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Nature's Gift: Study on Biologically Inspired Scenario for Construction Industry

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Abstract : *The current society's infrastructure systems are generally based on giving more priority for human – designed systems that only focus safety but not the health aspects. This anthropogenic learning behaviour creates problems which have not been thought to present and is a serious threat to humanity. Many environmental professionals, who understood the impact of such system on the environment, are trying to solve these from nature as an alternative approach. This results in changing the aspect of approaching nature from "enjoying nature" to "learning from nature". For past two decades, many new innovative approaches were put forward to protect the humanity by providing sustainable solutions for the conventional construction process by mimicking nature. Biomimicry engineering in architecture and civil engineering industry is an innovative and creative method, inspired by nature to solve various engineering and environment related issues like reduction in energy consumption, saving energy and cost, and finally all together leads to the reduction of environmental impact. This study gives possible concepts to solve the problems faced in construction field by mimicking the nature as an alternative solution.*

Keywords: *Biomimicry engineering, anthropogenic learning, natural architecture, MemBrain, Engineered Cement Composite, eco-mimicry.*

I. Introduction

We are familiar with the concept of collecting raw materials naturally, bringing them together in an organized way and putting them together in a reasonable and recognizable manner that result in some new form or a structure. In pre – historic era there was a stronger bond between nature and man – made environment. Man started to learn nature, from nature and for nature; i.e., the way animals find shelter and birds building their nest to eat, live and protect themselves. We are doing this for thousands of years starting from Stone Age. At first, this was just a life-saving method, but later we understood the importance of it and started to manufacture new materials that could improve the life of the structure and to protect from even worst climatic conditions. This growth of human beings weakens the bond between nature and man – made environment and sometimes completely lost. For the past two centuries, the needs of society have increased; the global population has continued to rise and the impacts result in environmental pollution and affects earth in the form of challenges such as climate change, resource scarcity and an increasing demand for goods and services [4]. To solve such problems and to create a better solution, scientist approached the science behind nature which leads to the concept of imitating nature's model named "Biomimicry".

Natural Architecture: An endless source of inspiration for scientist and engineers to solve human designed problems. From seeds to trees, ants to mammals, nature provides various models that help engineers and architects to develop new solutions for complicated systems. The natural architecture was no different in receiving inspiration from nature, and it often goes deeper than imitating just the surface features of nature. The best example was the "Root Bridges of Meghalaya". The root of Indian banyan trees (Scientific name: Ficusbenghalensis) have a very strong and long rooting system, manipulated to grow horizontally through the tunnel of hollowed betel nut trunk, providing a stable foundation and can carry 50 people at a time. Initially, a banyan plant was planted on each side of the bank and a length of bamboo was secured across a river. Over the years, the secondary roots of the trees grow out along the bamboo until they meet the middle of the river which forms a stable foundation. Some of these bridges, which take approximately 15 years to become functional, are more than 30m (100 ft.) long and widely accepted that many are in excess of 500 years old.

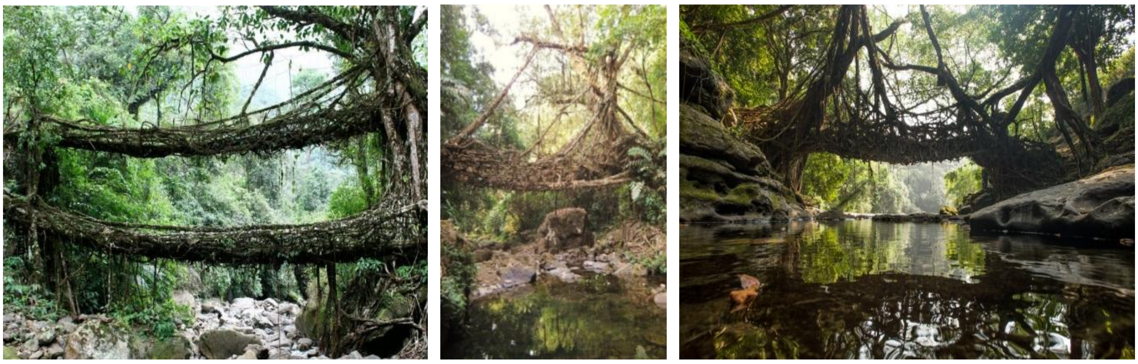

Figure1: Living Root Bridges, Meghalaya, India

This natural architectural concept was studied and coined as "Biomimictics" in 1969 by Otto Schmittin his article "Some interesting and useful Biomimetic Transforms". He has mentioned that some human problems can be solved using certain natural models [5]. In 1997, Janine Benyus describes Biomimictics as "a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems" and coined that nature should be approached as a model (study nature model and imitate its design), as a measure (judge the rightness – what works, what is appropriate) and as a mentor (new way of viewing and valuing nature) [6].

