University of Cihan - Erbil
College of Arts & Letters
Department of Interior Design

Seminar Title :

Kinetic Architecture

Assistant Lecturer: Omar Abdulwahhab Khalaf
B.Sc. in Architectural Engineering
MSc in Architectural Engineering – Urban Design
PhD Candidate/UKM

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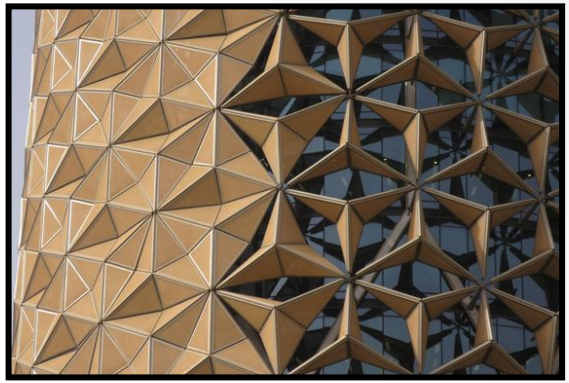
- **The Term “Kinetic”**

  According to the Oxford English Dictionary, the term ‘kinetic’ originates from the Greek κ¯ινητικός, which means ‘moving’, and is commonly used as an adjective with a number of meanings related to various fields. In the field of architecture, while Zuk and Clark (1970) do not give a concise definition, they do provide helpful architectural applications. Most of the things they describe as ideas of the future have been realized.

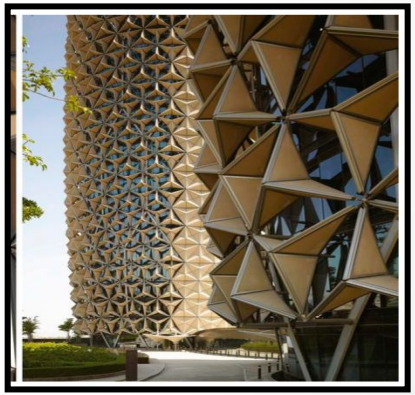
Definition

Kinetic architecture is a concept through which buildings are designed to allow parts of the structure to move, without reducing overall structural integrity.



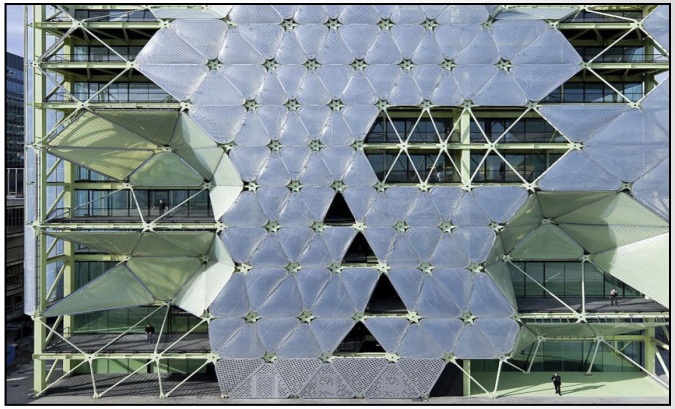
A building's capability for motion can be used just to:

- enhance its aesthetic qualities;
- respond to environmental conditions; and/or,
- perform functions that would be impossible for a static structure. The possibilities for practical implementations of kinetic architecture increased sharply in the late 20th century due to advances in mechanics, electronics, and robotics.



Architects Sarah Bonnemaison and Christine Macy have suggested that movement can be an inspiring idea for architecture without the designs having to allow for actual movement – they can merely suggest it as was the case for some of the constructions of Gaudi or their own recent work. The term *Kinetic architecture* can also refer to static buildings designed to accentuate human movement, such as the performing arts.

