CONCEPT OF BIOGREEN BUILDINGS: A NEXTGEN OF GREEN BUILDINGS USING BIOMIMETICS

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Abstract- BioGreen is about solutions refined and developed by nature. This paper discusses the potential of the concepts under the domain of 'sustainability' for human welfare by reducing the harmful effects of the built environment on us. It shows the connection between green techniques and biomimetics and to point out applicability of combination of both the methods in construction activities. Modifications in the building services are mimicked from nature such as walls from homeostasis in organisms, natural ventilation from termites, solar panels from photosynthesis, etc. Environmental services such as using CO2 as a feedstock for construction related activities, using Ornilux glasses and saving birds from collision with the buildings, using prefabricated steel for fast building members save time and generate almost no wastes as formwork is avoided. If sustainability is defined as a combination of practices and values, BioGreen fits in the picture with flying colors due to the coverage of both the methods.

Keywords- BioGreen Buildings, Biomimetics, Green Buildings

I. INTRODUCTION

A. Biomimetics

In 1997, Janine Benyus published a revolutionary book called Biomimicry. The word Biomimicry is derived from the Greek words 'bios' which means life and 'mimesis' which means imitation. In her treatise, Benyus describes biomimicry as a new science that studies nature's models and imitates or inspires from these designs/ processes to solve human problems, e.g. a solar cell is inspired from a green leaf [1]. Studying the hydrophobic surface of a lotus leaf to develop self-cleaning paints is an example [2].
Biomimicry as an innovation process that encourages transfer of ideas, concepts and strategies inspired from the nature and living world, with the objective of designing human applications aimed at sustainable development [3].
Biomimicry uses analogies to biological systems for developing solutions for various human problems [4].

B. Green Buildings

Green building (also known as **green construction** or **sustainable building**) refers to both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition [5]. In other words, green building design involves finding the balance between homebuilding and the sustainable environment. This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages [6].The history of green building dates back much further than the 1970's. It was in the midst of the industrial revolution that Henri Becquerel first witnessed the transformation of solar energy into electrical energy, known as photovoltaic power. Around this time, the late 1800's to early 1900's, a number of solar power plants were built to utilize the sun's energy for steam power. Then, in the 1950's, solar energy was used on an extremely small-scale, making way for the solar panel solution twenty years later. [7]Green building is a design and construction practice that promotes the economic health and well being of your family, the community and the environment. A smart step towards personal economic rewards, green building has positive social and environmental ramifications that assert your commitment to the future and the way we live for years to come. [8]

II. BIOGREEN BUILDING

BioGreen concept could offer sustainable alternative solutions to conventional design practice, as its basis is to reduce the energy consumed by the system by combining functions and reducing wastage. It can be applied not only to design the shape of the development but also to provide solutions in construction related operations and processes of development, as well as to the selection of the materials used for constructions

Objectives and scope of work

By applying biomimetics along with green technology the end product discussed herein is an ecofriendly and nature inspired building i.e. BioGreen building which is prefabricated to minimize the wastes produced by the formwork and time factor is looked upon so that it is built in lesser time. Thus the major factors forming the basis of BioGreen building are:

2.1) Green Building applications
2.2) Biomimetics

2.1 GREEN BUILDING

The growth and development of our communities has a large impact on our natural environment. The manufacturing, design, construction, and operation of the buildings in which we live and work are responsible for the consumption of many of our natural resources. LEED, Leadership in Energy & Environmental Design, is the nationally accepted rating system for commercial and institutional green buildings. [9]

2.1.1 Goals of green building

2.1.1.1 Life cycle assessment

A life cycle assessment can help avoid a narrow outlook on environmental, social and economic concerns by assessing a full range of impacts associated with all start to end stages of a process: from extraction of raw materials through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. Impacts taken into account include embodied energy, global warming potential, resource use, air pollution, water pollution, and waste. [10]

2.1.1.2 Siting and structure design efficiency

The foundation of any construction project is rooted in the concept and design stages. The concept stage, in fact, is one of the major steps in a project life cycle, as it has the largest impact on cost and performance [11]

2.1.1.3 Energy efficiency

Green buildings often include measures to reduce energy consumption – both the embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment. [12]

2.1.1.4 Water efficiency

Reducing water consumption and protecting water quality are key objectives in sustainable building.

