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Methods of Utilizing Natural Organisms in Technological Architecture[1]

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Abstract: This research aimed at identifying natural organisms and the way of their expression in the technological samples of contemporary architecture. The main questions were: "Which methods of utilizing natural organisms are effective on the technological works of contemporary architecture?" and "How and how much do they affect?" This descriptive-analytical research was conducted using archival method to access the theoretical literature and surveying method for collecting the data required. Case studies were selected and analyzed from the internationally famous technological works made from the sixties (Hi-Tech style) till now. The case studies were divided into two periods, 20th and 21st centuries and 8 works were selected in each period (totally 16 works). The results indicated that formal and structural methods have had most used between methods of utilizing natural organisms in technological works of contemporary architecture and functional method has been neglected. These methods generally have affects on both architectural structure and space.

Key words: Nature % Natural organisms % Technological architecture % Contemporary architecture

INTRODUCTION

The Importance and Necessity of the Topic: "In animal, plant and mineral climates, there are interesting structures that are undoubtedly the basis of construction projects and innovation in architecture" [1]. Nature has always been one of the most important inspiring resources of human in life and his products throughout the history. Manifests of nature from the beginning of history on the walls of caves until today in the most advanced industries are proofs of this claim. "Aristotle, the philosopher of archaeological eras, was one of the first people who wrote about nature as the giant source of inspiration" [2]. Conditions of survival in nature have caused the most exploitation gained by spending the minimum amount of energy [3]. Hence any type of development or promotion in the building engineering is possible by the help of nature regulations. There is a kind of inherent simplicity in the nature that by making use of it in architectural designing, we can make the most balanced and beautiful buildings. The inherent regulations within the nature are full of hints that can be used to create varied and endless combinations of structural forms [4]. For example, "snow crystals are fantastic samples of this capability of the nature. Every snow crystal has a six-side, symmetrical and even form and could create unlimited and non-repetitive patterns" [5]. A quality in the final product of architecture from different respects is an eternal necessity in architecture. Hence, with regard to cultural changes, increased awareness and growth of the level of human needs, the society needs new and real patterns for promotion and increase of efficiency of architecture. Therefore, referring to nature and natural patterns, as one of the most important inspiration sources of human in life and his products, could be an appropriate strategy for this purpose. Referring to nature has always been one of the important topics in architecture and its traces could be found in the works of architects and writings of authors. However, the important issue is that, in spite of all these efforts, no specific mechanism has been provided so far to the architects on how to deal with the nature and natural organisms in order to identifying the way of inspiration in architecture. In this research, we study the architecture works containing the desired approaches of research to deal with the amount and the way of exploiting natural organisms in a specific mechanism. In other words, we believe that this is exactly what is needed to help the architects to get inspiration from the nature for the

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conceptual design. Ultimately, this research will show architects the level of inspiration and the sources of nature for their design.

Research Goal: The main goal of this research is to identify such concepts as natural organisms and the way of their manifest in the examples of contemporary architecture works created based on the technology inspired by natural organisms. Here, we only aimed at identifying the existing strategies in natural organisms and getting inspired by them and not using materials and or the energies existing in the nature. To realize this goal, natural organisms, the ways of exploiting them and also the reciprocal architectural influence, technology and nature must be analyzed.

Research Questions: Which exploitation methods of natural organisms have influenced the contemporary technological architecture works? How much is this influence and in which architectural elements it happens?.

International Scope: In the contemporary world, ideas determine the validity and significance of issues. When ideas are pure, architecture, as an artistic and scientific activity, can be proposed as an important issue at the international level and can enhance the artistic and scientific position of the architecture work. So nature, as a huge source and full of useful strategies, can be considered as a pattern for architects seeking the new and efficient ideas in architecture and other technological areas. Scientists and architects have always stressed on the importance of utilizing the nature and pinpointed the natural systems as a measure of progress toward more complexity and beauty [6]. However, based on our studies, there are few reports on the methods of utilizing and patterning of nature in architecture. Nature is the subject of patterning and there is no geographical limitation for using it and this can be considered as a useful strategy at the international level by architects, designers and engineers. Alejandro Bahamon, an architect and researcher of nature, in his book entitled "Animal: analogies between the animal world and contemporary architecture" says: "Although this kind of architecture is considered simple and primitive, certainly seeing it again can achieve very valuable information for researching and developing contemporary architecture. Utilizing these original forms and yet, so practical, rational and stable, in architectural design and construction can be a good alternative for unbelievable complexities that surround us" [7].

