J. Basic. Appl. Sci. Res., 3(2)1037-1044, 2013
© 2013, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Architectural Constructions Inspired by Nature

Reyhaneh Hoselehdar Saber[1], Behrang Daryayelaal[2]

[1]Department of Architecture, Astane Ashrafiye Islamic Azad University, Astaneashrafiye, Guilan, Iran
[2]Department of Architecture, Roodsar/Amlash Islamic Azad University, Roodsar, Guilan, Iran

ABSTRACT

This article examines the nature as the main basis for creation of an architectural work and an effective context in the process of creating patterns and forming the final work. It continues to discuss the possibility of the application of its strategies in establishing an architectural configuration congruent with its structure.
Since the harmonious and simultaneous design of structure and architecture leads to extraordinary results in designing of an architectural work, many architectural and structural designers have used different methods and ideas in an attempt to integrate architectural and structural considerations. In this respect the role of nature as an important source of efficient ideas becomes evident. Nature offers unique solutions in response to architectural and structural issues; solutions that can prove useful in yielding optimum results.
The issue this article is to discuss is the consequences of separation of architecture from structure in the process of designing and, proposing a new trend based on the studying of nature. By reviewing the attempts by architects in this respect, we can obtain an insight into the question that how nature can guide us to a kind of harmony between architecture and structure which can turn an ordinary structure into an artistic work.
KEYWORDS: Nature, natural structures, a work of architecture, harmony between architecture and structure.

INTRODUCTION

Contrary to the notion that the nature model-being was founded by a group of modern architects and engineers in architecture, the nature has been always throughout the history of human life a comprehensive model and reference in meeting the human needs and formation of the artifacts manufacturing process.

Centuries ago, Leonardo da Vinci studied the body structure of the birds to build the flying machine. In comparing the body structure of different birds, he considered the only way to build the flying machine to inspire from the Bat wings; since the wings of other birds let the wind to pass through them, but the bat wings prevent the penetration and passing the through themselves as a complete membrane or curtain.

Dolphins' body form was a good idea for making submarine. Dolphins can move with a high speed underwater with consuming low energy, which is due the two-layer skin on their bodies that the outer layer acts as a shock absorber in contact with the water and causes the reduced water turbulence in the surrounding with its elastic behavior (Lucian, 1982).These effects in the nature show themselves in the architecture in other ways.

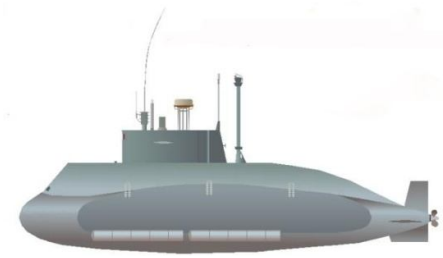

Figure 1: The submarine form

Figure 2: Bat wing structure

Most of the works derived from the nature are a comprehensive combination of diverse and efficient features that have collectively brought a multi-purpose result. In the field of architectural design and structure, nature provides a rich bed that is able to provide a source of countless various structural and architectural adaptations. Separation of structure and architecture in the nature is so difficult and in many cases meaningless, since the natural organisms are coherent structures that simultaneously respond to architectural, aesthetic and structural considerations.

John Ruskin is statesthat: "Architecture value depends on two distinct features: one is anexpression originated from human intrinsic energy and power, and the other is an image taken from the nature's creatures"

Corresponding Author: Reyhaneh Hoselehdar Saber, Department of Architecture, Astane Ashrafiye Islamic Azad University, Astaneashrafiye, Guilan, Iran, Email: r_h_patient @yahoo.com

(Portoghesi, 2000). He also suggests elsewhere that: "No form or layout of forms can be created unless somewhere in the world an example of it exists" (Portoghesi, 2000).

Obvious characteristic of the attention to nature approach and considering it as a model is that the architectural language and structural language of this approach is familiar to everyone without considering and special belongingness and dependency to any particular culture or ecosystem. Using natural ideas in an artificial structure obtains an optimum result that on one hand causes the optimal use of materials as well as the ideal structural stability and resistance. In other words, "there is a kind of inherent simplicity in nature that if can be used in the design of the structure, we could ensure that a harmonized and beautiful structure will be built. Nature teaches us the lesson of structure designing. The snow crystal has a symmetric and uniform hexagonal form and can create infinite patterns that none of them are repetitive.