There are many approaches in which architecture can be said to be kinetic, through structural innovation, material properties, mechanical elements, etc. As a result, designing kinetic structures requires transdisciplinary approaches, architects may have to overcome many difficulties in the mechanical and control engineering, and they should provide dynamic and structural stability, forces to be applied and many more in the design process.Consequently, it appears that designing kinetic architecture becomes even more difficult because it is expected to respond to changes in the general requirements, ranging from technical and operational issues to psychological, functional, and formal requirements during the movement process.



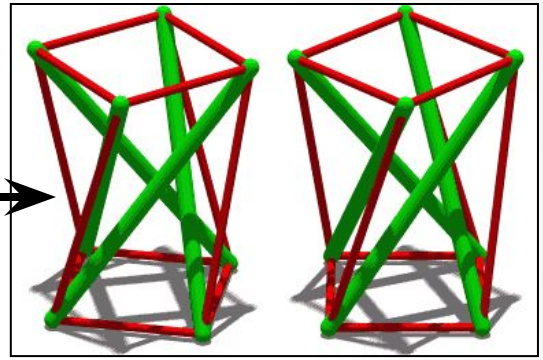
▪ Terms and typologies related to kinetic architecture.

Term	Description
Adaptable	• Structures designed to be easily altered or modified to fit different social functions before and after occupancy. Adaptable projects are generally residential, socially motivated, and often accomplished through movable-wall systems
Deployable	• Structures that can fold for transportation or storage. The principal conflict is between the definitions of transformable and deployable, which are often used interchangeably. Deployable structures are autonomously capable of major configuration changes
Intelligent	• Structures that have the ability to learn as well as respond in time according to the processed information measured or received from the exterior or interior environments by multi-input information detectors and sources, in order to fulfill the users' needs
Mobile	• Prefabricated structures that are built in a factory on a permanently attached chassis before being transported to the site.
Performance-based	• Structures that use digital technologies to challenge the way the built environment is designed, while benefitting the environment, users, and society
Responsive	• Structures designed to respond to the social and/or environmental stimulation at a specific place during the design phase of a project
Transformable/ transportable	• Structures that are able to quickly take on new shapes, forms, functions, or characteristics in a controlled manner by alterations in the structure, skin, and/or internal surfaces connected by articulated joints. Transformable projects are generally less focused on aesthetic effects than on fulfilling the functional requirements of the project

History of kinetic architecture

Rudimentary forms of kinetic architecture such as the drawbridge can be traced back to the Middle Ages or earlier. Yet it was only in the early 20th century that architects began to widely discuss the possibility for movement to be enabled for a significant portion of a buildings' superstructure. In the first third of the 20th century, interest in kinetic architect was one of the stands of thought emerging from the Futurism movement. Various papers and books included plans and drawings for moving buildings. For the first few decades of the 20th century kinetic architecture was almost entirely theoretical, but by the 1940s innovators such as Buckminster Fuller began experimenting with concrete implementations, though his early efforts in this direction are not regarded as totally successful.

In 1970, engineer/architect William Zuk published the book *Kinetic architecture*, which helped inspire a new generation of architects to design an increasingly wide range of actual working kinetic buildings. Assisted by new concepts such as Fuller's Tensegrity and by developments in robotics, kinetic buildings have become increasingly common worldwide since the 1980s.In 1989, architect Jose Leonidas Mejia explored in deep on MDS Multiple Displacement of Structures and created kinetic architecture in his region. Today, he keeps on new research to improve his experimental project he named "The Arkinetic House", which transforms its shape each two days in a special time cycle mechanism and fed by renewable energy sources.