Further, there is a kind of inherent simplicity in the nature. If it is converted into design language, a beautiful and delicate building would definitely be created [8]. Accordingly, in this paper, we discuss the methods of utilizing nature in architecture so that architects, designers and engineers can use them in the process of creating architecture-like concept, form, space, etc.

MATERIALS AND METHODS

In the present descriptive-analytical research, archival methods have been benefited to access to theoretical literature of the topic and surveying method (objective observation) has been used to gather anatomical information and analyze them [9].

The Process of the Research: First, by using the archival methods, the theoretical fundamentals about the importance of the issue of nature and the position of nature in the technology era architecture were studied. Then the ways of exploiting nature have been extracted. Surveying methods have been utilized to deal with the analysis of characteristics of case studies. Thereafter, the results of quantitative calculations as well as the qualitative results will be presented. The process of carrying out the research is shown in Fig. 1.

Research Samples: From a lot of the technological works of contemporary architecture created based on natural organisms mentioned in different sources, 16 works were extracted. Since the beginning of the process of using technology in architecture is accompanied by the beginning of High-Tech style, in 1960s, the case samples created from among the technological works in the two time intervals of twentieth and twenty first centuries (8 works per each time interval) and are known in national and international levels, have been chosen and studied in this research.

The Position of Nature in Architecture of Technological Era

Nature and Natural Organisms: Natural creatures, wherein form, structure, function and substance have formed in the direction of a unit purpose, fall under two titles of living organisms and non-living organisms. Each of these organisms has subsets. Living organisms can be divided into two i.e., plant and animals and non-living organisms can be divided into three subsets of minerals and non-minerals and by-animal medium. Mineral organisms include all solid non-living organisms

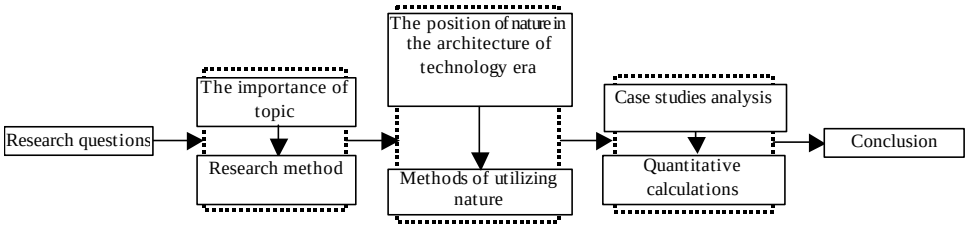

Fig. 1: The process of making research

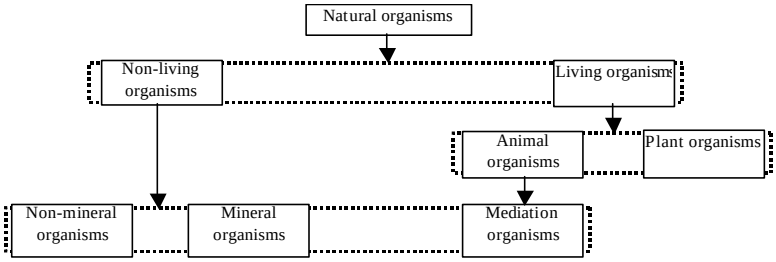

Fig. 2: Classification of natural organisms

and non-mineral organisms include all fluid non-living organisms. It is worth mentioning that some organisms in the nature exist by mediation. These organisms (e.g. bee nest and birds nest, etc.) are created by animals' inherent intelligence (Fig. 2).

