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Assessment of the efficiency of using kinetic facades in response to dynamic daylighting

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Abstract: This study aimed at evaluating the effect of using kinetic façade on the dynamic daylighting in the different types of buildings. The results of this study were based on a systematic review of the main related conducted studies in this field. the main results of this study confirmed the effectiveness of suing kinetic facades in achieving the desired daylighting levels with a certain emphasize on the importance of implying the updated technologies on the design and changing the designers perspective where they should take the environmental context into consideration while dealing with such designs. Moreover, as the advantages of this approach have been established by the previous literature, its justification has not been addressed yet properly.

1. Introduction

Current studies focused on the major influence of façade design on the quality of the indoor daylighting (Freewan, 2014; O'Brien, Kapsis, & Athienitis, 2013; Shen & Tzempelikos, 2012; Sherif, Sabry, & Gadelhak, 2012). The high integration between research and design amongst consultants, computational designers, and architects is significant for addressing the associated limitations with including performance criteria with the façade design through integrating various simulation tools (GhaffarianHoseini et al., 2013). However, it is still essential to discover the patterns of the kinetic skin for this kind of integrated design (Baldinelli, 2009). Patterns of kinetic skin are shaped by multiple singular movements. Many studies investigated the impact of kinetic facades on indoor day lighting. There is a need to conduct a review for the experimental investigations of such kinds of patterns in order to come up with more comprehensive results. This study will be carried out to evaluate the performance of kinetic façades that integrate different motions in response to dynamic day lighting.

2. Renewable energy applications in green buildings

It has been recognized internationally to endorse innovative approaches in carbon dioxide emissions mitigation because of associated energy consumption with the operation and construction processes within buildings. Therefore, the green buildings energy performance has a huge influence on the built environment sustainable development. According to Kothari, Tyagi and Pathak (2010), sustainable development is highly tangled with the energy deliberation. Therefore, sources of

renewable energy such as waves, winds, and solar etc. has a key role in the sustainable development; instead, the sources of sustainable energy such as the waste-to-energy sources are highly significant in the sustainability development (Kothari, Tyagi, & Pathak, 2010).

Reviewing different studies with focus on the green buildings concept (Berardi, 2013; Brown & Vergragt, 2008; Catto, 2008; Chen, Chen, Berardi, & Xu, 2012; Iqbal, 2004; Joelsson & Gustavsson, 2009; Lund, Marszal, & Heiselberg, 2011; Marsh, 2002; Mwasha, Williams, & Iwaro, 2011; Rosta, Hurt, Boehm, & Hale, 2008; Zhu, Hurt, Correia, & Boehm, 2009), the study establishes that green buildings are significantly influenced with advanced integrated technologies and energy efficient designs in order to decrease the energy consumption and demand in the electricity, cooling, heating etc.; by applying on-site renewable energy sources.

Regarding the green buildings sustainable energy performance, the best renewable energy supplies application in buildings is a vital criterion. Therefore, solar sustainability systems are key factors in the green buildings development. On the other hand, Kensek proposed using kinetic facades that are automatically responsive to the environment to be as an innovative solution for buildings sustainable design (Kensek & Hansanuwat, 2011). It was found that that the kinetic facade efficient design could offer improved daylighting while enhancing the buildings' aesthetical features (Kensek & Hansanuwat, 2011).

3. Kinetic envelope systems

Kinetic architectural design is able to mostly be found in building skins or envelopes in modern architectural design practice. This advance to designing architectural skins includes the kinetic mechanisms adoption for environmental responsiveness and adaptation. The expression "Kinetic architecture" was sited up by William Zuk and Roger H. Clark at the beginning of seventies as dynamic spatial design troubles were explored within mechanical systems (Ramzy & Fayed, 2011).

Kinetic structures at a scale beyond environmental screens or media are able to be assorted to 3 significant approaches (Moloney, 2011). The 1st approach is for Hoberman Associates, debatably the leading international construction and design consultancy in kinetics. He developed a flexible, mechanical and light structural system by a set of hinged units, to shape variable designs. His aesthetic is command via a distinctive advance to engineering that produces a minimal, singular motion while the structural element folds in on itself.

