The use of Structural Systems Inspired by Nature in Sustainable Architecture

Dr. Shimaa Abd El-Majeed Ibrahim
Assistant Professor in the Department of Interior Design - Faculty of Family Sciences - Taiba University - Saudi Arabia, Shimaa.allam@ymail.com

Abstract:

In light of the world's lack of resources and the weather changes caused by man's misuse and exploitation of his environment and the impact of our current lifestyles on the environment lead us to depletion of the natural resources of the earth. The way to deal with this situation is either to preserve natural resources or to simulate this nature which is inherently sustainable by taking nature as a model and scale. The process of mimicking nature, simulated, or biologically inspired designs as a tool and strategy for sustainability involves finding solutions to design problems by simulating the natural world. The nature of the systems, materials, processes, and structures, which have long been the ideal means and writers whose ideas are inexhaustible to inspire the solutions to the needs of successive generations and problems of design through the times To sustainable sustainability in a way that addresses design challenges more sustainably and more effectively. It is also an indicator of nature's work systems and thus a productive and inspirational tool to re-visualize the built-up world.

Hence, Nature can be inspired most as the experience of it is more than 3.8 billion years in the evolution process, so the idea can be taken and used to change the whole idea. In bio-mimicry itself, it is to develop an evolutionary process to enhance life, by creating new technology for mankind. The basic idea is to make a combination between technology and engineering by helping humanity to treat nature in better harmony, so that the entire world user can create better products by developing greener and more sustainable technologies, without harming nature.

Keywords:

Nature Architecture, Biomimicry, Architecture, Biomimetic Architecture, Sustainable Ecosystems.

Paper received 20th February 2021, Accepted 29th March 2021, Published 1st of May 2021

Introduction

Recent advances in digital technology and 3D printing mean that architecture can now boast of forms and structures inspired by the natural world that was once impossible.

The study showed the effectiveness of fluid form in morphological metaphors of nature, integration, and harmony, as well as the effectiveness of simulating the organic structures of living nature models, characterized by power load efficiency, load distribution and originality flexibility, integration of the original function of the architectural project with the resulting form, To create simulated policies for units and items and work with others.

To reach buildings using the energies of nature and materials in terms of adoption of negative systems, and integration with design systems, and adopt the effective design of architectural projects (to take advantage of wind energy in natural ventilation and solar energy). Integration of technical solutions to balance the natural environment and industrial energy and the adoption of natural plants and vegetation on surfaces and between floors.

Research Problem

The lack of adequate studies on the importance and role of simulating living natural systems in terms of form, composition, structure, and ecosystems as one of the means and ways to achieve sustainability in architecture.

Research goals

The research aims at extracting the indicators and the morphological and constructional determinants in the field of simulation of living natural systems and the possibility of transferring some of their transformations into sustainable architecture. The research was based on the hypothesis that nature and its models can be used by simulating its forms and choosing the appropriate structural and environmental systems that help In achieving sustainable architecture.

The research adopted the method of study for a group of international architectural projects within three axes:

- Simulation of living nature.
- Decisions of sustainable ecosystems.
- Simulated Regime Origins of Living Nature.

Material and methods

1- 'bio-mimicry mean:]

Bio-mimicry means to imitate life and originates from the Greek words

bios= (life) and mimesis= (imitate)

Biomimetic architecture is a contemporary philosophy of architecture that seeks solutions for sustainability in nature, not by replicating the natural forms, but by understanding the rules governing those forms

Biomimicry: Innovation Inspired by Nature as one which studies nature and then imitates or takes inspiration from its designs and processes to solve human. Rather than thinking of the building as a machine for living in, bio-mimicry asks architects to think of a building as a living thing for a living being.

