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Conceptual Research of Movement in Kinetic Architecture

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Abstract

In this study, the place of movement concept in architectural design is investigated; the possibilities provided to the user by evaluating the varying potentials in architectural design have been discussed as a hypothesis. In this direction, movement concept in kinetic structures applied from the 20th century to today are examined. The paper depends on a qualitative methodology, which is a non-numerical method that depends on constructed cases in order to support research hypothesis. Relations, differences and conceptual partnerships between cases have been revealed by investigating the application points of movement and user participation in the design of these structures that is fast-spreading particularly. From the studied examples, it is determined that the surface movement is preferred, when the movement point is taken into consideration the facades are primarily used, and the most common movement type is the sliding movement. Afterwards, it has been revealed that the different physical properties of the movement and the possibilities that are provided change independently of each other. Even in many cases the movement is preferred due to multiple purposes. The most common purpose is adapting to environmental conditions. As a result, this study, which aims to strengthen the perception of architects, will set an example for the development of kinetic architecture.

1. INTRODUCTION

With 21st century, our age develops faster and faster and with this, lifestyles, daily activities and needs change constantly. This flow no doubt affects the spaces that are used. This creates a need for redesign as there are functional differences and aesthetic worries. However, rigid and immovable structures do not have the ability to respond to these ever-changing situations. From primitive times, the architectural discipline has been questioning the design process of the structures and looking for new solutions in order to adapt to changes with the help of movement [1].

In design with movement, it is desirable to achieve transformable, motion-capable and user-friendly designs. The words used to describe buildings with movable parts or components associated with a shape change include adaptable, collapsible, deployable, enabling, evolutionary, flexible, intelligent, kinetic, mobile, performance based, reconfigurable, responsive, revolving, smart, transformable, and transportable. Architecturally, it is viable to say that the typologies may overlap and that an example can fall into more than one category [2,3]. In this study, without any distinction between these nomenclatures, the designs consisting of motion are discussed in general, and all are referred to as the most general definition "kinetic". Kinetic architecture is defined generally as buildings and/or building components with variable mobility, location and/or geometry [4].

Kinetic design has been used throughout history. Actually, interest for the production of these structures goes back to first human civilizations. Yurts with opening and closing elements and movable components are one of such designs (Figure 1a) [5]. Leonardo da Vinci is one of the first designers who studied the design methods of kinetic structures such as movable bridges (Figure 1b) [6]. He applied the movement mechanism existing in the birds' wings to flight instruments and also to the first movable roof.

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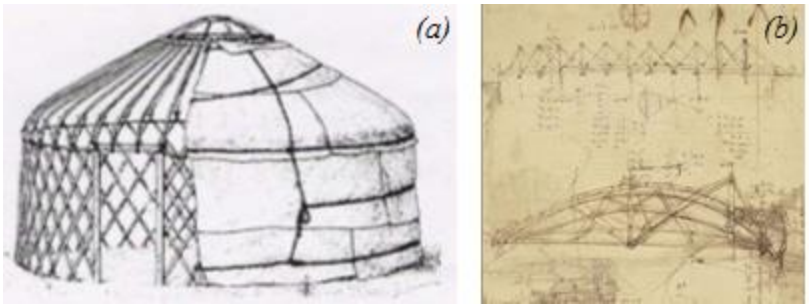


Figure 1. *a) Illustration of Asian yurts [7],b) Leonardo da Vinci's movable bridge design*

In recent years, due to urgent need for multi-functional buildings and also the necessity to maintain and respect the environment, the demands for kinetic structures has increased rapidly [8]. Contrary to the widespread notion that architecture focuses only on the planning of rigid and immovable structures, the increasing use of kinetic structures in our built environment proves that the border between "building" and "movement" has already been crossed [9]. 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 [10]. These structures, which create a new identity, are regarded as a living body adapted to different environments and change people's perception. Possibilities provided by kinetic structures and what it makes one feel in terms of space made it possible to prevent rigid and immovable structures. Equipping the structural elements with the movement mechanisms enables the change of form according to user requirements and environmental influences. Space diversity that arises due to this concept has allowed the structures to be used in different functions at different times, increasing their popularity.

