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Kinetic Elements in Residential Designs

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Abstract

'Kinetic architecture' conception shows development through the improvements in construction and production today. Kinetic construction elements' usage possibilities within functional flexibility in residences are researched here. Unit locations were designed with kinetic systems in selected housing typologies within study. Kinetic systems are classified according to their location and action aim within construction elements. Principle designs were devised with kinetic elements that would provide flexibility out of shell within residences; moving residences were investigated; constraints and possibilities in residence type were determined. Usage of such elements in architectural design and construction technologies seems an important development for next period in terms of providing functional flexibility and producing formal new compositions through kinetic construction designs despite constrains.

1. INTRODUCTION

Today, the development of technology has ensured architecture field to improve in parallel with computer technologies by influencing it too. On the other side, the improvements in construction and production increased the interaction of architecture with other disciplines and gave acceleration to data exchange with fields like mechanics, electric and mechatronics. Considering the developments in architecture with this data flow, it can be seen that 'kinetic structure' as actual development area is a conception under development and a new design input. As a result of integration of kinetic structure and building elements with design, it becomes possible to make designs that can be adapted to more flexible, transformable and predetermined objectives.

The usage possibilities of kinetic construction elements within functional flexibility in residences are being researched in the study. The aim of study is to provide data for residence designs that will be constructed in the following periods. Unit residences were designed with kinetic systems in the selected housing typologies in the study. First of all, kinetic systems are classified according to movement purpose in structure element scale in terms of their environment where they exist. Conceptual designs were made with kinetic elements that would provide flexibility out of shell within residences, and moving residences were investigated and constraints and possibilities in every residence type were determined. Positive aspects of using kinetic construction elements are that they provide areal usage flexibility in all residence types, regulating the heating and cooling costs depending on spatial flexibility, visual changes in mass geometry, heat protection and natural lighting achievements. The negative aspects are that the first investment costs are high, maintenance costs, non-compliance of the current taxation to kinetic buildings, isolation problems against rain and snow, adaptation to the current buildings, non-compliance of the constraints in reconstruction regulations. The use of kinetic construction elements in architectural design and construction technologies seems to be an important development for the following period in terms of providing functional flexibility and producing formal new compositions through kinetic construction designs in spite of constrains.

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2. KINETIC ARCHITECTURE and ITS HISTORY

Kinetic architecture is basically an interdisciplinary field which tries to create the optimum conditions for users by responding to environmental impacts by means of smart systems. Kinetic architecture is defined as the technology of the necessary elements that can adapt to the changes that are included in pressure resources which make an influence on it, and can produce answers by assessing such influences, and show this as an activity. Kinetic architecture is the skill of adaptation to the environment and changing needs as architectural contents [1].

It is necessary to touch upon the conceptions relating to kinetic architecture in order to understand better its principles.

2.1. Kinetic, Mechanism, Kinematic and Movement Conceptions

Whereas kinetic literally means relating to the movement and those taking form as a result of movement; it researches the relation between the mass of an object and movement in terms of the relationship with the force influencing the object. Kinematic is the basis of mechanism. While kinematic deals with the movement and geometry of an object it does not have any relation with forces. Geometry of the movement is its basic investigation field. Kinetic architecture is the sub-field of kinematic discipline [2].

The conception of mechanism is a system serving for the transmission of force and movement consisting of rigid body and rigid joints. The architects deal with the movement occurring with mechanisms in terms of kinetic architecture; they have no relationship with the force and tension generating movement [3].

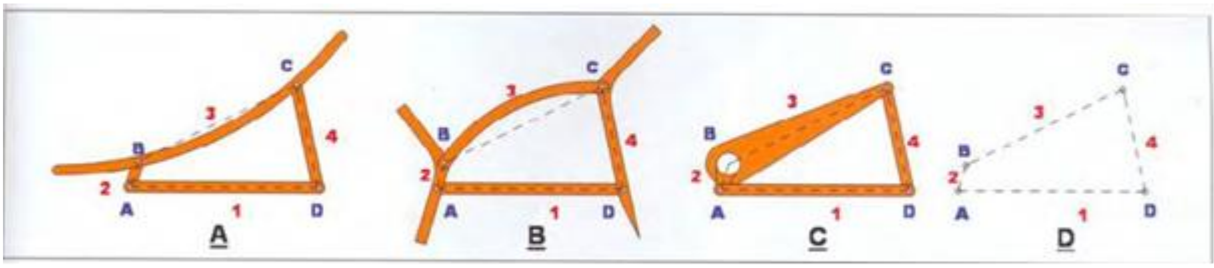

Figure 1. *The simplest plane mechanism samples consisting of four bars [4]*

Kinematic mechanism diagrams of plane mechanism samples in Figure1 are the same, and all of them are defined by the diagram in D. Many designs where architecture and movement are associated come out of this simple four bar mechanism [4].

Kinetic architecture is animated architecture type. Direct investigation field of kinetic architecture is the animated structures. The movement which is defined as the situation of an object and changing its place divides into two, as reciprocating and rotational motion. If all positions of a line taken on it when an object is moving are parallel to each other, the object holds over; on the other hand, if all points of an object are at the same distance to a line perpendicular to the movement plane the object shows rotation movement [5].

Another conception which is related to the movement and kinetic architecture is the mobility. Mobility which is defined as passing from one situation or time to another means the structures or elements to be mobile in terms of architecture. The residences in such characteristic are named as mobile house or residence [6].

2.2. Necessary Power Supplies and Power Transmission Tools in Mechanism

Structural elements or structures in kinetic architecture need power supplies and power transmission tools in order to move. It is important to know the necessary systems in order to make kinetic architectural designs precisely.

The necessary power supplies for mechanisms are fundamentally animal or human power, hydropower, wind power, steam power, solar power or electric, hybrid motors [7].

Spinning wheels can be given as example of human power. The spinning wheels that are the simplest power transmission tools consist of cylinders rotating around a fixed axis. Other important power resources are engines. Engines can perform several objectives by using solar, water, steam and wind power. They are used for obtaining mechanic energy in terms of kinetic systems [Figure 2].

Figure 2. *Wind, water and electric driven engines [7]*

The primary ones of power transmission tools that are placed in kinetic mechanisms and responsible for the load they take are manual levers, pistons, straps and chains transmitting power and movement, gear wheels, rails and bearings making changes regarding the speed and direction of the movement [7].

2.3. History of Kinetic Architecture

The movement in structures has been used since the first caves where human being lived as well as being a new design input although it is a new architecture design. For example, bolt stones that are used to separate locations in underground caverns are introduced as the first kinetic structure elements. At the same time, movement was used mostly in doors, windows and roofs in architecture throughout history [7].

According to Tzonis, we face movement firstly as some temple gates in Hellenistic period. According to Tzonis and Lefaivre, those gates are a pneumatic system working by displacement of compressed air principles and pressurized water vapour installed underground, so the gates open and close in this way [Figure 3] [8].

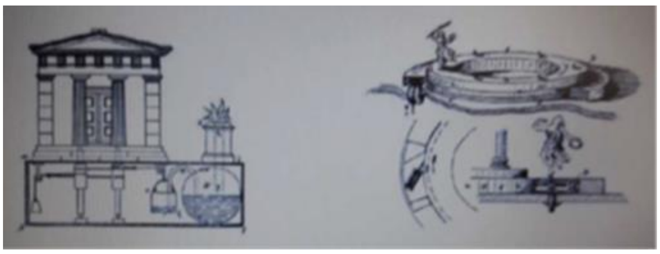

Figure 3. *Temple gate opening pneumatically and animated theatre in alexandria [7]*

We can classify kinetic architecture history as before settled life, after settled life and kinetic architecture from 2000s until today in itself.