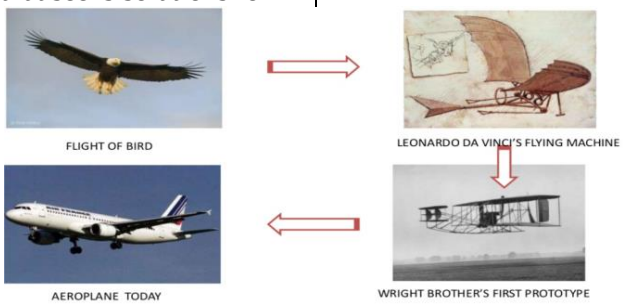


Fig (1): Imitation in natural installations

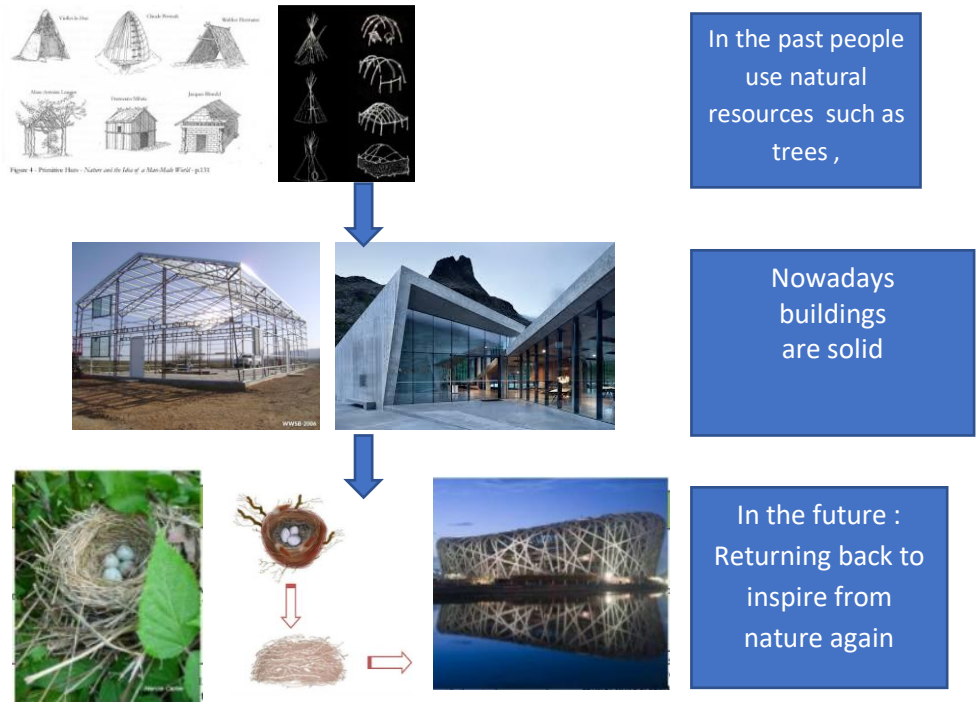


Fig (2): Imitation in natural installations

2- Approaches to biomimicry as a design process typically fall into two categories:

A-**Design looking to biology**

Defines: human problem and looking to the ways other organisms or ecosystems solve this,

- The approach requires designers to identify problems and biologists to then match these to organisms that have solved similar issues.
- An example of such an approach is DaimlerChrysler's prototype Bionic Car

Fig (3): Imitation in natural installations

- more efficient in terms of fuel use BECAUSE the body is more aerodynamic due to the

mimicking of the boxfish.

- It is also more materials efficient BECAUSE mimicking tree growth patterns to identify the minimum amount of material need in the structure of the car.

B- **Biology influencing design**

DESIGN ⟶ BIOLOGY

BIOLOGY ⟶ DESIGN

Identifying: a particular characteristic, behavior, or function in an organism or ecosystem and translating that into human designs.

An example is the scientific analysis of the lotus flower emerging cleanly from swampy waters, which led to many design innovations including Sto's Lotus paint which enables buildings to be self-cleaning.

3- Application of Bio-mimicry

The design may be biomimetic for example in terms of

A. Organism Level:

An example is the mimicking of the Namibian desert beetle

Bio-mimicry at the organism level, where the surface of the beetle has been studied and mimicked to be used for other potential applications such as to clear fog from airport runways