II. Approaching Biomiimicry

Approaching a biomimicry as a design process typically falls into two categories [7]: To solve a human problem by looking to the ways other organisms or ecosystem solve it (design looking to biology), identifying particular properties or characteristics in an organism or ecosystem and translating that into a human need (biology influencing design).

Design looking to Biology approach was carried out by identifying the problem, and then matching it to organisms that have solved similar issue. The approach was effectively led by identifying the initial goals and parameters for the designs. This approach helps us to solve a major problem of heat loss from the buildings, since 32% of energy produced at thermal and nuclear plants were utilized in residential and commercial buildings for humans comfort. Loss of heat will lead to discomfort for human beings and by reducing it, the temperature can be maintained that supports human life. The attempt of solving this problem was succeeded by deriving a solution from biology, inspired by leaves. During photosynthesis, the leaf uses the transpiration process to extract in the carbon dioxide and flush out oxygen into the atmosphere. The skin of the leaf covers by tiny valve-like stomata allows moisture and air to pass through the membrane while excluding large dirt and dust particles from the process. [1] This biology has helped to derive an idea of creating a vapor barrier in buildings that act much like a leaf's stomata. Years ago, several researchers developed a product named MemBrain that acts like a continuous indoor air barrier and creates a better performing building envelope. This membrain was a temperature sensitive product that changes its process according to the temperature. During winter season, when the air was cold and humidity was low, MemBrain closes its pores to reduce air infiltration and improve energy efficiency. In summer months, when humidity was high, the pores of the vapor barrier open up and its permeability increases and again improves energy efficiency. This artificial skin senses climatic conditions and adjusts its permeability to allow the wall to breathe [8].

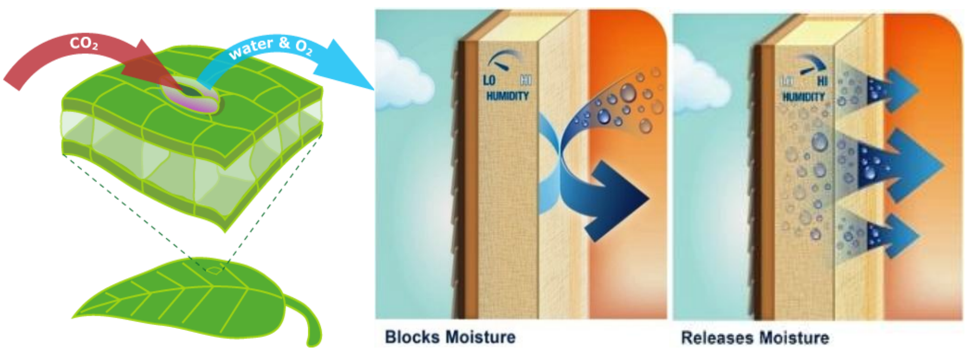

Figure 2: (a) Carbon dioxide enters, while water and oxygen exit, through a leaf's stomata - graphical image, (b) MemBrain blocks moisture – during winter, (c) MemBrain releases moisture - during summer

Biology influencing design needs a detailed study of principle, properties, and the process of biology. This approach was initially dependent on people having clear knowledge about the relevant biological or ecological research rather than on determined human design problems. An example for this approach was demonstrated by Mick Pearce's Eastgate building in Harare. The building was based on termite mounds which have passive ventilation in order to create a thermally stable interior environment. Termite lives in tall mounds (26 feet in height and 10 feet underground) that can maintain the inner temperature constantly (around 85 degrees), even when the outer temperature varies from 104 F to 34 F. This was due to the structure of the termite mound is like a smokestack which consists of small openings or tunnels at the bottom that catch the prevailing breezes. The wet mud of the openings or tunnels lowers the temperature of the air through evaporative cooling [11]. Architect Mick Pearce used the termite idea as the basis for his design of the Eastgate Building in Harare, Zimbabwe. He developed an air - change system that uses a central atrium to passively move air from the base of the building to the stacks on the roof. Along the way, it passes through the hollow spaces under the floors and then into each office through baseboard vents [12].