The basic needs of people before settled life were sheltering and hunting. They met their needs with tents which were the first mobile structure samples for tracking their herds and for sheltering. As tents are used actively even at the present time, we can say that they can remain longer than any architectural form [9].

Even the names and types of tents that are the first samples of mobile architecture and used widely around America, Asia and Africa show difference from one region to another, the most widely known ones are yurt, tipi and black tent. Another important example of portable tent is the wagon used in long distances outside West by American pioneers. Following this, the first caravan was designed by Dr. Stables in 1886 officially in England [Figure 4] [10].

Figure 4. *Tent types Yurt of Asia and Tipi tent [10]*

Spatial needs changed after settled life was adapted. Static structures began to be built as migration was not obligatory anymore. Moving structure elements were used as movable theatre cover as folding doors in castles where they were built. Utopic projects that were developed in a way that the whole city could move were designed in the same period. Tatlin and Archigram became the pioneers of that period with such projects.

At the same time, another movement which made a tremendous impact by coming into the picture in Japan is the metabolism. Architecture is regarded as living organism on the basis of metabolic movement; and making expandable, flexible and functional designs is taken as basis. Capsule Tower and Ufo Village that were constructed of prefabricated elements during the period when prefabrication began to develop can be given as exemplary [Figure 5].

Figure 5. *Capsule tower and Ufo village [10]*

The fact that technology has entered in every area of our life in 2000s which is called as information period did not only decrease the devotion of people to locations but also let the dynamic of social life reflect on the residences. The designers tended to sustainable designs as a result of increased concerns for the nature and environment in that period; for this reason, they focused on using photovoltaic panels and recycled materials in their designs. Another issue which was considered important was easily adaptable structures to environmental conditions, handling and mounting light mobile units easily. Self Sufficient house is one of the important examples of this period. The house could produce its own energy and recycle water. The house, having the dimensions 9x3x3 is portable easily adaptable to any place. The unit can perform several functions at the same time; for example, it can be transformed from a vacation home to a mobile home or it can be joined with other modules and so a static structure can be created [Figure 6] [10].

Figure 6. *Self sufficient house [10]*

3. METHOD OF THE STUDY

Detached house, twin house, point block, wall block, ribbon building, penthouse were chosen as housing typology in this study, and the unit locations of the houses of this typology were designed by kinetic systems. The fact that cell system kinetic elements that provide spatial flexibility and ergonomics are usable in residences having the chosen residence type and residences to be designed in future is authentic in terms of the study's scope.

Before making principle designs for the specified purposes in the chosen residence types in the study, kinetic systems were grouped according to the location of the kinetic element, type of kinetic element, movement type of kinetic element and usage of kinetic element [Table 1].

Table 1. *Classification of kinetic mechanisms [22]*

TYPOLOGIC CLASSIFICATION OF KINETIC MECHANISMS	
LOCATION	INSIDE SHELL
	OUTSIDE SHELL
KINETIC ELEMENT TYPE	CELL SYSTEM
	PANEL SYSTEM
MANNER OF ACTION	SLIDING SYSTEM
	FOLDING SYSTEM
	SHRINKING AND EXPANDING SYSTEM
	ROTATING SYSTEM
USE AIM OF ACTION	FUNCTIONAL FLEXIBILITY
	PHYSICAL ENVIRONMENT INSPECTION
	PRODUCING AND SAVING ENERGY
	VISUAL TRANSFORMATION AND AESTHETIC

3.1. Kinetic Systems in Terms of Location

Kinetic systems are divided into two parts, as inner shell and out of shell systems in terms of location. Kinetic mechanisms in inner shell systems take place in building or structure shell. The needs that emerge within time can be met thanks to the fact that internal structure elements are mobile. For example, mobile sections and mobile panel walls can be used for such purpose in the shell.

Mechanisms take place outside structure shell or its intersection in outside shell kinetic systems. Volumetric flexibility can be ensured by the movement of structure's exterior shell or adding or removing new volumes [7]. Planning should be provided while these systems are under design phase. Kinetic systems outside shell will be mentioned under the scope of the study.

3.2. Kinetic Systems as Type of Kinetic Element

Kinetic systems as type of kinetic element are cell and panel systems. Cell systems are the systems hosting conveyor system in itself having monolithic feature. They can be open, closed and mixed cell systems. In order that these systems which are produced as prefabrication could be kinetic, the elements such as tracks, power transmission organs which will allow it to move should be included. As it can be seen in Figure 6, kinetic rotating closed cell in Sharifi Ha House project that was carried out in Iran was added to bedroom by using system. Effective daylight and temperature control can be performed thanks to this kinetic system [Figure 7].


Figure 7. *Sharifi Ha house visual [11]*

Panel systems are the conveyor elements created from horizontal and vertical panels which can be used as structure elements of wall or furnishing. The panels are expected to be mobile in order that they could be kinetic panel systems. Rail systems and power transmission tools can be added in order that panel systems could move. For example, sliding panel walls and sliding folding panel roofs are mobile panel systems [Figure 8].


Figure 8. *Sliding folding panel wall [7]*

3.3. Kinetic Systems by Manner of Action

These are kinetic systems, sliding systems, folding systems, shrinking and expanding systems and pivoted rotating systems according to movement type. Samples of these systems are given in Figure 9. Folding, sliding and rotating systems were used in conceptual designs that were made within the scope of the study.

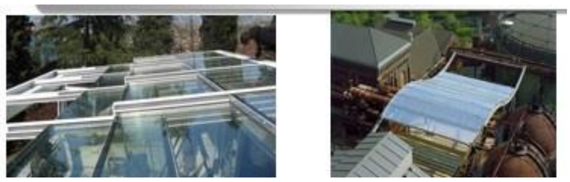

Figure 9a. *Sliding roof systems*

Figure 9b. *Folding chair and M-House project [7]*

Sliding systems are the kinetic systems where sliding movement takes place. Today sliding systems are often used in windows, doors, roofs and furnishings as kinetic elements. As it can be seen in Figure 9a, sliding roof panels slide and move by sliding on one another. Accumulation realizes in a fixed module in those samples. Accumulation movement could be either manual or motor-driven.

Figure 9c. *Hoberman sphere and Theo Jansen bridge [7]*

The form changes before the structure is deformed in folding systems. The simplest exemplary to these systems is the folding chairs and furniture that can be seen in Figure 9b [12] 90 square meter single bedroom M-House project which consists of modular parts in Figure 9c and was built in 2009 by Jantzen is a project including folding systems. It consists of the panels that can be demounted and remounted. The panels can be mounted and demounted in different types in order to meet changing needs in a wide range [13]

They come about by becoming in a fixed location in a way to convey their own loads provided that they increase and decrease the volumes of small elements that were produced as prefabricated and forming the system by merging with mobile connections. As the system has some advantages such as being practical to install, re-used, coming to a desired volume and form, easily movable, it is usually preferred in space industry, provisional and military structures and it has a high potential of giving idea for future architectural designs [14].

The sphere that Hoberman introduced to the market in 1991 in his name can be seen in Figure 8c. The sphere that is known as the sphere of Hoberman and entering into the toy market has a folding mechanism can expand and shrink 3 times of its own volume [7]. Another example is the 'Rolling Bridge' project of Heatherwick in London. The pedestrian bridge, which turns into octagon when closes down, shrinks and expands thanks to the movement of totally sixteen pistons. It is satisfying in terms of visual aesthetic as well as the advantage of its functional use [15].