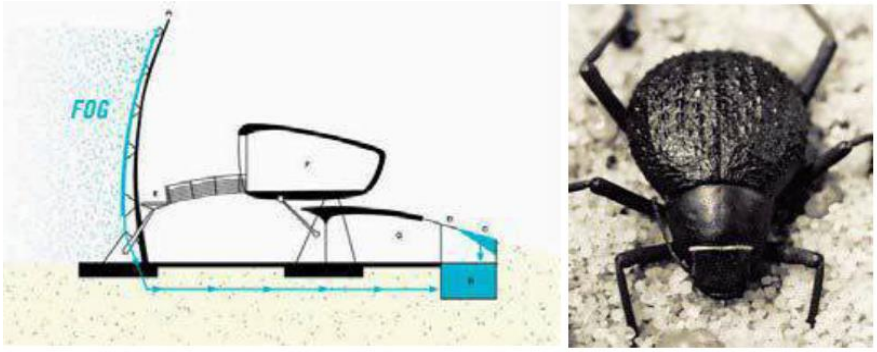


Fig (4): Hydrological Center for the University of Namibia

B. Behavior Level

Buildings work the same way as a termite mound would.

Both buildings are based in part on techniques of passive ventilation and temperature regulation observed in termite mounds, to create a thermally stable interior environment. (Eastgate Building in Harare, Zimbabwe and CH2 Building in Melbourne,)

Water that is mined (and cleaned) from the sewers beneath the CH2 Building is used similarly to how certain termite species will use the proximity of aquifer water as an evaporative cooling mechanism

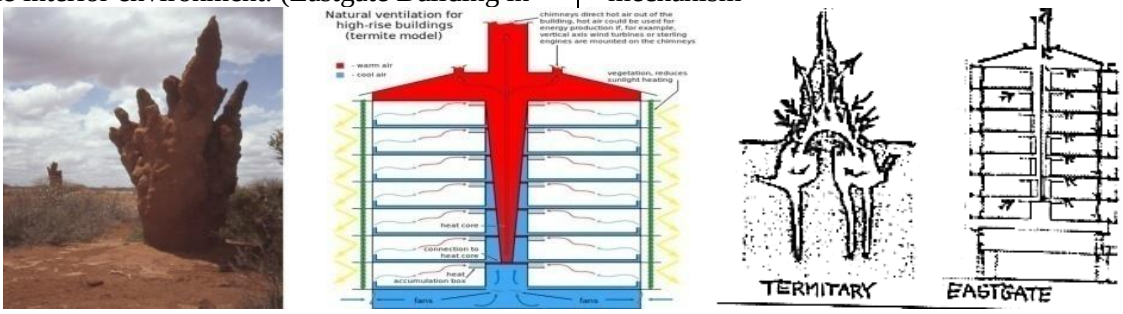


Fig (5): Termite Mounds

C. C- Ecosystem Level

An advantage of designing at this level of bio-mimicry is that it can be used in conjunction with other levels of bio-mimicry (organism and behavior)

1. Water: The plan envisioned a "water neutral" site that lives within the average annual rainfall budget that falls on site.
2. Solar energy and carbon cycles were also calculated to determine pre-development energy cycles. The resulting energy design goals were to exceed pre-development solar utilization conditions and reduce carbon emission to pre-development levels. This would be achieved through several buildings, landscape, and infrastructure strategies, such as designing high-performance buildings, maximizing renewable on-site energy generation, district energy and water systems, and utilization of the carbon sink potential of green spaces.

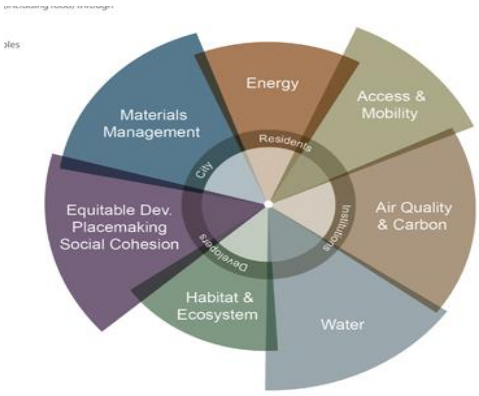


Fig (6): Requirements to be met by the system

4- Buildings simulation of nature

A- buildings with structures with the ability to self-growth

Lalvani was able to create "temporary structures by their nature". They are structures that can shape themselves through the use of external force such as gravity or wind. This makes it possible to deploy quickly in the event of disasters such as earthquakes, floods, or escalating political conflicts that leave large numbers of people homeless.

