern Academy for Engineering and Technology*

Abstract

Today, architecture is one of the finest products of the creative human mind that God has given us. Its existence is a necessity which makes the aspects of human life and way of thinking balanced between endless desires and needs. This confirms the strong relationship between the architectural product and humans. This relationship is based on providing humans with their needs and it aims to find appropriate solutions to the problems facing them. Additions that can be added to the architectural product such as motion help in activating the interaction in this relationship. The movement is added to the architectural output to express a new relationship between the environment and the human who was affected by the existence of motors and its utilitarian, technical, and aesthetic issues. The research focuses on how these effects can be exploited to solve problems like energy consumption that is a main problem in the construction process.

Keywords

Energy Consumption; Energy saving; Design Considerations; Kinetic building

1. Introduction

According to the design considerations necessary for the implementation of any kinetic building efficiently and successfully, Considerations can be classified into: architectural considerations - technical considerations and considerations of implementation. The main idea of this paper based on trying to prove that if these bases or considerations meet the goal of energy saving and the use of environmentally friendly alternative sources, the principle of saving energy for kinetic buildings will be achieved, and it is no longer limited to the kinetic interfaces that contribute to climate adaptation and energy saving. The following is an account of these considerations and how they can be channeled to energy saving and know which considerations have a prominent role in achieving this goal.

2. Kinetic Architecture Design Considerations

Design considerations are the main factors for getting a successful kinetic building, some of these considerations have a direct impact on energy consumption rate and other have an indirect effect. This consideration including the following, Figure1.

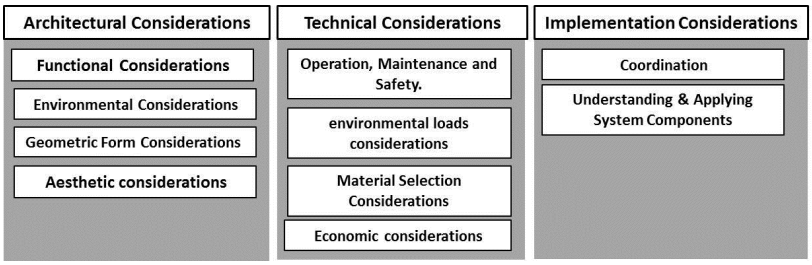

Figure 1. Kinetic Architecture Design considerations.

2.1. Architectural Considerations

Successful architectural work requires many of the basic architectural considerations to meet the human different needs by achieving functional, aesthetic, psychological and social comfort, which can be expressed as follows:

First: Functional Considerations:

Including the followings:

- Studying the ability of the building to achieve its purpose - in terms of choosing the appropriate motor system for different architectural needs, and the compatibility of the design solution of the kinetic system with the requirements of internal spaces (study the purpose of movement)

Studying the Purpose of Movement

By tracking and studying many kinetic buildings, the purpose of applying motion can be classified into the followings, table 1:

1- Providing design flexibility to fit with the natural variables or to make the building multi-use.

2 - Providing design flexibility in accordance with the functional requirements, such as the movement of doors and windows that perform specific function

3- Achieving maximum benefits from the surrounding environmental conditions.

4 - Attracting the attention of the recipient and achieving luxury. This category includes restaurants, revolving exhibitions and residential units.

Table 1. Kinatic building examples for different purpose of movement.

1- Providing design flexibility to fit with the natural variables or to make the building multi - use.	
Swedbank Stadium	Located just north of Stockholm, and designed to be a truly multi-purpose facility. The arena seats 50,000 guests for international football matches and other sporting events, and can be configured to hold an additional 15,000 guests for concerts and other shows by controlling the roof design that can protect guests from inclement weather, while still retaining the advantages of an open-air stadium when the weather is favorable (Project Gallery). See figure 2.
Sharifi-ha House	Designed by Tehran studio Next Office, consists of three rooms that can be rotated 90 degrees to open up views and terraces during Iran's hot summers, and turned back to a horizontal position to keep the house warmer during the cold, snowy winters (Taghaboni, 2014). See figure 3.
2 - Providing design flexibility in accordance with the functional requirements.	

