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EXPLORING THE DESIGN METHODOLOGIES FOR ADAPTIVE KINECTIC SOLAR SHADING DEVICES

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***Abstract*— In construction, the building skin is the primary subsystem through which prevailing external conditions can be influenced and regulated to meet the comfort requirements of the user inside the building. Nowadays a comfort interior environment is achieved by utilizing the maximum of resources like electricity , fossil fuels and other natural resources which are in phase of extinction . also by using such resources there are a certain amount of heat and other harmful gases that is being released into the atmosphere which again causes further damage . Aim of this paper is to elaborate the different aspects of building skin design an study current examples that pioneer in sustainable and climatic performance in order arrive at guidelines and strategies.**

The framework will provide the strategy that can be followed for designing adaptive kinetic pattern within digital modeling phase. The main aim establish a design framework that provides a design strategy for adaptive kinetic pattern systems.

Keywords – ***kinetic shading devices , kinetic façade ,design methodology .***

I. INTRODUCTION

Despite changed cultural, economic, building technological and energetic parameters, the principal task of architecture is still to create a comfortable "shelter."

In other words, the fundamental aim of building is to protect people from external climate conditions, such as intensive solar radiation, extreme temperatures, precipitation and wind. This topic will explore the software's used, materials , computational methods used to achieve the kinetic façade . it will also explore the design process that has been followed in various projects .

II. BACKGROUND STUDIES

A. Shading devices (History and evolution)

Shading is a key element for achieving thermal comfort in the summer' but, at the same time, it plays also an important role on controlling light and passive solar gain during winter seasons. So , the type and shape of a sun shading device must be linked to the local climate conditions. In warm or hot climates sun heating and glare have to be avoided through the use of shading devices that allow the natural ventilation inside the building. However, in coldest climates free sun energy gains are an important contribution to the thermal balance of buildings and should be encouraged.

The movement system is the last considered variable. Sun shading device can be

- fixed,
- rotating,
- sliding or could be characterized by complex movement obtained by sliding and rotation.

B. KINECTIC architecture

The term "Kinetic" is an adjective that refers to everything produced by movement. A building's success has been judged depending on the ability to survive time and nature ravages but not by satisfying changing human needs and desires as well as the changing surrounding environments.

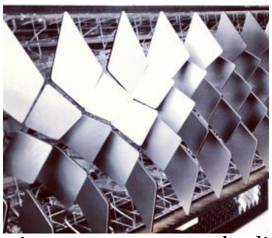

Fig-2 Adaptive shading devices

"Kinetic Architecture" can refer to buildings or building components that act in respond to surrounding changes whether changes are indoor and/or outdoor and whether they are forced by environmental factors and/or human ever-changing demands .

Fig-3 A built form that rotates the entire space.

- The invention of the wheel was the motive of using kineticism in architecture.
- The removable rope and canvas roof over the Roman Colosseum spanning the oval form 620 feet by 513 feet.
- Movable bridges may be classified into several types. Some are employed occasionally such as: bobtailed swing spans, double rotating cantilever draws, transporter bridges, and floating bridges.

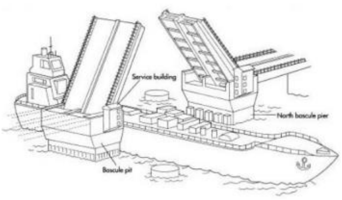

Fig-5 Old for bridges *Fig-6 Latest adaptable bridges*

C. *Classification of kinetics*

Kinetics is divided into two categories: pragmatic and humanistic.

- Pragmatic applications concerned with solving problems, optimizing solutions, and implying space efficiency, shelter, security, transportation, safety, and economics.
- Humanistic are concerned with the physical and psychological effect of the architectural environments' changes upon their users.

Kinetic trends in architectural environments currently address pragmatic or humanistic conditions or even both, and are divided into four categories:

- i. Spatial optimization systems
- ii. Multi-function design
- iii. Contextual adaptability
- iv. Mobility

Principles for intelligent kinetic design

- Structural innovation and materials advancement,
- Embedded computation,
- Adaptable architecture.
- Structural Innovation and Materials Advancement

D. *Kinetic structures Structural classicfiaction*

Embedded structure

- Systems that exist within a larger architectural whole in a fixed location

Deployable structure:

Structures that typically exist in a temporary location and are easily transportable .

Dynamic kinetic structure:

Dynamic kinetic structures exist within a larger architectural whole but act independently with respect to control of the larger context.

Considerations For Case Studies

A few projects that have installed the kinetic shading technology has been chosen and analyzed their process innovation in technology and materials and their design process involved .

