

A Review on Structures Mimicked from Nature and their Concepts

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ABSTRACT: The concept of imitation of models, systems and elements of the nature to solve complex human problems is termed as Biomimicry. It is an efficient, innovative and sustainable way when compared to conventional techniques and hence it has scope in future. The various levels in biomimicry are utilized in the construction of the structures inspired from the nature thus giving way to innovation and sustainability. The key idea is to analyze a portal frame by mimicking the femur and humerus bones as compression and tie member respectively. The structures inspired from nature and literature study of the bio-inspired structures were discussed.

KEYWORDS: Biomimicry, Structures, Literature.

I. INTRODUCTION

Biomimicry can be stated as the imitation of the models, systems and elements available in nature or inspired from nature for the purpose of solving the complex human problems. The term “biomimicry” implies imitation of life in Ancient Greek. Human beings have always looked at their surroundings for solutions to problems they face throughout their existence. Nature has solved many engineering problems by providing examples that showcased various abilities of the organisms and their surrounding. In the course of evolution, several organisms gained more efficient ways to use their environment and to inspire others. Nature has taught us to solve the challenges that we face in a more sustainable and effective way. This concept of biomimicry can be used to improve the design of structures in the field of architecture and in the effective construction techniques which lessens its impact on the environment. The imitation of birds to build a human flight can be stated as an early example of biomimicry. Biomimicry helps in the reduction of natural resources by inspiring engineers to construct more efficient structures. The natural form of various organisms are for instance mimicked so that the structure leads to stronger buildings. The three levels of biomimicry includes the imitation of the appearance of the element, the natural process and the entire element in the ecosystem. The form refers to the shape and size of the element while the material refers to the type and the mechanical properties of the element, function implies the purpose of the element and the way it is used and the construction in the building of the structure.

II. Various Biomimicked Structures

The Kunsthau Graz as shown in Figure.1 is a well known architectural landmark in Austria which was inspired from the natural form of a deep sea blob. The nozzles on the roof of the building are very distinct.



Figure 1. Kunsthaus Graz, Austria

The National Taichung Theater shown in Figure.2 was inspired from the formation of rocks, caves and it was designed with high precision.



Figure 2. (a) National Taichung Theatre, Taiwan (b) A rock cave

The Eastgate development centre in Harare, Zimbabwe as shown in Figure 3 was designed such that the ventilation was by natural means. The way the insects use very limited resources to create ventilated mounds and permeating them with holes all over the surface giving rise to passive ventilation was the inspiration for this structure. The skin of the tower absorbs the heat from outside during the day time into the body of the structure. The air becomes cool when it reaches the middle of the building and during night the heat that's been previously absorbed during the day warms the now cool air, thereby providing comfortable conditions for people inside the building.



Figure 3. The Eastgate development centre, Zimbabwe

The DNA Towers, China as shown in Figure 4 is inspired from the DNA helix like in a DNA molecule where two strands that twist around each other. It provides better functioning under wind loads.



Figure 4. DNA Towers , China

The Aldar Headquarters, United Arab Emirates as shown in Figure 5 is the first circular building of its kind found in the Middle East. The shape of this building is inspired from the form of a shell and it was achieved through the use of structural diagrid, which is a diagonal grid of steel.

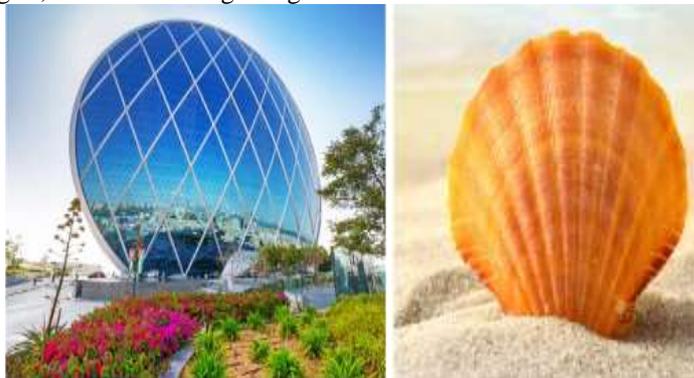


Figure 5. (a)Aldar Headquarters,UAE (b)Shell

The Palm Islands are the three artificial islands that are located in the coast of Dubai, United Arab Emirates as shown in Figure 6 was built entirely from sand and rocks and was inspired from the palm trees.



Figure 6. (a)Palm Islands, UAE (b)Palm tree

The Chicago Spire as shown in Figure 7 is a tall and twisting sky scraper designed from the inspiration of a rotating form of a snail shell.



Figure 7. (a)Chicago Spire (b)Snail shell

The Olympic Pavilion,Barcelona as shown in Figure 8 was inspired from the form of a fish and it was designed such that it could change its appearance depending on the sun and the weather conditions.