Continued on next page

Table 1 continued

American Airlines by Uni-Dock	Uni-Systems has designed the Uni-Dock as a way to perform needed safety inspections, maintenance and repairs in less time with more accuracy. The Uni-Dock allows maintenance staff fast, easy access to an entire aircraft for all repair and inspection activities, dramatically shortening the stay of each aircraft and optimizes productivity and air time of each aircraft (En-Fold® Retractable Awning by Uni-Systems). See figure 4.
3- Achieving maximum benefits from the surrounding environmental conditions.	
The dynamic solar shading of Kiefer Technic Showroom	The Kiefer Technic Showroom is a hybrid exhibition space and office building in Bad Gleichenberg, Austria that moves according to the general weather conditions. The façade expands and contracts to regulate the amount of sunlight permitted to the interior. This responsive design minimizes the necessity of air conditioning by maintaining a constantly moving shield against external heat (Uys, 2016). See figure 5.
Penumbra	Providing shading across a building facade for both low evening sun and high afternoon sun conditions. Our solution was a series of vertical shading louvers, that can independently pivot to maximize solar protection, and when the sun reaches an altitude in which vertical louvers would be ineffective, completely rotate upwards to act as a horizontal shading element and light shelf (Short, 2014). See figure 6.
4 - Attracting the attention of the recipient and achieving luxury.	
Shanghai theater	Designed by Foster, Partners and Heatherwick Studio, Inspired by traditional Chinese theatres, the three-story building features a curtain-like facade of bronze tubes. These tubes hang in three layers, moving in a vertical direction creating semi-transparent movable screens in front of windows and balconies (Frearson, 2017). See figure 7.

Figure 2. Swedbank Stadium

Figure 3. Sharifi-ha House

Figure 4. American Airlines by Uni-Dock

Figure 5. The dynamic solar shading of Kiefer Technic Showroom

Figure 6. Penumbra

Figure 7. Shanghai theater

- Studying the relationship between fixed and moving parts and the impact of each other, while maintaining the stability of each part of them separately.

- Studying the horizontal and vertical communication elements like stairs and corridors, their relationship to the movement and directions of escape to achieve safety for users (Ishii, 2000).

- Studying services location and facilities taking into account the absence of overlapping service paths and facilities especially in the revolving projects.

- Studying the percentage of used spaces for mechanical and operating systems, including studying the effect of moving elements on the fixed parts.

- Studying the compatibility of architectural design with laws, legislations and regulations, respecting laws and regulations of the surrounding.

Second: Environmental Considerations

Environmental considerations are necessary by:

- providing thermal and optical comfort to the user of the architectural space, without affecting the environment and the energy conservation rates. Using some environmental design strategies like green architecture and sustainable buildings increases the performance of the building in the field of environmental conservation.

-Providing thermal comfort gained by using natural ventilation and shades, studying ratios of openings, finishing materials , efficiency of joints for moving parts.

-Achieving acoustic efficiency gained by studying the effect of the internal structure of the moving part on the acoustic efficiency of the space, as well as the effect of materials used and the great effect of motors and joints

- Saving energy, including thermal and optical considerations and the energy type required for the operation of the building and the operation of motors.

Third: Considerations of Geometric Form

Determination of the geometric form must be integrated with the purpose of the building and the nature of the movement, whether functional or environmental, which requires the following:

- Determining the basic form of the kinetic building by studying the style and nature of the movement.

- Taking into consideration the structural and mechanical aspects of the structure as a whole, moving parts and joints. The design of kinetic blocks, which sometimes produce the whole structure by moving them all separately at the same time (Hoberman Associates, 2007).

- Studying the form and behavior of the building in motion, by making real or digital initial models of the movement style.

-Taking into consideration the achievement of movement safety especially for buildings that move with a transformation of the structural skeleton, and check stability during movement.

- Taking into account the ease of use of the facility by achieving flexibility in responding to various functional and environmental requirements.

Fourth: Aesthetic Considerations

Although elements of kinetic buildings are mechanical component, it requires some aesthetic considerations through:

- Studying the esthetics of the form of movement in the case of stability and in case of movement.

- Studying the compatibility of the final form taking into account the relationship between the movement parts and fixed parts.

- Study the compatibility of the building with the environment.

2.2. Technical Considerations

Technical considerations are the most important considerations necessary for the implementation of the kinetic buildings for the continuation of its work efficiently, including the following:

Operation, maintenance and safety - environmental loads - material selection - economic considerations

First: Operation, Maintenance and Safety

Kinetic buildings are exposed to collapse and failure by breaking parts of them over time or affect the efficiency of the movement or response to exogenous stimuli, so specialists must follow some steps to reduce the size of risk and reduce the costs of periodic maintenance and safety for users in the framework of (Asefi, 2009):

Taking into account achieving good detailed design for all operation and maintenance programs.

- Providing the complete specifications of all components of the kinetic system.

- Taking into account the integration of the roles of the architectural and structural designer with the manufacturer and continuity of the relationship between them.

- Preparing the equipment for periodic and surprise maintenance.

Second: Considerations of Environmental Loads

It is one of the most important challenges facing the process of design of kinetic buildings includes the process of assessment and identification of all internal and external environmental loads that can affect the movement of moving components. Environmental loads can cause the collapse of the joints before or during the motion, which requires study of the following:

-The external environmental loads are divided into expected loads such as wind loads, and unpredictable loads such as earthquakes. Therefore, the structure must be designed with a degree of flexibility that resist the

horizontal forces of the earthquakes, or sets up special systems such as those that causes closing the building shell when the wind speed rises.