They are rigid three-dimensional structures of flat metal sheets, perforated with variable openings in specific patterns. These structures can "grow", based on the encoded instructions contained in the material encoded by genome instructions, just as trees grow based on genetic information contained within cells. These variable openings can be extended by applying gravity, giving the structure the ability to take different shapes.

The structures are made of just a thin layer of metal and do not require tools to assemble. They can bend in shape in less than a minute and can be covered with an outer layer of fabric to create a shelter such as a lightweight tent making it easy to transport.

B- Termite-inspired buildings to regulate temperatures

The Eastgate building, designed by architect Mick Pierce and Aropp, Zimbabwe's largest shopping and office complex, is a prime example of a building inspired by the principles of nature. Although the complex does not contain conventional heating or cooling systems, its temperature remains constant throughout the year. These are methods for regulating the temperature inspired by African termites. Inside their piles, termites plant their food: mushrooms. Mushrooms thrive at constant temperatures of 30 degrees Celsius, and Termites succeed in regulating this temperature completely, even when the degree of zero outside the night at night or 50 degrees in the hot sun during the day.

Which consumes much less energy than similar buildings with conventional air conditioning systems are highly efficient and environmentally friendly, achieved by termites constantly opening and closing cooling and heating holes throughout the hill. Termites create a system of adjustable thermal currents in which air is absorbed down the hill and transported up through different channels in the mud. To regulate the temperature, the termites close old openings and dig new openings throughout the day and night. The Eastgate center ventilation system operates in the same way as termites depending on the hottest floors in the air. The outside air is drawn by the fans on the ground floor to the building where it is cooled or heated by the building block. The air is then routed through the floors and offices of the building and then is taken out of the building via private chimneys.

Fig(7): Eastgate center

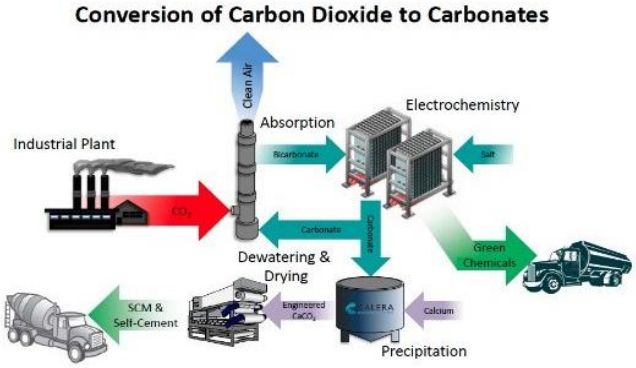
White cement buildings are similar to coral reefs

White cement buildings are similar to coral reefs

Marine organisms such as coral reefs are formed by their solid external structures - they take minerals and carbon dioxide and secrete calcium carbonate to form their solid outer structures.

World and biogas expert Bryant Constanza of Stanford University has developed new ways to create carbon-free cement. Constanta has been able to find ways to capture carbon dioxide from the surrounding industrial emissions sources and

to dissolve them in seawater to form calcium carbonate, which is a solid white powder material that is well suited for use in construction and may replace traditional cement at the end, The environment.



Fig(8): A picture showing how to make white cement from nature environment.

C- **Floating buildings clean contaminated rivers and grow healthy food inside**

Floating buildings clean contaminated rivers and grow healthy food inside Architect Janine Hong of the Philippines also thought about the establishment of the Jellyfish Lodge, a solar structure that cleanses polluted water and air while producing healthy food in the inner garden. They are "floating" houses, each with a living area, a kitchen, a bedroom, a bathroom, a toilet, and a garden, garbage collection claws gather under the structure carefully without damaging the

The water purification system tests water for toxicity and purifies polluted water through the sophisticated electrostatic system responsible for air purification through unique microbial digestion chambers. The treated water is then released back to the river or stored in one of the four tanks on board to help the gardens grow, as well as to inspire the population in the area to preserve it, taking advantage of the vegetables and fish it grows. that grow on board.