Figure 9d. *Rotor house and Fischer tower [7]*

Rotational motion in rotating systems realizes through fixed elements in different sizes and the movement of moving elements correspondingly. Aim of using rotational motion in architectural structures is to see the picture from different viewpoints and to determine the position to benefit from sun light at maximum. Kinetically rotating floors, rooms and structure-building elements to follow the daylight in terms of providing physical environmental inspection and benefiting from the landscape in the projects carried out in recent years are designed. Figure 9d shows a house having the minimum dimensions but maximum area of use in Rotor House project of Colani. The house of Hanse-Colani Rotor has the quality of being mobile and ideal with its requirement of a 6 x 6 m space only. The basic logic of the house is that it is a rotor house and sheltering fundamental function areas like sleeping, recreation and eating. In this way, the necessary space is turned into the related room [15].

3.4. Kinetic Systems by Use Aim of Action

Kinetic systems are used as functional change-flexibility, energy production, physical environment inspection and visual transformation-aesthetic based on the use aim of the movement.

The aim in functional flexibility is to meet the location and function needs that may be needed in future without touching the conveyor system of the structure. Functional flexibility should be provided with fixed and mobile systems in the structure. Expanded internal volumes in fixed systems are offered at first and locations cannot be privatized. No adding or removing can be made and there are no corridors. As for the mobile system, it is a matter from component to integrity or from integrity to components, and the entirety is unknown. Later volumetric additions can be made [7]. It will be mentioned about moving systems in the study.

Another aim of using kinetic systems is to inspect physical environment conditions. Life is always in motion, it is not stable. Compliance to continuously changing environmental conditions is one of the main problems of kinetic architecture. Thus, it is a matter of adaptation to the environment in kinetic architecture. The purpose is to design residences that could be both flexible and respond to the needs. Being a solution for rapidly increasing environmental problems in recent years and creating designs benefiting from the climatic factors by saving energy are among the main objectives of kinetic architecture. Physical environment inspections like the control of daylight, wind, solar radiation, ventilation, energy production become possible with the integration of kinetic architectural elements.

Figure 10.a. *Court house of Madrid [16]*

Figure 10.b. *Media-TIC office building [17]*

The fronts of Madrid court house ensures physical environment inspection by heating, cooling and ventilating actively [Figure 10.a].

The feature of Media-TIC office building is that efficient coatings in 2500 square meters coated with ETFE (ethylene tetrafluoro ethylene) settled in southeast and southwest fronts in order to save energy from daylight are used. ETFE coated panels provide the isolation of the front by working with a principle similar to the diaphragm in the front getting 6 hours of sunlight approximately in a day. This situation realizes thanks to air storage as a result of swelling of panels. Transparent panels have the sunshade role. 20% saving is ensured through these all systems, and the interactive structure in the front creates dynamic effects on people at the same time [Figure 10.b] [17].

The heliotrope house project, a design of Rolf Disch, which can be seen in Figure 10.c has the residence rotating wooden mechanism that was made in Germany in 1994. It is the first house in the world following the sun by making rotations. The structure is integrated to a pillar as a mechanism, and it follows the sun having the ability of rotating 180 degrees. The house which completes its rotation as kinetic motion allows the inspection of environment by maximally benefiting from daylight [18].

Figure 10.c. *Heliotrope house [18]*

Figure 10.d. *World trade center building of Bahrain [7]*

Another energy type that is produced by makimg benefit through kinetic fronts is the wind energy. World Trade Center Building of Bahrain meets 35% of its energy need itself from wind energy [Figure 10.d].

Wind turbines with a diameter of approximately 29 meter having horizontal axis to 3 separate bridges of 30 meters between two towers. At the same time, towers' form was designed to meet and use the wind. The towers using effectively the wind which comes from Basra gulf are the first trade centers producing energy in the World [7].

One of the aims of integrating kinetic mechanisms into the fronts is the visual transformation and aesthetic concerns. Dynamic effects created in the fronts become alluring aesthetically. The fact that kinetic architecture elements provide visual transformation by performing sliding, rotating, folding actions makes positive contribution to the building and environment in the public context.

Impressive fronts of Kiefer Technique Showroom which can be seen in Figure 10.e consists of the panels that can be adjusted and make sliding-folding by moving in accordance with daylight in every hour of the day [19].

Detached house, twin house, ribbon building, wall block, point block and penthouse type residences were chosen in the study, and cell sliding, folding, pivoted rotating systems were combined with such typologies.

Figure 10.e. *Kiefer technique showroom [19]*

Principle designs were made in the context of using kinetic elements that provide outside shell flexibility in detached house, twin house, ribbon building, wall block, point block and penthouse type residences. Expanding possibilities, expanding directions of residence types and locations of kinetic elements that will be used are determined. Each system was modeled separately for each housing typology (sliding, folding, rotating).

3.5. Construction Principles of Kinetic Systems and Its Use in Residences

Schematic construction drawings showing manufacturability of these moving outside shell elements and action mechanisms are given in Figure 11. It can be seen in construction drawings that the main framework of containers is generally steel construction. They are used for several purposes and functions making changes on these containers (like adding transparent surfaces) or being accumulated [22].

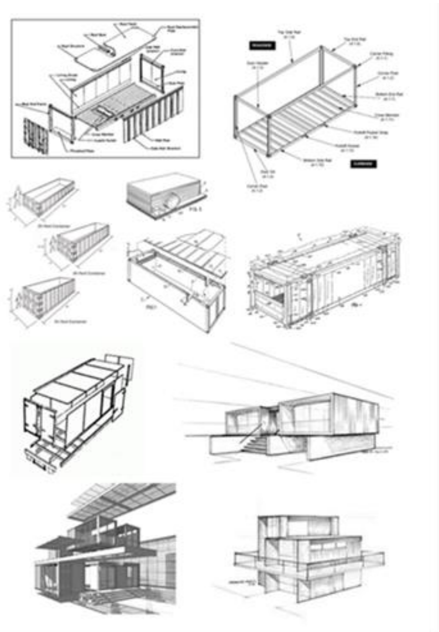

Figure 11. *Construction drawings [20]*

Figure 12. *Several functions of containers [21]*

Kinetic elements that are matter of work as their main residence structure could be steel, reinforced concrete are articulated to the main residence structure. Production type of these motion modules is similar to the containers. Figure 12 demonstrates the containers to be used in several functions and types as stable modules (cafe, home, library, etc.). Containers can be accumulated and their surfaces can be changed and used in several functions.

The difference of kinetic volumes that are used in housing typology is the necessity of adding mechanic elements such as wheel, guide rails, power supply (electric engine) to the system allowing them to move. For this reason, the container manufacturing drawings that are show in Figure 12 should be reproduced in accordance with kinetic purposes [22].