Every grain of snow crystal is unique meanwhile having different patterns within. Snow crystals are the result of nature miracle in spend the least amount of energy and materials for its formation in interacting with the environment conditions, temperature, humidity, wind speed and atmospheric pressure"(Margolius, 2005).

On the other hand, it addresses the natural attitude and attentions of human being to the nature due to form similarity with natural forms. Aesthetic approaches to the nature are in agreement with architects and artists in recognition of the human tendency to admire patterns referred to the nature. Jenkins alludes in this regard: "It is obvious that the beauties dependent on the nature beauty are older than us and have somehow excited the beauty in us. A fractal pattern of a fern, the Mandelbrot set discovered by computer, math language expressed in the snail's clam, etc prove such a claim"(Jenkins, 2006).

In fact, the nature can be considered as an artistic – structural model, which influences the architecture and structure harmony in addition to providing aesthetic considerations and structural considerations.

From Bionics to bionic architecture

Bionics as a word means biologism or using the nature artificial organs. This term was used for the first time by the American scientist, Major Jack Steel, the U.S. Army Aviation Regiment officer in 1959. He called the science of underlying systems that their foundation are living systems or having the features of living systems or similar to living systems as "Bionics".

At first, Bionics used to study the machines designed and built based on living systems; and now bionics, in any aspect, is considered as the art of deployment of living systems knowledge to solve technical problems.

Nowadays, anywhere speaking of technology, the same picture of critical technology achievements comes to mind that address the basic needs of now and future human being. But looking at the technology path with little care, we will more or less understand the cause of some phenomena, such as every industrial or structural phenomenon has been inspired from which living pattern of the nature.

For years researchers have sought to prove the causation and the existence of this relationship through which they can study and explain the formation process of different systems of life, and that they are who created the "Bionics" by combining two words of "biology" and "technique" from the achievement of these studies as a knowledge to solve the technical issues through biological means.

Although the bionicsis a new and young science, but the bionics scientists activities who are always in search of a living model to explain any phenomenon can be discussed in the field of applied sciences.

Charley Lokston as one of the pioneers in the arena of bionic architecture argue that the focus point of bionic architects is appropriate use of such items in the nature, which cause the building strength and create variety and comfort in the space.

Quickening the building is one of the tendencies in bionic architecture that the designers in this field will achieve it by considering the structure power for respiration (showing livingness) withthe help of pure straight or curved lines and slow induction of the structure integrity. The most important thing for bionic architecture is the building ability to induce its living nature.

Interaction between architecture and nature

Throughout history, many attempts have been done to use the nature in the architecture, and the man has tried in various ways to imitate and use the nature deep knowledge in his work.

Among all these efforts, simulation and replication of environment approaches are as the important methods. For living creatures, simulation and replication processes have reflected respectively based on functional as adjustment and structural adjustment in the architecture, and are seen in typology processes, artificial structures growth, and in a larger scale, at generating and growth of urban contexts. It seems that in searching for the missing link between nature and architecture, the study of simulation and replication trends in nature is essential.

Nature interacts with architecture in various forms, some of which may include:

1. Nature as a bed for architecture
2. Nature as an architectural element
3. Nature as a guidance in architecture

For example, we will outline few natural models considered in the designing process:

1. Human Body: the human body, with its unique form and consisting of several and distinct parts, has taught the man the first composition law: “Unity in diversity”. Using and inspiring the human body in designing, either consciously or unconsciously, has formed an essential part of all human civilizations regardless of their course of time and place.

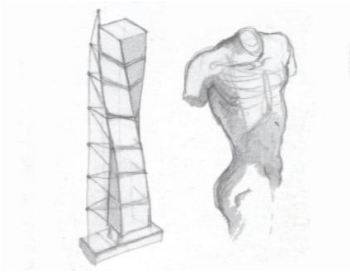

Figure 3: Design of the human body

2. Animals: The use of properties of the various animals’ body forms and shapes has enabled the designers to establish a connection between their ideas and values of society by symbolic imitation. Using the characteristic features of animals and their body parts (wings, claws, skin, etc) in making buildings has been done in order to achieve the magical form. Examples of animals ‘forms in consideration are as defensive form of the turtle body, flexible and fluid forms of birds and aquatics or spiral-shaped body of the snail.
3. Flowers: Centralist models of flowers not only give endless ideas to architects for decorative forms, but the distribution principles and natural organisms formed based on vertical axis with various forms of layered structure display a decorative overlapped layer of petals arrangement around a central axis perpendicular development.