Technology, Architecture and Nature: Technology in architecture includes using the techniques to erect a building to confront threatening factors. Jarvis believes that technology is a practical knowledge. Hence, he questions "If the extreme of knowledge and practical wisdom is increased dominance on the nature". Is the entire rational attempt and wisdom of human to dominate the nature and gather knowledge out of it? [2]. Technology is the mother of nature, i.e. architecture is born from technology [10]. Little attempt has so far been done to redirect human's attitude toward the environment in order to restoring the balance that has vanished through the growth of technology. As technology is growing faster and faster each day, some scientists believe that the nature can be the best source for humans to learn from it. They believe that organisms did all the things that humans want to do but without demolishing their environment and future [11]. In a near future, unifying science, technology and humanism, restoring a balanced relationship with nature and reducing pressure on natural resources will be desired [1]. According to Renzo Piano, the process of architecture evolution has changed from High-Tech into Organi-Tech in a slow move because these are the technology and interests seeking that govern the nature and Organic-Tech. Richard Rogers believes that architecture seeks to value the advance of technology and create a human environment adoptable with the environment in accordance with the nature and climate. It seems that throughout the history, technological advances have always been steps that scientists have made one after the other by searching the nature and, in the contemporary period, high ambition ideas of architects with a look at the nature are horizons that make the human be closer to his living environment [12]. The ideas of Alvar Alto in architecture should be sought in a special divergence with architectural topics of Organi-Tech. He looked at nature as a source of inspiration that had a living and dynamic organism but what we witness is an abstract nature that has been specifically manifested in his works [12]. To current architectures, it is desirable that we move from traditional high-consumption developing mode to low-consumption and low-pollution developing mode. Bio-architecture is the essential way for such transformation and also an essential trend to the current world's development [13]. Bionic and biomimicry are some of these trends that try to answer these essentials.

Ways of Utilizing Natural Organisms in Architecture: Juan Torres believes that architecture of future will get inspired by the nature because this method is more rational, sustainable and cost effective than all other methods. Any kind of development or promotion in engineering to reach a favorable architecture is possible by the nature's regulations. Hence, it seems that referring to natural patterns could be an appropriate strategy for architectural efficiency based on Vitruvius's Triangular and newer human concepts in architecture. In this general strategy, different methods exist in using the nature. The principle of deformation enables the designer to

choose a natural pattern that its appearance and system of parts seem appropriate and logical. For its conformity with special conditions and environmental conditions of the desired project, it is changed through separate strategies. The first requirement of deformation is the way of understanding the organizing principles of the initial or main pattern. Therefore, through a set of limited changes and conversions, the main idea of designing could be seen apparently, boosted and made on its basis and not vanished. By methods of using natural organisms, means it is meant optimum strategies that existing in the nature and could inspire and open the ways for human needs in architectural designing. In this research, through analyzing some contemporary technological architecture samples, the ways of using natural organisms fall under six main categories: ornamental use, structural use, functional use, formal use, spatial use and conceptual use. By incorporating the nature into design processes, we can create architecture that continues and expands the natural elements of the location in its morphology. Architectural design is influenced by pre-learned formal languages and the past design experiments of the designer, thus limiting the possibilities. Through designer controlled, we can expand our range of influences and reduce the limitations of our abilities [14]. Hence, by understanding and identifying the characteristics of natural organisms, we may use one or several methods to create architecture work.

Ornamental Use Method: Regarding that aesthetic tendencies exist inherently and by acquisition in human, ornament can satisfy part of these aesthetic tendencies of human. John Berger says: "The aesthetic feeling governing the human being is due from the nature and this feeling is prior to the aesthetic feeling due from human-made products" [15]. Since the nature is beautiful, architect makes his utmost effort to use the attractions of nature and reflect them in his work to create an architectural work for human need. This issue has always been true throughout the history; one of the levels of using natural aesthetics is ornamental use in the nature; either in the architecture of Iran, where natural impressions have been used on bricks, tiles and other products, or in the architecture of the west, e.g. in the Corinthian column heads. All of these prove this claim that using in the level of ornaments in architectural works by architects and artists will always exist. In the ornamental use method, natural forms and shapes are used only to decorate the architectural elements, which occur mostly in two dimensions and in the surface.