2.1.1.5 Materials efficiency

Building materials typically considered to be 'green' include products that are non-toxic, reusable, renewable, and/or recyclable. For concrete a high performance or Roman self-healing concrete is available [13]

2.1.1.6 Indoor environmental quality enhancement

Indoor Air Quality seeks to reduce volatile organic compounds, or VOCs, and other air impurities such as microbial contaminants. During the design and construction process choosing construction materials and interior finish products with zero or low VOC emissions will improve IAQ. Most building materials and cleaning/maintenance products emit gases, some of them toxic, such as many VOCs including formaldehyde. These gases can have a detrimental impact on occupants' health, comfort, and productivity. Avoiding these products will increase a building's IEQ [14]

2.1.2 FEATURES

1. Energy efficient equipments for lighting and air conditioning systems & use of onsite renewable energy.
2. Measurement and verification plan to ensure energy & water savings
3. Reduction of building footprints to minimize the impact on environment
4. Minimal disturbance to landscapes and site condition.
5. Use of recycled and environment friendly building materials.
6. Use of Non toxic / recyclable materials.
7. Efficient use of water recycling
8. Indoor air quality improvement for Human safety and Comfort
9. Effective Controls and Building management systems
10. Installation of high efficiency irrigation methods and selection of vegetation which have lower water consumption.
11. Recycling of construction debris to other sites.
12. Use of building materials having a high recycled content.
13. Use of rapidly renewable materials.
14. Declaration of site as “Non Smoking” area or have designated area of smoking.
15. Providing daylight and views for the occupied areas. [15]

2.2 BIOMIMETICS

It offers a theory that can be referred to as model, mentor and measure. As a model, it helps emulating natural design in relation to forms, processes and systems. As a mentor for design, it offers a new way of viewing and valuing nature. As a measure, it uses an ecological standard to judge the sustainability of our innovations [16].

2.2.1 Significant Developments

2.2.1.1 Materials

1. Artificial Aggregates

Coarse aggregate in the conventional concrete are replaced by newer ones by mimicking the natural coarse aggregate. The material is a mixture of waste paper sludge, ash and rubber wood dust. They are produced in the form of pellets of the same size and shape which becomes aggregate after hardening. Its use in concrete is found to yield acceptable compressive strength as compared to the normal concrete mix. Thus it has a good potential to mimic the natural coarse aggregate in concrete which would prevent environmental degradation to a large extent [17].

2. Cement

Production of every ton of Portland cement, which is an important and essential ingredient of modern day concrete as a construction material, emits about 1 pound CO2. Brent Constantz, a bio-mineralization expert from Stanford University (California), utilized biomimetics by observing the construction of the coral reeves. He found coral reef as an application technology for cement manufacturing. It is formed by CO2 gas and ocean water, which have a natural reaction that gives rise to calcification. Thus this process uses CO2, a huge waste resulting from all human activities, as a raw material to create the coral structure. Manufacturing of artificial coral reef using waste gas from a local power plant and dissolving it in water was undertaken [18]. Constantz and his company Calera use CO2 as a feedstock for cement production. Calera's calcium carbonate produced from CO2 is in the form of a fine, free-flowing white powder as shown in Fig. 1. Fig. 1: Calera's Supplementary Cementitous Material [19] It can function as supplementary cementitous material (SCM) that can be used in the traditional concrete mixes where the environmentally sustainable calcium carbonate can replace a portion of Portland cement, helping reduce the overall carbon footprint of traditional concrete without compromising on the strength [19].