Figure 4: Body form of the birds

4. Geologic terrains: The form and structure of the earth and the variety of forms resulted from natural forces on the lifeless body of the ground has been inspiring for human constructions, from several thousand years old arches of pendulum to non-linear fluid forms in today’s architecture, which reveal instability and inflammation of values in the society.

Beauty, usefulness and sustainability

If we consider the three categories stated by Vitruvius as the three basic goals in evaluating and building architectural work, we will have a triple triangle that comes in the focus of attention in the process of designing an architectural work. This triple according to his theory includes beauty, usefulness, and stability. According to Sir Henry Wotton, these theories were quoted as:

"In architecture, as in all other practical arts, the result should be a guide to practice; the objective should be well building. Well building has three conditions: firmness, commodity, and delight"(Lang, 2005).

But separation of these principles, and in particular their firmness are something that became so obvious in the postmodern era, since by separating structure from architecture during the modern era by people like Le Corbusier, a discontinuity occurred in the architectural design process that thenceforward each of architects, and even the founders of Modernism in architecture tried to repair it somehow. Comparing the Free Plan of Le Corbusier with the Ronchamp Church represents a retrying for joining and integration of aesthetic and firmness considerations.

Beauty, usefulness and sustainability are considered as three integral and fundamental properties in natural components and phenomena, and since the nature essence of nature represents the accumulation of these three categories, revelation in nature and applying hidden lessons and principles in nature can be effective in founding an architectural building or inclusion of three mentioned key principles. Christopher Alexander writes: "In a

system achieved the nature features, the components must have reached to the maximum subtle adaptation and this requires the constant establishment of adaptation process in the current systems"(Alexander,2003).

The elegance established in this system is such that the separation of performance, structure and the beauty of a natural organism would be impossible. Patterns in nature have combined the aesthetic, structural and functional considerations in an ideal way and provide a considered incorporation of a sustainable and pleasant performance. Perhaps, the best way to meet the three main purposes of architecture would be applying the patterns in nature.

Today, many of the structures that can be structurally considered appropriate and efficient necessarily encompass aesthetic considerations. Although, many solutions can be found in constructing a structure to provide the firmness and stability of the building of the structure, aesthetic considerations need a comprehensive approach and application of a multi-purpose structure to be provided by the structure; such a strategy can be achieved by studying and revelation of the nature. The existing structures in the nature provide a numerous range of different characteristics simultaneously.

Lessons of nature

Here, it was tried to provide some examples in four fields of form, structure, compatibility with environment and coordination capability with changes (flexibility) of nature's teachings and its solutions for construction of different buildings associated with images. To do this, a project inspired by nature somehow and capable of meeting its needs, was analyzed.

Water cube project

Unlike normal building in which the building structure is a combination of linear or surface components, at now in answering to the question that how a structure should occupy the space, it can be said that the structure should have the maximum functional and form consistency and fitness with architectural form so that the structure cannot be separated from the architecture.

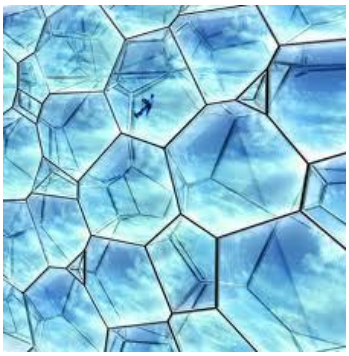

Figure 5: Project appearance

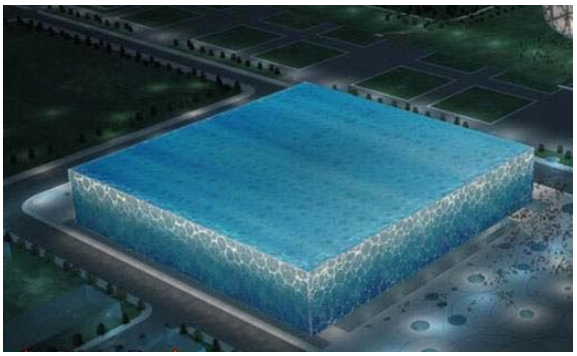

Figure 6: Water cube project

The model of using regular complex volumetric combinations is discussed as one of the best solutions. Volumetric idea of the structures that is repeated with a particular combination and provides the necessary flexibility to the building is the structural pattern of most objects in the nature. The best example in this regard is the crystalline arrangement of the constituent minerals of the rocks. However, this pattern is observed abundantly in the living cells of animates. One of the advantages of volumetric structures is their reproducibility in different directions that the water cube project is a remarkable illustration of it.

