Kinetic design principles for structural systems for architectural spaces

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Introduction:

Certainly, the interconnected social trends, in addition to the increasing human pressures and needs, require a trend towards creative design to achieve flexibility and spatial dynamism in the urban space. Exploiting the expansion of this space has also become of economic importance, as its efficiency isn't only about utilization of an area from the total actual area, but also reduces the amount of energy consumed and the costs associated with building construction and maintenance.

One of the main characteristics of the flexible interior spaces is their dynamic state of transformation and fulfillment of functional needs and aesthetic demands, and to be responsive to environmental factors underlying the perimeter of interior spaces.

To achieve this dynamic state, it requires familiarity with the design principles of its structural elements and being subjected to kinematics and mechanical laws. Knowing the characteristics of this movement and its outcome and predicting its results, accurate knowledge and deep study of the rules of movements to achieve the desired goal of their application.

1- Definition of concepts

1-1 Kinematics.

Kinematics is a branch of mechanics that describes the physical concept of motion of bodies without any regard for masses or forces that cause motion. Kinesiology studies how the position of an object changes with time as the position is measured in relation to a set of coordinates.

1-2 Dynamism

Dynamic or kinetic refers to the word "Dynamo" and refers to the meaning of force, while "Dynamical" refers to the thing distinguished by its continuous effectiveness. Dynamics is a science that studies the effect of force on both moving and stationary bodies. In the literary field, the meaning of dynamism refers to vocabulary; Harmony, reproduction, growth, dialogue, movement, transformation, transition, strength, and change.

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2- Kinetic (dynamic) Space.

Ungers, who is one of the pioneers of contemporary dynamic intellect, considers transformation and dynamism as a phenomenon that represents a process of cutting or isolating the influence of the determinant of the idea and not only showing the feature of contradiction, but allowing for mutual exchange in the relations that express the origin of the idea and reliance on reduction to show transformation.

As for the American architect "Eisenman", he believes that the architectural formal structure from his point of view is the basis of the dynamism strategies and the disintegrating transformations that take place within the design work, as the kinetic text of the internal spaces is not only an integrated and closed thing on itself, but it is a dynamic network characterized by transformation and interdependence. Thus, we can build on that and conclude that the dynamic space is the vacuum that stimulates movement and transformation through the properties of interconnection, transition, growth, openness and reduction.

- **Evolution of dynamic space.**

According to the book “Space, Time and Architecture” by Sigfried Giedion, the dynamic void has passed through three stages, the first and the void may be through the confluence of different blocks, while the second is the passage of the void through stages of development in formation and treatments (constructive and environmental), which led to a continuous and developed internal flexibility, as for the last stage, it was by adding the temporal dimension to the three dimensions of the void, in which the void was realized through movement, and thus the plurality of its vision.

3- Characteristics and morphological transformations of kinetic systems.

Antoniades defines morphology as the process of changing a shape to reach a final stage in response to multiple combinations of external and internal dynamics. He also pointed out that transformations are the process of processing the shape without returning to the functional requirements, which gives the shape an impetus for the development of new design techniques. Eisenman defined it as a set of processes that take place on the deep levels of architecture to transform it into the superficial levels, whose reading and interpretation represents the key to a successive and continuous series of readings that gradually progress in depth to reveal the transformation processes that generated it.

Gandelsonas defined it as those rules or movements that follow in the deep structure to lead to a superficial structure and a certain form, it relates to the relationship between what is declared and implicit. It allows to see the forms in a new way. The characteristics and formal transformations of kinetic systems are important indicators for determining the nature of the relationship between the inside and the outside, and include measuring the following:

- The nature of the part in terms of whether it is empty or solid.
- The degree of closure, which expresses the ratio of the number of formal elements defined for the nature of the space.

4- Classification of dynamic systems.

The classification varies according to the method, aim and location of the research work. There are several visions for classifying these systems, including the classification of the designer "Hoberman" who classified them into three types, which are either by the movement of the structural structure, or by the internal elements, or by the sheathing of the movable structure.

There is also a classification based on the geometry of the structure and its movement by the designer "F. Escrig" in the book (l′ Architectura Transformable) and divided it into seven sections as follows: (Applicable tension structures, integrated tension roofs, retractable roofs, flat structures, mobile structures, raised structures, structures that function as parachutes).

The researcher's classification, "Elizabeth Erin Lee" on the basis of the kinetic system and the structural form, came into four categories, and it generally includes the tangible physical aspect in addition to the visual and tangible aspect. The four types are: Stow, Pivot, Chameleon, and Pulsate, entirety, they represent exemplary solutions to keep pace with technological progress and meet the requirements of contemporary and changing lifestyles.

There is a classification of the researcher in the flat and easy to navigate structures "Ariel Hanaor" and this classification was based on the structural structure of the mobile structure and was divided into systems with grid structures, and with continuous structures.

As for the classification of the "Kinetic Design Group" team at the "MIT Institute" in the United States of America, it is one of the most important classifications, and it was according to the movement mechanism. It is divided into seven sections:

- Movement resulting from two components, one with a fixed joint and the other moving on a linear path.
- Mixture of hinges and connections.
- Movement by wheels on a linear path.
- Movement of the hinged chassis by cables surrounding the chassis.
- Movement resulting from two joints between them, the first is completely stationary and the second moves outside it.
- A movement resulting from two joints between them, the first is completely stationary and the second moves within it.
- Movement between two components with a spherical joint that facilitates movement and rotation.

