Rereading and Analysis of Inspiration from Nature in Design of Structure in Architecture[#]

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Abstract

Surely, the nature has acted as a very favorable guide for human in all sciences, techniques, and arts etc. In architectural field, ancient patterns (sustainable archetypes), clay domes at Arsacid (Parthian) and Sassanid ages (inspired from birds egg), Da Vinci's flying machine (derived from bat feather), manufacturing of submarine (affected by body of dolphins), glassy roof of Crystal Palace (inspired from water lily), conchoidal form of roof in Chapel of Ronchamp, spider-web roof of Montreal Exhibition Building etc. are totally assumed as numerous works which have been designed by receiving original idea from natural elements. Although, the track of architecture- nature relationship is visible in all architectural periods more or less, some of architectural styles after industrial revolution such as romanticism, art nouveau, organic, green architecture, Eco-Tech, Organi-Tech, bionic, and sustainable architecture etc. each of which chose a specific type of relationship to the nature where it has been tried in this study to deal with them. The current research aims to indicate how nature and exploitation from its strategies lead to type of harmony among architecture and structure and such a structure is converted into artistic work. Thus, by analysis of impact of modern structural systems by natural structures and following of successful examples in architecture and structure over the history and resulting styles from architecture, special attention was paid to structural strategies of natural patterns. The achievement of present research lies in employing natural pattern that can be not only an appropriate method to solve architectural issues and technical and professional subjects in construction, but also deemed as an exclusive technique to meet architectural requirements whether from aesthetic and psychological perspective etc. and generally in modern advanced architecture with all the related dimensions. And at the same time the consequences of isolation of architecture and structure in process of designing work results in interpretation of new approach in subjects of designing structure based on study of nature and this approach will be more developed by modern technologies, particularly for introducing modern construction materials.

Key words: Harmony of architecture and structure, Organic- bionic structure, Naturalist architecture, Eco-Tech

INTRODUCTION

Among architectural approaches, relationship with nature has been proposed as the most controversial discussed topic. However, this has been reflected in architectural space at different subjective and physical levels. Some groups have addressed nature in terms of sanity and



logic. Some others have experienced form and space and emphasized in relationship with physical nature. Occasionally, the interwoven relationship among form and function with free and natural forms has been focused. The other group has also sought for apparent relationship with natural elements e.g. water, rain, wind, and sky etc.

With brief implication to geometric structure of nature in this article, developing trend of relationship among architecture and nature has been analyzed over various periods and afterwards it has been discussed about some cases of designing techniques in which the nature, as a platform for creating effect as well as efficient ground has been involved in process of creating pattern and formation of given work. However, what it more

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considered in this paper is to refer to geometric forms in a group of architectural works and in particular for review of responsiveness of structural patterns and their compliance with architectural and structural requirements of construction.

Whereas the homogeneous and synchronous design of structure and architecture always results in design of an architectural work dramatically in its construction process and especially architectural and structural designers have recently achieved various techniques and ideas in trying to integrate architectural and structural considerations therefore among this trends nature has been assumed as intact source for presentation of effective ideas. The structure of nature gives unique patterns in response to each of subjects of architectural and structural designs thereby to become efficient in creating optimal outcomes.

METHODOLOGY

At first step, the development trend of relationship among architecture and nature has been discussed in various period in this essay by means of interpretive- historical method with analytical descriptive and critical expression. In another step, in addition to conduct qualitative review, the important achievements of this paradigm have been mentioned in modern architecture and post period by case studies and hybrid strategy and finally, this issue has been emphasized by introducing distinct examples of this type of design in giving all-out response to loading and structure for this problem.

RESEARCH LITERATURE

Many books and essays have been printed about interaction among architecture and nature in various publications for which the main achievement was a type of implicit glance at architecture- nature relationship and the most relevant and proximate book about interaction among structure and nature is 'Bionic Architecture' written by Mahmud Golabchi and it has been exclusively dealt with case examples in this regard and they have failed to achieve a pervasive model for way of inspiration from natural structures.

Interactive Relationship among Architecture and Nature (From the Beginning to Modern Era)

Any comprehensive insight requires for continuity of thinking in the past and future (Giedion, 2002: 12). Therefore, paying attention and architectural analysis can be assumed as connection and separation links of this topic in architectural subjects in terms of relationship with nature and the criticized structure and decorations thereby to take a step toward future. Review on noticing and taking model from the nature is not a difficult task in all of dead civilizations and in most of examples left from dead civilizations paying to attention is found including the most distinctive artifacts from ancient Egypt i.e. pyramids both traces of cosmic mount and their arrangements are observed from Pleiades cluster, the fractal-like temples in India, mount-like slaughterhouses in South America, pagodas in China and japan, and ziggurats in Mesopotamia are some examples of consideration and inspiration from architecture of nature in the architecture. As it seen in Table 1, this approach still remains (Golabchi, 2012: 41-71).

Similarly, due to adjacency to Mesopotamia civilizations in Iran, the pattern of cosmic mount (Elamite), rock architecture (Medes), architecture with decorations and model of nature (Achaemenid), pendentive arch inspired from quadruped and standing elliptic domes derived from egg shape (Arsacid and Sassanid) etc. are only small examples which witness for paying attention to nature in terms of concept, form, decorations, and in structure (Figure 1).

Adjacency of architecture and nature in Greece (e.g. Epidaurus) and decorations of capitals are good examples. Human, sanity, and nature were three choices for art builders and ancient Greek civilization. Although in most of occasions in ancient Rome, architecture has tried to prevail over nature in terms of linking of architectural size to nature of coliseum (amphitheater), it has looked at nature at least in terms of decorations and forms (After Zarei, 2004: 263-301).