-Internal loads: such as internal heat transfer to the structural components or resulting from the motion of the building.

Third: Material Selection Considerations

These include structural materials and covering materials, and there are many criteria and considerations that can be classified into environmental, structural and mechanical, aesthetic considerations. And some computer database programs help in comparing between different materials such as Cambridge Selector Cambridge (Ashby, 2005). Material selection considerations include:

Environmental Considerations:

Environmental impact is one of the most important considerations for material selection (Asefi, 2009), it includes:

- Choosing materials that have little effect on the environment which is also less energy consuming during manufacturing and operation.

- Choosing materials that are most resistant to environmental conditions, like the lighter and more fire-resistant or recycled materials.

- Choosing the easy cleaning materials which are small enough to reduce the possibility of plankton, microbes and dust existing, thus reducing the cost of maintenance and cleaning, such as self-cleaning materials and anti-adhesive materials (Lehman, 2008).

- Selection of materials which are available at the surrounding environment to reduce costs and adapt to the surroundings.

Structural and Mechanical Considerations:

The study of the mechanical properties of materials is a basic requirement for the structural design of the kinetic structures, including the study of some factors like the factor of decreasing material efficiency over time, the

thermal and sound behavior of the materials in terms of insulation, the material lifetime and durability, resistant material to buckling (Asefi, 2009).

The Aesthetic considerations:

It means the consideration that concern of the aesthetic properties of materials such as color, patterns, appearance and compatibility with the visual perception of the structure.

Fourth: Economic Considerations (cost and value)

Kinetic buildings are characterized by the high initial cost, making them sometimes be excluded as a design alternative. Cost elements include (Ashby, 2005):

-The cost of the initial design including the various researches and studies of the method of movement and behavior of the building as a whole and the costs of making study models.

- Manufacturing cost including the methods of manufacturing different parts of the kinetic structure and the cost of covering materials.

- Operating and controlling cost including the energy used to move the building, especially large-scale installations that need high-capacity engines. As well as the necessary energy for monitoring, sensing and computer control. - The cost of periodic and sudden maintenance. It includes the cost of maintenance materials and all spare parts for the system covering materials.

2.3. Implementation Considerations

These include coordination between the different design teamwork which include the architect, the structural, electro-mechanical engineers, the engine & control systems exper.., etc., who have to fully integrate the work

under the previous considerations, in addition to understanding the movement system which can be simplified in the following (Fox & Kemp, 2009):

The kinetic systems components.

The kinetic systems generally consist of: Structure skeleton, Actuators, input systems and controller.

The input can be presented by the sensors and the different input methods which give different information about the surrounding environment. The control systems are in the computer that is responsible for making the decision to carry out the movement by receiving the information from the input systems and giving the orders to the animation systems that move the structure. Not all previous items are required because:

-If the system consists of motors and structural skeleton, it is a simple kinetic building, easy to control.

- If the system consists of sensors without engines, they will be sensitive building, such as monitoring and safety systems used in fixed buildings.

- If there are sensors and motors together, this system is responsive/ smart building.

- If the system simulates neural networks systems, this is a smart intelligent self-learning has many characteristics that facilitate the response to the surrounding environment and achieve the desired needs efficiently (Sheriden, 2000).

The movement occurring in the parts of the kinetic building requires an engine to generate this movement and a controlling system to achieve its purpose in the best possible way, which is known as the control system. There are many techniques to control this movement ranging from simple manual systems to complex technical and mechanical systems, and the more complex the control systems the more energy consumed in the operation of the building.

Parts of control systems include:

- Mechanical motors that are extended by a source of energy

- usually electrical energy or pressure of liquids (hydraulic) or pneumatic pressure and pneumatically turning it

into motion.

- Sensors that respond to stimuli - physical - chemical stimuli (such as motion, temperature or chemical concentration) and send signals or impulses, including light sensors, sound sensors, heat sensors, humidity sensors, touch sensitive sensors, positioning sensors, motion sensors, chemical and magnetic sensors, as well as environmental sensors used in studying temperature, air pressure, humidity and others.

- Transducers, a device that converts energy from one image to another, such as converting mechanical energy into electrical energy.

- Detectors, devices consisting of sensors, in addition to other electronic components , used for conversion of signals from the sensors and converted into a understandable and usable formula.

- Actuators, which convert the incoming energy which are in the form of signals to mechanical movement.