Themes of Kinetic architecture

By the early 21st century three interrelated themes had emerged:

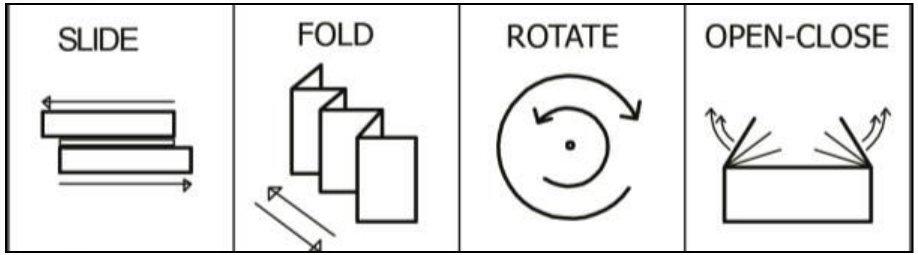
- **The first is for functional buildings** such as bridges which can elevate their midsections to allow tall ships to pass, or stadiums with retractable roofs such as the Veltins-Arena, Millennium Stadium in Cardiff, or Wembley Stadium.
- **A second theme is for fantastic structures** that can perform Transformer style changes of shape or which have a visually stunning appearance. The bird-like *Burke Brise soleil* at the Milwaukee Art Museum is a well regarded example of this, though it also has a functional aspect in that its movement allows it to shade the crowds from the sun or protect them from storms.
- **The third theme is for movement** to occur on the surface of the building, creating what Buckminster Fuller called a "skin-like articulation" effect. A classic example of this is the Institut du Monde Arabe.

Movement in Kinetic Architecture

- In design with movement, it is desirable to achieve transformable, motion-capable and user-friendly designs.
- Kinetic design have changed the idea of creating structures, by designing interactive and kinetic structures that can change and can dynamically adapt to environment and demands with the realization that ever changing needs cannot be met with static spaces.
- Zuk and Clark state that " nothing is permanent", the design is a continuous process that will persist after the building is erected; "the architectural form could be inherently being displaceable, deformable, expandable or capable of kinetic movement"
- Kinetic architecture, which was recently been included in architectural fashion, is a study area that accepts the concept of motion as a design input.
- Behavior, such as the orientation of plants towards the sun, animals instinctively protecting themselves, and animal and human skeletal systems have been inspirational in the design of movement mechanisms

Kinetic structures

Kinetic structures can be classified depending on the type of movement, the material used, and the type of kinetic building elements.



movement

Meanwhile, the materials to be used can be classified as rigid and deformable.

and kinetic elements can also simply be classified as surface and volume elements

- **Kinetic Architecture Designs for Active Envelopes**

Kinetic Architecture: Designs for Active Envelopes is an essential resource for architects, engineers, students, and researchers seeking an in-depth study of how architectural façades dynamically respond to interior and exterior conditions in a manner that saves energy, without sacrificing human comfort. In His book, Charles Linn and Russell Fortmeyer, ocuses on façades with dynamic components, such as active shading devices and hydronic systems, which form an emerging and significant new development in architecture.

- **The most significant kinetic structures :**

	PROJECTS	IMAGES	KEY WORDS
1	**Villa Girasole (1930)** Location: Verona- Italy Architect / Office:Angelo Invernizzi Building Type: House		Volume Element, Floor Movement, Rotational Movement, Harmonization with Physical Environment, Hard Flexibility,
2	**Civic Arena (1961-2010)** Location: Pensilvanya Architects: Mitchell&Ritchey Architects Building Type: Sport Building		Surface Element, Roof Movement, Opening-Closing Movement, Harmonization with Physical Environment, Hard Flexibility
3	**Ernsting Warehouse (1985)** Location: Germany Architect / Office: Santiago Calatrava Building Type: Warehouse		Surface Element, Facade Movement, Opening-Closing Movement, Functional Change,Soft Flexibility
4	**Arab Institute Building (1987)** Location: Paris Architect / Office:Jean Nouvel Building Type: Institute Building		Surface Element, Facade Movement, Opening-Closing Movement, Harmonization with Physical Environment, Imaginative Change, Soft Flexibility