E. *AL-BAHAR TOWERS -ABUDHABI*

- Al Bahar Towers inspired by "Mashrabia" which is a traditional Islamic and Arabic motif of wooden lattice screen that was considered as a vernacular architecture, it was made for creating an interesting façade, an efficient shading system, reducing solar gain, reducing glare, and providing privacy.
- The "Mashrabia" at Al Bahar Towers consist of a series of transparent umbrella-like modules that open and close in response to the sun's path.

Al Bahar Towers – External Automated Shading System

Fig 10 : Al-Bahar towers

Country: Abu Dhabi, United Arab Emirates
Climate: Hot Arid climate
Designer: Aedas Architects
Building Function: Office Building
Pattern system: Triangular automated shading
Pattern features: Shading oriented strategy, filtering light.
Facade construction system: Steel structural frame, glass curtain wall
Application in project: External facades
Contains more than one thousand individual shading devices.

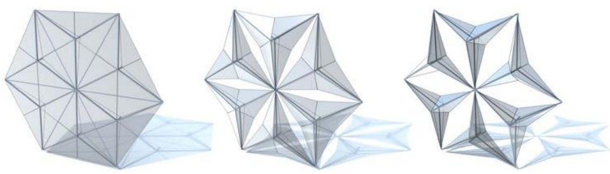

Fig 11 : Mashrabia inspired kinetics

The effects of this system are :

- Reduced glare,
- Improved daylight penetration,
- Less reliance on artificial lighting, and
- Over 50% reduction in solar gain.

Reduction of CO_2 emissions by 1,750 tonnes per year. **One unit - Polytetrafluoroethylene panel - Actuators - Pre programmed sequence - To cut direct sunlight striking the façade -Solar gain < 400w/linear m**

PTFE Panels is a material that can stand

- Against wind,
- Dust,
- Sand, and
- Ultraviolet radiation, it
- Self cleaning material and can handle about
- 150 years. The material has a pattern of perforations with a suitable density that enables light and air to go through it .

Façade skin and pattern import：
After designing the kinetic pattern by the parametric software, the designer has imported the original building to compact the kinetic pattern on it. Then, the designer has loaded the building and the kinetic pattern into project environment to make the final model ready for rendering.

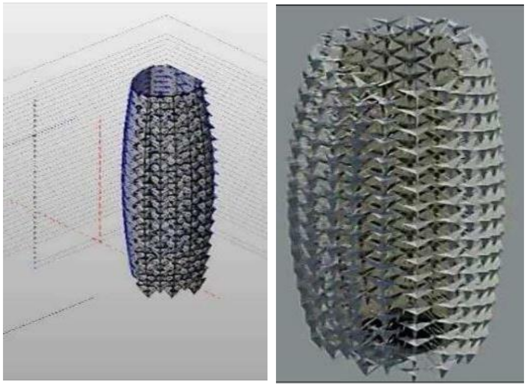

Fig-13 Simulation of panel in whole building

Shading system:
Al Bahar Towers façade is controlled by a computer for responding to ideal solar and light situations. Design team developed modified applications to simulate facade movement in response to the sun's path like java script. Grasshopper and Rhinoceros software were the main applications that the group used in designing and simulating the kinetic pattern .
The entire installation is protected by a variety of sensors that will open the units in the event oh this system are comprehensive:

- Reduced glare,
- Improved daylight penetration,
- Less reliance on artificial lighting,
- 50% reduction in solar gain which results in a reduction of CO_2 emissions by 1,750 tons per year.

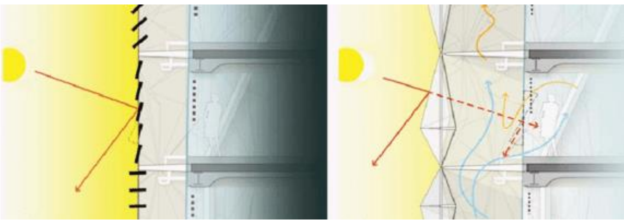

Fig-14 before and after effects of shading devices.

F. SIMONS CENTRE AT STONEY BROOK UNIVERSITY

Dynamic installations has been made for the new Centre for Geometry and Physics by Adaptive Building Initiative.
The first application of Adaptive Building Initiative Tessellate system has served art and function, it is a masterpiece that has a sections of geometric pattern reflecting occupant scientists science and mathematics , it also achieving the requirements of the building plan.
Country: New York, United States of America
Climate: Humid subtropical climate
Designer: Perkins Eastman
Building function: State University of New York
Pattern system: Tessellate; constantly evolving surfaces.
Pattern features: Complete shading control, Controlling solar gain, glare, ventilation, airflow and privacy .
Facade construction system: Adaptive patterns coverage of stainless steel manufactured by Water jet cutting, glass curtain wall
Application in project: Southern façade