The 2nd approach was originated via the MIT Kinetic Design Group, it offered a classification of control systems for kinetics. (M. A. Fox, 2003) classification of control systems summarizes the different methods kinetic structure possibly will be controlled. For broad general kinetic categorization, (M. Fox, 2016) collected them into 3 categories: embedded, deployable, and dynamic. He illustrates the embedded system like one which exists in a greater architectural whole within a permanent location; the deployable as presented in a impermanent location, that is simply transportable; as well as the dynamic system as presented in a greater architectural whole, however acting separately regarding to control of the grater context. The studied of the kinetic façade systems will be of the embedded form. The embedded system is able to be straight measured, and relatively considered for quantitative values; as well it has the most direct effect on the users of the building in addition to their comfort through controlling such factors as ventilation, light and thermal comfort.

The 3rd approach in dynamic kinetic structures is proposed by (Oosterhuis, Xia, & Sam, 2007). They summarized creating interactivity by Hyperbody'siA/Protospace software that is based on flocking algorithms. Projects are usually considered as a singular double-curved surface, through the kinetics based on the surface deformation through pneumatic structure. Generally, the projects compress on the realization mechanics, with minimum looking at of the probable kinetics range

enabled through the technology. In the theoretical contribution, the application of an agent fundamental approach of the control mechanism utilized by Oosterhuis has synergies through the compound 'heuristic responsive indirect' form identified during Fox's taxonomy. However, the control mechanism concept based on self-organizing activities, like that attained with flocking algorithms, as potentially useful within indicating single approach to control systems, is not looked out at in terms of imagining the kinetic composition opportunity (Moloney, 2011).

The Kinetic architecture concept investigates a building's capacity of motion. On the other hand, additional consideration of reaction to environmental conditions is necessary. (M. A. Fox, 2003) as well sees the require to the environmental mediation systems stating, the integration and implementation of computational procedures in architectural components when an environmental moderating system pose a novel developmental opportunities level. There is a significant require to focus such new technologies toward a significant architectural responsibility; that is, sustainable strategies in buildings. Research and industry efforts are rapidly moving to this area. A general approach is to enlarge buildings through kinetic capability, permitting buildings to change their physical shape in response to climate situation (Beesley, 2006). Further approach is to enlarge physical space through sensing capability. Present intelligent kinetic systems happen from the isomorphic convergence of 3 key elements: responsive architecture, mechanical engineering and embedded computation.

Moloney design experiments were done throughout 3 stages (Moloney, 2011). Stage one was undertaken for identifying the most characteristic compound kinetics which result from coupling the base kinetic transformations of scaling, translation and rotation. These produced alike compound types, of that 4 were selected – spring, twist, yaw, and roll– as being the mainly distinctive. Yaw, twist and roll are precise and well-known forms of compound transformations applied in flight dynamics. This approach will be the bases of different kinetic motions for the design stage moreover on that the research proceeds to evaluate and test potential configurations to optimize daylight presentation.

Table 1: Summary of the main related studies

Reference	Method	Main results
(Wanas, Aly, Farghal, & El-Dabaa, 2015)	The simulation was conducted on a simulated office space prototype in desert hot dry climate in Egypt.	The results showed that using kinetic louvers rise the day-lit zone percentage to 63% instead of 53% without shadings where the percentage decline to 35% if improper kinetic system is used.
(Bacha & Bourbia, 2016)	Modeling simulation by using GECO-grasshopper (parametric plugin for Rhinoceros).	That equipped kinetic facades with PV modules positively influence the daylighting level
(El Sheikh & Kensek, 2011)	Developing and simulating simple example to see if the criteria of performance could be accomplished using Rhino modeling tool, DIVA for daylight evaluation and Galapagos for problem solving and Grasshopper as a parametric interface	Kinetic façade can be employed with complex parametric design in order to offer better performance that came along with the designer intent.