Structural Use Method: Whatever exists in the world has a structure. The nature provides a structure for the elements that are created and grow in it. The phenomena of the world are created to achieve objectives and necessary conditions should be realized for these objectives to continue survival [4]. The structure is created as a natural organism structure in various forms based on the function of organisms and interacts with other themes such as form and space that constitute the organism. In some cases, this internal structure is external, while in other cases, structure and other constituting elements of the organism are inseparable, which could be observed for as long as the natural organism has not been decomposed and continues to exist. Unlike a tree where there is no separate structure and skin, conversely, in the organization of an animal, there is severability and if has been made of two different kinds, though none of them exists without the other. "In this process, both the architectural and structural designers attempt to accumulate the architectural and structural considerations by various methods and ideas, which the nature is a manifest and special source for presenting efficient ideas in this regard" [16]. Therefore, when the architect observes and studies the structural elements of natural organism in different moods and analyzes the transfer of forces in it, he/she uses the structure of natural organism and matches it to the architecture work based on the type and objective, like design of Westfield Commercial Project in London.

Functional Use Method: By studying the form and existing characteristics in the nature, we notice that there are precise reasons for their form and existence, such that their forms perform the functions [1]. Hence, the function in natural organisms is a process that leads to the production of a product. Every natural organism has a specific function and has found existence for an objective or set of objectives inside it. For example, in the life system of a tree, production of oxygen and CO_2 is one of the functions of this organism, or in parts of a natural organism like birds' feathers, which are used to protect against warm and cold. Accordingly, nature has many lessons for human in this regard; Erich Hofer says: "By learning the internal functions of the nature, human has changed into manufacturer of machines" [1]. It is obvious that not all functions of the organisms have been discovered yet. The issue of function in architecture is known as an important factor too, because in designing area, the aim of architect is to form the elements in a way that they accomplish their tasks completely [1]. Although

many dimensions of this issue remain vague, but by far we have witnessed numerous cases of the issue of the function in architecture; whether it is an anatomical factor or considered as an external factor.

Formal Use Method: John Ruskin expresses his idea about using the form of nature in architecture as: "Do not imitate anything except the natural forms" [17]. In the nature, what is not strong enough is sentenced to ruin. Hence, only the most efficient and most flexible natural forms have survived during millions of years [18]. As a result, the nature could be a source of formal inspiration for architect designer to identify the samples of natural organism regarding the context and objectives of a project and by considering their natural form, try to understand their proportions, shape, volume and curves. In this way, the potentials of natural form are discovered and used in the architectural work. In this process, the architecture form gets inspiration from the designed natural form. Calatrava is one of the architects who used form and technique in his works: "He has been in search of a new alphabet of form based on principal technique and know-how but he has not always been limited to technique" [19]. From this type, many samples could be referred to in the contemporary architecture of the world. For example, in designing the building of Lotus Temple (India), the inspiration has been got from the Lotus flower.

Spatial Use Method: Space is the essence of architecture and a matter of quality, though formless in the nature but understandable. Lao Tse says: "To make a house, we install the door and windows; however, using the door and windows depends to nothing but space. Therefore, as we use what exists, we should understand using what does not exist as well" [20]. Sometimes to assure a specific quality of space, the architect searches into the nature through specific organism so as to be able to extract spatial quality. As the nature itself is space maker, spatial use could be considered as a method. Natural organisms make a space and a special spatial sense inside themselves or in the environment, which are understandable for some human beings such as the space that exists under a tree and guessable for some humans such as the space inside the shelf of a mollusk. Hence, if we could create the same spatial quality in architecture that a natural organism has created, then the nature has been spatially used.

Natural Organism as a Concept: Natural symbolism is among the other ways of dealing with the nature in the building, which its trace could be seen in the works of a few contemporary architects [21]. "The spiritual message of nature is not only in the general aesthetics of forms, moves and generalities but in the symbols that are direct reflection of various divine specifications" [22]. Hence, this concept is sometimes a reflection of a cultural issue and sometimes of the inherent characteristics of the organism, which are manifested by the architect in his/her architectural work (Fig. 3).

By integrating the nature, technology and humanity in architecture, we may get a kind of architecture that is not only in harmony with the nature, but also in accordance with the locality, culture, spirit and identity that will, eventually, lead us to a sustainable quality of life [23] that is an Utopia in architecture.