In this study, the concept of movement applied from the simplest to the most complicated has been examined. The main purpose is to determine the similarities, relations and conceptual partnerships of the examples of kinetic structures designed and implemented since 20th century. Flexibility possibilities have been discussed by examining the type, location, situation, purpose, possibilities and associations of movements of the structures partially or as a whole. The objective of this research is to understand kinetic structures, concepts, and approaches that are relevant to architecture. This understanding enables architects to think about the major aspects of kinetics and explore its potential in architectural application.

2. MOVEMENT IN ARCHITECTURAL DESIGN CONCEPT

Movement is simply a means of changing position. It has existed from the start of history and been part of the cycle of life. Living things, in order to fulfill their daily needs, become part of this movement. It is quite new to input movement into architectural design, even though searching for movement in spaces has existed since ancient times. With the industrial revolution and developing technology, lifestyles, everyday life and even cultures have changed and the need for renewal in architecture has been felt. The fast living person expects his work and the place he lives to adapt to his own movements.

While Futurism and Constructivism trends cannot find a common application area in architecture, they are important to bring a different perspective on movement in terms of conceptual and architectural implications [11]. In 1970, in one of the first books that classified and described movement in architecture, 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" [12].

During the 19th and 20th centuries, fairs and exhibitions were held for different functions, and it was desired that these structures should be portable, easily dismantled and re-constructed. With the development of the materials and systems used in these movable designs, visual impact and aesthetics became important, and flexibility in construction increased. Kinetic architecture, which was recently been included in architectural fashion, is a study area that accepts the concept of motion as a design input. Architects working in this area need to know some movement laws, analyses and different disciplines.

While designing the movement mechanism in the buildings, the importance of natural life cannot be denied in the creativity of the designs and the foundations of the obtained inventions. 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 [13].

Kinetic structures can be classified depending on the type of movement, the material used, and the type of kinetic building elements. These classifications are summarized below. Primarily the movement type is generally classified as sliding, rotating, opening-closing and folding (Figure 2). Depending on the design of the mechanism, different types of motion can be constructed in the same structure. For example, an end folding type of movement is formed by connecting the two structural members in such a way that the two structural members are pivotally moved from one end to the other, and the resulting ends of the elements are narrowed in the form of scissors [11].

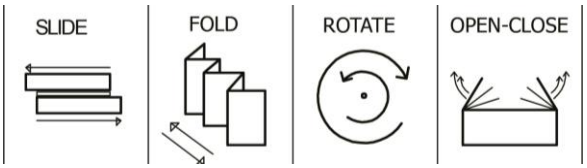


Figure 2: *Basic Movement Types [11]*

Meanwhile, the materials and elements from which the movement is obtained are related to each other. The kinetic elements which the movement is applied on are decided according to the material. To make a general classification, the material to be used can be classified as rigid and deformable; and kinetic elements can also simply be classified as surface and volume elements [14]. Surface elements are load-bearing elements formed from horizontal and vertical panels. These elements are designed in accordance with different functions on the facade, roof and upholstery. On the other hand the volume elements are load-bearing systems which are monolithic. In this way, a part of the structure is completely moved.

3. PURPOSE OF USE OF MOVEMENT IN STRUCTURES

The rapid developments in social, economic and technological fields change the lifestyle, behaviors, habits and needs of today's people at the same rate. Accordingly, our expectations from the spaces that we act in constantly change. Designed initially for a specific action and need, the same building does not provide expected functional performance after a period of changing user requirements [10]. With the flexibility provided in architectural design, they must be convertible and changeable after the design has been completed.

Kinetic architecture is a large field of studies applied with different system typologies and constructions forms. However, in this variety it is important to establish a link between movement, construction system and its purposes. Kinetic structures in architecture has generally emerged with concerns about creating spatial diversity, location and direction change, providing energy efficiency in construction and security and aesthetic concerns. In this context, it is possible to design the form of movement through the collaborations of different disciplines with its relationship with the user and its function in the space. The intended use of the movement in architecture can be varied and increased according to the usual circumstances and demands. The main motivation for moving toward kinetic architecture lies in the increasing demands for comfort, flexibility, the ability to change appearance, as well as the need to use natural resources more prudently. In some cases, there are multiple reasons for using movements [2]. However, within the scope of the study a general and comprehensive classification was established and the details were examined.