(Kensek & Hansanuwat, 2011)	Solar Thermal and day lighting simulations	Appropriately designed kinetic facades have the ability to minimize the energy use in a building that can yield sufficient natural daylighting amounts, bring preferable velocities of ventilation air, and produce more energy.
(Lee, Koo, Seong, & Jo, 2016)	A simulation was conducted on an example building with a drop awning with length-angle-length changes	The optimal kinetic operation scenario can deliver potentially effective energy performance.
(Hosseini, Mohammadi, & Guerra-Santin, 2019)	A combination of quantitative and qualitative methods to study innovative daylight systems functions, its relation with the building forms and the kinetic façade development forms as innovative real-time daylight control.	High kinetic interactive facades performance in improving visual comfort. The results suggested also the three dimensional shape changes façade multifunctional aspects, as an innovative interactive daylighting system that has the ability to control solar radiation in the ambient environment of the facade for avoiding thermal discomfort.

Kinetic movements are able to always be decreased to 3 basic types of movement: scaling, translation and rotation. This classification is applied in spite of where the joint or hinge is located as well as without considering gravity. On the other hand, both of these have major suggestions for the design (Schumacher, Schaeffer, & Vogt, 2012). Combinations of transformations, for example rotation and translation making a rolling motion, present rise to composite movement. The description of kinetics contained material deformation the same as a further type of the complex movement (Moloney, 2011). It is important for the scaling motion to understand the possible materials which can be related to it in order to choose the right substance in Diva that was not studied yet. For the reasons of these experiments, kinetic form will be restricted to test 2 essential geometric transformations. Within the case of linear movement, supposed translation, the position of a thing in space goes parallel to the coordinate axes in a constant planar direction; though in the case of rotation, the thing varies its orientation in space through revolving about the coordinate axes. For every kind of movement, one is able to identify 3 freedom degrees, depending on how the orientation or position of an object varies with respect to1, 2 or 3 coordinate axes. Geometric constraints are able to be applied to bound the degree of freedom of an object (Moloney, 2011; Schumacher et al., 2012).

4. Review of the literature

As mentioned above, many studies have investigated the effect of using Kinetic facades on the day lighting of the different types of buildings; the following table summarizes the main studies in this field with their main findings and used methodologies.

5. Discussion

While most of the studies emphasized on the role of kinetic façade on improving the daylighting performance, some argued that when sun is at the peak position, the kinetic louvers will then have the optimal effect; however, the lowest effect can be found in the lowest the angle position of the sun. Therefore, December or on the months where the sun is at its lowest position, the number of louvers are have to be incorporated (Wanas et al., 2015).

As most of these implementation of additional louvers to the buildings is refused by the

arcchitects, Bacha and Bourbia (2016) suggested that architecture has to be changed to incorporate the climate change and the biosphere destruction. They suggested an active ecological design that is becoming more and more a difficult task, because of the increasing demand to meet more ambitious economic, societal and environmental performance necessities. The building has to be more related to its climatic context where the envelope design is now a vital parameter in energy efficient and sustainable building design (Bacha & Bourbia, 2016).

Moreover, light deflection techniques integration in the intelligent dynamic panel system contributes on enhancing the daylight quality and quantity, harvesting, within the south-facing spaces (El Sheikh & Kensek, 2011).

However, many critics argued that these kinetic systems have high maintenance and construction costs in a way that cannot justify their use (Kensek & Hansanuwat, 2011). Therefore, future research has to focus on the justification of such techniques and their cost savings on a wide range of the potential functions it has including visual and thermal comfort, minimizing artificial light use, producing electricity and sun tracking (Hosseini et al., 2019).

6. Conclusion

After reviewing the related literature on the effect of utilizing kinetic façade on the daylighting, it was noticed that most of the studies are dealing with proposed and stimulated cases where real-life cases are limited. The real performance of such approaches has to be measured in realistic ways. Moreover, there have been limited studies that discussed the requirements that each type of buildings need in terms of daylighting capacity and standards when applying kinetic facades. The differences between the high-rise and regular buildings were not discussed properly as well.

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