Water project is a name that was considered for the project of "Center for swimming and water games "of Olympics in 2008, Beijing. The project looks like a simple and transparent cube with a structure modeled from the accumulation of water molecules (H2O).

1. ***Form***

In addition to the unique structural system of the water cube, which has created a volume equivalent to 177 × 177 meters and 31 meters in height, it can be studied and analyzed regarding several other aspects such as its external covering and function in optimal using of solar energy in the building as well as how to use water use and the recycling of consumed water due to the shortage of water in Beijing. The project has built in a way that its components like roof and walls are combined together such as they become a unit set.

Modeling from water bubbles and soapsuds and their arrangement together creates a cover and membrane that is the most extended coverage between multiple supports. Thus, the best possible covering with the lowest surface was modeled from the soapsuds model. This model provides the least weight than to the most covering.

The project appearance is completely organic regarding the shape and the form, since it is the pattern form of space coverage in several cases in the nature. The form is quite evident in molecular formation of crystals as well as the living organisms' cells.

2. ***Structural systems***

To describe the structure in the water cube building, it can be divided into two components of internal structure and external structure. The internal structure has been used in the depth of the building, and the external structure has covered the exterior sides of the ceiling and walls. The structure is as repeating form as spatial truss components, in which circular steel plates are made with some anticipated holes in every face to connect the corresponding elements with the nodes.

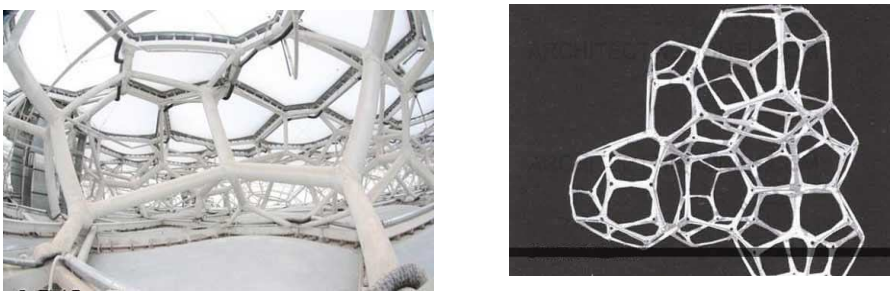

Figure 7: Structural system designed for water cube

Connecting the surrounding components of a node to that node creates a new "component" created by interconnection of these components or elements of space truss. The body structure is formed by placing rectangular components alongside each other. The connection of these components is performed with screws, and finally the structure body is installed above, below and around the internal structure and the integrated key structure is created.

As mentioned, the shape of the final spatial truss is similar to the form resulted from placing a large number of "bubbles" organically together. A total of 4 thousand bubbles form the main structure.

In the idea of this project, architecture and structure are purely integrated and the resulting project has a completely organic property. It is worthy to say that the design of this building, due to its architectural and structural form and the order arrangement of its components together, has made it very flexible and robust regarding the behavior against earthquake forces.

3. ***Compatibility with environment***

4. ***Ability to coordinate with changes***

The final covering of the water project was prepared from a transparent substance called as ETFE, which is an abbreviation of the Ethylene tetrafluoroethylene. This compound is one of the derivatives of fluorine that has extremely surprising properties, including its high durability and lifetime. It is very light as well as insulated, and light can easily pass through it. Compared to glass, the capability of UV waves passing through it is more, and with each time raining, it becomes clean spontaneously.

Figure 8: Compatibility with environment in water cube project

Natural structures

Nature is an inexhaustible source of pure ideas in an evaluated combination of form, structure and function, and the forms found in nature have the most efficiency in order to force transferring by using the

minimum amount of material, and the efficient and functioning natural forms are often accountable regarding aesthetic perspective. Common words such as balance, rhythm, repetition, symmetry, etc. that are often used to describe the beauty of an artwork, have been derived from functional considerations such as efficiency in nature.

Many architects and engineers by considering the natural characteristics and organisms as the basis of their works have done an effective effort in the direction of harmony between architecture and structure in the design process that review of a few samples can be resentful in explaining the considered approach of this paper.