Case Studies

In this section, we deal with the analysis of case examples of the research that have been selected from among the contemporary architectural works with architecture technology approach.

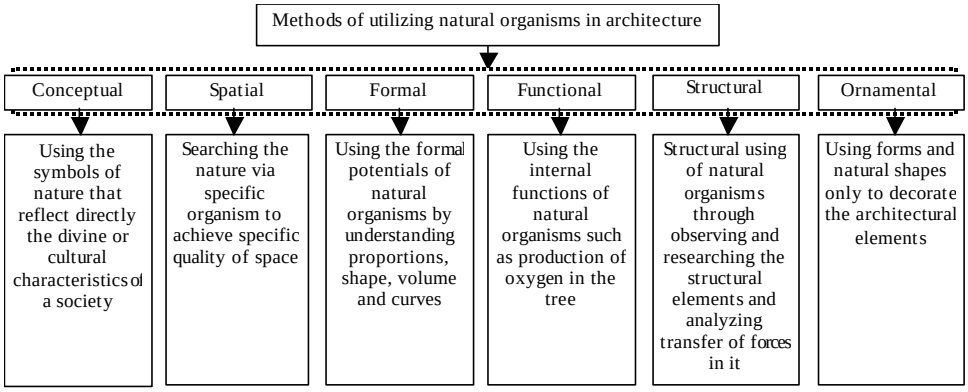

Fig. 3: Methods of utilizing natural organisms in architecture

C.N.I.T. (Nicola Squilla, Paris, 1958): This building reminds sea pearls. In this building, the volume and structure conform to each other. The pearls are used as ornament in form and, hence, the structure of the building. The use of chaff structure of pearls in the building's structure is seen. The pearl form has been used in plan, structure, volume and space.


Fig. 4 and 5: C.N.I.T. and it's inspired natural organism [24].

U.S. Pavilion in Expo 67 (Buckminster Fuller, Montreal, 1967): The geometry of geodesic domes is to great extent similar to the microscopic structure of sea coral. In this building, the volume and structure conform to each other. The structure of coral structure has been used in the structure and volume of the building. The influence of the form of coral structure is seen in the plan, structure and volume of the building.


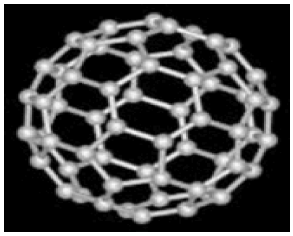

Fig. 6 and 7: U.S. Pavilion in Expo 67 and it's inspired natural organism [25].

Munich Stadium (Frei Otto, Munich, 1972): The stadium of Munich is an example that has been constructed with cobweb inspiration and has a high elasticity as simplicity and beauty. In this building too, the volume and structure conform to each other. Cobweb has been used in the coverage and structure of the building.

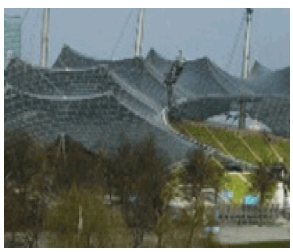


Fig. 8 and 9: Munich Stadium and it's inspired natural organism [25].

Sydney Opera (Jorn Utzon, Syndey, 1973): This building enjoys a port scene with blue coral waves and has an unbelievable brilliance under the sun rays. The idea of architect was to make a building that mirrors the waves of ocean and a clear-cut symbol of the sea pearls. Using the pearl chaffed structure is seen in the building structure. The form of pearl and sea wave has been used in the plan, structure, volume and space of building.


Fig. 10 and 11: Sydney Opera and it's inspired natural organism [25].

Lotus Temple (Fariborz Sahba, New Delhi, 1986): In designing the dome, blue water Lotus flower has been used for inspiration. This beautiful flower is a symbol of purity and worship in India. Lotus has not been used as an ornament but its chaffed structure has been imitated in the structure and the volume of the building. The influence of the form of Lotus is seen in the plan, structure, volume and space of the architecture.