Fig.1. Calera's Supplementary Cementitous material

3. Paint

The phenomenon of self-cleansing in case of the lotus leaves and flower was known in Asia since ages. The lotus effect refers to the very high repellence between the leaves of the lotus flower and water. Water droplets pick up dirt particles from the leaf surface due to complex nanoscopic architecture of the surface [20]. This structure is very useful and now widely used for different applications such as self-cleansing paint, known as Lotusan. Fig. 3 depicts the analogy between the lotus leaf and Lotusan paint as well as the concept of self cleansing [20].

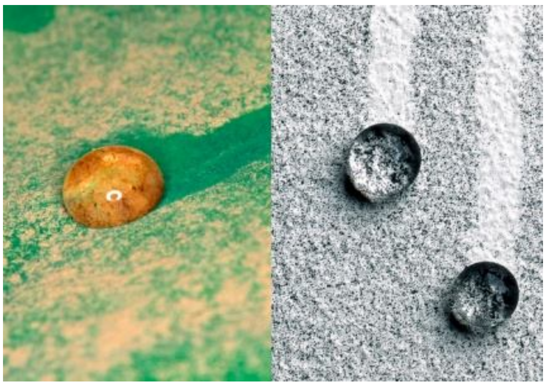

Fig.2 Paint inspired from the Lotus Flower

4. Ornilux Glass

Millions of birds are killed each year by flying into the reflective glass of multistoried buildings of the office and apartments. The reflections of trees, landscape and the sky can make it appear as if the glass is not there. Green building has increased the need for additional glass for interior day lighting creation. The result is an increased frequency of bird deaths each year. The Arnold Glass Company, through the use of biomimetics, looked to spider webs and their ability to avoid destruction by bird flight. Spider webs include a reflective component in the UV range that deters birds from flying into their webs, yet they attract insects such as moths towards their reflective light. This UV component increases the spiders foraging success and avoids destruction at the same time. Arnold Glass has created a product called ORNILUX (Ref. Fig. 4) that integrates this UV reflective pattern into its glass. This resulted in 76% fewer bird collisions in field-testing [21].

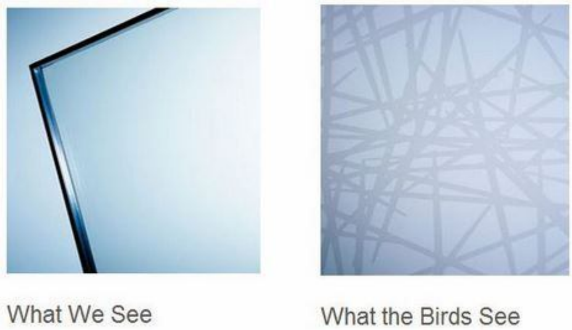

Fig.3 Views of the Ornilux Glass

2.2.1.2 Structures

1. Suspension Bridges

The natural environment in fact inspires a number of structural systems, which are considered great man-made achievements. Suspension structures, such as long span suspension bridges, share the same structural principles with spider's webs. [22]

Fig.4. (a & b) Suspended Bridges and Spider's web

2. Stadia Roofs

Membrane structures, such as modern stadia roofs and canopies behave very similarly to cell walls, gaining strength by being constantly in tension. [22]

Fig.5. (a & b) Stadium roof and cell wall

3. Dome Curvature

The Pantheon of Rome is a biomimetic example, not in terms of its material but because of its structural behavior, which is similar to that of a seashell. Like seashells, the roof of the Pantheon gains its strength from its multi-dimensional curvature, which results in a structure not requiring extra reinforcing and hence being much lighter than conventional reinforced concrete spanning structures. [22]