Structural principles of nature in design of architecturalwork

Architecture always involves different issues, and obviously, designing a responsive and efficient work is considered as a major objective in this regard. In this context, many of designers explore and study the potentials of nature from the structural landscape and model a natural structure proportionate to the considered architectural work characteristics. Such an approach initially seems quite structural, but simultaneously with potential structural-oriented basis, smart selection of the pattern can result in aesthetic consequences.

Milwaukee Art Museum

Construction of this building in an area of 13,000 square meters began in 1994 and ended in 2004. While crossing the Wisconsin street in Milwaukee, Michigan by boat riding, we face with a giant and white structure located over a transparent and white building while and takes its wings open and close like a bird. This structure placed on the attached part of the museum is called as canopy. This complex combination of architecture and structure has been inspired from the birds' flapping. Opening and closing of the bird wings of birds is the most complex and critical part of the job, and if it gets out of control, huge losses will occur. Therefore, the bird wings controlling systems have been designed with high precision and predicting all the possibilities.

Figure11: Milwaukee Art Museum

Figure12: Interior appearance of Milwaukee Art Museum

Figure 13: Milwaukee Art Museum

Today, with science advances in genetic fields and fractal theories, new perspectives have created concerning the surrounding nature. With the help of these perspectives, proportional to the environment, and inspiration from the structural styles of nature concerning the new architecture and structure, environmental compatibility and performance type of the designers have led to approached that are complex in terms of technology, form and function, in which the conscious modeling as well as the designers and engineers genius of these projects will be proven.

Buildings Yokohama naval wharf in Japan or most projects of Santiago Calatrava, including Milwaukee Museum amendment plan are as world 's top works concerning inspiration from nature. It is a large building that is similar to bird wings in terms of form and structure with a transparent and white covering. Fro compatibility with the environment and having harmonizing capability with environment changes including the sun set to adjust internal conditions of the galleries concerning lighting and shading, the huge wings are lifting and provide appropriate and essential internal conditions.

On the other hand, the Spanish architect, Santiago Calatrava, also believes that morphological perspective and the nature structure are inspiring of new forms and shapes, and man can discover a complex mystery by studying the nature and creatures skeletons, which are quite stable in its fundamental and structural principles. Calatrava refers to the dinosaur skeleton. He, himself, as an architect and a great engineer of structure, acquire the ability to build his rare and strange combinations through inspiration in a world with so difficulties to create an architecture work (Diba, 2006). He uses dynamic ideas of natural biological structures that simultaneously encompass flexible firmness, aesthetic and functional considerations. His work instances have created statuesque, sustainable as well as flexible structures by taking ideas hidden in the nature. A structure designed by him in Milwaukee Art Museum, with similarity to a bird wings, has the capability of opening and closing feature, and thus, has created a stable and meanwhile dynamic structure.

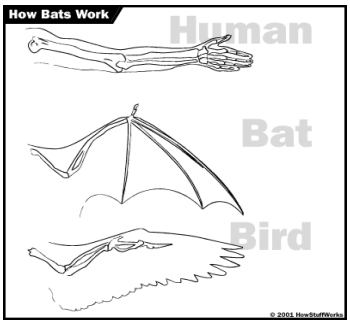

Figure 14: Inspired from the bird's wings

The functioning system of the wings, which gives the flexibility capability to the project, consists of four main components:

A. Small hydraulic power plants with strong pumps and motors for producing power
B. Hydraulic cylinders with eleven symmetrically arrangement on each side of the central axis of the building that open and close proportionate to the environment conditions.
C. Hydraulic manifolds that determine the consistency and operational logic of the system.
D. Central electric control system

Solving the dynamic problems of wings and determining the forces exerted from wind on the structure is of complex actions of the project that while preserving its beauty could provide a proper performance in terms of structure and setting the environmental conditions within the building.

<u>City of science & arts</u>

With an area of 350 thousand square meters, is located in Valencia, Spain. The building contains different parts, including SkyView, Museum of Science, Parking Building and House of Art.