In theoretical field, Vitruvius has also mentioned that the Greeks or people believed that there was no reason what did not exist in real (natural) work to be seen in the imitated work as well since in all their works, Greek people operated according to specific principles of proportion and they enjoyed the methods that resulted from reality of nature. Therefore, using of nature he founded his theory based on this fact that the Greeks had obtained some proportions about aesthetics based on the harmony and symmetry of human body in which the rules and features of construction resulted from them in their architecture. He gave new and symmetrical outlook to architecture; one that originated from most amazing proportions in world architecture i.e. body of human! Then such a perspective appeared in eternal work of Vitruvius human from Da Vinci and several centuries later Le Corbusier as the pioneer of modern architecture put it as the basis in his works and today it is also assumed as the inseparable part of contemporary architecture (Capon, 2009: 64).

Vitruvius believed that the most prefect architecture of world i.e. human body should be considered as the basis

Table 1: Archetype patterns in nature used in architecture (Authors)						
Archetypical	Specific natural samples	Ancient architectural sample	Similar samples from modern architecture			
Cosmic mount	Fuji mount, prehistory natural caves	Ziggurats, the pyramids, Aztec temples	Louvre Museum, Lego Towers			
Spiral cosmic	Spiral Milky Way, conchoidal form	Spiral in Maya civilization, Spiral Nazca, Hegmataneh at Medes era	Guggenheim Museum of New York, City Hall London			
Cosmic tree	Cypress tree, oak tree, pine tree	Angkor Wat temples in India, plant designs in Takht-E-Jamshid	Sagrada Familia Church			
Cosmic dome	Human imagination of sky	Treasury Atreus (Tholos tomb) and numerous domes after it in ancient civilizations	Reichstag dome, America- Expo booth dome 1967			
Flight archetype	Myth of phoenix, Ghoghnoos, Shaman	Lamassu, Faravahar symbol	Chrysler building			



Figure 1: Inspiration from nature in architecture and structure in Ancient Persia Civilization (Authors)

for architecture. For this reason, he classified and called Greek capital based on proportions and arrangements in human body. He also assumed decimal system as the basis for number of hand fingers. In fourth book, he expresses Doric column as holder of power and beauty of man's body proportions and ionic column with feminine intricacy and a decoration similar to tresses of the female and also further coronet column as slim body of damsel with thin decoration. Therefore, height of Doric column should be 6 time longer than its least diameter by assuming capital. As a result, by inspiration from body proportions in female human, he suggested (1:8) ratio (the least diameter to height) for ionic column. Doric style along with masculine beauty that was bare and without decoration was suitable for temples such as Mars as temple for goddess of war and deity of sanity (Minerva). With spiral columns similar to curly and hung hair, ionic style indicated feminine intricacy and proportion and it was appropriate for some temples like temple of goddess of moon and hunting (Diana) and Corinthian style which was seen in different forms from any side on the most beautiful and perfect column he assumed it by inspiration from a slim and lean Greek girl for the temple of goddess of beauty and love (Venus). (Capon, 2009: 64)

The nature appears in Greek architecture in different forms which are visible in foremost architectural aspects (Figure 2).

Tendency to the nature in architecture is seen in many post Christian styles where the peak point of these effects can be observed in Gothic period by utilization from light in architectural work in which exaggerating forms, avoidance from regular and straight lines, creation of dynamics and liveliness, disharmonic decorations, apparent dissymmetry, colorful light in space and also forms with type of geometry close to geometry of nature are visible (Figure 2). During Renaissance and Baroque periods (Figure 3) and especially Baroque era, the first wavy surfaces derived from natural surfaces and shapes as the start point for such naturalism and went to the peak pointin Rococo architecture (Images 1 and 2).

Following to advent of industrial revolution and the time after, the modern movement of theorists such as John Ruskin and William Maurice exacerbated the concern for industrial advancements and leaving art and nature- centered architecture was again reviewed (Mozayeni, 2009: 13-17). In nineteenth century and by arising of romanticism paradigm in architecture, term 'normality' was replaced by word 'regulation' and then natural styles such as Gothic was more widely spread and this factor was led to emerging of naturalistic approaches e.g. neo-gothic (Gardner, 2002: 561).







Figure 3: Effect of compliance of industry with naturalism on art nouveau architecture (Authors)

As a result, the architects such as Horta and Guimar achieved a type on interaction in industrial approaches and naturalism by embedding irony decorations and by the aid of natural forms for which Art Nouveau was the development point and paved the way to form expressionism movement in architecture (Figure 3). Regardless of this trend, the roots of expressionism can be also sought in movements of 'industries and professions' and 'work-bond' (Mozayeni, 2009: 13-21).

Expressionists attached importance for their personal expression and impression about subject or landscape not



Image 1: Notre Dame Church at France (southern edge landscape) as the architecture exploited from natural forms (Gardner, 2002,222)



Image 2: Saint Eve Borromini Church (Gardner, 2002,510)

the related facts [1] and their works could be classified in terms of two features. First category is related to employing circular ductile elements (plastics) derived from organic and biologic structure in human and animals and the second group includes the works for their creation they inspired from crystals and they were especially close to them semantically both with cosmic mystery and geometric perfection and they had special positions in expressionist movement. Expressionists practically assumed Euclidean geometry and platonic and Newtonian shapes as unreasonable tyrannical constraint for art manifestation and they have looked for freedom of living forms and liberty in plurality of formable shapes as well as any type of restrictive classification (Bani Masoud, 2012: 241) (Image 3).