3.1. Flexibility Status

One of the most influential architectural trends in the 20th century was flexibility. When the notion of elasticity of an object's behavior in relation to physical forces is examined in the discipline of architecture, it has been described as a natural and non-controversial method on the road to good

architecture [15]. Early flexibility strategies are based on equipping spaces with mechanisms that allow a space to transform into a limited number of spatial variations to serve a set number of tasks. Forty expresses that these mechanisms are usually sliding walls or folding slabs [16]. At this point, the pursuit of flexibility with kinetic designs has begun to become feasible and the flexibility in the structures has been ensured by movement in general.

Schneider and Till introduced the concepts of flexibility strategies as hard and soft use. Hard use is the approach that states that different use alternatives have been defined by the architect and soft use means the architect remains at the background and the design that makes it possible to change the space for the user according to needs [17]. With the soft flexibility approach, users can make freer changes on the spaces and the lifetime of the structures can be longer. Hard flexibility has more to do with the architect than with the user. The concept of flexibility in general improves building performance.

3.2. Harmonization with Physical Environment

People are constantly interacting with the geography they live in. There are times when people benefit from the nature or avoid it: climate change, daily weather conditions, sun, wind, and the user's preference to be inside or outside the structure. While designing rigid and immovable structures, physical environment usually become the most important design problem. Adaptation to the environment is an important input for usability and lifetime. For kinetic structures, physical environment has been the cause of movement. Energy saving can now be provided thanks to constructions that can be adapted to daylight, wind and climate conditions. Thus, a building with movement mechanisms can make a significant contribution to the reduction of energy dissipation in buildings, and assist in maintaining and improving internal comfort levels [18].

3.3. Functional Change

One of the reasons for the use of movement is that it can convert spaces according to the different requirements of the users. In this context, expandable, shrinkable foldable and opening and closing surfaces are designed to increase space diversity. Due to movement, space forms can be changed for different functionalities. Also, depending on the number of users, the capacities of the rooms can be increased and restored when they are not in use. The volumetric elements provided in the structures change the location of the structure in according to the usage requirements.

3.4. Imaginative Change

One of the most important effects that the movement brings to the structure while gaining a new dimension through architectural movement is to change the aesthetic perception and create an imaginary appearance on the users. Changing the appearance of kinetic structures brings different emotions in people. This formation, in constructions, increases the popularity of the buildings at the same time. Imaginative change brought by structural forms or created by movement may construct new meanings in mind and increase visual memory.

3.5. Location Change

Real movements that adopt to changes in nature and its shapes have unlimited amount of variations. This adaptation guarantees survival and is necessary for all species. In the simplest terms, principles have been developed to make buildings stand straight to ensure that the buildings survive against the effects of the wind; this is inspired by the human body, which is capable of tightening the muscles and changing their posture. For example, in skyscrapers, the principle of moving the building is widely used to prevent excessive deformation against earthquakes and wind loads [10]. There are systems that allow displacement to occur in the structure as well as those that prevent movement with a controllable movement mechanism. The need to change the location in the building is mostly due to the desire to adapt to the environmental conditions, and sometimes to change the view or to create spatial diversity.

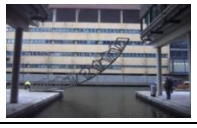
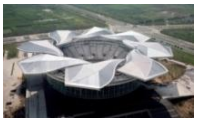
4. METHOD OF STUDY

In this study, the possibilities provided by the user by evaluating the changing potentials of architectural design are discussed as a hypothesis. In order to confirm the hypothesis, examples of important kinetic structures that were firstly constructed from the 20th century to the present-day are chosen. Thus, a chronological catalog was produced (Table 1). The projects in the catalog are produced with different construction techniques that appeal to different types of users and cultures in different regions of the world. Examples consist of totally or partly mobile buildings with different functions such as houses, offices, cafés, sports, health, and educational buildings. Through the examples, the behaviors of the structures are examined and an evaluation is made on their similarities and partnerships.

