The Design Characteristics of Nature Inspired Architecture

Kanggeun Park*1

1 Professor, Architectural Engineering Dept., I’ST Institute of Technology, Republic of Korea

Abstract

The forms, structures, systems, processes and organisms in nature have been widely assisted designers and architects in finding improved and innovative solutions. Architects have been inspired from the shape and function of nature in order to seek new design sources from natural elements in building design. A nature inspiration design gets a lot of new ideas from pictures, shapes, mechanisms or organisms that occur in nature. This research is going to find out a way to apply for nature inspired ideas, and then is analysed the existing buildings which include nature inspired techniques and designs. The nature scene offers the glimpse and innovative ideas to draw inspirations for design. When looking at trees, landscapes, flowers, animals, mountains and nature elements, architects can find unusual perspectives, visually interesting ideas, special shapes and structures, creative details and mechanisms. Nowadays the most of cities are filled of buildings similar to supermarkets or boxes, if possible, architectural designs should try to fulfil human emotion through bio-eco-friendly architecture with the beautiful scenery and intimacy as nature. When planning for the future cities, it is important to find how to satisfy our yearning for harmonious interaction with nature, and how to presence the historical character of old buildings well. All of these are related to our fundamental human feelings, can establish holistic relationships between buildings and nature for people. This study is to propose what is nature inspiration for the visual and conception building designs, and then the characteristics of innovative designs and technologies inspired by systems and organisms found in nature. The author will propose for a new retractable cable roof system for long span inspired by spider web and curved shells inspired by sea shell and egg.

Keywords: nature inspired architectures, new retractable cable roof systems, curved shells, systems and organisms

1. Introduction

The nature inspired progresses can be classified into three levels of inspiration that are named as visual, conception and computational level by Janine M. Benyus. A visual inspiration is well understood the shape of various organisms or their systems, and to imitate similarly looking functions and systems. A conception inspiration occurs when designer or engineer applied principles found in nature, and a computational level is inspired by mechanisms or organisms occurring in nature. This study is going to find out ways to create the design of nature inspiration architecture. The research is necessary for architects to get the new design

* Contact Author: Kanggeun Park, Professor,
Hyundai Knowledge Center C-2014, Munjeongdong,
Beobwonro 11, Songpagu, Seoul, South Korea
Tel: 82-2-2306-1111
e-mail: pkg6952@naver.com
sources of inspirations from nature for visual and conceptual design. The study focused on new design buildings are inspired by nature, and it will be explained the design strategy of some famous buildings, structural concepts and technical procedures to create a nature inspiration design. The design characteristics of bio-eco architectures which replicate organisms and mechanisms of nature in order to create an innovative design will be surveyed, and then it will be shown how to seek design processes of nature inspired architecture, and how to get new design sources in nature. This research will propose the retractable cable roof system and curved shell structures inspired by nature.

2. Progresses for Finding Nature Inspired Design

Looking at the world we live in, a design requires seeing nature from a new and different perspective. Depot Staff proposed technical procedures to create a design inspired by nature. 
(1) Take a closer look. The nature scene offers an innovative from all of the details of wet leaf, raindrops, wind waves and color harmoniousness. (2) Find new ideas inspired by shapes, textures and colours from the source for trees, green landscapes, flowers and other foliage. (3) When looking nature of unusual perspectives, we can find more original and visually interesting results. (4) Think of nature in motion. Motion can make nature surprisingly more interesting, and then consider adding motion elements. (5) Think some nature elements such as animal, plant or landscape from dramatically different parts in nature, and try to combine them into an integration design. (6) Focusing on shapes and forms in nature can help designer rethink what they see. Designers can find interesting design details to add creative images to the clouds, birds and other nature elements. (7) Think how you want to feel. We usually fall back on moods in nature that evoke carefree and happy emotions such as four seasons are featured from a clear day to a cold night in winter. Each image sets a different mood. (8) Create an abstract composite of photographs. Another practice is to gather photographs of a variety of things from nature such as landscapes, plants, animals, textures, mountains, valleys, etc., and merge them into one design or composite landscape. (9) Use your imagination. Researching the scenery of new imagination can be an entertaining and educating process that leads to inspiration. (10) Try zooming out and viewing nature from a distance to get a fresh perspective. A broader view of the nature world may be just what you need for inspiration. (11) Create an imaginary nature world. Think of the future for an alternate reality and natural elements in it. Imagining an alternate reality can really get the creative design. Fig. 1 and 2 are important results of new technologies and building designs inspired from the world of nature by Janine M. Benyus.