Jellyfish Lodge Fig (9):

5- For Examples

A-City on Fire | City in Bloom

- Designer: West 8
- Location: Rotterdam, Netherlands
- Date Designed/Planned: Spring 2007
- Client/Developer: CBK Rotterdam
- City on Fire | City in Bloom was a temporary design installation that sought to memorialize the 1940 bombing of Rotterdam. West 8's design was a wire-framed flower sculpture, comprised of 64,000 red and purple flowers, shaped to look like flames. The flower sculpture was situated in the heart of Rotterdam and depicted the burning of the city during the bombing and the blossoming of the city after World War II. It was a temporary installation that was on display for six weeks and bloomed while it was installed

Fig. (9): A-City on Fire | City in Bloom

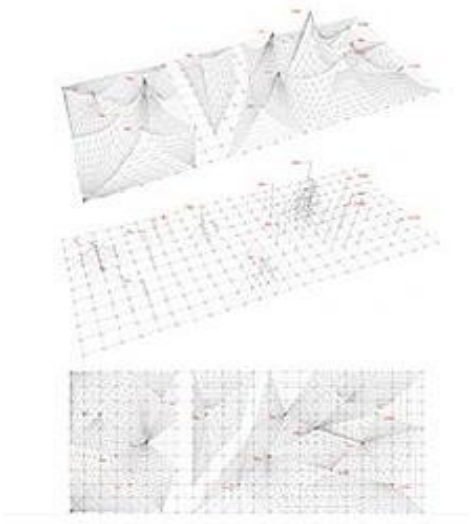


Fig (10): Different points in the grid to simulate the flame structure in the design

It is designed for 3D Studio Max, mixed with photo modification software such as Adobe Photoshop and Adobe Lightroom to highlight their design. Using 3D Studio Max, by pushing and pulling various points in the grid to simulate the flame structure in the design. The software was also able to analyze the surface area of their sculpture, allowing them to know how many flowers to purchase to fully cover the structure

B- Whispering Garden

- Designer: NOX
- Location: Rotterdam, Netherlands
- Date Designed/Planned: 2005
- Client/Developer: CBK Rotterdam
- Whispering Garden, a competition-winning design, is an interactive public artwork. The project consists of an interactive structure along the River Meuse in Rotterdam. Based on the legends of sirens, who would lure passing ships onto the rocks. Whispering Garden utilized advanced wind studies, including direction, force, and duration. Sound artist Edwin van der Heide interpreted these studies to create computer-generated voices that sing within the structure based on the current wind dynamics.
- Through the aid of software such as AutoCAD, 3D Studio Max, Rhinoceros, and Photoshop NOX can realize its design goals
- the use of digital design software allows them to utilize a 'method that augments human experience' and they believe that their designs are not capable without the computer
- The designers decided to create an object, a sculptural piece in the landscape, which could be placed along any waterfront. If they had taken the next step and changed the topography to match the structure, the entire site could have become a unique experience.
- There are two main drawbacks to this project. One is the unique shape they chose for the on-site structure. While it is aesthetically pleasing, it does not seem to consider the full range of needs for people who may be visiting the site. The shape seems to be driven by the design concept and not the desires of people who come onto the site.