3. Design Considerations Analysis

Table 2.Energy Consumption Evaluation Balanced with the Design Considerations

		Details	Energy Consumption Options	Energy Consumption Amount/ fixed time			Architectural Solutions	Engineering & Technical Solutions	Risk Management Strategy		
				High	Moderate	Low			Prevention	Reduction	Acceptance
Kinetic Architecture Design Considerations	Architectural Considerations										
	Technical Considerations										
	Implementation Considerations										

- The relation between the building and energy is an old and prominent relationship which nowadays constitutes one of the most important scientific studying trends to maintain the correct environmental balance. This is the mathematical equation in which the architect and the work team compare the different design solutions for each of the above mentioned consideration elements with different grades to assess the energy consumption rates that can be classified into: maximum consumption, medium consumption and low.

Thus all elements can be balanced to reach the energy consumption rates of the building as a whole to make the necessary design decisions.

- According to the rate of consumption, one of the risk management strategies can be used. These policies provide three solutions according to the risk assessment in terms of probability and impact and these policies are: prevention or avoidance policy, reduction policy and acceptance policy (Airmic & IRM, 2002; Lough, Stone & Tumer, 2006).

4. Conclusions

- There are some design considerations that mainly affect the energy consumed, the most prominent one is the consideration of studying the purpose of movement and environmental basics of the design and materials used. Therefore, the decision to apply kinetic buildings or moving parts or elements must be carefully evaluated since the efforts of different institutions in many countries going into limit and control the rates of energy needed for construction, operation and maintenance. However, some architectural projects may gain international fame in terms of idea and implementation because they are kinetic buildings, and thus attract many visitors and users who are financially capable, despite consuming a lot of energy to attract the attention of passers-by. And it is difficult in these cases to assess the consumption of energy in order to choose the appropriate risk management policy, but choosing the policy of reduction will be the best solution.

- The functional reasons for applying kinetic buildings placed in a strong confrontation with the analysis of the

necessity of movement because they provide solutions to many problems of architectural design, so in the case of energy consumption remains, the option of reduction policy will be the ideal alternative rather than prevention.

- Estimate the ratio between the average energy consumption and the rate of saving are difficult to determine precisely in many cases because they influenced by the performance of users of architectural spaces and their understanding of the concepts of environmentally friendly buildings and problems of depletion of energy sources and other topics.

- The necessity of cooperation of the various parties involved in the design, implementation and formation of kinetic buildings ,so that it will be easy to complete all the necessary data for architectural, technical and operational design considerations.

5. Acknowledgments

The author would like to acknowledge Modern Academy for Engineering and Technology in Egypt for the financial and moral support for carrying out various academic researches.

6. References

1. Airmic, A., & IRM, A. (2002). A risk management standard. AIRMIC, ALARM, IRM.
2. Asefi, M. (2009). Design management model for transformable architectural structure, Valencia: Proceedings of International Association for Shell and Spatial Structures (IASS).
3. Ashby, M. F. (2005). Materials selection in mechanical design. MRS Bull, 30(12), 995.
4. En-Fold® Retractable Awning by Uni-Systems. (n.d.). Retrieved from https://www.uni-systems.com/
5. Fox, M., & Kemp, M. (2009). Interactive architecture. New York: Princeton Architectural Press.
6. Frearson, A. (2017, June 9). Foster and Heatherwick complete Shanghai theatre with curtain-like facade. Retrieved from https://www.dezeen.com/2017/06/09/foster-heatherwick-complete-shanghai-arts-centre-curtain-like-facade-fosun-foundation-theatre-architecture/
7. Hoberman Associates. (2007, January). Changeable form: Transformable architecture. Lecture presented at Smart Geometry Winter Conference.
8. Ishii, K. (2000). Structural design of retractable roof structures. Computational Mechanics.
9. Lehman, M. L. (2008). Bringing architecture to the next level. Sensing Architecture.
10. Lough, K. G., Stone, R. B., & Tumer, I. (2006, January). The risk in early design (RED) method: Likelihood and consequence formulations. In ASME 2006 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. American Society of Mechanical Engineers.
11. Project Gallery. (n.d.). Retrieved from http://www.uni-systems.com/en/projects/featured-projects/swedbank-stadium
12. Sheriden, J. (2000). The engineering of style, Naval architecture,Current thinking on smart products and materials(Doctoral dissertation) [Abstract]. Retrieved from http://www.designpartners.co.uk/Smart.html
13. Short, T. (Director). (2014). Penumbra - A Kinetic Daylighting and Shading System [Video file]. Retrieved from https://vimeo.com/88143073.
14. Taghaboni, A. (2014, July 7). Harifi-ha House / Nextoffice - Alireza Taghaboni. Retrieved from https://www.archdaily.com/522344/sharifi-ha-house-nextoffice
15. Uys, E. (2016, August 30). The dynamic solar shading of Kiefer Technic Showroom. Retrieved from http://www.designindaba.com/articles/creative-work/dynamic-solar-shading-kiefer-technic-showroom