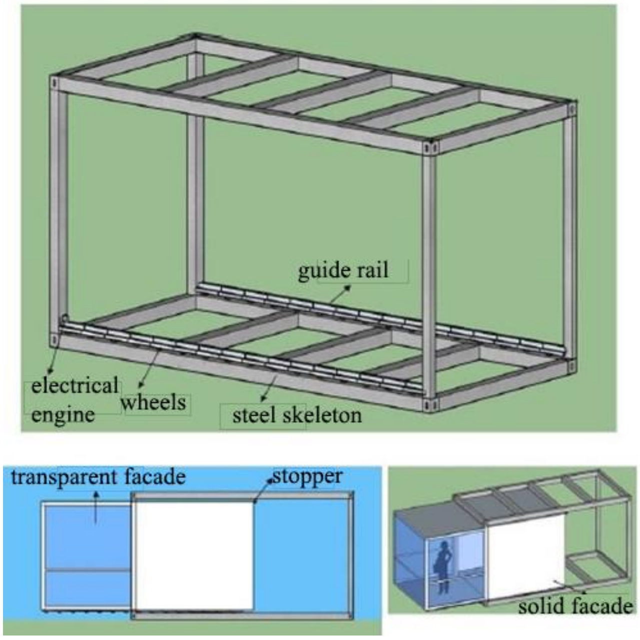

Figure 13. *Cell sliding system construction drawings [22]*

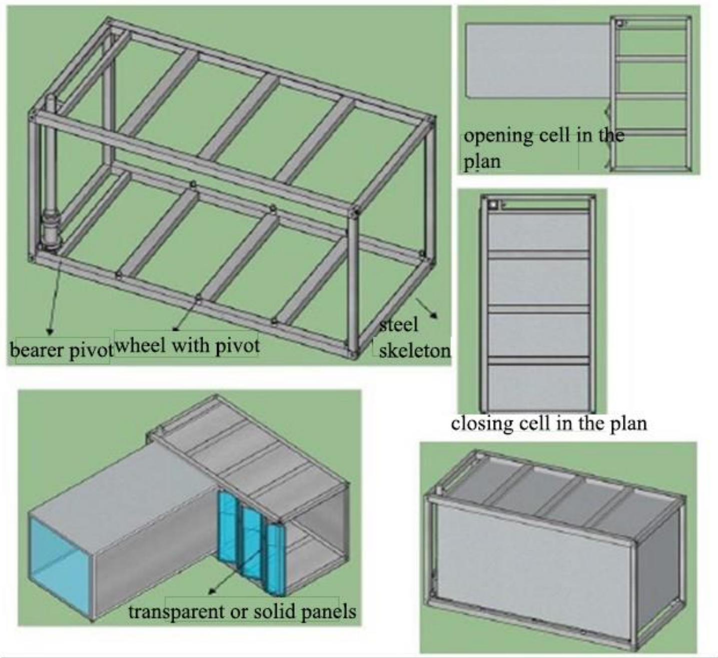

Figure 14. *Pivoted cell system construction drawings [22]*

Schematic construction drawings that can be seen in Figure 13 and 14 are principle drawings of the applicability of cell sliding, folding and pivoted rotating kinetic systems to the residences. Steel coating which is the main structure of container structures is used in these drawings, and guide rail, wheel, power supply (engine) and semitransparent cell are added to the main steel structure for cell sliding systems [Figure 13]. Carrier pivot and pivoted movable wheels that will let cells rotate differently for pivoted rotating systems were articulated [Figure 14]. The stable containers were turned out to be kinetic with those elements added [22].

3.6. Expanding Alternatives of Home Typology through Cell Sliding System

Expanding alternatives of housing typologies that are selected in cell sliding kinetic systems were investigated through conceptual designs. Unit location of each residence type was designed as cell sliding movable part. Those moving cell modules are believed to have a construction as shown in Figure 13 [22].

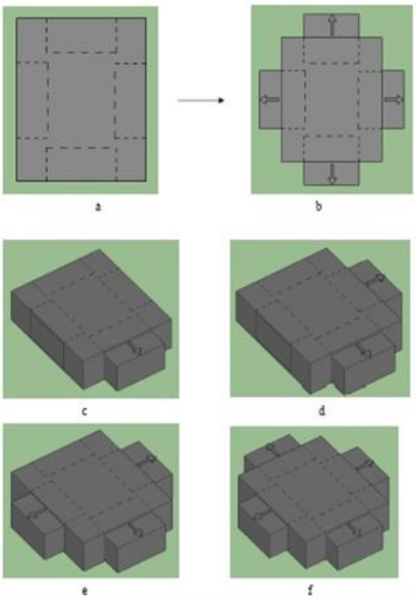

Figure 15.
a. Single-storey house closed scheme
b. Opening directions of single-storey house
c. Expansion of detached house to one direction
d. Expansion of detached house to 2 directions
e. Expansion of detached house to 3 directions
f. Expansion of detached house to 4 directions [22]

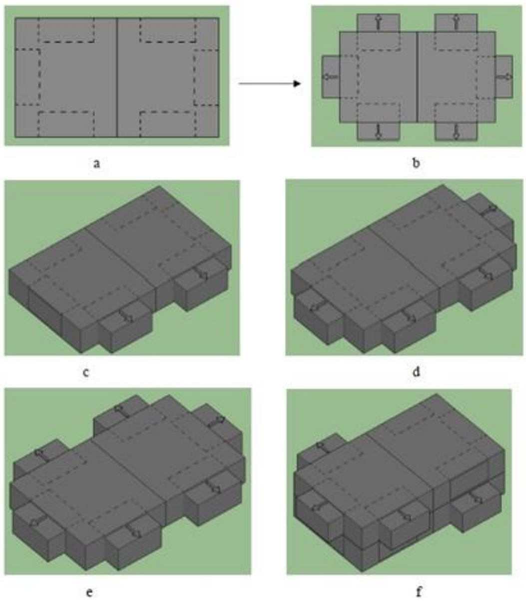

Figure 16.
a. Twin house closed scheme
b. Opening directions of twin house
c. Opening of twin house to 1 direction
d. Opening of twin house to 2 directions
e. Opening of twin house to 3 directions
f. Opening of two-storey twin house to 3 directions [22]

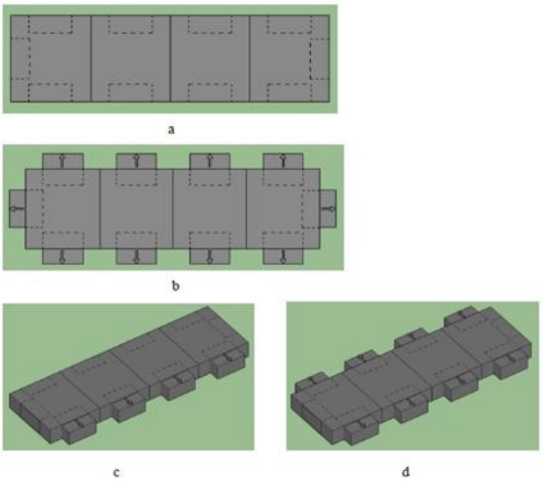

Figure 17.
a. Closed schema of ribbon building
b. Opening directions of ribbon building
c. Opening of ribbon building to 1 direction
d. Opening of ribbon building to 2 directions
e. Opening directions of ribbon building [22]

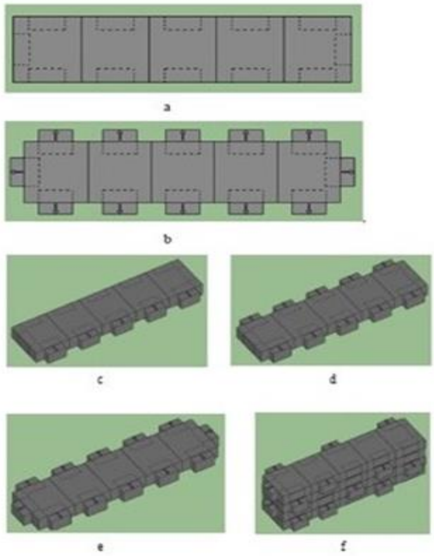

Figure 18.
a. Wall block closed schema
b. Wall block expanding directions
c. Opening of wall block to 1 direction
d. Opening of wall block to 2 directions
e. Opening directions of wall block
f. Multiple storey wall block [22]