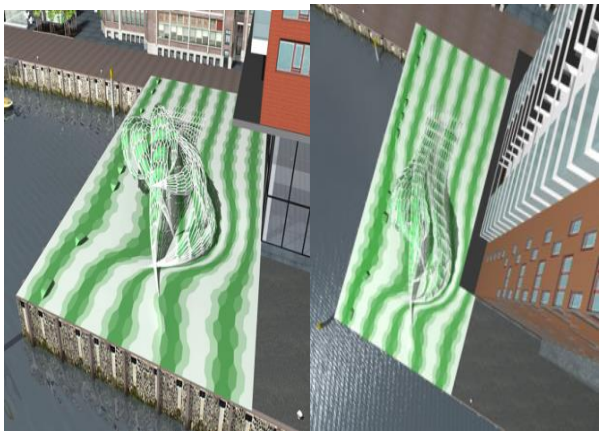


Fig (11): Whispering Garden

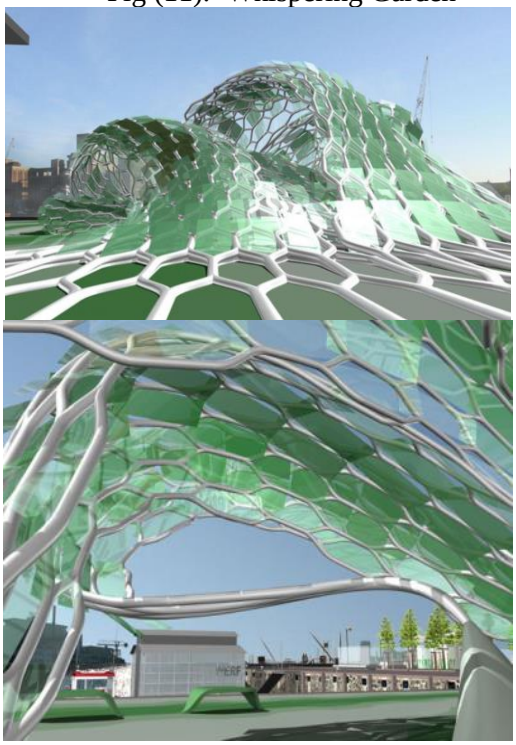


Fig (12): Whispering Garden Inside

C-Beijing National Aquatics Center

Name: National Swimming Center

Title: Inside the Olympic Park

Beijing Olympic Games: Swimming, diving, and swimming

The purposes during the Olympic handicaps:

swimming, diving, and swimming plastic
Construction area: 79.532 thousand square meters
Number of seats fixed: 4000 fixed and 2000 can be removed.
Number of temporary seats: 11 thousand seats
Construction start date: December 24, 2003
Date of completion: in the second half of 2007

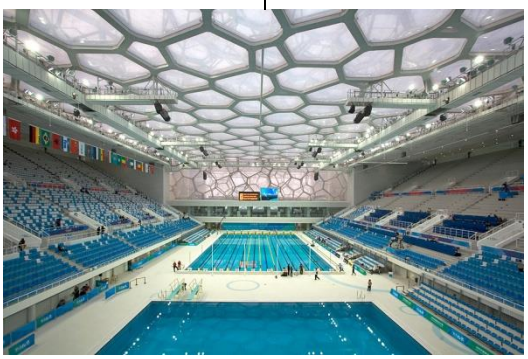


Fig (13): The swimming pool is covered

The shape of the water cube is square, looks like a square box from outside, and envelops the building of the "blue body" cube, which is filled with engineering designs such as the water molecule. The building appears to be a cube filled with many water grains. Especially at night, after opening all the lamps inside the cube, the cube becomes a bright blue crystal.

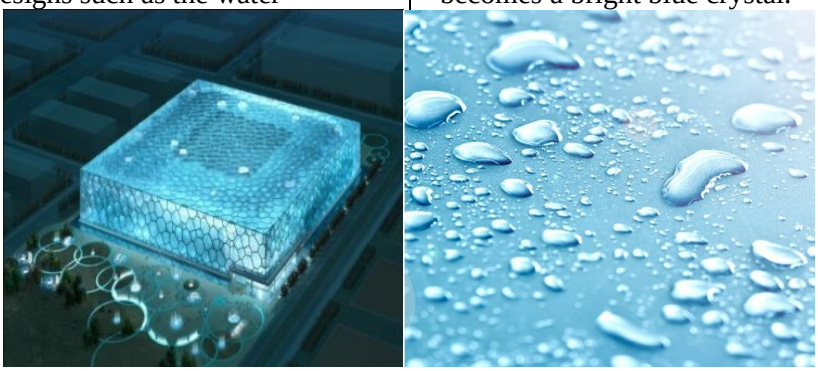


Fig (14): Water cube filled with many water grains

Fig. (15): National Swimming Center Outside

China's National Swimming Center is the "Water Cube" of one of the symbolic buildings of the Beijing Olympics, where swimming, diving, swimming, and volleyball are held.
It was designed in cooperation between Chinese and Australian designers. The water cube can accommodate 17,000 seats, including 6,000 permanent ones.
It weighs almost as much as the weight of the metal in the Eiffel Tower, and inside its walls and roof rises to 30 meters with an area of 70 thousand square meters.
It is made up of 90 kilometers of steel, 22,000 models. This steel is enough to hold 200 Olympic rinks covered with plastic and 100,000 square meters to cover 14 full yards, a nine-meter-shaped cushion.

