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Adaptation of biomimicry in civil engineering

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ABSTRACT

Biomimicry is a novel approach to developing design's and products to solve construction problems by taking inspiration from nature. It could offer a sustainable alternative solution to complex and conventional design in the best eco-friendly way. Biomimicry includes mimicking the shape, properties, methods, principles, and processes of nature. This paper reviews the existing biometric inspired civil engineering systems and architectures. In this paper various examples are taken from the nature and applied in design, like the regeneration process in lizard inspires the self-healing property of concrete, by mimicking termite mound, a passive cooling system could be developed, bridge design is one of the vital aspects of structures of biometics which is derived from the load carry process of trees. In a similar way, various other structures are being developed by getting inspiration from the creation of nature, as we move towards creating more sustainable construction and decreasing the carbon footprints in the infrastructure industry. Hence incorporating the potential of the mother earth will lead to the enhancement of structural stability and elegance. It will in turn preserve the earth in her best form.

Keywords*— Biomimicry, Architecture, Biomimetics, Bacillus Sphaerius, Military, Self-healing, Concrete, Sustainable.*

1. INTRODUCTION

It is well understood among the research fraternity around the world that the 20th century was the century of physics and the 21st century will be the century of biology and these is evident from the research budget that is being allotted to biology compared to physics worldwide. Major construction companies have started hiring biologists to understand the natural phenomenon and their application in the industry.

1.1 Biomimicry over view

"Biomimicry is the design of materials, structures, and systems that are modelled on biological entities and process" (dictionary). The word biomemetics is used along with biomimicry but, biomemetics is the word that is applied to military technology field. The term biomimicry first came to existence in a scientific literature in 1962 and started becoming popular among material scientists in 1980's. The interests have grown considerably in last ten years.

Biomimicry is the most efficient and genius way to look for sustainable solutions to human problems by copying and emulating nature analogies, phenomenon and patterns. The main aim of biomimicry is to develop great designs by mimicking the living organisms which has been evolving from billions of years.

1.2 Application

(a) Minimal Surfaces: A soap film is a pattern of nature which has been studied intensively by mathematician around the world to develop a geometric surface called minimal surface. The minimal surface inspired architects to build domes. Domes were used extensively not just because of its aesthetic value but, it is a surface which allows the stress to be transformed uniformly to the supports, i.e. stress concentration is avoided.

(b) Tree: A tree is a living organism which carries the large amount of load by effective load transfer mechanism (Twig->Branch -> Trunk->Roots). Tree helped engineers optimize various civil engineering structures. A model is prepared by the help of StadPro.

(c) Smaller living forms: The spiral pattern which is abundantly found in nature in sea shells, hurricanes, spider web, galaxies etc. were mimicked for the structural engineering principles of ultra-high towers etc. The spiral forms traverse around a centre and gradually recedes away from it, this results in most effective cantilever structure.

The **termite** have an amazing capability to maintain a constant temperature in their mounds. This inspired the engineers in Harare, to construct a midrise complex name East Gate Centre to have a passive cooling system.

A concrete is structure undergoes various stress during the course of its life as a result of it cracks are formed and hence the moisture creeps in through those cracks and corrode the reinforcement. These lead to the invention of self healing concrete inspired from the self-healing property of Lizard.

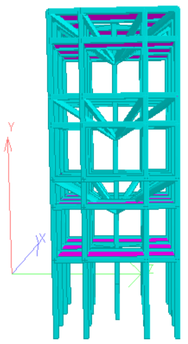

Fig. 1: General G+3 storey building is analysed containing a central column that resembles a tree

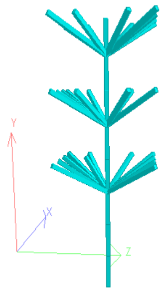

Fig. 1: Central column that is the main column. The choice of central column in the shape of a tree decreased the size of other supporting columns and as a result the structure is optimised efficiently

2. CASE STUDY

The ordinary concrete used here consisted of cementing materials, mineral aggregate and corrosion inhibitor with the following specifications.

- Ordinary Portland cement (53 Grade)
- Graded fine aggregates
- Water
- Bacteria: Bacillus Sphaerius

Mix as per Indian Standard stipulations

- Concrete: M25
- Exposure: mild
- Size of aggregate: 20 mm
- Workability: 0.9
- Cement : OPC 53 grade cement
- Grading of sand: III

2.1 Bacillus Spharius

It is a Gram-positive, mesophilic, rod shaped bacterium commonly found in soil. It can form resistant endospores that are tolerant to high temperatures, chemicals and ultraviolet light and can remain viable for long periods. It is frequently used as a biological pest control.