Table 1. *Chronological catalog of significant kinetic structures*

	PROJECTS	IMAGES	KEY WORDS
1	**Vılla 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

Table 1. *(Continued) Chronological catalog of significant kinetic structures*

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

Considering movement as a design problem provided productive new design ideas in architecture. Questions such as 'What are they?', 'How are they?', 'What are the causes?' and 'What are they providing?' for the design of kinetic structures have helped to create the qualitative methodology of the paper, which is a non-numerical method that depends on constructed projects in order to support research hypothesis. The examples were coded with key words under the headings to be investigated, and the answers to the questions asked were obtained from them. As a result, the relation between different factors related to the concept of movement has been removed and the main idea of the study has been revealed.

5. EXAMINING OF THE CONCEPT OF MOVEMENT WITH ACTUAL EXAMPLES

The key words in this research are examined in two main categories: "physical features *(the type of movement, the location of movement, the state of movement)*" and "possibilities of movement *(flexibility status, harmonization with physical environment, functional change, imaginative change, and location change*)". Key words are presented in a comparative table (Table 2) in order to be able to observe the relationships of the emerging data with one another. When the data is examined, it becomes obvious that the concept of movement in architecture is a very deep-rooted phenomenon and the design may serve in very different functions.

Firstly the physical properties of the concept of movement that in projects are examined: These include the type of kinetic building element, the point where the movement occurs on the structure and the type of movement that is applied on the structure. The kinetic building elements can be classified as surface and volume elements, the point of movement as roof, facade and floor. After determining these, the observed movement types are classified as sliding, folding, rotating, and opening-closing movements.

When the type of kinetic building elements is examined, it is seen that %72 is surface and %28 is volume. The reason why surface elements have a higher percentage compared to volume elements is the fact that it's simpler; the approach to kinetic structures is still at an experimental stage. Designing kinetic volume elements requires a wider scope of study and the applicability of the resultant product is tried in digital environment.

In the future, use of kinetic structures will probably increase. There are studies for kinetic structures that provides different usage possibilities, sometimes with partial movement, and sometimes movement of certain parts of a traditional structure, but so far no holistic design method and application methodology for architectural design, mechanism design, surface coating, structural design of motion mechanism and motion analysis have been developed [19]. However, the current technology and the work done are evidence of progress in this direction.

When the movement points are taken into consideration in the examples, usage rates in roof, facade and floor vary by 24%, 44%, and 32%. Kinetic elements have been used on the facades more than the structure itself due to the fact that the internal and external balance of the building needs to be provided and the building should be able to communicate with its surroundings. Furthermore, kinetic facades give a visual identity to the building and respond to user requirements in terms of aesthetics. The movement provided in the floor ensures that space is functionally reorganized. Looking at the examples of roof movement, it is interesting to see that the interior and exterior communication can be achieved and the building can gain visual identity in the general sense with movement.

When the types of movement are compared according to frequency of use, the rates for the four most basic movements discussed are close to each other: 24% sliding, 20% folding, 24% rotating, and 32% opening-closing. Depending on the building function and user needs, the species of the movement change. In the analyzed cases, the application of different types of movements on the roof, facade and floor provided imaginative, functional and spatial diversity. Movement has more applied to facade than roof and floor. The most common type of movement applied on the facade within the surface elements has been opening-closing. The use of different types of movements in different regions for different purposes will undoubtedly provide new improvements in the design of the kinetic structures.