5	**Skydome (1989)** Location : Canada, Ontario Architect / Office:Rod Robbie Building Type: Baseball Stadyum		Surface Element, Roof Movement, Opening-Closing Movement, Harmonization with Physical Environment, Hard Flexibility
6	**Kuwait Pavilion(1992)** Location: Spain Architect / Office: Santiago Calatrava Building Type: Exhibition		Opening-Closing Movement, Surface Element, Roof Movement, Hard Flexibility, Harmonization with Physical Environment, Imaginative Change
7	**Jufo Youth Center(1992)** Location: Germany Architect / Office: Peter Hübner Building Type: Sports Building		Rotational Movement, Volume Element, Roof Movement , Hard Flexibility, Harmonization with Physical Environment
8	**Gucklhupf (1993)** Location: Austria Architect / Office: Hans Peter Wörndl Building Type: House		Opening-Closing Movement, Surface Element, Facade Movement, Soft Flexibility, Functional Change, Location Change

9	**Houselife (1998)** Location: France Architect / Office: Santiago Calatrava Building Type: House		Sliding Movement, Surface Element, Soft Flexibility, Functional Change
10	**Pfalzkeller Emergency Service Center (1998)** Location: Switzerland Architect /Office: Santiago Calatrava Building Type: Health Care		Folding Movement, Surface Element, Roof Movement, Hard Flexibility, Imaginative Change, Harmonization with Physical Environment
11	**Quadracci Pavilion (2001)** Location: United States Architect / Office: Santiago Calatrava Building Type: Museum		Opening-Closing Movement, Surface Element, Facade Movement, Hard Flexibility, Imaginative Change, Harmonization with Physical Environment
12	**Water Villa (2002)** Location: Netherlands Year: 2002 Architect / Office: Herman Hertzberger Building Type: House		Rotational Movement, Volume Element, Sliding Movement, Soft Flexibility, Harmonization with Physical Environment, Location Change

13	**Falkirk Wheel (2002)** Location: United Kingdom Architect / Office: Tony Kettle Building Type: Boat Lift		Rotational Movement, Volume Element, Sliding Movement, Hard Flexibility, Functional Change
14	**Métro St. Lazare (2003)** Location: France Architect / Office: SarteCharpentier Building Type: Station Entrance Door		Sliding Movement, Surface Element, Facade Movement, Soft Flexibility, Functional Change
15	**Leaf Chapel (2004)** Location: Japan Architect /Office: Klein Dytham Building Type: Church		Opening-Closing Movement, Surface Element, Facade Movement, Soft Flexibility, Functional Change
16	**Rolling Bridge (2005)** Location: United Kingdom Architect / Office: Thomas Heatherwick Building Type: Bridge		Folding Movement, Volume Element, Floor Movement, Hard Flexibility, Functional Change, Imaginative Change

17	**Phoenix University Stadium(2006)** Location: USA Architect / Office: Peter Eisenman Building Type: Sport Building		Sliding Movement, Surface Element, Floor Movement, Hard Flexibility, Functional Change
18	**Magnolia Stadium (2007)** Location: China Architect / Ofis: Mitsuru Senda Building Type: Sports Building		Sliding Movement, Surface Element, Roof Movement, Hard Flexibility, Harmonization with Physical Environment
19	**Kiefer Technic Showroom(2007)** Location: Austria Architect /Office: ErnstGıselbrecht Building Type: Office		Folding Movement, Surface Element, Facade Movement, Soft Flexibility, Harmonization with Physical Environment
20	**Cafe-restaurant OPEN (2008)** Location: Netherlands Architect / Office: DeArchitektenCie Building Type: Restaurant		Folding Movement, Surface Element, Facade Movement, Soft Flexibility, Harmonization with Physical Environment