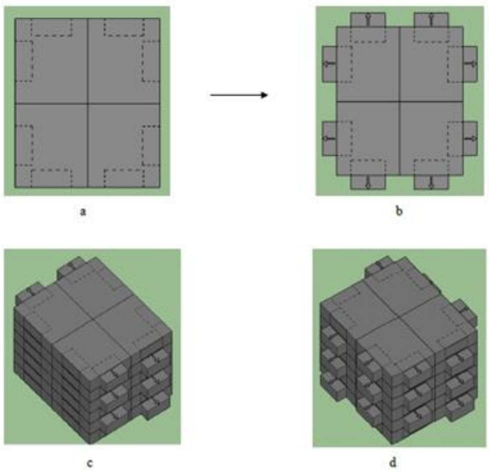

Figure 19.
a. Point block closed schema
b. Opening directions of point block
c. Opening of point block to 1 direction
d. Opening of point block to 2 directions [22]

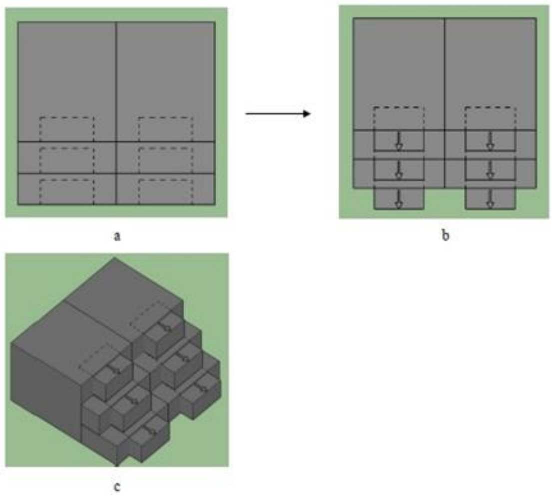

Figure 20.
a. Closed schema of penthouse
b. Opening direction of penthouse
c. Opening perspective of penthouse [22]

Figures between 15-20 show expanding alternatives of home typologies with kinetic systems having a construction as in Figure 13 in the designs produced by cell sliding system.

It is shown in Figure 15 that the independent house could be expanded to 4 different fronts thanks to its features to be free in all fronts and through sliding system cells, the twin house in Figure 16 could be expanded to 3 fronts due to having a common wall typologically, the initial and last residences of ribbon buildings in Picture 17 are free in 3 fronts, but the initial and last residences could be expanded to 3 fronts as the residences in-between have 2 free fronts each, and the residences in-between could be expanded to

2 fronts each, the initial and last residences could be expanded to 2 fronts each due to the same feature of ribbon buildings having multiple floor typology with wall blocks in Figure 18 could be expanded to 3 fronts each and the residences in-between could be expanded to 2 fronts each, the corner residences of the point blocks in Picture 19 (each floor is considered to have 4 flats in schematic design) could be extended to 2 sides each, whereas the residences in-between could be extended to one side, the penthouses could be expanded to 1 front due to having 1 free front and as they touch to the ground from 3 fronts due to their typologic features in Figure 20 [22].

3.6. Expanding Alternatives of Home Typology through Folding System

Expanding alternatives of housing typologies that are selected in folding kinetic systems were investigated through conceptual designs. Unit location of each residence type was designed as folding movable module. Those moving cell modules are believed to have a construction as shown in Figure 13, but to consist of folding panels [22].

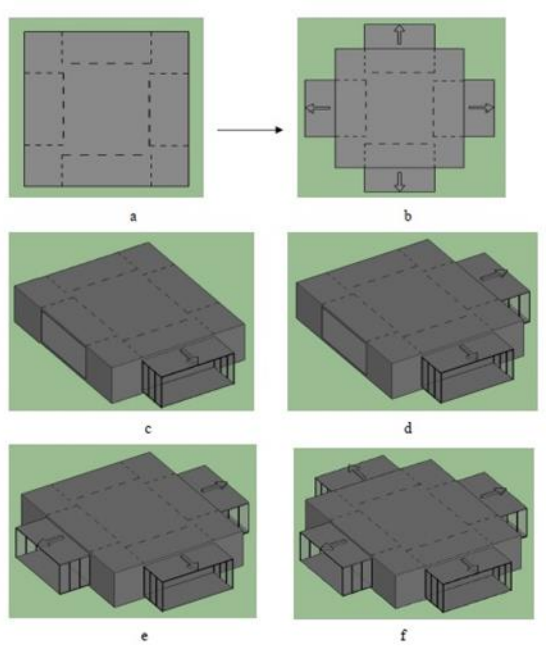

Figure 21.
a. Closed schema of detached house
b. Opening of detached house by folding system
c. Opening of detached house by folding system to 1 direction
d. Opening of detached house by folding system to 2 directions
e. Opening of detached house by folding system to 3 directions
f. Opening directions of detached house by folding system [22]

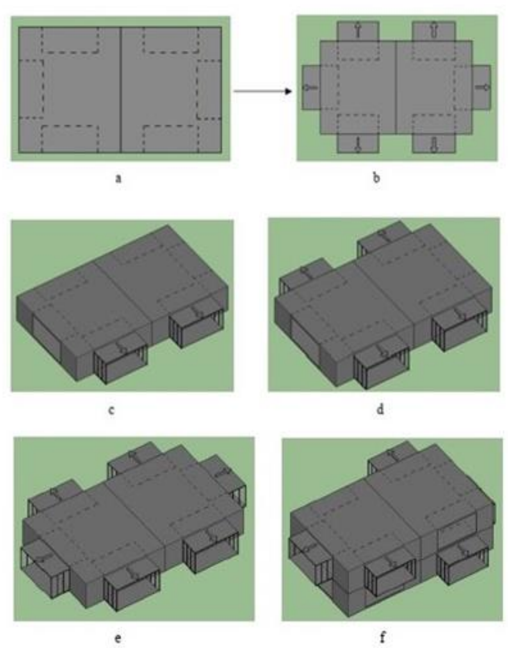

Figure 22.
a. Closed schema of twin house
b. Opening of twin house by folding system
c. Opening of twin house by folding system to 1 direction
d. Opening of twin house by folding system to 2 directions
e. Opening of twin house by folding system to 3 directions
f. Opening of two-storey twin house by folding system [22]

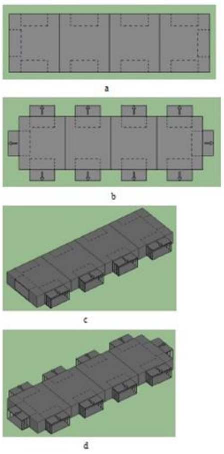

Figure 23.
a. Closed schema of ribbon building
b. Expanding directions of ribbon building by folding system
c. Expanding of ribbon building to 1 direction by folding system
d. Expanding of ribbon building to 2 directions by folding system [22]

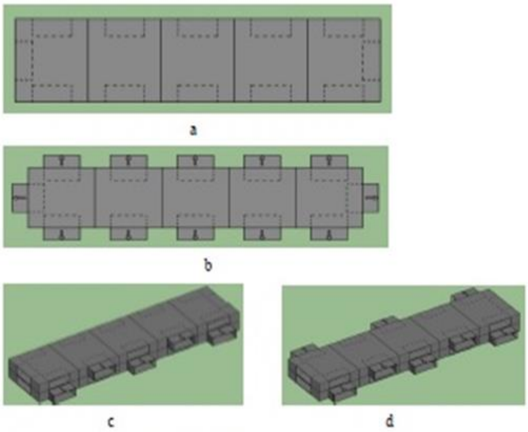

Figure 24.
a. Closed plan of wall block
b. Opening of wall block by folding system
c. Opening of wall block to 1 direction by folding system
d. Opening of wall block to 2 directions by folding system [22]