Fig. (16): National Swimming Center Inside

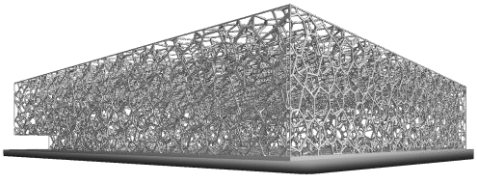


Fig. (17): Steel made of water center

Results

1- The design philosophy of nature is conscious, the philosophy of design, the material objects, the built environment, the services to conform to the built environment, and the services to conform to the principles of economic, environmental, and social sustainability with its cultural, spiritual and aesthetic value. It is a sustainable and environmentally conscious design with all its ideas.
2- Sustainable design seeks to harmonize with nature in terms of its ideas and orientations to meet the dimensions of sustainability. It seeks to activate the positive influence with human well-being and health, through the study of natural systems and their effect is called ".
3- The simulated design of natural systems is associated with natural ecosystems in the recycling of materials, energy, and the use of nature without or leaving side effects of waste or pollution that harm the environment to achieve environmental health and economic vitality

Recommendations

1- Interest in the use of water recycling techniques and resources posed by sustainable design to maintain this revolution with the attention to the techniques of generating electricity using natural energies
2- Interest in building natural materials and its side effects on human health and well - being of the human does not release toxic substances adversely affect health, but on the contrary, it launches negative ions beneficial to improve the ionic content in the atmosphere surrounding the human and has shown a positive impact on the raising of serotonin important to human health and well - being Thus increasing the productivity, human well-being, and well-being.
3- Reduce the use of ferrous materials in construction such as rebar in construction for its role in the development of amplification of man-generated electromagnetic generators and naturally generated electromagnetic and magnetic fields.
4- To take care of the techniques of natural materials and studies on their development to keep up with technological progress.

Conclusion

The concept of nature-inspired technology or biomimicry is gaining popularity all over the globe. Nature's organizational methods and processes are influencing not only architecture and construction but transportation systems, production processes, sustainable city development, and infrastructure solutions as well. In this Search, we have shown just some of what biomimicry has to offer, but as new methods and materials start to evolve, we will get better and better at imitating nature's intricate processes. There is an unlimited world of time-tested, sustainable concepts and processes to learn and draw inspiration from. If we continue to invest time and energy into studying them, we will be able to release a host of superpowers to take us into the future of architecture, engineering, and construction.

References

1- D. Michelle Addington and Daniel L. Schodek, Smart Materials and New Technologies: For the architecture and Design Professions Harvard University Architectural Press 2005.
2- Gyula Sebestyen New Architecture and Technology Architectural Press, 2003.
3- Christopher Hight and Chris Perry Collective Intelligence in Design, Wiley Academy Publisher 2007.
4- Michael Fox and Miles Kemp Interactive Architecture - New York: Princeton Architectural Press, 2009.
5- Lucy Bullivant Responsive Environments: Architecture, Art and Design - London: V & A Publications, 2006.
6- https://www.architravel.com/architravel/building/surry-hills-library-and-community-centre/
7- 7-https://www.mesiniaga.com.my/about-us/menara-mesiniaga.aspx
8- http://www.jetsongreen.com/2006/11/skyscraper_sund_3-4.html
9- https://www.richardvanhooijdonk.com/en/blog/architecture-engineering-construction-inspired-nature/
10- www.bbc.com/earth/story/20150913-nine-incredible-buildings-inspired-by-nature
11- https://www.scribd.com/document/35312207/Intelligent-Technologies-and-Their-Influence-on-the-Experience-of-Space-by-Grunkranz
12- Usman Haque, "Architecture, interaction, systems", in Past Present, ed. Ranulph

Glanville (Wien: Edition Echoraum, 2008)
13- https://www.slideshare.net/DiegoFooter/permatecture-architecture-permaculture
14- Dina Soliman Baghdady, The Use of Interactive Applications in the Design of Public Buildings, Master thesis, Faculty of Engineering Ain Shams University,2013
15- Kas Oosterhuis and Nimish Biloria Interactions with Proactive Architectural Spaces: The Muscle Projects, 2008.