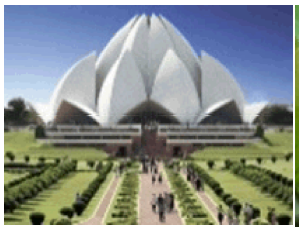
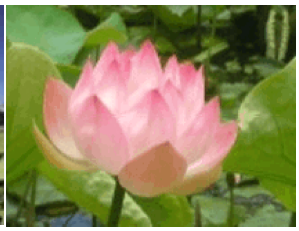

Fig. 12 and 13: Lotus Temple and it's inspired natural organism [26].

TGV Train Station (Santiago Calatrava, Lion, 1994): The symbol designed by Calatrava was a simulation of movement and flying. The curve of structures in the ceiling and transparency of rays in the sides inspire the sense of moving and flying of the birds' wings. The structure of spinal cord and wing of birds have been imitated in the structure and volume of building and ornamental elements have been used in the wings. The influence of the bird form in plan, structure volume and space of the architecture is seen.

The Contemporary Museum of Art (Oscar Niemeyer, Rio De Janior, 1996): Regarding his work, Oscar Niemeyer says: "The ground was narrow and surrounded by the sea. The solution came to my mind automatically


Fig. 14 and 15: TGV Train Station and it's inspired natural organism [27].


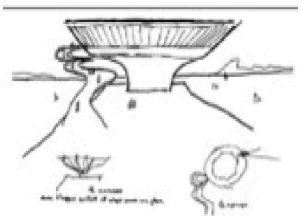

Fig. 16 and 17: The Contemporary Museum of Art and it's inspired natural organism [25].

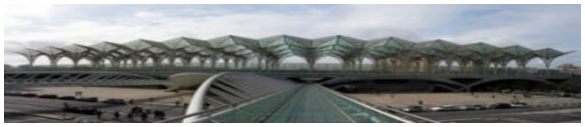

Fig. 18: Orient Station [26].

and naturally. The solution was that the beginning point be a central maintainer. Therefore, the architecture was became automatically a flower; the created line from the ground that grew and expanded continuously." The structure and volume of the building has been inspired by plant structure. The influence of plant is seen in the plan, structure, volume and space of the architecture.

Orient Station (Santiago Calatrava, Lisbon, 1998): The structure of this station has been inspired by the mingled branches of trees according to the regional climates and conditions, which make sunshades that while making shade, facilitate the passage of air. The volume and structure of this building concord and have made use of their own pattern structure. The function of shadowing and air passage has been used in the space. The influence of form of trees is seen in the structure, volume and space.

Paul Klee Museum (Renzo Piano, Bern, 2005): In vicinity of the arched streets of the old city of Bern, a building consisting of three hill-like arches are seen, which like the hills of Alp slopes are part of the topography of this region and no clear border could be seen between it and the surrounding environment. Hence, one can say that the form of topography and hills have been used in the plan, structure, volume and space of the building.


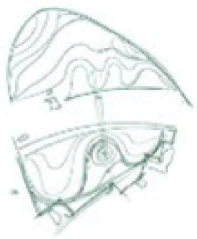

Fig. 19 and 20: Paul Klee Museum and it's inspired natural organism [28].

Parasol Metropolis (Jürgen Mayer, Seville, 2007): This project with its big mushroom-like structure has become the symbol of Seville city. The sunshades have a mushroom-like structure and bee nest nets giving the idea of designing to Jürgen Mayer for Parasol metropolis. Using the mushroom structure in both the structure and volume is seen. The form of mushroom was effective in the plan, structure, volume and space of the building.


Fig. 21 and 22: Parasol Metropolis and it's inspired natural organism [29].

Leaf House (Ivo Mareines and Rafael Patalano, Rio De Janiro, 2007): In this region, many date trees have grown. Hence, the architects have designed a house that its ceiling is like the leaves of a date tree so that when we look at the site from above, it seems as if a bigger date tree has grown in the site. For this reason, in the coverage and structure of the building, the structure of date tree has been used in the coverage, structure and architectural space. Besides, the shading function of the leaves has been used as coverage.