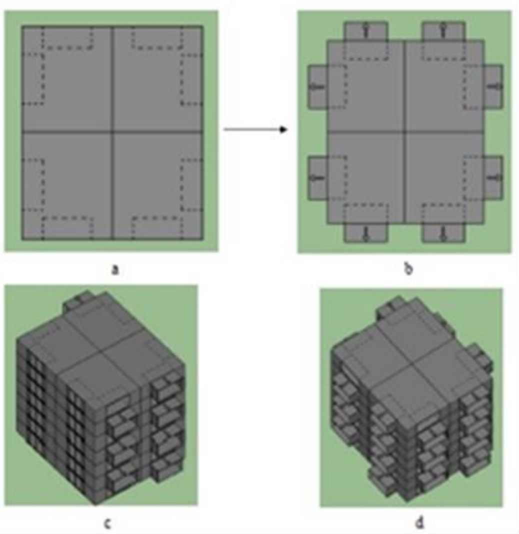

Figure 25.
a. Point block closed schema
b. Opening directions of point block by folding system
c. Opening of point block to 1 direction by 1 folding system
d. Opening of point block to 2 directions by folding system [22]

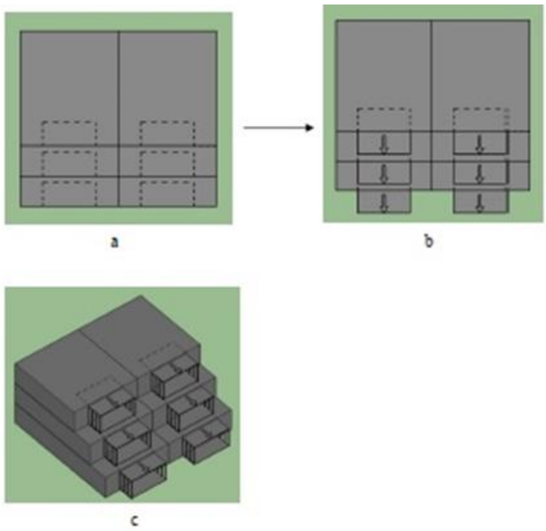

Figure 26.
a. Closed schema of penthouse
b. Expanding of penthouse by folding system
c. Expanding and perspective of penthouse by folding system [22]

Figures from 21 to 26 demonstrate expansion alternatives of housing typologies by folding panel system. This system has a similar construction to cell sliding system; differently, its side walls are in panel shape and folding system. By using this system, it was shown in Figure 21 that the detached house could be expanded through folding panels freely to 4 fronts, the house shown in Figure 22 could be expanded to 3 different fronts as system can be applied to 3 fronts of the free side due to the fact that the twin house has neighbour wall typologically, the ribbon buildings in Figure 23 could be expanded to 2 fronts freely excluding the initial and last residences due to their adjoined feature, yet the initial and last residences could be expanded to 3 fronts, the wall blocks in Figure 24 could be expanded to 2 fronts excluding the initial and last residences in a similar way with ribbon building and 3 different fronts of the initial and last residences, the corner residences of the point blocks in Picture 25 (each floor is considered to have 4 flats) could be extended to 2 sides each, whereas the residences in-between could be extended to one side, penthouses in Figure 26 could be expanded to only one front due to their feature of being free for only one front [22].

3.6. Expanding Alternatives of Home Typology through Pivoted Rotating System

Expanding alternatives of housing typologies that are selected in pivoted rotating systems were investigated through conceptual designs. Unit location of each residence type was designed as pivoted rotating movable module. Those moving cell modules are believed to have a construction and mechanism as shown in Figure 14 [22].

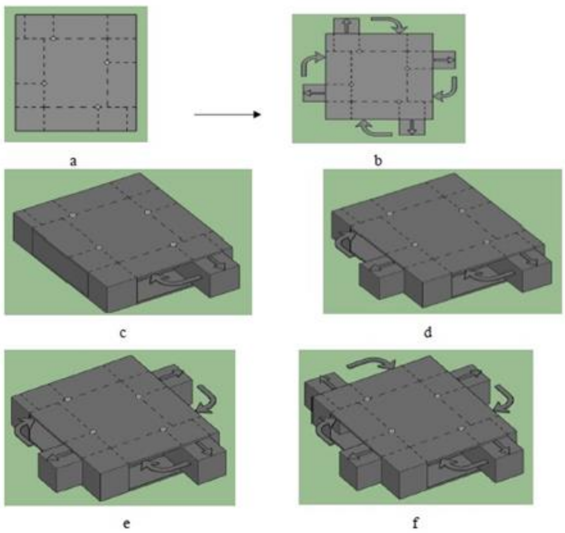

Figure 27.

a. Closed schema of detached house
b. Opening of detached house by pivot system
c. Opening of detached house to 1 direction by pivot system
d. Opening of detached house to 2 directions by pivot system
e. Opening of detached house to 3 directions by pivot system
f. Opening of detached house to 4 directions by pivot system [22]

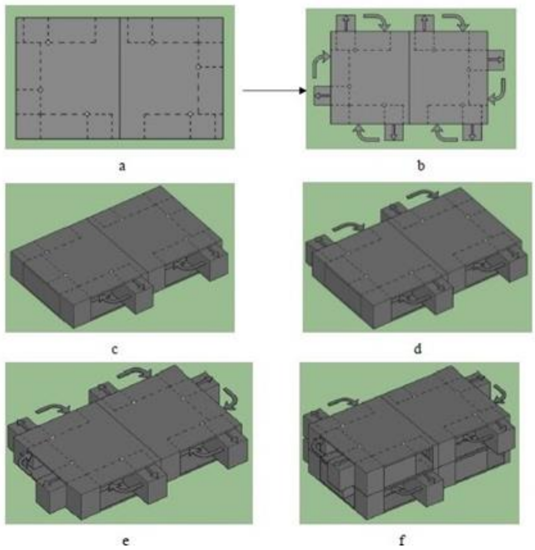

Figure 28.

a. Closed schema of twin house
b. Opening of twin house by pivot system
c. Opening of twin house to 1 direction by pivot system
d. Opening of twin house to 2 directions by pivot system
e. Opening of twin house to 3 directions by pivot system
f. Opening of two-storey twin house by pivot system [22]

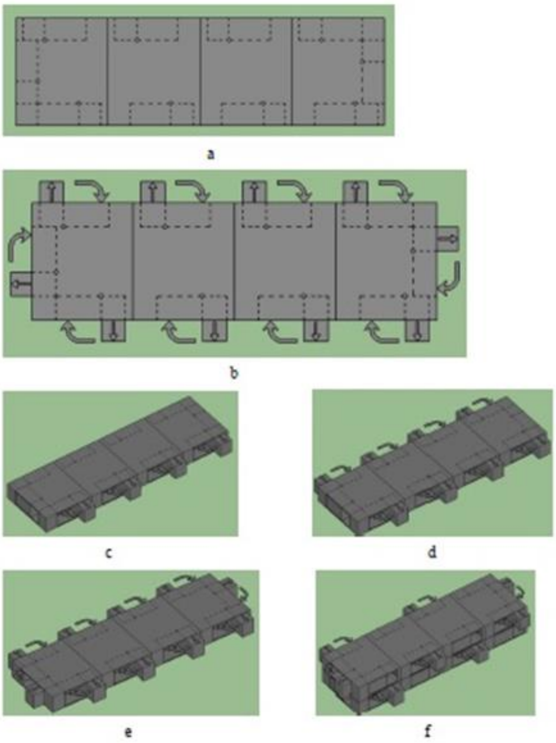

Figure 29.
a. Closed schema of ribbon building
b. Opening directions of ribbon building by pivot system
c. Opening of ribbon building to 1 direction by pivot system
d. Opening of ribbon building to 2 directions by pivot system
e. Opening of ribbon building to 3 directions by pivot system
f. Expanding of two-storey ribbon building by pivot system [22]