New Tendencies in Architecture- Nature Interaction in Primary Modern Era

After the second half of 20th century ad developments caused by modern researches in various fields of disciplinary sciences, wide efforts were made to remove deficiencies due to primary paradigms in modern architecture (Figure 4), particularly regarding the possible relations among architecture and nature. Organic trend, structuralism, or modern sustainability and ecological approaches have greatly influenced toward revival of primary defects of modern architecture. This attention grew more deeply during postmodern period since necessity of paying attention to ecosystem inevitably caused human to notice nature and related lessons over the history. Under such circumstances, it seems this proximity might appear at the level more than what it imagined in postmodernity so that the outcome of this attention has reached to the climax in some paradigms e.g. deconstructive, folding with themes of localism, regionalism, and fractal patterns and eventually in bionics (Figure 5) (Roohizadeh, 2009: 114).

Modular: During modern period when reasoning (sanity) was assumed as important not body proportions, a type of equalitarianism emerged that led to metric system. Substitution with metric system initially did not exert many changes in proportions and architectural formation system but over the time and discovery of latent features in this system, modulation of modernism and modular system of Le Corbusier was created. Such a discovery caused geometry, which was so far assumed as a connection bridge among architecture and natural proportions, to be destroyed and the architecture to become more dependent on mind. Due to new observation that was completely different from the past in the nature, human could dramatically impact on architecture during recent decades; a type of effect which has been still followed by a lot of hesitation because it stands against all of multi-thousand history of architecture (Bani Masoud, 2012: 139).

Once again in twentieth century, Le Corbusier talked about proportions, but his proportions became known as modular. Unlike other proportions which entered into architectural field from mathematics and geometry, this was calculated and employed by an architect. Although such proportions had been recognized previously, the contribution of Le Corbusier to this subject was in that he could mix a fundamental geometric principle with logical Figureures and various and significant dimensions for human body and motions (Von Meis, 2011: 81) (Image 4).

Organic: The origins of organic architecture can be found in romanticism movement in eighteenth century that was considered as a reaction to rationalism of modern sanity. What it caused to introduce organic architecture as the outcome of romanticism movement was praising of nature, emotions, and imagination by romantic poets. This architectural style was formed by Frank France and Lewis Sullivan in 19th century and the peak point of flourishing of this architecture style may be seen in writings and designs of Frank Lloyd Wright at first half of twentieth century.

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Figure 4: The relationship among nature and structure with architecture in primary architecture (Authors)



Figure 5: Relations of architecture, technology. And nature of postmodernity (Authors)

Sullivan also seriously believed in natural forms and organic style and unlike other modern architects who assumed the form as function of technology and machine performance, he saw function of performance in the process of natural growth and motion.

The organic architecture has been formed under the influence by some cases e.g. integration of architecture with environment and nature, local or environmental architecture, expansion of construction from inside and then outside, use of natural materials and creation of arboreal city. Wright believed in architecture as a natural phenomenon namely organic where humans had right to live in free space; therefore, he mentioned message of space in design of sweeping house not volume (size). Designer draws long, continuous and attached lines to the ground in which construction is perfectly aligned with its natural site (Roohizadeh, 2014: 90).

Paying attention to mechanical conditions and inspiration from anti-seismic nature in a project are the bases for



Image 3: Expressionism architecture; Fredrick Kiesler in endless house (Bani Masoud,2012, 243)



Image 4: Human ergonomics; Human body proportions in design of Le Corbusier (*fa. wikipedia. org. aspx*)

intellectual foundations of Lloyd Wright. After his trip to Japan and paying attention to seismic site of Japan, he design for construction of Imperial Hotel in Tokyo (1916-1922) based on this issue. Wright did not assume modern technology as the ultimate goal in modern architecture, but saw it as a means to achieve higher architecture called organic. The primary houses built by Wright were wellknown as 'floor plan houses' since they had been often built outskirt of Chicago and they were designed in integration and harmony with flat and verdant plains (Ghobadian, 2002: 30-35) (Images 5-7).

Some tendencies to organic architecture are also visible in works of Alvar Aalto and Le Corbusier. Liberty of form is deemed as the foremost reason for popularity of Aalto among modern architects and later this case was considered as one the important of features of postmodern architecture.



Image 5: Organic architecture; waterfall house- Frank Lloyd Wright (Bani Masoud,2012, 252)



Image 6: Organic architecture; Imperial Hotel in Tokyo- Wright; looking at Japanese seismic nature

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Aalto looked at nature as an inspiring source with living and dynamic organism but what it seen distinctively in his works was abstract nature based on which was called ecological modernist (Bani Masoud, 2012: 259) (Image 8).

Architectural sculpture: It denotes benefitting from natural patterns in avant-garde modern architecture in two forms of architectural sculpture with geometric quality (works of Luis Kahn) and architectural sculpture with organic forms (works of Lloyd Wright). The important point lies in sculptured buildings is that in all of them (without exception) concrete was assumed as a very suitable material similar to sculpture paste for creating novel and innovative objects (Images 9-11).

Ecology: Ecology tries to propose new technique to resolve environmental problems and create interaction and balance among artificial and natural environments. Some ecological approaches which have been formed in architectural



Image 7: Organic architecture; Ruby house in outskirt of Chicago/Tallassee, respectively (Ghobadian, 2007,35)



Image 8: Organic architecture: Mira Villa, Aalto (Bani Masoud,2012, 259)



Image 9: Sculpture architects: building of airlines terminal of TWA Inc. at New York (1956-1962), Eero Saarinen, rising birds (Bani Masoud,2012, 244), has constructed concrete, dynamic, buoyant, attractive and suitable statue for the subject

field during recent years have been derived from ectopic attitude [2] and they have typically tried to accept ecological principles as general criteria and framework by ignoring other subjects. However, some others have tried to employ useful features of both by creating peace and interaction among technology and ecology and they are recognized as Eco-Tech [3] (Lafafchi- Jahandar, 2012: 125).