Table 2. *Relationships, intersections and differences between projects*

			PHYSICAL PROPERTIES									
			Type of Kinetic Building Element			Point of Movement			Movement Types		
			Surface	Volume	Roof	Facade	Floor	Slide	Fold	Rotate	Opening-Closing
PURPOSES OF MOVEMENT	Flexibility Obtained	Hard	Civic Arena	Villa Girasole	Civic Arena	QuadracciPav.	Villa Girasole	Magnolia Std.	Rolling Bridge	Civic Arena	Kuwait Pav.
			Skydome	Jufo Y.C	Skydome		Rolling Bridge	Phoenix Std.	Pfalzkeller	Jufo Y.C	Skydome
			Kuwait Pav.	Falkirk Wheel	Kuwait Pav.		Falkirk Wheel			Villa Girosole	QuadracciPav.
			Pfalzkeller	Rolling Bridge	Jufo Y.C.		Phoenix Std.			Falkirk Wheel	
			QuadracciPav.		Pfalzkeller						
			Magnolia Std.		Magnolia Std.						
			Phoenix Stadium	Civic Arena							
		Soft	Ernsting	Sliding House		Ernsting	Houselife	St. Lazare	Cafe Open	Water Villa	Ernsting
			Arab Institute	Sharifi-Ha House		Arab Institute	Sliding House	Houselife	Al Bahar T.	Sharifi-Ha House	Arab Institute
			Gucklhupf	Water Villa		Gucklhupf	Water Villa	Sliding House	KieferT.S.		Gucklhupf
			Houselife			St. Lazare	Sharifi-Ha House	M.A. House			Leaf Chapel
			Cafe Open			Cafe Open					SduCampus
			St. Lazare			Leaf Chapel					
			Leaf Chapel			SduCampus					
			SduCampus			Al Bahar T.					
			Al Bahar T.			M.A. House					
			M.A. House			KieferT.S.					
			KieferT.S.								
	Harmonization with Physical Environment		Civic Arena	Villa Girasole	Civic Arena	Arab Institute	Villa Girasole	Sliding House	Pfalzkeller	Civic Arena	Arab Institute
			Arab Institute	Jufo Y.C.	Skydome	QuadracciPav.	Sliding House	Magnolia Std.	KieferT.S.	Villa Girasole	Skydome
			Skydome	Sliding House	Kuwait Pav.	KieferT.S.	Water Villa	M.A.House	Al Bahar T.	Jufo Y.C	Kuwait Pav.
			Kuwait Pav.	Water Villa	Magnolia Std.	M.A. House	Sharifi-Ha House		Cafe Open	Water Villa	QuadracciPav.
			Magnolia Std.	Sharifi-Ha House	Jufo Y.C.	Al Bahar T.				Sharifi-Ha House	SduCampus
			Pfalzkeller		Pfalzkeller	SduCampus					
			QuadracciPav.			Cafe Open					
			KieferT.S.								
			M.A.House								
			Al Bahar T.								
			SduCampus								
			Cafe Open								
	Location Change		Gucklhupf	Water Villa		Gucklhupf	Water Villa			Water Villa	Gucklhupf
				Sharifi-Ha House			Sharifi-Ha House			Sharifi-Ha House	
	Functional Change		Ernsting	Falkirk Wheel		Ernsting	Falkirk Wheel	St. Lazare	Rolling Bridge	Falkirk Wheel	Ernsting
			Gucklhupf	Rolling Bridge		Gucklhupf	Houselife	Houselife			Gucklhupf
			Houselife	Sliding House		St. Lazare	Rolling Bridge	Sliding House			Leaf Chapel
			St. Lazare			Leaf Chapel	Sliding House	Phoenix Std.			
			Leaf Chapel				Phoenix Std.				
			Phoenix Std.								
	Imaginative Change		Arab Institute	Villa Girasole	Kuwait Pav.	Arab Institute	Rolling Bridge		Pfalzkeller		Arab Institute
			Pfalzkeller	Rolling Bridge		Al Bahar T.			Rolling Bridge		Kuwait Pav.
			Al Bahar T.			QuadracciPav.			Al Bahar T.		QuadracciPav.
			Kuwait Pav.								
			Quadracci Pav.								