Since it has high tolerance to high temperatures, chemicals and its higher life expectancy makes it a natural choice to be used in constructions. It is mixed with concrete along with other ingredients, remains inactively in concrete till it encounter moisture after hardening of concrete. The cracks formed allow the moisture to flow through them, as the moister comes in contact with bacteria it activates them and it undergoes a reaction and calcite is released as a waste, these calcite being a binding material fills the crack and close the passage, and protect the reinforcement from corrosion as a result the life of concrete is shown in table 1.

Table 1: Physical properties of materials

Material	Specific gravity	Bulk density
cement	3.14	1450
Fine aggregate	2.7	1650
Coarse aggregate	2.7	1575
water	-	1000

Table 2 shows Quantity of material in m3 of concrete.

Mix proportion by weight = 1:1.27:2.89:0.45
Mix proportion by volume = 1:1.11:2.66:0.65

Table 2: Quantity of material in m3 of concrete

Material	Weight in kg	Volume
Cement	425.73	0.294
F.A	539.54	0.327
C.A	1231.77	0.782
Water	191.58	0.191

3. TEST'S ON CONCRETE

(a) Compressive Strength Test
(b) Split Tensile Test

3.1.1 Compressive strength test: It is a test performed on cubical test specimen of size 0.15m*0.15m. Four specimens is taken and they were cured for 3 days, 7 days, 1days and 28 days and they were subjected to compression in the above order. The results of the tests is compounded in tables and graph.

3.1.2 Split tensile test: It is method to find the tensile strength of concrete. Four cylindrical specimens is taken of diameter 0.15m and height 0.3m and were cured for 3 days, 7 days, 14 days and 28 days and they were subjected to compression in the above order. The results of the tests is compounded in tables and graph.
The tensile stress is found by formula 2P/pieDL

4. TEST RESULTS

Table 3: Compressive strength of conventional concrete

No. days	Compressive strength at first crack (mm)	Ultimate compressive strength (N/mm2)
3	4.3	20.21
7	6.13	23.54
14	5.78	27.56
28	7.56	30.52

Table 4: Compressive strength of concrete with 10 ml of bacteria

No. days	Compressive strength at first crack (mm)	Ultimate compressive strength (N/mm2)
3	6.67	29.78
7	6.28	24.11
14	5.92	27.56
28	7.61	30.84

Table 5: Compressive strength of concrete with 20 ml bacteria

No. days	Compressive strength at first crack (mm)	Ultimate compressive strength (N/mm2)
3	6.67	29.78
7	6.28	24.11
14	5.92	27.56
28	7.61	30.84

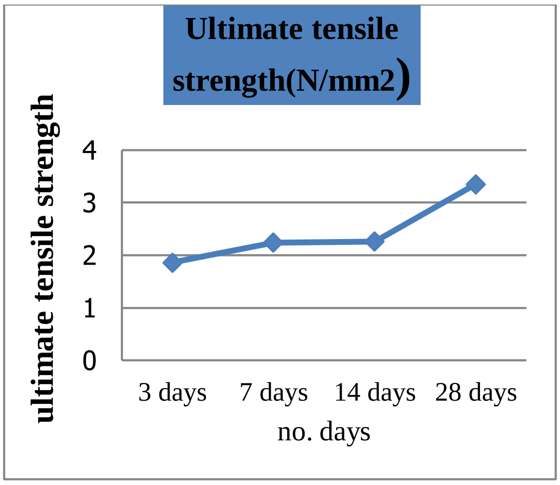

Fig. 3: Split tensile test on conventional concrete

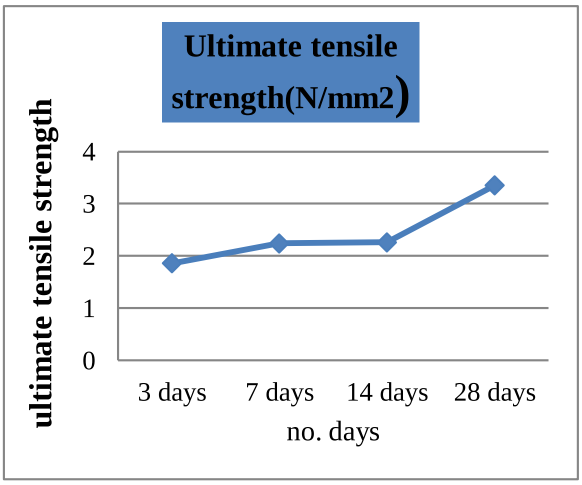

Fig. 4: Split tensile test on concrete with 10 ml bacteria

5. CONCLUSION

It can be inferred from above case study that the concrete though deforming but still it is showing more compressive strength when compared to the conventional concrete which can be understood that the concrete is healing itself. The difference is not much to provide a claim on healing mechanism but it only can provide a hint on healing, as the crack were not given sufficient time to heal.

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