Application of concepts of sustainability and sustainable development has created a topic in architecture called sustainable architecture in which the paramount headlines include titles such as 'Eco-Tech architecture', 'architecture and energy', and 'green architecture'. Sustainable architecture or environmental architecture denotes design and construction based on environmental considerations and by means of local and native materials (Ibid, 127) (Images 12-14).

Eco-Tech: The Eco-Tech architects argue that technology is not against nature but along with it and in parallel with the nature for further exploitation from environmental facilities



Image 10: Architectural sculpture, inspired from sea shells, Chapel of Ronchamp church of Notre Dame at France (Bani Masoud,2012, 285)



Image 11: sculpture architects: Sidney Opera House building has been assimilated to sea shells and ship sails. Concrete beams under levels may strike feathers of birds and flight in mind rather than serrating of shells. (Bani Masoud,2012, 245)



Image 12: Sustainable architecture: Interior design of great greenhouse (1995-2000) locating in national botanical arboretum in Wales, Foster. In this project, the maximum use of glassy surfaces has made possible for maximum exploitation from sunlight which is assumed especially important in design of greenhouse



Image 13: Sustainable architecture: City Hall in Great London (1998-2002), Foster ecological approach has been realized under the aegis of building form

and for providing comfort for the human. Eco-Tech architecture has juxtaposed two objectives i.e. technology and human goals and granted intellectual validity to create human relations. Eco-Tech style is implied with other titles such as Organi-Tech namely organism and technology (Ghobadian, 2002: 122).

Hi-tech: Hi-tech architects did not also overlook the nature. They call building shell as second shell. Similar to the first shell (human skin), the second shell is designed smartly. In other words, shell of some buildings may indicate appropriate reaction versus the given environmental conditions in various seasons. Richard Rogers calls those buildings which are adapted to different ambient conditions under title of 'mantis' (Roohizadeh, 2014:118) (Image 15).

Rather than meeting of human's physical requirements, green buildings also remove his/her spiritual needs and in fact they are systems which represent for sustainable development throughout the society based on human health, productivity, and welfare. For many years, Ken Yeang thinks seriously about climatic buildings. The design of Yeang mainly tends to plan of green skyscrapers. By analysis of climatic elements and their position in design of skyscraper, through structural facilities, he suggests



Image 14: Sustainable architecture: Commerce Bank Central Building (1991-1997) in Frankfurt; as the idea for integration of nature with workplace. This 53-story building is the first ecological tower in which the related concepts to merging of workplace with nature have been realized



Image 15: German Parliament Building in Reichstag; the jointed dome to the building is totally made of glass and this provides the maximum use of sunlight and daily light as well as natural ventilation for internal air

a new type of design for high-rise buildings which are consistent with environmental elements and factors of tropical zones.

- According to viewpoint of Yeang, sustainable architecture is the same as ecological architecture (Bani Masoud, 2012: 345) (Images 16-19).

Organi-Tech: The Organi-Tech (metabolist) architecture is another example of the related architectures to subject of inspiration from nature in architecture. This architectural technique is a theory of Richard Rogers under title that the future buildings will be living organisms i.e. a building with smart shell and structure and even non-static building such as airplane (Dubost, 1996).



Image 16: Eco-Tech- sustainable architecture; Hurst Tower- Norman Foster; this tower is a distinct example of a stable and smart construction



Image 17: Eco-Tech architecture, Ken Yeang, Menara Mesiniaga, Kuala Lumpur, Malaysia (1989-92)

Term 'metabolist' was coined by Kurokawa in Japan in 1960. As it characterized from the word 'metabolist' [4] (means changes in body of living organisms for survival), this school tries to create new relationship among urban elements and architecture (Roohizadeh, 2014: 131) (Image 20).

Dynamic: The open-closed or extensible structures (folding) have been formed and created by inspiration and modeling of nature similar to many human-made objects. Anything is changing and moving in nature all the times and motion also takes place with opening and closing and changing in mode of motor organs. Thus, many examples may be found in nature in this regard including opening of leaves and buds, opening of features in larvae have newly exited from cocoon and at last led to openness and expansion of universe.



Image 18: Eco-Tech architecture; Jean Marie Gibeault Cultural Center, New Caledonia- Renzo Piano, A maquette of climatic details of this complex has been designed under title of independence symbol of Kanak people by inspiring from local architecture of this region. This complex displays new phase as a composition among architecture and nature, and innovation and tradition (Bani Masoud, 2012,353)



Image 19: Eco-Tech: Nicholas Grimshaw, Eden project, UK (1996-2001). The main designing idea is the complicated relationship among human and nature. (Bani Masoud,2012; 355)



Image 20: Metabolist architecture, Nakagin capsule tower, Kisho Kurokawa (Golabchi,2014, 117)

The open-close structure may put many capabilities at disposal and for this reason history of human exploitation from this potential even dated back to ten thousand years ago. The Homo sapiens has lived in plains and has built primary shelters as opening-closed (folding) structures made by combination of skin and bones from skeletons of giant animals e.g. mammoths where this was in fact the first generation of membranous structures as well. However, over the time, the folding structures were utilized as transient structures (scaffold) in execution of heavy buildings (stony, adobe, and brick). Namely, two temporary and permanent structures were used for construction of a building and this made cost of building very expensive (Jahandar, Lafafchi, 2012: 103).

Today, Modern technologies enable us to build permanent structures in forms of temporary structures and scaffold. Namely, the permanent structure is built as quickly as the temporary ones by assembling parts and the folding units and final cover can be installed on this structure. It is noteworthy that folding structure differs from prefabricated structure. In other words, the prefabricated structure is typically used in all buildings. For instance, steel materials are not produced in building but they are transferred to site of building in various prefabricated forms and sections. Of course, a folding structure is also exception to this rule but it differs in that total building structure is perfectly assembled in factory and then structure becomes dense and accumulated with some arrangements (by unfastening of joints or removal of some parts in structure it can be temporarily folded and compressed) so-called flattened then to be opened and expanded later in site of building and to be composed as total structure in building (Images 21 and 22).