INTERSECTIONS BETWEEN KEYWORDS			
	Soft Flexibility- Harmonization with Physical Environment : 9		Harmonization with Physical Environment–Façade Movement : 7
	Hard Flexibility-Imaginative Change : 5		Floor Movement-Slide and Rotate : 7
	Facade Movement-Opening-Closing : 6		Functional Change-Floor Movement : 5

The potentials for the structures, regardless of their state of movement, direction, and variety arise from the actual design problems. If we consider the possibilities provided by the physical features of the concept of movement and the partnership, it is revealed that the soft flexibility is one of repetitive concepts among all the key words based on user participation. In the kinetic architectural structures selected from various regions of the world, important raw material of movement concept, and the soft flexibility are provided by the sliding movement more actively based on user participation. In 56% of the analyzed structures, the movement of spaces has designed in accordance with the daily activities since the desires of the users are a priority in residential buildings. In the examples where the space becomes flexible, it provides spatial variety with the sliding movement in the flooring, based on the desire for enlarging or the diminishing the room, changing its position and turning towards the view. Movements that are restricted by architects, which are described as hard flexibilities, often occur in volume movements. These are usually designed in roof motion with limits in large-scale constructions to ensure conformity with the physical environment of the structure.

The ever-changing needs drive the structures into a rapid transformation process. The need to move away from rigid and immovable structures and change the physical properties of structures in the direction of the determined purpose reveals the aim of movement. The functions of the structures can be varied according to their use patterns. If Table 2 is examined, it appears that there is more than one purpose of use in many buildings.

When we evaluate the purpose of the movement, it is seen that movement mechanisms are frequently used in order to adapt to the physical environment in 68% of the structures. The adaptation to the physical environment is mostly achieved by the movement of the facade. In recent years, day-light and wind have become easily controllable even in high-rise structures thanks to movement mechanisms. Thus, energy is saved, and new solutions for natural ventilation and light are presented.

In order to change location, or to provide functional and imaginative change, kinetic structures provide new opportunities in architectural technology. Functional change is achieved in 36% of the examples while imaginative change in 28%. With functional change by movement, the structures can provide the desired change at any time and respond to the necessary space requirements. Imaginary change, on the other hand, contributes more to the aesthetics of the structure. Movement, designed regardless of structure and function, often gives the building visual identity.

When the purposes of the movement are examined, it is seen that the least common one providing a view. Only 20% of the structures have been moved to provide a better view, and these are mostly residential buildings. In order to provide an alternative orientation, the movement mechanism must be devised for a large part of the structure. Therefore the examples of this case are mostly based on user requirements in small scale structures.

It is possible to draw more than one conclusion about kinetic structures with the intersection of key words in the analyzed examples (Table 2). In 36% of the structures, adaptation to physical environment and soft flexibility were preferred. Providing the user with the ability to decide on the movement in order to adapt to the physical environment is described as soft flexibility. Especially in residences, the design of movement is partially directed by the users based on their desire to use and change the space. Soft flexibility in floor and facade movement is possible, but not in roofs. Roof movement is designed for adapting to physical surroundings and imaginative change without user involvement.

The hard flexibility provided by the movement brought about imaginative change in 16% of the structures, and the structures of this feature could be moved by larger mechanical systems. The functions of the structures also greatly influence the motion systems. Movement in large-scale structures while providing user participation in the facades of the houses is not only a functional but also an imaginative change. Functional change is provided in 20% of the structures depending on user participation, and user wishes guided the design of this movement. Sliding and rotating movements have been effective in the systems applied to the floors.

5. CONCLUSION

There are many kinds of movement in living beings in the world, and there are different kinds of movement in various human-created systems. We are now living in a world in which objects and structures need to move and transform to adapt to various contextual, functional and environmental changes. There is an increasing demand for kinetic architecture that reconfigures itself physically to meet functional or climatic changes. The feasibility of architectural designs with movement has increased considerably in the light of technological developments, and efforts have been accelerated in order to establish kinetic structures with changing design criteria instead of rigid structures. The development of architectural design methods, which are mostly handled under the title of kinetic architecture, have resulted in the formation of functional and aesthetic structures. In this context, a detailed investigation was carried out on the examples inspired by the concept of movement. The type of movement, its location and condition, the point of departure, the intended use of movement and the possibility of flexibility are discussed in terms of analyzed examples.

When examining kinetic structures, it is observed that the understanding of today's architecture is preparing the environment for innovations in this area. The similarities and partnerships of successful kinetic structures applied from 20th century to today were analyzed in this context. It is an important input to create enthusiasm for users, while creating mostly different spaces, providing structural flexibility and adapting to environmental conditions. In contrast to rigid and immovable structures, movement is a popular field of study in the architectural discipline, thanks to the flexibility of use provided by kinetic structures.