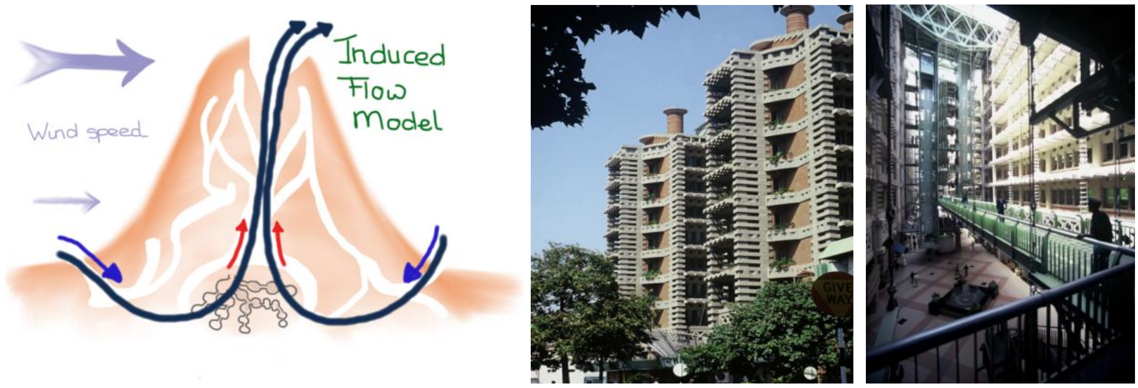

Figure 3: (a) Wind flow model in a termite mound, (b) Eastgate building, Zimbabwe, (c) Eastgate building, interior

III. Levels Of Biomimicry

Nature has a vast and varieties of solutions that make us difficult to select an appropriate solution. To apply the approaches quite easier, three levels were made: The organism level (mimicking a specific organism), the behaviour level (mimicking a specific behaviour) and the ecosystem level (mimicking the whole ecosystem). Within each of these levels, are a further five possible dimensions to the mimicry: what it looks like (form), what it is made out of (material), how it is made (construction), how it works (process) and what it does (function) [7].

The **Organism Level** refers to mimicking a whole organism or a particular portion of an organism. To mimic and produce a design with this level needs a little biological knowledge of the way the biology contribute and participate to the ecosystem. Cactus can be named as a best example for mimicking at organism level, since the plant can even grow in a dry climatic conditions (deserts) with the help of numerous spines that grows along the surface of the plant which not only protects the plant from animals, also they can collect water droplets from fog due to their conical shaped cross section and protects the plant from sun [3]. This concept was inspired by a designing company at Thailand named Aesthetics Architects. They designed a building for the new Minister of Municipal Affairs and Agriculture office (MMAA) in Qatar which has a dry and hot climate and an annual rainfall of approximately 3.2 inches. This building was designed based on the shading properties as like cactus spines in which the shades act like a filter which has the ability to an automatically fluctuate up and down, depending upon the desired interior temperature. This innovative solution allows this building to lower the usage of the artificial cooling system as well as providing a sustainable solution [13].

Figure 4: (a) Spines of Cactus plant, (b) MMAA Building, Exterior, (c) MMAA Building – Interior view.

In Behaviour level, it was not the organism itself that was mimicked, but its behaviour. As like organisms, several human organs also encounter various issues that tend them to change their properties naturally. The best example is the human skin, which has the property of bending, shrinking and expanding depends upon the need. In addition to this, whenever the skin was broken or cut, the tissues and the muscle cells, on each side of the wound start multiplying rapidly and build a "cell-bridge" across the gap results in a new skin. This self – healing and bending property of skin inspired Dr. Victor Li, University of Michigan. He developed a concrete known as an "Engineered Cement Composite" that bends instead of breaking and the cracks get cure by itself without any human intervention [2]. It uses microfibers that allow the final composite to bend with minimal fracturing and if fracturing does occur, the cracks near the dried concrete absorbs moisture from the air, makes the concrete becomes softer and eventually grows until the crack was filled in. At the same time, calcium ions within the crack absorb carbon dioxide from the air that results in the formation of calcium carbonate material that was similar to the material found in teeth and seashells. This regrowth and solidifying of calcium carbonate renew the strength of the cracked concrete. This increases the concrete's strength, durability and reduces premature cracking.