Figure 8. (a)Olympic Pavilion, Barcelona (b)Fish

The Gherkin as shown in Figure 9 is one of the iconic sky scraper in London. The Gherkin is supported by an exoskeleton structure, and is thus designed such that the air flows through the entire building. It is inspired from the air ventilation system which is similar to that of anemones and sea sponges.



Figure 9. The Gherkin, London

III. Literature Study

Shrestha and Nadarajah Ravichandran(2020) has explored on the various possibilities of developing a new foundation configuration that is similar to the root of a tree. The identification of three simplified foundation configurations and three more were developed by addition of the two sub-root and 3D Finite element models for each of the configuration in ABAQUS and then it was analyzed by applying the design loads and it was inferred that the addition of main roots contributed to a greater improvement in the performance as shown in Figure 10.⁽¹⁾

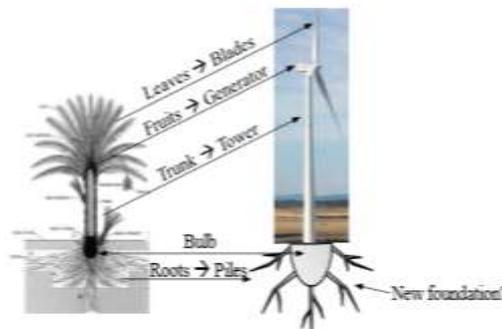


Figure 2. Potential new foundation through biomimicry

Figure 10. Potential new foundation through biomimicry

Sindhu Nachiar et al.,(2020) tells about the structural design concept that is inspired from the human skeleton. The behavior of the human bone is studied using the Finite element analysis wherein the human humerus bone is modeled by MIMICS and analysed in ANSYS using various boundary conditions for different shapes of tension members. The stress pattern obtained were compared with the original bone and optimized

model were arrived for the tension member from the various models having different diameter of the tension member as shown in Figure 11.⁽²⁾

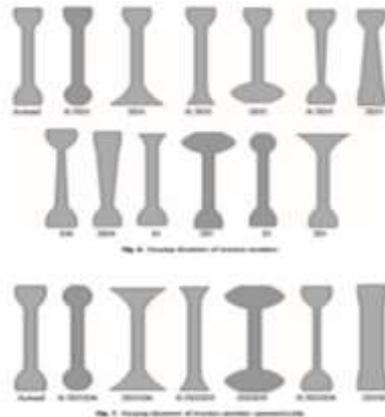


Figure 11. Varying diameters of tension members

Sindhu Nachiar et al.,(2020) has discussed on the consideration of the femur bone which is efficient as a compression resistance member for an adaptive model for columns. The modeling of the proximal bone was done by MIMICS and analysed by ANSYS for the different compression members. The optimized model was arrived based on the suitable shape and stress pattern among the various varying diameter of the compression member modeled as shown in Figure 12.⁽³⁾



Figure 12. Varying diameters of the compression members

Sindhu Nachiar et al.,(2019) has discussed about various structures inspired from the nature by citing examples and also about the nature as a structural system in itself. Biomimicry is described as a tool that increases the sustainability of the materials designed, and also the built environment. The possibility of mimicking of human femur and humerus bones as compression and tie member ,thus comparing skeletal system to structural system were discussed.⁽⁴⁾

Nurul Izzati Othmani et al ., (2018) tells about the three levels in biomimicry that is the organism, behavior and ecosystem respectively. The biomimicry levels need to be followed to create a design that is mimicked from nature in order to have biology in its design rather than just the shape of the organism.⁽⁵⁾

Amir Salihovic and Naida Ademovica(2017) investigates on the capacity of the various models to produce the non linear behavior of the reinforced concrete framed structures. The analysis of the frame was done using SAP 2000 and the definition of the plastic hinges through fibre elements gives best pushover results.⁽⁶⁾

Okeke F. O. et al., (2017) has reviewed about the theories and approaches on biomimicry that are employed in architecture thus providing sustainable structures. It discusses on the various approaches and the adaptability to the surroundings. The study on how nature solved its problems helps in analyzing ways to seek sustainable solutions for the design problems.⁽⁷⁾

Marzieh Imani et al ., (2017) has reviewed on the improvisation of the performance of the building with the help of biomimetic principles as it suggests nature provides sustainable solutions in terms of materials, functions and process.⁽⁸⁾

Senthil et al .,(2016) has discussed on the behavior of the frames when tested under cyclic loading to improve the ductility of the frames. The behavior of the ductile and non-ductile frames have been evaluated for monotonic and cyclic loading to determine the full range behavior of the frames for M40 grade concrete.⁽⁹⁾

Raritha Joshy (2016) has discussed on the biomimetic practices that can be followed to incur changes in the structural system. The structures inspired from plants referred to as the dendriform structures has high great

efficiency of transfer of forces than the regular geometrical structures and it reduces the distance from the point of loading to the supports.⁽¹⁰⁾