A good analysis of the need for daily change and responsive movement increases the number of types of motion as well as the emerging technological design possibilities. The work carried out in this context and the resulting products will make it easier to integrate dynamic living spaces in future designs. The architect has a very important place in the development of transformable architecture and in defining new pursuits; he/she becomes the guide. It should always be understood that movement will not provide maximum benefit to the structure, and its purpose must be well evaluated. This research suggests a conceptual framework that reveals the basic elements of kinetic architecture, classifies the potentials of movement, and presents a new perspective to architects. In addition, to ensure user satisfaction, new approaches and construction systems should be constantly analyzed and new technology developed. A comprehensive consideration of these concepts in the new architectural environment will strengthen the perception of designers. Furthermore, the development of kinetic structures will be a guide for future architecture.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

[1] Korkmaz, K., "Kinetik bir mimarlığa doğru", Ege Mimarlık, (37), 8-11, (2001).

[2] Megahed, N.A. "Understanding kinetic architecture: Typology, classification, and design strategy", Architectural Engineering and Design Management, 1–17, (2016).

[3] Werner, C., "Transformable and transportable architecture: Analysis of buildings components and strategies for project design", Master Thesis, Catalonia Polytechnic University, Barcelona, Spain, (2013).

[4] Fox, M. A., "Kinetic Architectural Systems Design", in Transformable Environments 2, Taylor & Francis Group, London and New York, 163-186, (2003).

[5] Kronenburg, R., Flexible: Architecture That Responds to Change, Laurence King Publishing, London, (2017).

[6] Chilton, J., Space Grid Structures, Scribe Design, Gillingham, Britain, (2000).

[7] Kronenburg, R., Houses in Motion, Great Britain: Wiley-Academy, (2002).

[8] Maziar, A., Transformable and Kinetic Architectural Structures: Design, Evaluation and Application to Intelligent Architecture, Berlin: VDM Verlag Dr. Müller, (2010).

[9] Schleicher, S. "Bio-inspired compliant mechanisms for architectural design: transferring bending & folding principles of plant leaves to flexible kinetic structures", PhD thesis, University of Stuttgart, Stuttgart, Germany, (2015).

[10] İnan, N., "Kinetik Yapı Tasarımında İşlevsel Esneklik Ve Entegre Sistemlerin Kullanım Önerisi*"*, Phd Thesis, Gazi University, Ankara, Turkey, (2014).

[11] Başar, C., "Mekan Hareketlerinin Fiziksel, Topolojik Ve Deneyimsel Bağlamlar Üzerinden İncelenmesi", Master Thesis, Istanbul Technical University, Istanbul, Turkey, (2014).

[12] Zuk, W., Clark, R. H., Kinetic Architecture, United States of America and Canada, Van Nostrand Reinhold Company, (1970).

[13] Gezer, H., "The Contribution of Potential Forces of Materials to Architecture", İstanbul Commerce University Journal of Science, 10 (20), 97-118, (2012).

[14] Schumacher, M., Schaeffer, O., Vogt, M., Move: Architecture in motion-Dynamic Components and Elements, Basel: Birkhduser, (2010).

[15] Gropius, W., Eight Steps Toward A Solid Architecture, In Architecture Culture, 1943-1968: A Documentary Anthology, Columbia University Graduate School Of Architecture, Planning, And Preservation: Rizzoli, New York, (1993).

[16] Forty, A., Words and Buildings, Thames& Hudson, London, (2000).

[17] Schneider, T., Till, J., "Flexible housing: the means to the end", Architectural Research, Vol 9 (3-4), 287-296, (2005).

[18] H. Ghamari, M. Asefi, "Toward Sustainability by the Application of Intelligence Building Systems". The Second International Conference on Sustainable Architecture and Urban Development, Jordan, 245-248, (2010).

[19] Bakbak, D.,Özakça, M., Göğüş, M.T., "Development of Design Methodologies for Deployable Fabric Structures in Civil Engıneering", Journal of the Faculty of Engineering and Architecture of Gazi University, Vol 31, No 1, 73-86, (2016).