Figure 15: View of the city of science and arts

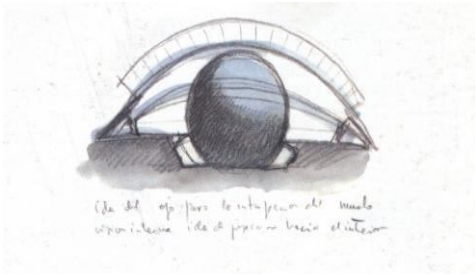

Figure 16: Blueprint of the city of science and arts

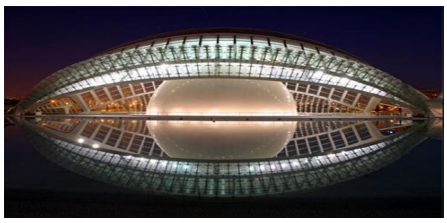

Figure 17: Night view of the city of science and arts

Calatrava, the creator, says: As this site is close to the sea and Valencia is a dry region, I decided to use water as an architecture reflector and an indicating element in the site. Shallow pools are placed around the building. The heights of entrance sunshades, which are adjustable by hydraulic arms, extend to the ground, and since the entrance is in the basement, it causes its closure whenever required. In addition to structural characteristics, in the sky-view section, the form of eye was used for inspiration.

Conclusion

According to Christopher Alexander, architecture needs to achieve a degree of natural features, since:

"The nature characteristic of nature is not only a poetic metaphor; it is a special form and body character that is in common among all things in the universe, which are not man-made.... Nature is never modular. Nature is full of similar units (waves, raindrops, leaves, grass). Although all the individuals of each type are similar in general structure, but no two of them are the same in details...."(Alexander, 2003).

An organism depends on its abilities to respond to the environment to survive. The life of a structure is also dependent to its relationship with nature. Considering that the form is formed due to interaction with nature and according to the processes occurred in past and at the present, it can be conjectured that nature-inspired constructions will be done in the future with more speed and precision.

This paper aimed at explaining comprehensive and encompassing approach of considerations related to form, function and structure in the designing process in order to create harmony between architecture and structure based on applying the lessons of nature. Accordingly, the goal was not merely formal, superficial or structural utilizing o natural patterns; rather, coordination, integration and non-separation of form, structure and functioning in the nature were modeled, and a holistic approach was accordingly developed. In nature, form, performance and structure are considered as indivisible and integrated principles, and separation of each one seems irrelevant. The forgotten comprehensibility in the design process of architecture and structure of a work as well as applying the nature's lessons can play a major role in creating an approach in this filed.

Review of the fundamental and important issues about the natural structures, such as simulation the trees system in the structure and building installations, enhancement of flexibility of building structures up to the structural system of the human body, the possibility of building self-healing like living organisms, achieving smart structures for compliance with different external conditions provide the required ground for achieving greater structural firmness and stability in the buildings.

REFERENCES

1. Alexander, Christopher, Architecture and Secret of Immortality, Ghayomi Bidhendi, Mehrdad, First Edition, Tehran, Shahid Beheshti University Press,2003.
2. Jencks, Charles, The *architecture* of the *jumping* universe, Ghobadian, Vahid and Sattarzadeh, Daruish, Second Edition, Tabriz, Azad University Press, 2006.
3. Lang, John, Creation of Architectural Theory, Einifar, Alireza, Second Edition, Tehran, Tehran University Press, 2005.
4. Margolius, Ivan, Architect, Engineer, Structure, Golabchi, Mahmoud, First Edition, Tehran, Tehran University Press, 2005.
5. Lucian, Jordan, Bionics (Technology Inspires from Animals), Translated by Behzad, Mahmoud/ Ghavami, Parviz, Tehran, Soroush Press,1982.
6. Gideon, Zygfryd, Space, Time and Architecture, Translated by Mozayeni, Manochehr, Tehran: Elmi-Farhang Press, 1987.
7. Salvador, Mario, Structure in Architecture, Translated by Golabchi, Mahmoud, Tehran: Tehran University Press.
8. Mashayekh, Faridani, Saeed, "The Art of Engineering", Journal of Sofeh, No. 27, 8th Year, School of Architecture and Urban Planning, Tehran University.
9. Sadighpoor, Robin and Raphael, "A Structure Made of Bubbles", Architect Magazine No. 31, 2006.
10. Afshar Naderi, Kamran, "From Idea To Form", Architect magazine, 1th Year, No. 4, 1996.
11. Nouhi, Hamid / Zibafar, Javad,"Structural Principles of Nature," Abadi Journal, No. 15.
12. Interview with Greg Lynn, "Dynamic Space", Journal of Architecture and Culture, No. 17, Spring,2005.
13. Hakim, Negar, "Bionic Architecture and Greg Lynn Thoughts", Architect Magazine, No. 23, 2004, Winter.
14. Diba, Darab, "Today's Pluralistic Views in Architecture in Tumultuous world", Journal of Architecture and Culture, Year VII, No. 24.