Fig.6. (a & b) Pantheon of Rome and Sea Shell

2.2.1.3 Services

1. Natural Ventilation

Nature inspired building cooling system comes from the African termite mound. The African termite lives in tall mounds so strong that humans use dynamite to remove them when they are in the way. Relative to a termite's size, these mounds are equivalent to a mile-high skyscraper housing the population of New York. But their real genius lies in their remarkable environmental control system. Even in the oppressive heat of African savannah where temperatures vary from 1040 F to 340 F in a single day. The design of these termite mounds keep them cool (around 850 F) without fans, chillers, or heat pumps. These tall mounds, which can reach 26 feet in height and 10 feet underground, are built like a smokestack, and the termites create small tunnels or openings at the bottom of the mound. These openings are oriented to catch the prevailing breezes, and as the air enters the mound it passes through chambers of wet mud, which lowers the temperature of the air through evaporative cooling. Because warm air rises, the air is drawn through the top of the stack through the 'stack effect' of convection. Architect Mick

Pearce used the termite idea as the basis for his design of the Eastgate Building in Harare, Zimbabwe [22]. Like the termite mound, the design uses the mass of the building as a "heat sink" that insulates the building from the diurnal temperature swings outside. Working with Ove Arup & Partners, 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 hollow spaces under the floors and then into each office through baseboard vents. As the air warms, it is drawn out through 48 round brick funnels. During cool summer nights, fans send cooler outside air through the building seven times an hour to chill the concrete mass of the hollow floors.

This project, which was completed in 1995, uses only 10% of the normal air conditioning required for similar buildings of its size [22]. Fig. 5 shows these details.

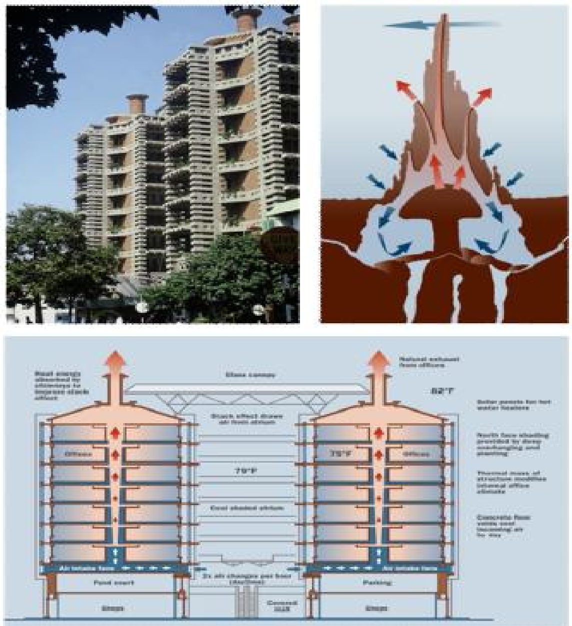

Fig.7. Eastgate Centre natural ventilation and Termite mound

2. Biomimetic Solar Cell

Solar energy drives natural ventilation and the lighting, thereby reducing energy loads during the whole-life operation of the building. The use of solar energy could also be implemented during construction. The building cannot totally provide its own energy needs. Adaptations on the building's external envelope or structure could harvest, store and provide energy when needed [22]. Scientists at Princeton University achieve major gains in light absorption and efficiency of solar cells after being inspired by the wrinkles and folds on leaves (Refer Fig. 6). They created a biomimetic solar cell design using a relatively cheap plastic material that is capable of generating 47% more electricity than the solar cells with a flat surface. They used ultra-violet light to cure a layer of liquid photographic adhesive, altering the speed of curing to create both shallower wrinkles and deeper folds in the material, just like a leaf [23]. Fig. 6: Biomimetic Solar Cell [23]