5- Kinetic structural systems.

The construction concepts were developed, other concepts were developed that led to the emergence of light constructions, subtraction, addition and replacement theories appeared in the already existing buildings, and the so-called capsule units appeared. The architect was no longer satisfied with using pressure forces to maintain the balance of the building, but also used tensile forces. Researches dealing with taut and blown structural membranes appeared, and structural theories appeared based on folding, sliding, stretching and change in shape and size, and the architect’s structural ambition reached its peak when he imagined the structure as a system that moves in a complex movement inspired by the movement of the human body, and the building becomes a skeleton that connects to muscles and tendons, and controls the movement of what resembles the human brain and is responsible for issuing the necessary

directions for the movement of the building's parts, which enables it to respond to the environmental changes occurring in the surrounding environment, which would reduce the dimensions of the structural sections of the building. This new trend is known as intelligent construction, sensitive construction, or responsive construction.

5-1 Foundations and structural relationships of kinetic design.

The nature of kinetic design which its visual appearance is related to the manner in which these forms are organized and the modalities of building the relationships formed for the surfaces, through the sum of the successive performance processes included in the kinetic design process. The structural foundations for building the design are the determinant of the relationships that are linked between the elements of the work or the design vocabulary and the extent of its impact on the surrounding elements and the unity and interdependence of the design. These plastic elements include endless patterns of interconnection systems between each other, and through a set of organizational methods that the designer uses to rule the formal relationships on the design plane, and the formal relationships represent the following: -

Shape and change of place	Shape and mode change	Shape and contrast
Juxtaposition relationship	Shape and additions	Shape and deletions
Overlap between shapes	Superposition relationship	Adjacency relationship
Repeating items	Resize	Interlacement between shapes

5-2 Transformation Methods.

It is mentioned that the process of generating forms from their first structural unit is always preceded by a pivotal process that is the first link between this structural unit and the point and between all the resulting plastic patterns, which is what was represented in the growth process with its three patterns "linear, central and free" and that the two growth patterns "linear and central" produce what are called the basic formation units of a straight line, a circle, and a sphere. Hence, the generation of forms is based on one of these basic units, given that there is always a process prior to it represented by the growth process. Formal and spatial solutions vary through formal transformations, which can be represented through the following operations-:

Stretching - Contraction	**Refraction**	**Bending**
Distortion	**Mutation**	**Rotation**
Addition	**Deletion**	**Condensation**
Repetition	**Moving in**	**Slash**

6- Considerations for the application of kinetic systems.

In order to apply kinetic design systems and the technology required in order to achieve functional flexibility of architectural spaces, it is necessary to restrict and codify this application with a set of considerations to achieve the goal of using it correctly and comfortably from all functional, aesthetic, formal and psychological aspects. These considerations are as follows.

6-1 Architectural considerations.

It is represented in meeting the different needs of the human being, by achieving functional, aesthetical, formal, psychological and social comfort.

- **Functional considerations.**

Its details can be viewed in the following points:

1- Study the ability of the transformed facility to achieve its purpose.
2- Study the relationship between the stator and the rotor.
3- Study the elements of vertical and horizontal communication.
4- Study the locations of services and facilities and take into account that their paths do not overlap.
5- Studying the percentage of space used by operating systems and their positions.
6- The extent to which the architectural design is compatible with laws, legislation and regulations.

- **Environmental considerations.**

It is achieved by achieving thermal, optical and acoustic comfort for the human being, without harming the environment and conserving energy.

- **Geometry considerations.**

Determining the geometric shape comes in what suits the purpose of the facility and determines its movements, whether functional or environmental.

- **Aesthetic considerations.**

This is achieved by:-

1- The study of the aesthetics resulting from the form of movement, by studying the aesthetic dimension in the case of stability or movement.
2- Studying the relationship of the movement shape with the stator elements of the origin, and the conformity of the resulting formation with the stator.
3- Studying the compatibility of the origin with the local environment and the special character of the region and the surrounding environment.

6-2 Technical considerations.

- **Maintenance, operation and safety considerations**

They are considerations that require steps to be followed to reduce the amount of risks and the continuity of the working efficiency of the moving components, reduce the cost of periodic and sudden maintenance, and achieve safety for users.

- **Environmental load considerations.**

Assessment and determination of environmental loads, whether external or internal, and studying dealing with them helps prevent or reduce the damage that may be caused to the structure and the movement of its components.

- **Material selection considerations.**

It is represented by the following:-

1- Environmental considerations.
2- Mechanical and structural considerations.
3- Aesthetic considerations for materials.

- **Economic considerations (cost and value).**

The elements for determining the cost of these facilities are concentrated in the following points:-

1- The cost of the initial design of the facility.
2- Manufacturing cost.
3- Operation and control cost.
4- The cost of regular and sudden maintenance.

6-3 Considerations for the stages of preparing the design process

The disciplines required for the application of transformed enterprises can be summarized into three scientific branches as follows: -

1- Architectural majors.
2- Engineering disciplines such as civil, construction, mechanical and materials engineering.
3- Mathematical and physical disciplines such as mechanics, descriptive and analytical engineering, and others.

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