Bionic architecture: Bionic specialists try to solve technical problems by user and systems mechanisms and comparable forms found in the nature. They have developed machines and tools for imitation or simulation and reactions and behaviors in order to be organized according to living organisms.

The engineering roots of this insight should be sought in works of Da Vinci. After passing 500 years from time of Da Vinci, today the engineers of various fields try similarly to create relationship between technical scientific rules with world of animals. This is a relationship which has acquired premium position at the beginning of twenty first century and ever-increasing growth in computers and also influenced in world of commercial ideas. One of the first uses of natural creations for innovation in architecture is visible at the start of first half of nineteenth century. The other cases including interdisciplinary cooperation study about structure of human's femoral bones can be observed for making economic and light-weight structure in 19th century as well (Lafafchi, Jahandar, 2012: 116).

Following to start of 20th century (period before modern time) and after a few years at the early modern period, similar efforts are more or less addressed of course they remained mainly as theories. The Le Corbusier's interest in shell-collectors and analysis of body structure of



Image 21: Dynamic architecture of dome, folding structure, Chuck Hoberman



Image 22: Dynamic architecture: Da Vinci's design for flying machine inspired from bat feather, thereby flying machine might fly (generalmedical.mihanblog.com)

these animals can be assumed an example in this regard (Images 23-25).

Calatrava [5] is one of salient architects in bionic style that his designed were inspired from anatomy of animals in the nature. His style is very private and it results from his plenty of studies about physiologic structure of human body and world of nature. He has inspired from structure of human body during rotation in design of rotary body tower in Sweden. The tower structure has been assumed independently in the given site and as a statue so that to be more manifested by its constituent elements. The external steel structure and apparent vertical central core around which spiral tower rotates gives appropriate visual consolidation to that building (Golabchi, 2012: 106-111) (Image 26).

Following to construction of bionic tower (1931) with 380m height, the vertical city was designed according to natural models including lighted weight and strength of birds' bones, flexibility of vegetable structure and growth based on natural model a tree and its dispersed roots and as a result the existing constraints were met in such cities (Image 31).



Image 23: Bionic architecture of Olympic stadium (2008) in Pecking inspired from bird's nest, (Jahandar, 2014, 112)



Image 24: Bionic architecture- Calatrava, TGV station at Lyon city, inspired from body of light-weight bird, (Jahandar,2014, 111)

This in turn was a change in new phase of inspiration from plants nature in architecture. The structural model of bionic tower is mainly inspired from excellent analysis on the existing structural changes in vegetables which may noticeably increase the limit of usual height boundary. This building is composed of several columns in which similar to what it occurs in plants trachea they are tasked with carriage and displacement of inhabitants, water, various available types of fluids and the needed energy for total complex. Structure of these columns is formed by thin and twisted membrane which is covered with specific concrete around it and final formed a capsule shape and it increases strength and consolidation of this system and also leads to flexibility versus decentralized and irregular loading due to wind pressure. The external shell has been inspired from birds' nest and it is solid and at the same time penetrable. The floating foundation and anti-seismic system of this structure has been also inspired from unique property of roots in tall trees (Lafafchi- Jahandar, 2012: 116) (Images 27 and 28).

In architecture, bionics is not summarized only to search in optimal structure of animals and inquiry in way of practices. A wide range of new exposures can be attributed to bionics today. Some topics include review of living processes and inspiring from them for optimization of design at large



Image 25: Bionic architecture- textures of spider's web, Frei Otto, roof of Montreal exhibition (Jahandar,2014, 111)



Image 26: Bionic architecture in design of human body tower at Sweden, work of Calatrava, building structure is also composed of a central core and an external steel structure. (Golabchi,2014, 263)

scale, analysis of processes of design and reorganizing of them by the aid of complicated mathematical models and organic algorithms, use of artificial intelligence and life algorithms for finding optimal forms and forms of growth and many other cases. Inter alia, Greg Lynn [6] may be assumed as one of the founders of new theory in bionic fields in architecture (Image 32). In his opinion, a bionic architect tends to create works which possesses distinct species and symbiotic flexibility with ambient conditions in terms of form or color similar to living organisms (Ibid, 118) (Image 29).

Bionic architecture tries to adapt optimal image of building to nature of animal in best possible way. Works and theories of bionic architects confirm their thoughts are uniquely innovative and they have transformed architectural subjects. The remarkable factors in designing by bionic technique are as follows:

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Image 27: Bionic and dynamic architecture-Valencia sciences and Technics Township, work of Santiago Calatrava, inspired from eye form



Image 28: Bionic architecture- Idea of vertical bionic tower, inspired from the existing structural changes in vegetables

- Nature as inspiring source: Human is deemed as the most essential designing axis and exclusive user of this space- Human is a creative organism that tries to discover unknown objects. Human is assumed as an organism with various spiritual and physical requirements- environment, as human heritage, where we are all shared identically there, and technology is a solution in design not as ultimate goal for it [7] (Ibid, 112).