Fig-15 Pattern design

CONCEPT
Pattern shifts like flower which blooms each morning, it is known as the "Morning Glory".
Every night the petals on the flower withdraw, and the flower closes itself to preserve energy, and opens at morning.
Tessellate cane with these organic philosophies to architecture. Tessellate pattern modules are independent, framed curtains with cribriform patterns that can constantly move and evolve; Which creates a dynamicity for an architectural element that adjusts
Light and heliacal gain, Ventilation and airflow, Privacy, and sights. Overlapping of these layers gives the kaleidoscopic visual representation of patterns aligning and then diverging into a fine, light diffusing mesh .
Each of the motorized panels revolve around one another on an engineered track defined by the designed components. The visual effect is like that of a flower, blossoming into a burst of patterns – hexagons, circles, squares and triangles. At one point in the cycle, the perforated patterns all are aligned, allowing the maximum open space. At the other end of the cycle, the pattern becomes an opaque mesh.

Fig-16 Northern façade *Fig-17 Morning glory*

PATTERN TECHNOLOGY

Aligning and diverging sparse a visual effect for geometric patterns, the result is a kinetic surface that provides the building with the functional capability to dynamically adjusts its opacity. Each one of Tessellate modules runs only on one motor. A module is controlled by a computer processor, which could be programmed for several objectives.

PATTERN DESIGN

The pattern has an overlapping Arabic motifs, Crafts fabrics, and optical art illusions. Simple geometrical shapes forming the diffused mesh, they are: hexagons, circles, squares, or triangles. Other shapes like rectangles are available, but the pattern will become more complex.

SHADING SYSTEM :

Tessellate has a location-based sensor that responses to light and weather conditions. When detecting high levels of direct daylight, the steel sheets change, and their patterns totally interlock, to block sun rays. The sensors are programmed in many ways to take full advantage of energy efficiency and savings. Patterns opacity can varies from ten to eighty five percent.

In real buildings, a BMS would monitor these parameters for adjusting the system's sheets so they can directly decrease solar gain or balance light levels .

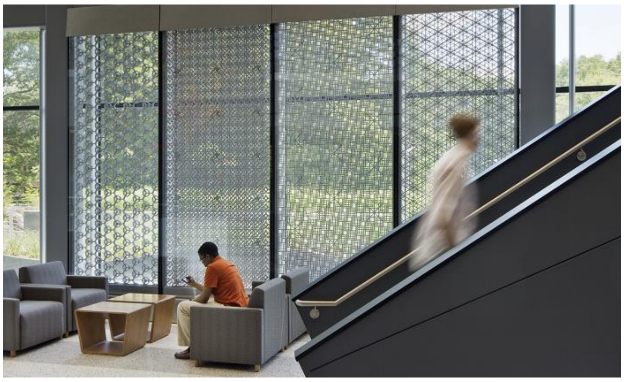

Fig-18 Pattern adaptiveness

Fig-19 Transformation in different stages

G. HELIO TRACE CENTRE OF ARCHITECTURE

Helio Trace kinetic curtain wall system can factually keep track of the sun path over the course of a day and a year. In contrast with other system mechanisms; this kinetic pattern will expressively develop daylight whereas decreasing solar heat gain impacts on building residents. The system preserves excellent daylighting at the surrounding area while it eliminates glare, decreases peak solar heat gain by 81% on a yearly basis .

Fig-20 Schematic views of shading devices

Kinetic patterns shade on the building facade is linked to a pre-fabricated, thermally efficient building covering, which enable interior chilled ceiling plates usage that have a lower energy efficiency than other standard air conditioning solutions.

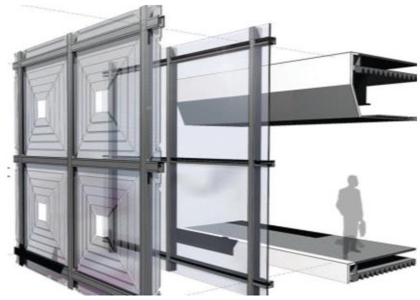

Fig-21 Fixing of the shading device in building

Daylight levels were adjusted to avoid extreme illumination which can be a reason of glare and to help increasing energy savings, also to provide user comfort. Finally, the problem of high solar gain (at bottom left) was analysed regarding the systems external shades, all of them together can cut the peak solar gain by an expected 81 percent. The parametric analysis calculated the ideal deployment level of every shading system at particular times of day, for every season

H. KEIFER TECHNIC SHOWROOM BUILDING

It is a pertinent example of modern interactive architecture with an outer framework of 112 tiles that shift and fold into rows on command. The façade of the Kiefer Technic building 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. It was designed by Graz-based architecture firm Giesbrecht & Partners. This system is able to adapt automatically and each panel on its self is able to move individually. As a result, the system is able to take a large amount of shape compositions, based on either the Weather conditions, occupants preferences or even outdoor architectural appeal.