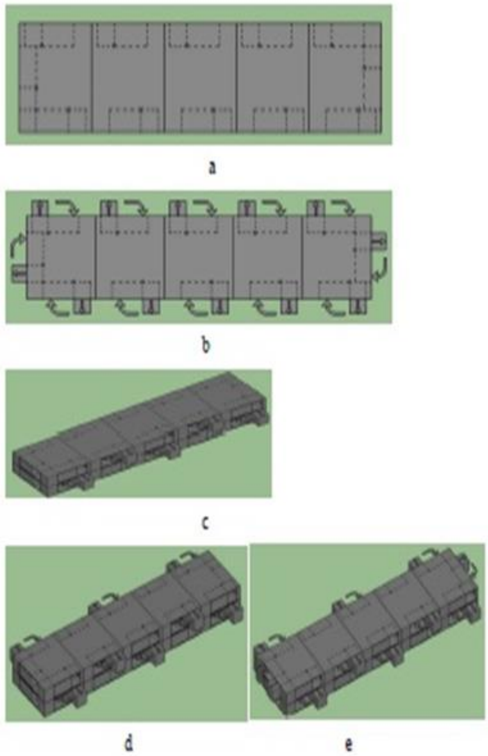

Figure 30.
a. Closed plan of wall block
b. Opening directions of wall block by pivot system
c. Opening of wall block to 1 direction by pivot system
d. Opening of wall block to 2 directions by pivot system
e. Opening of wall block to 3 directions by pivot system [22]

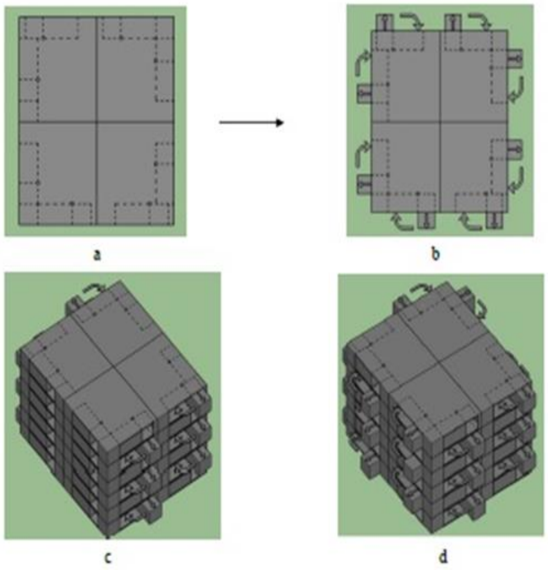

Figure 31.
a. Point block closed schema
b. Opening directions of point block by pivot system
c. Opening of point block to 1 direction by pivot system
d. Expanding of point block to 2 directions [22]

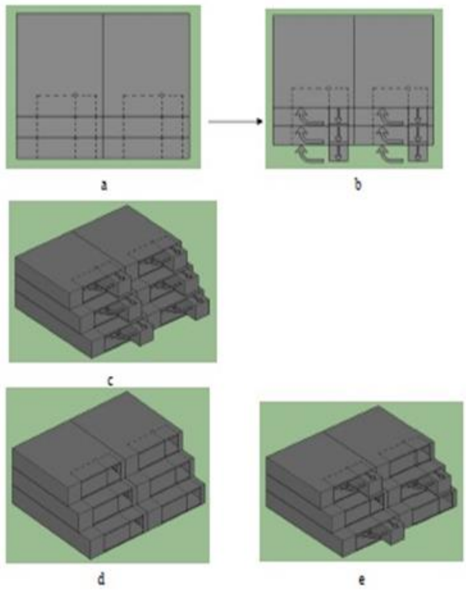

Figure 32.
a. Closed schema of penthouse
b. Opening directions of penthouse by pivot system
c. Opening of penthouse to 1 direction by pivot system
d. Previous perspective of penthouse before disclosure
e. Subsequent perspective of penthouse after disclosure [22]

Figures from 27 to 32 demonstrate expansion alternatives of housing typologies where the cell pivot system was applied. It was shown that; detached four houses could provide functional flexibility by opening into four fronts among the residents where cells rotating around a pivot are applied in Figure 27 and using the construction shown in Figure 14 in these residences, the twin houses could be expanded to three fronts due to typologic feature (one of the walls is joint with the next building) of the house in Figure 28, the residents in-between could be expanded as the initial ones to 2 fronts and the last ones to 3 fronts due to the fact that in-between residents of the ribbon buildings in Figure 29 have free fronts in 2 fronts each, the initial and last residents could be expanded to 3 fronts and the ones in-between to 2 fronts each due to the fact that wall blocks in Figure 30 have the same typology with ribbon building, the corner residents of the point blocks in Figure 31 (each floor is presumed to have 4 flats) could be expanded to 2 fronts each, whereas the residents in-between could be expanded to one front as the penthouses in Figure 32 have only one front [22].

3.7. Physical Environment Inspection Effects of Kinetic Elements in Residence Locations

One of the main objectives in using kinetic elements in residence locations is to be able to make physical environment inspection. When they are used for this aim, they realize their aim of benefiting actively from solar energy during the day, heat control in summer-winter use as well as functional flexibility. While more daylight control, usage of balcony or terrace in summertime could be realized thanks to cell sliding and folding system, effective heat conservation is realized by ensuring extensile and extendible capacities in summer by the protected capacities that are closed in winter in pivoted cell system.

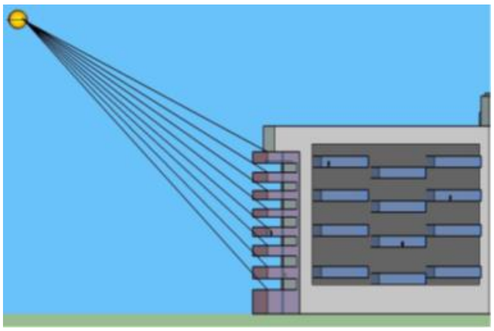

Figure 33. *Perspective of point block in getting light with kinetic systems before opening [22]*

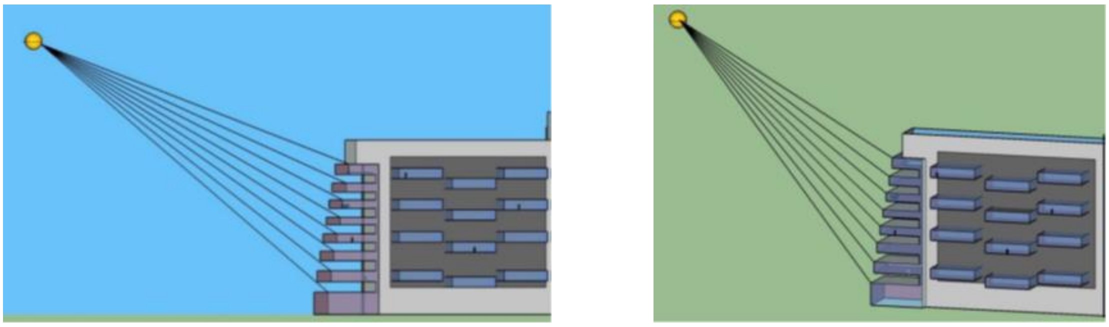

Figure 34. *Perspective of point block in getting light with kinetic systems after opening [22]*

The status of point block’s getting daylight before expansion by kinetic systems is schematized in sample drawings [Figure 33]. The usage area of daylight is increased by virtue of the cells opened by kinetic systems in point blocks and other housing typologies [Figure 34]. Particularly, the usage area of daylight is increased by the opening in kinetic systems in the residences that cannot be benefited from the daylight as desired and that are on lower floors in multiple storey housing typologies like point block. So, this lets an effective daylight control.

