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Learning from Nature: How Ant Nest Architecture Can Inspire Sustainable High-Rise Buildings

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Abstract: ***Since ages humans have been getting inspired and replicated nature in one way or the other. On Earth, ants are one of the many species that have survived through the process of evolution and adaptation by creating social colonies by building their nest underground by excavation. Each nest is species typical with the basic structural units being descending tunnels connecting compact, horizontal chambers of oval to lobed outline. The size, shape, number and arrangement of these basic elements may vary from species to species to attain the maximum efficiency in architecture. Similarly, our multi storeyed buildings also vary in size, shape, number of floors, etc. depending on the requirement of each individual building. These designs can become highly efficient in terms of energy usage and other building related services if they are inspired from nature. This paper aims to study and build interrelation between the ant nest architecture and the design of contemporary multi-storeyed buildings with respect to sustainable parameters. Case of Tower of Time skyscraper was studied and parallels were drawn on how the Ants' nest may serve as an inspiration for efficient structure & layout, energy efficiency, circulation & future expansion and community & social interaction.***

Keywords: ant's nest, sustainable, multi storey, architecture, biomimicry

1. Introduction

The shelters of each living being is built in a unique way, some carry their shelter on their back like the turtles; others have to build them using the materials available in the vicinity of their residence. Some insects build their homes by secreting certain ingredients like bees build their hives with the help of bee wax excreted by them. Then there are insects like ants who build their nest in a different method. The nest of the ants is generated by the method of excavation of soil; they do not build their nest by additive method but in a subtractive way. Since the ants' nest are underground it is difficult to study them. Though there is lack of quantitative data, researchers like Walter Tschinkel; have found a way to study these nests of ants by filling the nest with thin slurry of plaster and excavating the hardened cast. This type of study gives us the clear idea that ant nests are highly structured and species typical in both size and 'morphology' (Tschinkel, 2003).

2. Literature Survey

2.1. Biomimicry

Biomimicry is a discipline that refers to study of nature's best ideas and then imitate these designs and processes to resolve/ evolve human design challenges (Singh & Nayyar, 2015). Nature can teach us about systems, materials, processes, structures and aesthetics which can be applied in to design of art and architecture to derive the optimum design output. Over many millennia the organisms that inhabit this planet have gone through countless environmental filters that have shaped and continue to inform the shape of organisms today (El Ahmar, 2011). The Nature constantly evolves and these evolutions eradicates the unnecessary things and achieves a new level of evolution. The principle of Biomimetic strives to learn how nature has learned and to not necessarily imitate but filter from nature the qualities and characteristics of natural form and systems that are appropriate to our understanding of architecture.

2.2. Levels of Biomimicry

There are three systems/ levels of biomimicry that can be applied to any form of design be it mechanical or architectural design. These three levels can be being :

2.2.1. Organism Level

The first level refers to a specific organism like a plant or animal and may involve mimicking a part of or the whole organism known as Organism Level (Zari, 2007). This level of biomimicry can be better explained with the example of Nicholas Grimshaw & Partners' design for the Waterloo International Terminal. It is an example of form and process of biomimicry at the organism level. The terminal was required to be able to respond to variations in air pressure as speed/ bullet trains enter and depart the terminal. Also, there were some limitations to the extents of the site so the arch had to be flexible. The glass panel fixings that make up the structure mimic the flexible scale arrangement of the Pangolin so they are able to move in response to the imposed air pressure forces. (Aldersey-Williams, 2003).

Figure 1: (a) Pangolin (b) Grim Shaw's Waterloo Station (Zari, 2007)

2.2.2. Behavioral Level:

The second level refers to mimicking behaviour, and may include translating an aspect of how an organism behaves, or relates to a larger context known as Behaviour Level (Zari, 2007). A large number of organisms encounter similar environmental conditions like humans and they need to solve similar issues that humans face. These organisms tend to function within environmental carrying capacity of a specific region and within limitations of energy and material availability. These limitations as well as pressures generate some ecological niche adaptations in ecosystems. This means not only well-adapted organisms continue to evolve, but also well-adapted organism behaviour and relationship patterns between organisms or species evolves.

This level of biomimicry can be better explained with an architectural example of process and function biomimicry at the behaviour level is demonstrated by Ar. Mick Pearce in his East gate Building in Harare, Zimbabwe. The design of the building is based on techniques of passive ventilation and temperature regulation that are observed in termite mounds, so as to create a thermally stable interior environment. The building is designed in such a way that the airflow is streamlined and natural flow is maintained without any mechanical system.