21	**Sliding House (2009)** Location: America Architect /Office: DRMM Building Type: House		Sliding Movement, Volume Element, Soft Flexibility, Functional Change, Harmonization with Physical Environment
22	**Matharoo Associates House (2012)** Location: India; Architect / Office: Matharoo Associates Building Type: House		Sliding Movement, Surface Element, Facade Movement, Soft Flexibility, Harmonization with Physical Environment
23	**Al Bahar Towers (2012)** Location: United Arab Emirates Architect / Office: AHR Building Type: Office		Folding Movement, Surface Element, Facade Movement, Soft Flexibility, Harmonization with Physical Environment, Imaginative Change
24	**Sharifi-Ha House (2013)** Location: Iran Architect / Office: Alireza Taghaboni Building Type: House		Rotational Movement, Volume Element, Sliding Movement, Soft Flexibility, Harmonization with Physical Environment
25	**Sdu Campus Kolding (2014)** Location: Denmark; Architect /Office: Henning Larsen Architects Building Type: Educational Buildings		Opening-Closing Movement, Surface Element, Soft Flexibility, Harmonization with Physical Environment

Classifications of kinetic architecture

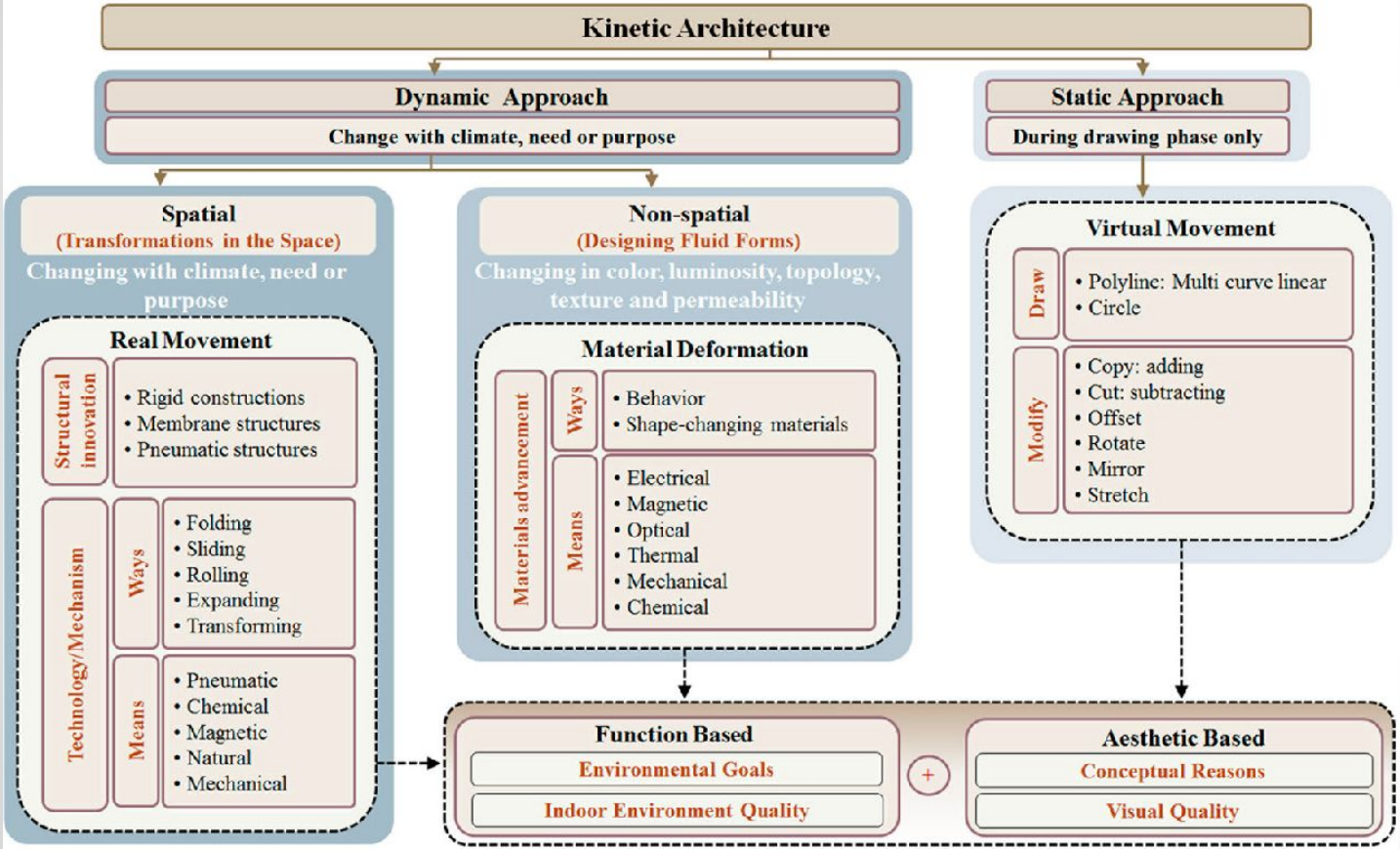
The classifications methods are based on the perspective and field of study of each author. As shown in the below table.