The skeletal frame of Kiefer Technic Showroom comprises Solid brick faces, Bolstered cement ceilings and Steel-encased columns.
The shifting façade is powered by 56 engines that activate automated shutters and folding panels of perforated aluminum.
It becomes a dynamic sculpture that controls its own inner climate. The shutters can be operated on human command alternatively.

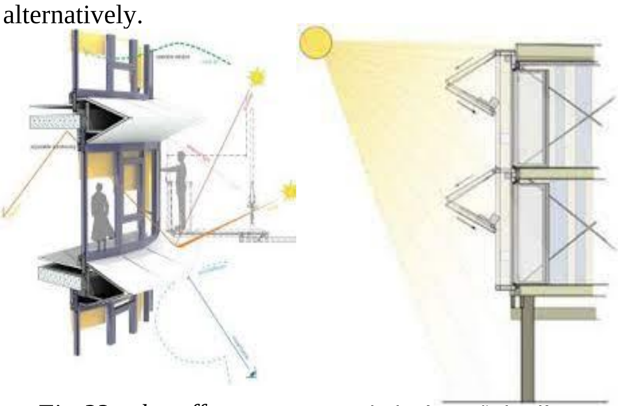

Fig-23 solar effect on open and closing of shading.

The aluminum panels are relatively lightweight, therefor moving the panels does not cost that much energy. But they do move against the force of gravity, so this makes it a little bit more inefficient power consumption wise.
Aluminum also makes the structure very weather resistant and therefor durable. When demolishing, the aluminum is recyclable by melting it.

Fig-24 adaptable building shutters

I. *SDU CAMPUS KOLDING*

The facade is an integrated part of the building and together, they create a unique and varying expression. Inside in the five floor high atrium, the displaced position of the staircases and access balconies creates a special dynamics where the triangular shape repeats its pattern in a continuous variety of positions up through the different floors. The activities open up towards the town so that the campus plaza and the interior study universe become one interconnected urban space with a green park at the back and a common recreational town plaza at the front.
The daylight changes and varies during the course of the day and year. Kolding Campus is fitted with dynamic solar shading, which adjusts to the specific climate conditions and user patterns and Provides optimal daylight and a comfortable indoor climate spaces along the façade.

Fig-25 shading triangular panel

The solar shading system consists of approx. 1,600 triangular shutters of perforated steel. They are mounted on the façade in a way which allows them to adjust to the changing daylight and desired inflow of light. The inner surface of the perforated screens are colored vibrant for a better appeal **.**

III. APPLICATION OF FINIDINGS

After analyzing the above case studies based on their , Design concept , Kinetic pattern design and technology , Generative Parametric Principles , Morphology , Material usage, Representation type , Daylighting parameters , Mechanism , Usage of the elements in the building I have come to a conclusion of a process leading to the final output .

1. **Design concept :**

There are two types of pattern design in this application: first one is focused more on function and delivering the best suitable day lighting, and the other one is focusing more on aesthetic aspects.

2. Setting the parameters:
   a. Creating the sun path
   b. Creating light parameters
3. Creating the pattern

The design is divided into units in order to flexibility to design, and design parameters will contain: unit X and unit Y counts this parameter will set the number of pattern in units X and Y axis . Changes in this parameter are depend on the required size of pattern.

   a. **Unit Width,**
   b. **Unit length, and**
   c. **Unit Thickness:**

Increasing thickness and length will decrease amount of daylight and heat.
3.1. Perforations density
3.2 Opening and Closing

4. Selecting pattern material

Patterns can be made from variant materials, materials affected by climate, every location earth has its suitable materials.

5.Visualizing the pattern

While adjusting the parameters for the required design, viewport in modelling software will animate the changes of pattern in real time, final visualizing for realistic images can be created by using **render engine or by any other presentation method.**

6. Design frame work

After analyzing data for determining general theories of designing kinetic patterns, case studies, and design implementation a frame work has been created regarding the outcomes of these analysis based on the methods used in various projects .

1. Design generation
2. Rationalization
3. Mechanism
4. Materialization

CONCLUSION

Based on the analysis of the case studies conducted and the strategies used in various projects to achieve the required design , I have explored the possibilities for formulating various methods involved in designing the kinetic adaptive buildings in which one prominent method is

Design Generation (formalizing)
Design approach
Concept
Initial form
Basic representational models
Sketches
Technology (morphology)
How it works
Actual design
Parametric and generative models
Movement philosophy
Generative system
Rationalization (validation)
Function
Accurate form modelling
Response to environment
How to transform concept and technology to real design
Mechanism (creating motion)
Machines
Tools
Crafting
Materialization (reality)
Structure
Materials
Environmental adaption
Maintenance

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