National Stadium of Beijing (Herzog and De Meuron, Beijing, 2007): The internal pattern of this building has been attributed to one of the architectural designers in Beijing and its external architecture to bird nest. In the structure and volume of the building, the structure of bird nest has been used and in the plan, volume, structure and space of the building, the form of bird nest has been imitated. One of the functions of nest is being a house, which has been used here.

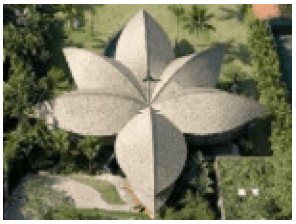
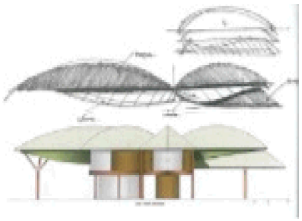

Fig. 23 and 24: Leaf House and it's inspired natural organism [29].


Fig. 25 and 26: National Museum of Beijing and it's inspired natural organism [30].

Water Cube (Joint Designing, Beijing, 2007): This project is like a simple and transparent cube and its structure is very much like the society of water molecules, which have been crystalized as a big cube. The bubble has been used as ornament in the form of volume patterns in the coverage and façade of the building and its structure has been used in the structure. Using bubble as insulator is of functional usage. The bubble form is used in such elements as façade, coverage, structure and space.

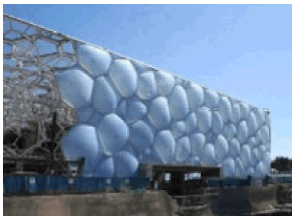
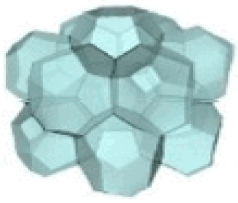

Fig. 27 and 28: Water Cube and it's inspired natural organism [27].

Westfield (Michael Gablini and Kimberly Shepherd, London, 2008): This building has been inspired by the move of wave and interference of water in the nature, in which water, light and soil are the main elements in creation of plants. The pages that remind water and light movements are used as ornament in the coverage. The structure of tree has been used in its coverage and structure. Passage of light and creation of shadow are of the functions of water and tree used in this project. The form of the movements of water and tree has been imitated in the coverage, structure and space of the building.


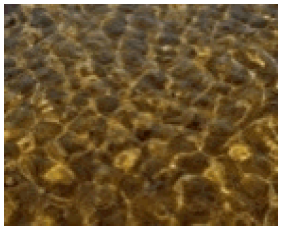

Fig. 29 and 30: Westfield and it's inspired natural organism [27].

Mopi School (Ivo Mareines and Rafael Patalano, Rio De Janiro, 2009): The initial idea and design of this school is attention to the texture of nature and the surrounding forests. The entry façade manifests the trees in jungle due to making the form of trees branches on the entry façade, using the green and white glasses and also using wood for the form of glasses. The structure of tree has been used as the maintaining structure of façade.


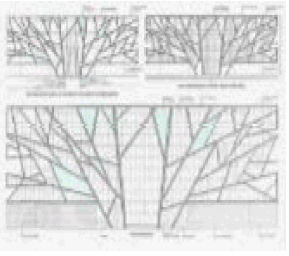

Fig. 31 and 32: Mopi School and it's inspired natural organism [31].

Aqua Tower (Jeanne Gang, Chicago, 2010): The primary idea of Aqua Tower is the coastal rocks of the region and its wavy bank. This wavy nature is shown in the reflection of light during the day. The way of using these organisms is the form that has occurred in the façade. The glass surface, which plays the role of water remaining within the rocks, is regarded as ornamental usage.


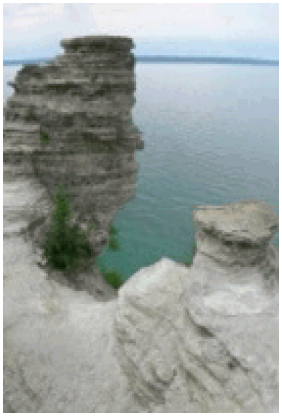

Fig. 33 and 34: Aqua Tower and it's inspired natural organism [26].