<table>
<thead>
<tr>
<th>Nature</th>
<th>Inspired technology</th>
<th>Building inspired by nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>Energy reservoir</td>
<td>Plants/Flower: Self-sustainable, Energy efficient, Recycling, Aesthetically appealing, Low maintenance</td>
</tr>
<tr>
<td>Spider web</td>
<td>Tough materials</td>
<td>Spider silk: Resistance to imposed forces, Structural stability, Controlled energy, Regulation of internal temperature, Aesthetics, Acoustics</td>
</tr>
<tr>
<td>Flagellum</td>
<td>Mechanical motor</td>
<td>Bacterial flagellum motion: Dynamic form, Acoustics, Energy efficiency</td>
</tr>
<tr>
<td>Eye</td>
<td>Camera</td>
<td>Arthropod eye: Increase thermal mass capacity, Effective channeling of wind</td>
</tr>
<tr>
<td>Brain</td>
<td>Super computer</td>
<td></td>
</tr>
<tr>
<td>Dolphins</td>
<td>Ship</td>
<td></td>
</tr>
<tr>
<td>Lotus leaf</td>
<td>Hydrophobic surface</td>
<td></td>
</tr>
</tbody>
</table>

Fig.1. Nature Inspired Technology

Fig.2. Building Design Inspired by Nature


Buildings have extensive direct and indirect relationships on the environment surrounding us. During their construction, occupancy, renovation, repurposing, and demolition, buildings use energy, water, and raw materials, generate waste, and emit harmful atmospheric emissions. These facts have prompted the creation of green building standards, certifications, and rating systems aimed at mitigating the impact of buildings on the natural environment through sustainable design in Fig. 3. When constructing buildings, the architects must be responsive to design a home that uses less energy than the average home for net-zero energy,
carbon neutral, an air-tight and well-insulated wall system and a high-performance home design: accessibility, aesthetics, cost effectiveness, functionality, productivity and health, history, safety/security, and sustainability. Fig. 3 shows nature-friendly green building certification criteria and high performance building design criteria.

![Green Building Design and High Performance Building Design](image)

(a) Green building design  (b) Performance building design  (c) Green home design

Fig. 3. Green Building Design and High Performance Building Design

4. The Existing Nature-friendly Inspired Architectures

4.1 Nine Incredible buildings by BBC

Nature-friendly inspired designs are a way of observing the natural world to identify solutions that may enable us to create new design elements that are sustainable. The nine incredible buildings by BBC are the existing nature inspiration architectures lead to new strategies for achieving specific environmental goals.

1. Sagrada Familia; Antoni Gaudi was deeply inspired by the idea of a forest that invites prayer for tree-like columns branch for support and skylights contain green and gold glass to reflect light.

2. Milwaukee Art Museum; The elegant Museum’s most eye-catching feature is its huge sunscreen roof which is reminiscent of great white wings for an open and closing mechanism controlling the screen.

3. Kunsthaus Graz took inspiration from natural forms included looking at microscopic images of sea creatures. The roof nozzles were supposed to move and interact with the sun.

4. National Taichung Theater; Toyo Ito drew inspiration from the formation of rocks, caves and the transience of water for his design.

5. The Gherkin was one of the first environmentally progressive buildings in London. The 180m tower has an air ventilation system similar to sea sponges and anemones, these creatures feed by directing sea water to flow through their bodies designed by ventilation flows through the entire building.

6. Eden Project was inspired by the shape of soap bubbles, and the building’s education center mimics the Fibonacci spiral pattern found in many natural objects such as pinecones, pineapples, sunflowers and snail shells.

7. The “algae house” contains tiny, growing algae which can control light entering the building and provide shade when needed. It’s the world’s first example of a “bioreactor façade”. Algae produced within the transparent shell are continuously supplied with nutrients and carbon dioxide by a water circuit which runs through the building’s surface.

8. The Eastgate was inspired by structures of ant house to create ventilated mounds, permeating them with holes over the surface, the idea that buildings use renewable energy from the environment around them in place of normal air conditioning and heating systems. Eastgate is the best example of biomimicry.