Year	Authors	Approach	Classification groups
1968	Popper	Understanding kinetic methods and movement in art	• Virtual or real movement • Spatial or non-spatial • Predictable via mechanical methods or unpredictable via natural forces
1970	Zuk and Clark	Investigating kinetic architecture through architectural applications and structural aspects	• Dynamically self-erecting structures • Mechanisms or kinetic components • Reversible or non-reversible assembly • Incremental architecture • Deformable or transformable structures • Mobile or disposable architecture
1972	Otto and Burkhardt	Using lightweight structures, convertible roofs in particular	• Tensile structures • Membrane structures
1992	Brookes and Grech	Investigating the types of structures in portable architecture from a prefabrication perspective	• Flat-packed • Pantograph • Membrane systems • Pneumatics • Tensegrity structures • Pods or capsules

2000	Fox and Yeh	Exploring kinetic systems on the basis of three key elements: structural engineering, sensor technology, and adaptable architecture	• Dynamic (mobile, transformable, and incremental kinetic systems) • Deployable • Embedded
2005	Sanchez-del-Valle	Understanding adaptive kinetic structures with digital tools	• Simulation-based design • Performance-based design • Digital prototyping
2010	Asefi	Investigating the types of transformable roof structures that respond to the user's requirements	• Self-supported and non-self-supported structures • Permanent or temporary architecture • Tensegrity and tensile principles
2010	El Razaz	Exploring the sustainable vision of kinetic architectural structures	• Dynamic • Static
2011	Friedman and Farkas	Investigating different types of movable roof structures either for enabling quick and/or safe construction, or in order to adapt the structure to external stimulations	• Retractable roofs with rigidly moving parts • Retractable/deployable pantograph structures • Deployable tensegrity structures • Retractable/deployable membrane structures • Pneumatic structures

2011	Moloney	Exploring architecture that changes with time	• Geometric translation in space • Material deformation
2012	Lee	Classifying kinetic structures or components that have actual variable mobility, location, and/or geometry	• Adaptable • Kinetic • Responsive • Transformable
Year	Authors	Approach	Classification groups
2013	Oungrinis	Classifying kinetic techniques and mechanisms appropriate for transformable-adaptive structures	• Building components where transformability can be applied • Transformations of peripheral parts
2014	Kronenburg	Exploring the philosophical and technological issues raised by kinetic experimental and futuristic prototypes	• Portable and transportable buildings • Demountable and temporary architecture

- **The key elements of kinetic classification**



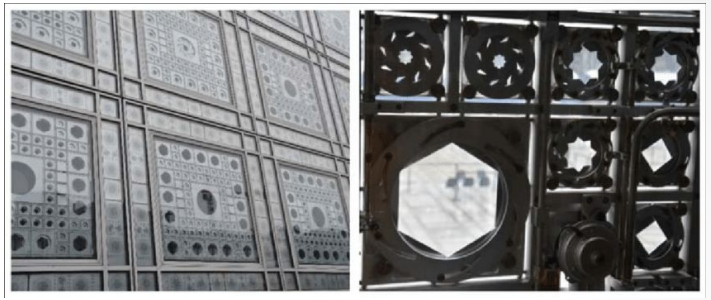
- **The Most Significant Examples of kinetic architecture**