CONCLUSION

Based on the analyses we made and the quantitative results obtained in tables and considering the research objectives, the following points can be concluded:

50% frequency in utilizing plant organisms and the high difference of this number with that of other types of natural organisms (Animal, Mineral, Non-Mineral and by Mediation) show the importance and capability of this type of natural organism in taking influence by the architect designers. Although all types of natural organisms are utilized to get inspired in the contemporary architecture works, 100% of samples have been influenced by the form of natural organisms. Then the most important and efficient method of utilizing the natural organisms is the method of formal utilization. Designers, from Future Systems Company to Santiago Calatrava, have used a series of natural forms and tested their effect in creating beauty relative to the ugly designs [32]. Using the structural regulations governing the contemporary architectural works (Method of Utilizing Structure) with 88% frequency come in the second rank, due to the high efficiency of natural organisms. Sha Sha has focused on variation in modern bridge design becoming more difficult. However, by the help of nature, now designers find some new material and structural system in a bridge design that may help innovation in it as well [33]. As mentioned in the text, natural organisms have spatial quality that is sometimes the aim of architect designers in utilizing the organisms in order to access the desired quality. About 69% frequency for the method of spatial utilization confirms the attention of architects. The method of functional utilization with 19% frequency has the minimal attention among the methods of utilizing the natural organisms, which could be due to less attention of the architects to this way of utilization and or lack of technological promotion in using it. This is while using this method could be effective in realizing the objectives of green architecture process, which is one of the vanguard processes of architecture at the present day. In this regard, William McDonough says: "From my designer's perspective, I ask: Why can't I design a building like a tree? A building that makes oxygen, fixes nitrogen, sequesters carbon, distils water, builds soil, accrues solar energy as fuel, makes complex sugars and food, creates microclimates, changes colors with the seasons and self-replicates. This is using the nature as a model and a mentor, not as an inconvenience. It is a delightful prospect" [34].

The effects of the methods of utilizing natural organisms in architecture are reflected on the constituting elements of architecture. Due to the importance of the method of structural utilization of natural organisms and also the influence of structure on the architecture space,

Table 1: Frequency of the type of natural organisms and methods of utilizing them in case studies

		Type of organism																
		Living organism		Non-living organism			Methods of utilization						Architectural elements					
		Plant	Animal	Mineral	Non-mineral	Mediation	Ornament	Structural	Functional	Formal	Spatial	Conceptual	Plan	Coverage	Structure	Volume	Space	Facade
1	CNIT		*				*	*		*	*		*		*	*	*	
2	US Pavilion in Expo 67	*						*		*			*		*	*	*	
3	Munich Stadium					*		*		*	*		*	*	*		*	
4	Sydney Opera		*		*			*		*	*	*	*		*	*	*	
5	Lotus Temple	*						*		*	*	*	*		*	*	*	
6	TGV Train Station		*				*	*		*		*	*		*	*	*	
7	The Contemporary Museum of Arts	*						*		*	*		*		*	*	*	
8	Orient Station	*						*	*	*	*	*			*	*	*	
9	Paul Klee Museum			*						*			*		*	*	*	
10	Parasol Metropolis	*						*		*	*		*		*	*	*	
11	Leaf House	*						*	*	*	*	*		*	*		*	
12	National Stadium of Beijing					*		*	*	*	*	*	*		*	*	*	
13	Water Cube			*			*		*	*	*		*	*		*	*	
14	Westfield	*			*			*		*	*			*	*		*	
15	Mopi School	*				*	*		*								*	
16	Aqua Tower			*	*		*			*			*					*
	Frequency (%)	50	19	13	25	13	25	88	19	100	69	44	69	25	88	63	88	19

among the constituting elements of architecture, the structure and space elements (88% frequency), have taken the most influence from natural organisms. Flexibility and deformation in order to resist the forces in natural structures are much obvious. It is because the birds build their nests on fragile and flexible branches. Using structures with less materials and more flexibility is the example of those architectural works [35]. After that, the elements of plan with 69% frequency and volume with the frequency of 63% have the highest influence. Façade and coverage have the minimum influence among the architectural constituting elements from the natural organisms, which could be attributed to deleting these elements and combining them in the contemporary technological architecture works.

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