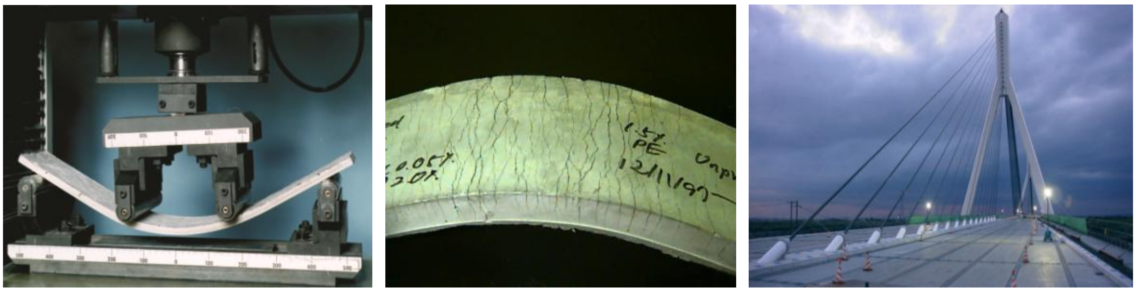

Figure 5: (a), 4 Point Flexural test on a concrete slab, (b) Concrete slab after flexural test (cracks formed due to bending and cured itself without any human intervention), (c) Mihara Bridge in Hokkaido, Japan.

The weight of ECC was 40% less than traditional concrete, consisting mostly same ingredients except the coarse aggregates with some admixtures. Mihara Bridge in Hokkaido, Japan was constructed with ECC for deck slab, with an estimated lifespan of more than 70 years with no maintenance and the cost of construction of the bridge deck was 37% lesser than traditional method since the deck thickness was reduced from 10 inches (25 cm - average deck slab thickness) to 2 inches (5 cm) [10].

The **Ecosystem Level** refers to mimicking an ecosystem (i.e.) its principles, process and elements that are required for it to function successfully. This mimicking of the whole ecosystem leads to a concept called eco-mimicry. An advantage of this level was that it includes the other two levels of biomimicry (organism level and behaviour level). Mimicking a forest can be considered as an eco-mimicry. A forest live and grow by itself (i.e.) it takes everything from natural source, no need for artificial or external source. In such a way, an island was designed by BjarkeIngels Group (BIG) architects that act as a Zero Energy resort, situated within the crescent bay of Azerbaijan's capital Baku, on the Caspian Sea. They designed the whole island that produces enough energy to power the entire island with the help of the sun, the water and the wind. The island also contains desalination plant that converts salt water into fresh water. Photovoltaic panels were designed to be installed on the exterior facades and at the top of the buildings to generate power. With all of these concepts working together, the island becomes a self-sustaining, independent ecological system [9].

Figure 6: (a) Zira Island Master Plan, (b) Zira Island – Beshbarmaq, Savalan Building.

IV. Future Scope

For the past few years, biomimicry is often referred as the tool that increases the sustainability of human designed products and materials. These applications results in a sustainable outcome including better performance, increased efficiencies and environmental friendly. There is scope for further enhancing these applications to achieve solutions with multiple benefits. Future research will be done to replace the conventional shape and size of building foundation by mimicking tree's structure and properties.

V. Conclusion

Considering nature as a source of inspiration was not new, but when we look back, we get a clear picture of the damages that had been done to our nature. The better solution is that we should move in a different direction towards tomorrow without which we may lose our mother earth. Considering nature as our Model, Measure and Mentor can help to design a better and sustainable future. Biomimicry offers a transformational approach to meet the needs of the construction industry through emulating natural form, function, process and systems. Many infrastructure projects understood the current problem and have begun to take measures to address their impact on the environment. Plants and animals have been hard at their work in the classroom of the natural world for a few billion years, preferring solutions for problems and biomimicry offers us a whole new world of possibilities and answers for our modern world. Thus, approaching nature is the right step and is a natural choice. This project has made one understand about the alternate ways by which the construction could be bio mimicked ensuring sustainability of the nature.

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