The team reported in the journal, ‘Nature Photonics’ that these curves on the surface made a sort of wave-guide that channeled more light into the cell, leading to greater absorption and efficiency. The researchers found that the greatest gains were at the longest (red) end of the light spectrum. Solar cell efficiency typically tapers off at that end of the spectrum, with virtually no light absorbed as it approaches infrared, but the leaf design was able to absorb 600 percent more light from this end of the spectrum. Plastic solar cells are tough, flexible, bendable and cheap. They have a wide-range of potential applications, but their biggest downfall is that they're much less efficient than conventional silicon cells. A team at UCLA was recently able to achieve an efficiency of 10.6 percent, which put the cells into the 10 – 15 percent efficiency range considered necessary for commercialization. The Princeton team expects that their leaf-mimicking design could push that efficiency even further because the method can be applied to almost any plastic material. The curing process also makes the cells stronger because the wrinkles and folds relieve mechanical stresses from bending. A standard plastic solar panel would see an efficiency dive of 70 percent after bending, but the leaf-like cells saw no diminished effects. This tough flexibility could lead to the cells being incorporated in electricity [23].

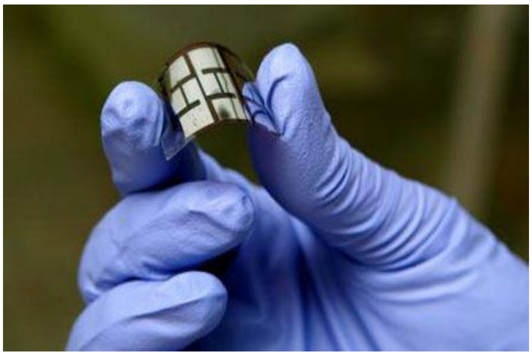

Fig.8. Biomimetic Solar cell

2.2.1.4. Shape/Aesthetics

Our environment’s ever shifting nature has allowed both plant and animal life to evolve and adapt to be able to survive. This amazing process has long been a source of inspiration for designers, engineers and architects for their building projects. This is because these designs are not just aesthetically pleasing but are also practical and innovative as some of them also take on the adaptive features of the things they were based on. Some of them are as follows:

1. Bird’s Nest Stadium

Swiss architecture firm Herzog & de Meuron designed the Beijing National Stadium or better known as the Bird’s Nest Stadium, for the 2008 Summer Olympics and Paralympics in Beijing, China. As the name implies, the stadium looks like a giant bird’s nest made out of 110,000 tons of steel, Refer Fig. 18. [24]

Fig.9. Bird’s nest stadium China inspired by a Bird’s nest

2. BURJ KHALIFA

Burj Khalifa is an excellent example of Biomimetics. The architects say that the organic inspiration for building the structure the way they did was the Hymenocallis flower. Like petals from a stem, the towers wings extend from the central core. One of the architectural engineers, Adrian Smith said that his most inspiring muse was the flower, whose harmonious structure is one of the organizing principles of the towers design. The structure of the building has a triple lobed footprint which has been adopted from the structure of the flower. Below is a picture that relates the flower to the structure. The 3 wings that stick out provide a Y-Shaped structure which In turn gives the tower a stable base configuration which is primarily the most important factor for a 0.8 km building. There are 26 spiral levels which are a part of the building. The function of these is to reduce the cross sectional are of the tower as it heads to the sky. The reason this is done is to maximize the height and wind tunnel testing proved that having a smaller cross sectional area will prove to be safer for climatic changes in Dubai. [25]

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ig.10. (a & b) Burj Khalifa inspired by Hymenocallis Flower

CONCLUSIONS

The main concept of BioGreen is that since Biomimetics and Green Technology have already solved many of the future engineering problems, such as self-assembly, harnessing solar energy, and self-healing abilities thus reducing total energy loads no doubt it will be a central theme for the development of new applications in the near future. BioGreen buildings can be executed for our benefits, and for better economy and efficiency. As a Civil Engineer, Architect and Designer we should not come together to learn about nature and circumvent or control her, but to learn from nature, so that we might fit in, on the Earth from which we sprang. BioGreen concept will become a race and a rescue and not just a new way of looking at nature. There has to be a paradigm shift in our understanding and concepts about implementation of the built environment. If we learn through these organism models, we would survive happily on this planet for billions of years.

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