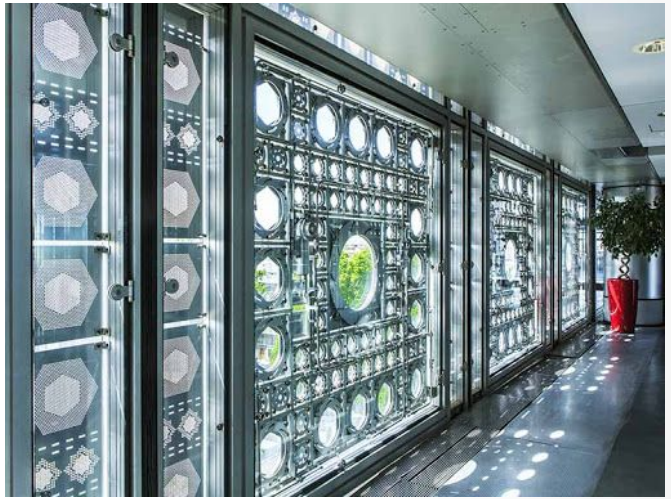
1- Arab Institute Building (1987)

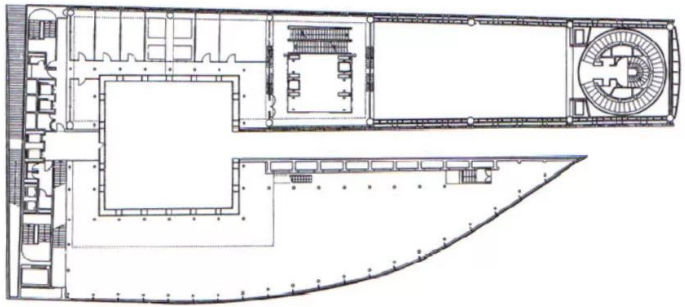
Location: Paris
Architect / Office:Jean Nouvel
Building Type: Institute Building

Elements of kinetic

Surface Element, Facade Movement, Opening-Closing Movement, Harmonization with Physical Environment,
Imaginative Change, Soft Flexibility







Sexto piso

2- Al Bahar Towers (2012)

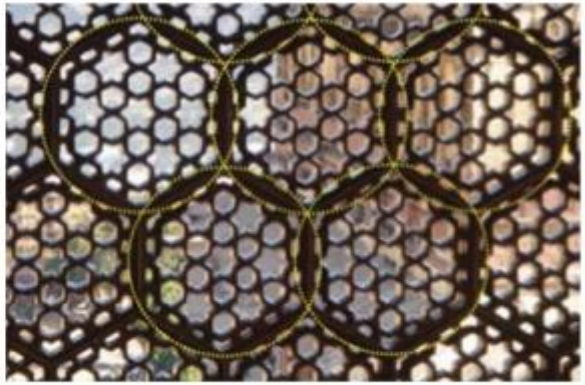
Location: United Arab Emirates
Architect / Office: AHR
Building Type: Office

Elements of kinetic

Folding Movement, Surface Element, Facade Movement, Soft Flexibility, Harmonization with Physical

THE INSPIRITION FOR THE FACADE

- THE TOWERS FEATURE A DYNAMIC, TRANSLUCENT FACADE THAT OPENS AND CLOSES IN RESPONSE TO THE SUN'S MOVEMENT, REDUCING SOLAR GAIN ON THE FACADE BY UP TO 50%.
- THE FACADE IS INSPIRED BY "MASHRABIYA", A FORM OF WOODEN LATTICE SCREEN USED IN ISLAMIC ARCHITECTURE AS A MEANS OF RETAINING PRIVACY WHILE SIMULTANEOUSLY REDUCING GLARE AND SOLAR GAIN.
- TRANSLUCENT, UMBRELLA-LIKE COMPONENTS MAKE UP THE FACADE; THERE ARE 2,000 OF THESE "MASHRABIYA" COMPONENTS ON EACH TOWER.



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