9. Downland Gridshell uses the double-curvature wood structures were inspired by natural observations by a very close relationship to its natural setting when a bird creates a nest from separate pieces of straw.
4.2 Nature Inspired Architectures

The study was a part of wide area that determines how to get inspirations from nature and how to apply visual and conceptual designs in architectural designs. The methodology used the literature survey. (1) Natural spider webs have an analogical structure to a radial cable net, even though spider nets have no any stable or rigidity. Spider web cable is stronger than steel cable in original material properties. (2) The shell construction techniques are well suited for complex curves. Concrete shells used the curved shapes for allowing wide areas to be spanned without the use of internal supports, giving an open and unobstructed interior. (3) Frei Paul Otto designed a lightweight roof of particular tensile and membrane structures, the roof of the Munich Olympic Stadium was inspired the Swiss Alps. (4) The Eden’s bio-dome consists of hundreds of hexagonal and pentagonal, inflated, plastic cells. ETFE film systems can incorporate a number of frit patterns on one or multiple layers to alter their solar performance. Colors can be showed in various tones from red to violet or adding lighting with unlimited color options. ETFE film has approximately 70% acoustic transmission. (5) Beijing National Stadium, also known as the Bird’s Nest, is a main stadium in Beijing. With the removal of the retractable roof, the building was lightened and helped it stand up to seismic activity. (6) The Qizhong Forest Sports City Arena has a steel roof with eight sliding petal-shaped pieces which resembles a blooming magnolia with white color, Shanghai’s city flower. China Wujin Lotus Building and London Lotus City Plan were inspired by lotus flower. In Buddhism the lotus is known to be associated with purity, spiritual awakening and faithfulness.

5. The Development of Retractable Cable Roof System and Shell Structures Inspired by Nature

The structure of natural spider web is an analogical prototype structure to a radial net. Such tension structures inspired by a spider web include inner hoop cables, upper ridge cables and bottom valley cables along radial direction, and bracing cables extending there between. These cable structures can be found in sports arena such as tennis court roof, football stadium roof and retractable cable truss roof systems which have span 100-300m. Retractable roofs are playing an increasingly important role in the development of flexible sports facilities that can be operated in optimal conditions. The retractable roof can be opened and closed in a few minutes. Retractable roofs are generally used in sports stadium where inclement weather, extreme heat, or extreme cold are prevalent during the respective sports seasons, in order to allow for playing of outdoor sports in more favorable conditions. The retractable roof offers perfect playing conditions. A retractable cable roof system is a type of structures in which the part of entire roof can be opened and closed. The cable roof is an effective structural system for large span retractable roofs, the outer perimeter of the roof is a fixed membrane roof and the middle part is a roof that can be opened and closed. The double arrangement cables of a radial cable truss roof system with reverse curvature works more effectively as a load bearing cables, the cable system can carry vertical load in up and downward direction. This paper is to propose a new radial cable roof system with central posts as shown in Fig.6 and 7. Fig. 8 and 9 show curved shell structures inspired by the shape of sea shell and egg.
The nature inspired designs and technologies are a way of observing the natural world to identify new designs and technologies that may enable us to create mechanisms and processes that are sustainable.
for natural ecosystem. (1) The natural inspirations lead to new strategies for achieving new technologies for solving human problems. (2) Nature inspired models are a science that studies nature’s elements and then imitates or takes inspiration from innovative designs. (3) Nature has an ecological standard to judge the rightness of innovation design and technology. (4) After 3.8 billion years of changes and evolutions, nature has learned what is optimal, what is appropriate, and what is last. (5) Nature is a laboratory in which life has evolved adaptations to the challenges of its diverse environments. The organisms of nature are the creative results that developed a sustainable equilibrium conditions in their environments in the Earth. (6) Visual inspirations are used to create building designs or engineering systems that share the same visual appearance of nature. (7) Conceptual inspirations are the use of the knowledge found in rules, principles, or patterns. (8) Computation inspirations such as algorithmic bio-mimicry are searching through nature to find algorithms like evolutionary technologies.

7. Conclusion

This research is a part of wide area that determines how to get inspirations from nature and how to apply the visual and conceptual designs in architectural design. And it showed that nature can be dominant sources of inspiration for understanding and simulating nature’s processes. Nature inspired design seeks to exploit the new concepts of biological design such as bio-eco-friendly sustainable processes, creative designs and complex systems. Inspirations through the forms and bio-system of nature are classified with visual, conceptual and computational inspiration. Nature-friendly sustainable green designs inspired by nature are the concepts for application of the nature’s elements, this challenge seek to new design solutions that can function without pollution rather than just reducing pollution. In the nature inspired progresses and green design concepts, architects will be able to design not only passive, sustainable, nature friendly, bio-eco-friendly, null-emission buildings, but also integrate the entire equipment and power system into the building designs by the visual, conceptual or computational inspiration of nature. The author proposed the a new cable roof system and curved shell structures inspired by sea shell and egg.

Acknowledgements

This research was supported by a grant (17AUDP-B100343-03) from Architecture & Urban Development Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

References