Paying attention to bionics is considered as the most updated engineering sciences nowadays. There are many inventions since the second half of former century that can be embedded under the aegis of bionics. Inspiring from design of scales and structure of shark's skin was used for invention of a type of paint for airplane that can extremely reduce air friction; structure of water lily in hydrophobic surfaces in nanotechnology; adhesion of gecko foot because of nano-structural form etc. were some of engineering achievements in new exposure. In the architectural field, roof of Montreal Exhibition as a



Image 29: Bionic- dynamic architecture; Kleiborg construction complex locating in Bijilmermeer at Netherlands; Lane gave new shell of mobile corridors to façade of this building with 500 units and area of 1'000m². A layer composed of porous metallic strips, photovoltaic elements and transparent meshes gave completely new character to the building



Image 30: Bionic architecture- Flexibility and displacement of wings has been utilized in building of airplane so that wing tip can be displaced up to 2m in some of these airplanes. This Figureure indicates Gossamer Airplane designed by Paul Maccready. (Source: Image; Jahandar,2014, 96)

work of Frei Otto inspired from solid spider's web; TGV station (1989) in Lyon city built by Santiago Calatrava by inspiration from bird's light-weight body; and or stadium of Olympic games (2008) in Pecking which was inspired from bird nest and roof of Kansai airport in Japan (1995) as a work of Renzo Piano was inspired from eagle skeleton are some of practical example of structural approach toward bionic architecture. It is an interesting point in bionic structural strategies that whenever problems in nature are more difficult, the natural solutions found for them also become equally beauty, accurate, and complex. For example, bone structure of vulture's feather should merge maximum strength and loading in minimum weight of structure at the same time. In this sense, nature solution is extraordinarily fabulous and very beautiful. Bone structure is form in spatial and porous mesh and as a result both strength and light weight structure are provided. The laminar nature causes these forms to be affected by exerted loadings of axial deformations and only tensile and or compressive reactions are created in them. This issue is well visible in wheat stem and or in trunk of tall trees which are bent due to strong winds at any side. Consequently, the flexibility is namely used against loads in manufacturing of airplanes. The needed flexibility is related to take-off in airplane from the ground and led to flight. For this reason, tip of wing in some airplanes may be displaced up to 2m. However, all of structures made by humans are not similar to them and they may not tolerate exerted loads by noticeable flexibility and displacement. For instance, housing and servicing buildings are almost inflexible. It is very difficult, impossible, and improbable for us to think a building with 20 stories is able to move and bend and tolerate loads under impact of exerted loads similar to a tall tree at any direction. In other words, human designs may act completely primitive in tolerance of exerted forces where they may not be comparable with natural methods in this regard at all. For this reason, it is important to study and notice primitive constructions of animals. These are related to the forms of with hundred million years developmental background in some of them form and concept went to the highest level of perfection (Figure 6) (Golabchi, 2012: 123) (Images 30 and 31).

Tensegrity or floating compressed structure has special position in modern structural systems since its structural pattern is very close to nature and at the same time it is light weight with high mechanical capacity particularly in terms of tensile force. The composition of continuous tensile element with discrete compressive elements are respectively similar to performance of muscle and tendons (tensile) and bone (compressive) in body of human and animal (Ibid, 270) (Image 32).

Eco-friendly architecture: It is another type of inspiring architecture from nature; an architecture that is neither hidden from eye of onlooker nor imposes it to the nature but it takes form of nature; an architect has communicated with ecosystem cycle in nature and used maximally the



Image 31: Bionic architecture: Bone structure in vulture wing includes spatial and porous grid. As a result, both strength and lightness are provided. Style of this structure has been utilized in roof of Kansai airport



Image 32: Bionic architecture- Comparison of tensegrity structure in a bridge with skeletal- structure of human muscle



Figure 6: Interactional fields of architecture and structure with nature in bionics, (Sources of images: Golabchi, 2014 & internet)

minimum amount of energy by means of technology. An example of local types of free geometry is visible in world rock architecture. In this mode, space is created inside mass of rock. In rock (stone) architecture, form is the product of space. Such architectural patterns may be probably revived again at present age so that the first-rate architects of present time are not prepared for creation of objects not for prevailing over and display their skill in the nature but architect has tried to create something similar to site and in fact architecture is the continuance of natural volumes on its bed (Lafafchi-Jahandar, 2012: 86) (Images 33-35).

Metamorphosis: It means transformation. It is another type of approaches close to nature. The characteristic of building reinforced by metallic façade includes sharp edges with protruded inclined parts derived from pattern of steep rocks which have been often covered by slant or folded metallic plates. The foremost feature of this structure is linear arrangements of facades which advance toward Hi-Tech style with grandeur and attraction. Designs are usually composed of various organizational systems which finally create a consolidated totality (Greg Lynn, 1993) (Image 35).

Morphogenetic: (Design of algorithmic structures based on natural studies) it is another approach in treating with nature. Inspiration from biologic forms is deemed as a rich and valuable source for innovations at current time where in addition to orientation of design toward eco-friendly forms, it is led to creative forms as well. There is algorithmic complexity behind any natural form that determines its geometry. Complex natural geometric and fractal forms often possess very simple structural dimensions which can be inspiring in structural forms in architecture. Using computerized models it is possible to discover organizing algorithms for geometry of natural forms and creation of complex and exciting forms which are latent inside simple geometry of that structure (Toni Osterlund, 2010) (Image 36).

Fractal architecture: It is assumed as the peak point for inspiration from nature in architectural form and structure. The fractals are not regular forms unlike forms of Euclidean geometry (there is no straight line). These forms are totally irregular at first place. Secondly, the level of their irregularity is the same at all scales. Fractal object is seen identically both from remote and close distance. In other words they are fractal. Many examples of fractals are visible in the nature. They possess complicated structure at any level of magnitude and their edges and internal faces are not flat and even but they are porous or twisted. A fractal is composed of several connected structures at different scales (Ghobadian, 2002: 166).