3.7. Visual Transformation Effects of Kinetic Elements in Residence Locations

Kinetic elements form different front compositions that were designed before in residence design especially in the fronts. Kinetic architecture elements should be included in the design while they are still in design stage in order to fulfil the object in residence fronts. It is provided tempting and impressive visual transformations that are created with dynamic fronts in this regard [22].

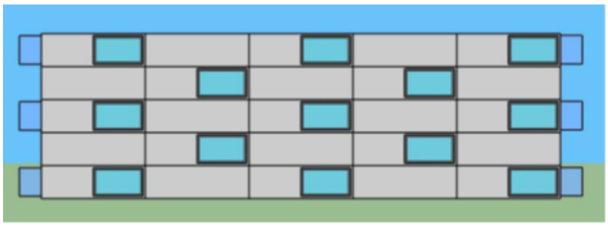

Figure 35. Alternative *appearance of the 1st front designed with kinetic systems [22]*

Figure 36*. 2nd front alternative designed with kinetic systems[22]*

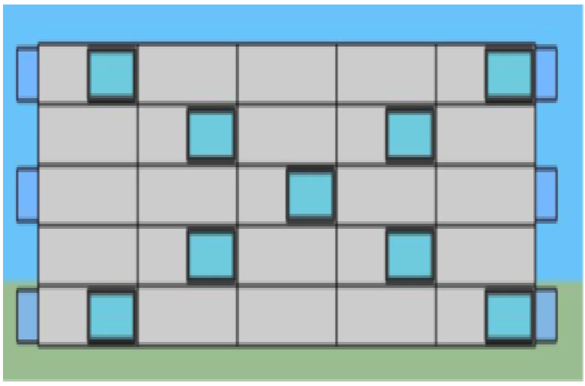

Figure 37. *3rd front alternative designed with kinetic systems [22]*

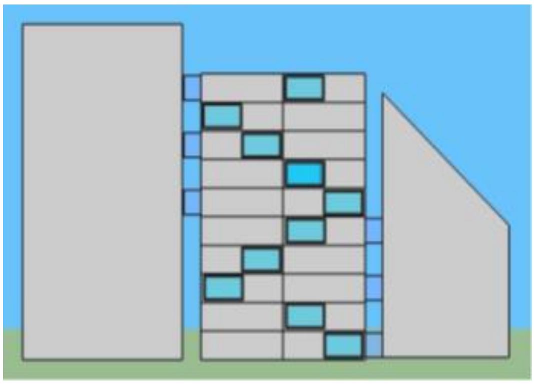

Figure 38. *4th front alternative designed with kinetic systems [22]*

Different front alternatives which were designed with kinetic systems are given between the Figures 35-38. Effective visual-aesthetic fronts were created thanks to the patterns created by a certain design prediction by the cells opened in visuals.

3.8. Findings

Table2. *Evaluation of kinetic systems in terms of their use aim, area of use and limitations [22]*

		CELL SLIDING SYSTEMS	FOLDING SYSTEMS	PIVOTED ROTATING SYSTEMS
1. USE OF LOCATION	APPLICATION TO THE HALL	+	+	+
	APPLICATION TO THE KITCHEN	-	-	+
	APPLICATION TO THE BEDROOM OF PARENTS	+	+	+
	APPLICATION TO THE BEDROOM OF CHILDREN	+	+	+
2. PHYSICAL ENVIRONMENT INSPECTION	BENEFITING FROM DAYLIGHT (USE IN BALCONY, TERRACE)	+	+	+
	FUNCTIONAL FLEXIBILITY (VOLUMETRIC EXPANSION)	+	+	+

	USE DURING WİNTER AND SUMMER	+	+	+
	CHANGING EXPANDING VOLUME TO A DESIRED DIRECTION	-	-	+
3. CORE DESIGN LIMITATION		+	+	+
LEGENED: EXISTING FEATURE: + NON-EXISTING FEATURE: **-**				

Positive and negative aspects of the use of residence type kinetic structure elements, their design limitations and possibilities were evaluated with a matrix.

When Chart 1 is examined, it can be seen that kinetic systems give similar results in terms of their use in residence locations, yet the expansion through pivoted system in kitchen area seems to be possible. It can be seen that every system gives positive results in terms of the use of daylight in physical environment inspection, use of summer-winter residences and functional flexibility. However, it is obvious that the size to be expanded could be turned to a desired direction by using only pivoted system (depending on the degree of freedom of the front). It is understood that kinetic systems of the core design cause limitation in the residences to be used. It can be concluded that the center of core should be designed in the middle in order to make optimum benefit [22].

4. RESULTS and EVALUATION

Positive sides of using kinetic system in consideration of this data in housing typologies are as follows;

- It gives different composition alternatives that were designed before in front and mass composition of the building.

- Cooling and heating costs can be adjusted based on spatial flexibility depending on the conditions of construction management.

- It allows flexibility in spatial and volumetric use of residence use. It may grow up in parallel with the increase in the use of residence area and other needs.

- The use of kinetic architectural elements that were investigated in housing typology is suitable for the functions of other structures. For example, it can be adapted to the functions like hospital, school, etc.

- It provides different facilities in summer and winter use based on climate changes. While the decrease in volumes in winter is possible, it allows expansion of terrace, balcony in warm and hot summer months.

Negative sides of using kinetic system in housing typologies are as follows;

- The first investment cost is high due to using mechanic parts and movable building elements.

- There are insulation problems against rain and snow.

- It is hardly adaptable to the current buildings.

- Today, taxation of building takes place on the basis of predetermined independent section. It is ambiguous how to fix such taxation in kinetic residences. Area calculation which is subject to a new taxation should be made according to off position and on position.

- Kinetic building design is not suitable for the reconstruction and regulations of our day. Pull structure that allows building to fit on the ground breaches approaching distances. For this reason, the related distances should be re-arranged according to kinetic movements.

- When cell structure element which moves kinetically within cell system is fully closed, elevation difference emerges in flooring inside the building. Vice versa, when it is fully open, elevation difference again emerges in the flooring where the cell comes out. Although elevation difference that will be the size of approximately a stair is regarded to be negative for inner use of residence, it can also be seen as richness of design [22].

Adaptive kinetic architectural structures that can be adapted to the changing environment and users' needs through construction and production gain importance. The expectations of users can be met through kinetic architectural structures, so it -becomes possible to design flexible residences and structures. In this context, kinetic architecture is defined in this article, related conceptions are explained, the improvements in kinetic architecture are examined within historical process and actual samples are given. Subsequently, kinetic architecture elements are grouped with regard to their locations, kinetic element types, action types and the use aim of action. Out of such grouping; cell sliding, folding panel systems and cell pivot systems are modeled separately by being applied in the selected housing typologies (detached house, twin house, ribbon building, point block, wall block, and penthouse).

Considering the data and findings obtained, it can be seen that design of kinetic structure has expanded new horizons and positive sides outweigh negative ones even they cannot be denied. Flexible design purpose was realized by obtaining locations that can be adapted to particularly functional flexibility and different functional purposes.

Continuous improvements of technology, increasing importance of interdisciplinary studies and becoming inevitable in designs support kinetic architecture applications. It is believed that kinetic applications will increase in near future not only in residential buildings but in multiple function structures too. The flexible design which allows user demands changing within time to be met becomes inevitable for the structures having several functions. In this regard, the applicability of kinetic systems for the functions like school, office, hospital, etc. among the structures whose space quality is influenced by users and that are changing continuously is inevitable.

It is believed that new horizons will be opened in architectural design thanks to enlightenment of designers as well as engineers having such qualities with this new design input.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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