Claggett et al. ,(2016) has examined the structural stability by employing biomimicry of the termite mounds. The interaction of soil by termites to improve material properties, and the development of the mound shape as a function of termite species under environmental conditions and local soil properties will integrate the mechanical building system. The structural form of the mound is affected by some of the environmental factors and the soil type indicates the structural stability in its construction practice.⁽¹¹⁾

Gehan Radwan and Arch. Nouran Osama(2016) has discussed about the entire exterior of the building which is formed from the building skin. The ability to reduce the energy consumption by the application of the biomimicry approach on the exterior skin was investigated. By the way of applying the characteristics of nature into architecture energy efficient buildings can be achieved.⁽¹²⁾

Ming Hu (2016) has discussed about the framework and the properties of materials involved in the performance driven structural design thus integrating material sciences and biology study in the structural design.⁽¹³⁾

Sameer Ansari and Ashish Waghmare(2016) has discussed about the concepts of green building using the idea of biomimetics. It discusses about the meaning of biomimicry and how these theories are implemented in the field of construction. It is the science that studies nature's models and emulates or inspires from the design or the process to solve the human problems.⁽¹⁴⁾

Moheb Sabry Aziz and Amr Y.El Sherif (2016) has discussed on the new technologies paving way in mimicking of complex structures since they provide as an accurate and sophisticated tool for computing and simulation and thus helps designers to imitate various natural forms. It helps in creating structures that prove more efficient for various architectural purposes.⁽¹⁵⁾

Mustafa M Wagh and Milind V Mohod(2016) discusses on the behaviour of the concrete filled steel tubes with reference to different shapes of the columns. The behaviour and the characteristics of the columns are analyzed with respect to its performance. Using the ETABS 2015 software, the performance of the various shapes such as circular, rectangular were analysed and their performance, storey drift, displacement were found for the respective shapes of columns.⁽¹⁶⁾

Chen et al.,(2015) has discussed that the coral skeletons has strength similar to man-made construction materials in spite of its higher porosity. Coral reefs can adapt itself to its surrounding thus enhancing its performance. A bottom up approach provides insight to the properties of the organism and its emergent functions.⁽¹⁷⁾

Aditya Bhandari et al.,(2015) has reviewed the applications in various types of eco friendly structure construction and the implementation of the nature inspired techniques such as ventilation ,lighting and climate control. Living organisms have been evolving and the mimicking of their design and of the behavior can prove beneficial for human beings as well as nature.⁽¹⁸⁾

Sumit Kumar Majumder and Purnachandra Saha(2014) reviews the vital aspects of the existing biomimetic inspired civil engineering system .He discusses about the Bridge design derived from load carrying process of tree and a very positive point regarding sustainability such as reduction in consumption of materials due to the development of biomimetics inspired optimized tools. The less pollution due to the non utilization of mechanical cooling systems in buildings, by applying the passive cooling systems by mimicking a termite mould.⁽¹⁹⁾

Rajshekhhar Rao(2014) explores the application of biomimicry in the present architectural design and the design approaches, levels and principles obtained. The work inspired by nature are facilitating the development of the eco performance principles that can be used to build biomimicry solutions into their own designs.⁽²⁰⁾

Iasef Md Rian and Mario Sassone(2014) discusses on the shape and the structural strength of a number of dendriform structures. It discusses on the mechanical strength of tree like structures and the fractal geometry of the trees. The similarity includes its property to carry a large surface supported by a narrow element constituting a branching mechanism. The research on the various behaviours, geometries and mechanical properties of the trees give way to innovative, creative, economical and sustainable designs.⁽²¹⁾

Mohd Syahrul Hisyam Mohd Sani et al .,(2013) tells about biomimicry engineering which is the area recognized to solve various issues including the impact on the environment and its reduction strategies by employing mimicking of the materials such as coarse aggregate for replacing of the natural coarse aggregates. This can be introduced to the industry for the purpose of promotion of innovative, creative techniques.⁽²²⁾

Maibritt Pedersen Zari(2010) has explored the aspect of biomimicry in the built form. The positive integration with the ecosystem helps in the mitigation of the anthropogenic emissions and to adapt climatic changes. Mimicking the functions of the ecosystem to facilitate the buildings to adapt to the climatic changes.⁽²³⁾

Michael Helms et al.,(2009) has discussed on the biology inspired design analogies to solve the various engineering problems. The biology inspired design is a rapidly growing field for design research. It provides an opportunity to enhance the understanding of biology inspired design solutions to develop various strategies to improve the performance in design of the structures.⁽²⁴⁾

IV. Conclusion

Biomimicry helps to solve the complex human problems. With the above literatures the research is to be done for mimicking the shape, form, function from the nature to create a structural system that is more efficient, innovative, sustainable and economical.

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