Image 33: Eco-friendly architecture: Kandovan village as a type of direct relationship among architecture and nature



Image 34: Eco-friendly architecture: Yokohama International Terminal in Japan (1997-2002); Farshid Moosavi and Alejandro Sao Paulo have both called this design as no-return harbor. A striated shell distributes and conveys the loads through these striations and leads into ground multiplicatively. Furthermore, this type of structure has been designated for coping with transversal forces caused by seismic motions



Image 35: Eco-friendly architecture: Form of Galician peep show, Peter Eisenman, an outlook of eco-friendly architectural site in which main form has been completely reconstructed based on land topography

There are two theories about fractal and its use in architecture and urban development: First group sees fractal geometry and chaotic space that id followed by architecture of cosmic jump as a completely natural subject. What it resulted from human order such as symmetry is considered typically as disorder in disorder and this order is real in disorder [8]. However the second group has introduced geometry as more powerful tool for science and their claim can be assumed as local that is coordinated with introduction of first group. With respect to definition of fractal and chaos there are many examples in architecture which have been formed by inspiring from natural fractals and fractal shapes and use of proportions and iteration at micro and macro scale [9] (Ghobadian, 2007: 167).

Overall, fractal architecture can be divided into two parts: One is classic fractal architecture existing in works of former architects as inspired from the nature and the other fractal architecture belongs to modern period that has been finally led to cosmic jump architecture in contemporary world. Inspiration from local architecture has been explored in natural fractals in 4 different points of world i.e. Africa, Europe, and India and finally in Islamic architectural decorations (Lafafchi- Jahandar, 2012: 66) (Images 37-39).

In book of new paradigm in architecture [11], Charles Jencks [10] has mentioned seven approach of contemporary architecture in his opinion these



Image 35a: Metamorphosis- San Francisco Federal Building and new building respectively (Copper Union)



Image 36: Morphogenetic: The design offered by Ting and Luis Kahn for Philadelphia Tower

seven approach either of them forms some part of great approaches in today world including complexity, inspiration from natural forms, inspiration from structures and data of synthetic world structures and data, application of bubble and dripping forms, utilization from local signs and structures, use of the related icons to modern cosmology and finally creation of ambiguous structures may be interpreted in different forms. In his opinion, these approaches comprise of deconstructive buildings [12] where Guggenheim Museum at Bilbao of Spain, as a work of Frank Gray, is a good example and on the other hand the projects which have not been yet built, they cover architects such as Peter Eisenman,



Image 37: Fractal architecture (Right to left): The top shows Borges cathedral in Spain; Notre Dame de Reims cathedral in France, and the bottom indicates St. Peter dome in Vatican, perhaps this organization has been classified by inspiration from the nature and to conceptualize the intellectual and divine aspects of such a place or the fact is probably is that building of arch in Gothic church has been executed to convey arch, dome, and co nnecting them to other spaces



Image 38: Fractal architecture- The plan of an African house- Zambia; Geometry of these houses is deemed as interpretation of this fact that the father is the boss and members of tribe are his children

Daniel Libeskind, Zaha Hadid, and other architects in this style. He claims that style of aforesaid architects has emerged with applications of new science and they can be perceived with respect to such uses. Namely, theory of complexity includes self-organized systems, fractals, linear dynamics, and arising and self-similarity (Charles Jencks, 2002) (Images 40-44).

Pursuant to power of computer, bionic architects could achieve architectural design in new dimensions but in this course the calculations of complex mathematical model, non-geometric forms, and simulation of living processes



Image 39: Fractal architecture- Fractal geometry in Hindu temples looks like thousands of trees with thousands of branches on each of which thousands of ripe fruits are placed and any fruit follows pattern of branches and these branches also follow the tree as whole



Image 40: Fractal architecture: Holy Family church as a work of Antoni Gaudi in Spain is a symbol of structure of church of Saagra Familia built by Antoni Gaudi in Spain that can be imagined in created forms due to falling a drop into a calm brook where the effect of energy is reduced by leaving away from center of energy (Main tower of church) but this effect is the same as what is visible (Golabchi, 2014,121)

became possible. Of course, it is seen that some tool is used in complex designing systems in many projects during two recent decades. Projects such as Guggenheim Museum [13] (1991) built by Frank Gray [14] after making the clay stereotype and it was totally design in 3-D virtual world of computer and or some project e.g. Max Reinhardt Huss [15] (1992) designed by Peter Eisenman where they utilized complex software systems to develop primary forms based on nonlinear mathematical algorithms (Image 45).

DISCUSSION AND CONCLUSIONS

Always a point is assumed as noticeable i.e. construction by exploring previous architectural works in which design was formed in coordination with structure and also the recent works such as ones from Norman Foster where the principle of stability and conveying forces form his buildings and or designs made by Calatrava in his works inspiration from the nature moves from analysis to comparison and also works of followers of deconstruction style in which they



Image 41: Distinct example of fractal geometry in cornices: Sheikh Lotfollah Mosque in Isfahan (Jahandar,2012, 73)



Image 42: Fractal architecture- Guggenheim, Bilbao (Jahandar, 2014,71)



Image 43: Fractal architecture: Respectively Royal Pavilion Briton in UK and a complex of water sports in Olympic (2008) at Pecking- a type of fractal architecture is visible in this complex that is inspired from a shell of water bubbles connected together (Jahandar,2014, 72)



Image 44: Fractal architecture: Eiffel tower and Chrysler building in New York, William Von Allen. The Eiffel tower is one of the first modern buildings in which reflection of fractal geometry in its general composition. The geometric frame of Eiffel tower is a perfect symbol of iterated shapes and selfsimilarity and fractal in one word. It is one of the foremost fractal samples. (Source: Golabchi, 2014.69)

hesitantly look at principles of stability. The architecture has always inevitably constructed the works over the history since construction is deemed as the condition for realization of architectural work and regardless of which architecture only remains in theoretical field and never enter in to practical field in architecture. From this perspective, if we assume it requires paying attention to structure as a necessary condition for construction, we can find the initial question mentioned in this study in construction that may involves architecture to be present in this field. At the same time, there is no scape except resorting to nature. (Figures 7 and 8)

During recent period, most of new ideas and concepts are deep-rooted in discovery of attention to hidden angles which are amazingly revealed by observation and natural reflections. An example of these cases which are considered in architectural design by inspiration from the nature is given in the following Figure 9.



Image 45: Fractal architecture - Max Reinhardt Huss (1992) designed by Peter Eisenman based on nonlinear mathematical algorithms (Jahandar,2014, 117) (Image 46)



Image 46: Arta Isozaki, Tower of Mito Art Museum (top), educational complex (bottom)

Architectural modeling of nature takes place unconsciously (archetypical and local architecture etc.) and or consciously (post-Renaissance architecture and especially modern time and postmodernity in the nature and human awareness of the existing rules).

Therefore, architecture should be considered as a living organism since moment of creation with specific attributes and at the same time it should train simultaneously regular and free geometry inside architecture. From this perspective, architecture has many commonalities with topics of biology and nature of course this subject was followed as one always considered by the human; therefore, based on this implication construction is presented as a small component if surrounding nature. Thus, it should operate as a part of ecosystem and enter into life cycle. Hence, quality of interior spaces becomes important in building.

Since the beginning of architecture, inspiration of the nature has persisted similar to a continuum and it had some intensity and weaknesses of course. However it has not stopped and especially following to growth in

Architectural style	Key points	Strategy	Architect	Examples
Renaissance	Human- centered, attention to human dimensions, rationalism	Architecture serves for human	Leonardo Da Vinci	Public halls, servicing spaces
Baroque & Rococo	Mirror versus nature, wavy forms of natural decorations	Emotion is prior to ration.	Michel Angelo	St. Peter church
Romantic (neoclassic, neo-gothic)	Natural sense, spirit, zest and enthusiasm, fantasy	Tendency to imagination and dream, emotion-based, toward unknown land	Charles Garnier	Paris opera, UK Blenheim Palace, Cave Garden UK
Art nouveau	Natural and plant decorations, motion and growth	Peace among art and industry, unity of decoration and structure and favorable performance, deep respect for nature	Horta, Gaudi	Tassel house, Saagra Familia
Expressionism	Excitation, structuralism, circular, crystal	Holiness of emotional perception, creation and manifestation of excellent inspirations	Erich Mendelssohn	Einstein tower
Organic	Naturalist, integration of architecture and nature, local architecture,	Form as function of practice in process, growth and natural motion of garden city	Wright, Alvar Aalto	Wrights; waterfall house,
Architectural sculpture	Free geometry, organic Rome, dynamic and buoyant architecture	Building as an urban statue	La Corbusier, Eero Saarinen, Ando	TWA airport, Chapel of Ronchamp
Eco-Tech	Ecology, technology, mantis and green building	Form is a function of climate, maximum use of natural features	Norman Foster	Commerce Bank, Ken Yeang tower
Hi-Tech	Smart architecture, technology coordinated with climate	Second shell, mantis	Norman Foster	Reichstag building (Germany)
Organi-Tech	Live architecture, smart shell, smart structure, metabolist	Building as a living organism	Richards Rogers	Nakagin capsule tower
Bionic architecture	Living systems, dynamics, simulation of nature, motion, dynamism, growth	Benefitting from all aspects of form, function, structure, structural details, formative decorations	Calatrava	Turning (torso) tower
Metamorphosis	Metamorphosis, transformation, deformation	Designs are visually statue-like.	Eisenman	San Francesco federal building
Fractal architecture	Disorder, chaos, fractal, scale-less, fuzzy logic	Peak of inspiration of architectural form inspired from the nature and natural structures	Eisenman, Frank Gray	Guggenheim museum
Eco-friendly architecture, folding	Ecosystem, topography, laminar architecture, buoyant, endless	Architecture takes form of nature	Eisenman, Zaha Hadid, Moosavi	Columbus meting center
Morphogenetic	Biological forms, sustainability, dynamism, growth and adaptation	Design of algorithmic structures based on natural studies	Celestino Suddo	The offered design by for Ting and Luis Kahn for Philadelphia tower
Sustainable architecture	Human, environment, pollution, nature, green architecture, energy	Design and construction based on environmental considerations and by means of local materials	Norman Foster	Masdar city

Figure 7: Conclusion of architectural styles inspired from the nature in modern period, ***



Figure 8: General patterns of nature in architecture and structure (Authors)

technology and unlike expectation of modernists, it was strengthened every day while this point may be perceivable that dimensions of this modeling become widespread daily. Inspiration from the nature in architecture and other sciences will be never outmoded and it is surprising that in postmodernist world all industries and particularly

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Figure 9: Works of productivity of nature in architecture and structure (Authors)

architecture have tried to take models from the nature since the works of world first-rate architects these days have been likely culminated in subjects of form, concept, installations, construction, and structure by benefitting from the nature and the way is still open for new discoveries.

ENDNOTES

- Philosophical bases of these movements include negation of history and status quo, belief in its own authenticity, sacredness of sensual perception and finally creation and creativity as manifestation of excellent inspirations.
- 2. Ecotopia has been translated as eco-city similar to term 'Utopia' which has been translated as ideal city.
- 3. Eco-Tech
- 4. metabolism
- 5. Santiago Calatrava
- 6. Gerg Lynn
- Lecture made by Greg Lynn in Max Museum on 11th November 2003
- 8. Symmetric in Choas
- 9. Term fractal is derived from Latin term (fractus) means a stone broken into irregular forms- In 1975, this term was coined by Benoit Mandelbrot.
- 10. Charles Jencks
- 11. The New Paradigm In Architecture, Charles Jencks, 2002
- 12. Deconstruction
- 13. Guggenheim Museum
- 14. Frank O. Gehry
- 15. Max Reinhardt Haus

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