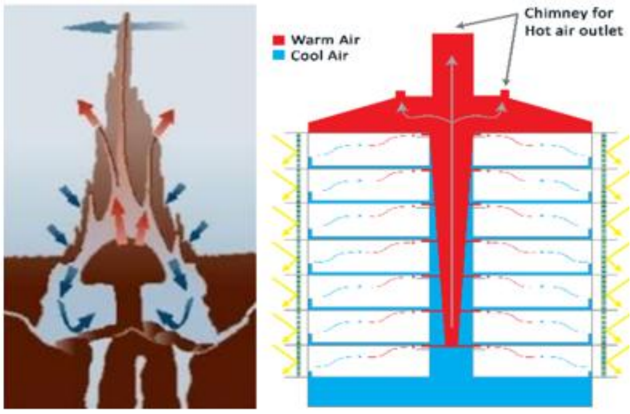

Figure 2: (a) Air flow in Termite Mound (b) East Gate Building by Mike Peirce (Zari, 2007)

2.2.3. System Level

The third level is the mimicking of whole ecosystems and the common principles that allow them to successfully function known as System Level (Zari, 2007). On a functional level, an ecosystem mimicry could mean that an in-depth understanding of ecology drives the design of a built environment that is able to participate in the major biogeochemical material cycles of the planet in a reinforcing rather than damaging way (Charest, 2007)

2.3. Classification of ants

The species of Ants come under the family of Formicidae of the order Hymenoptera of the Animal Kingdom. While Humans come under the family of Hominidae in the order of Primates of the Animal Kingdom (Bharti, Guénard, Bharti, & Economo, 2016). Out of the 100 genera that are found in India, Camponotus is the most found with over 83 named species (one Tenth of total known Indian Species) (Bharti, Guénard, Bharti, & Economo, 2016). There are about 181 species of Ants that are found out of the 46 Genera that are found in Maharashtra itself. (Bharti, Guénard, Bharti, & Economo, 2016).

2.3.1 Camponotus Socius:

These species of ants come under the genus of Camponotus, commonly called as the Carpenter Ants. The maximum population that is found in nests of these species were up to 600. The average height of the nests was up to 60 cm deep. The nest was made up of descending shafts connecting up to approximately 10 horizontal chambers. Nest volume was about 800 cubic cm. and total chamber area of almost 500 sq. cm. Both volume and area were closely related to the number of workers residing in the nest. (Tschinkel, 2005) According to Tschinkel, in his report in most cases 1 vertical shaft was found and there was a 20% chance to see more than one shaft in the Nest architecture of the species of Camponotus Socius. nest enlargement occurred through the simultaneous enlargement of chambers, deepening of the nest and addition of more chambers. It was found that the Chambers near the surface were elongated and tunnel like, while the chambers which were located deep underground were more compact in outline. (Tschinkel, 2005). The figure 4 shows how the nest of this species grows over the years as the population increases. Note the increase in nest depth, number and size of chambers, and the occasional occurrence of two shafts.

Figure 4: All plaster casts of Camponotus Socius nest are shown to the same scale. Seen from left to right, these approximately represent the progress of nest growth (Tschinkel, 2005)

2.3.2 Pogonomyrmex Badius:

These species of ants come under the Genus of Pogonomyrmex, commonly called as the Harvester Ants. The maximum population of these species of ants found in the nests were up to 5000 workers. The average height of the Nests was up to 3m deep, that composed of descending shafts connecting the horizontal chambers. The total chamber area is almost 3000 sq. cm. There is a single vertical shaft found in the initial stage but gradually increases as the size of the colony increases. Most of the Nests of this species usually have a single entrance, though there is a possibility of having multiple entrances as evident samples were found where few nests had 2 to 3 entrances. From the entrance, a shaft descended at an angle of about 20-30° from horizontal, gradually increasing to 45 to 60° by about 50 cm and below. Near-surface chambers begin as horizontal or nearly horizontal shafts, and are gradually widened and branched until they appear like complex, lobed, interconnecting, looping chambers. Chambers had more or less horizontal floors and a horizontal outline ranging from near circular wall outline in case of small Chambers, to multi-lobed wall outline in case of large Chambers. (Tschinkel, 2005).

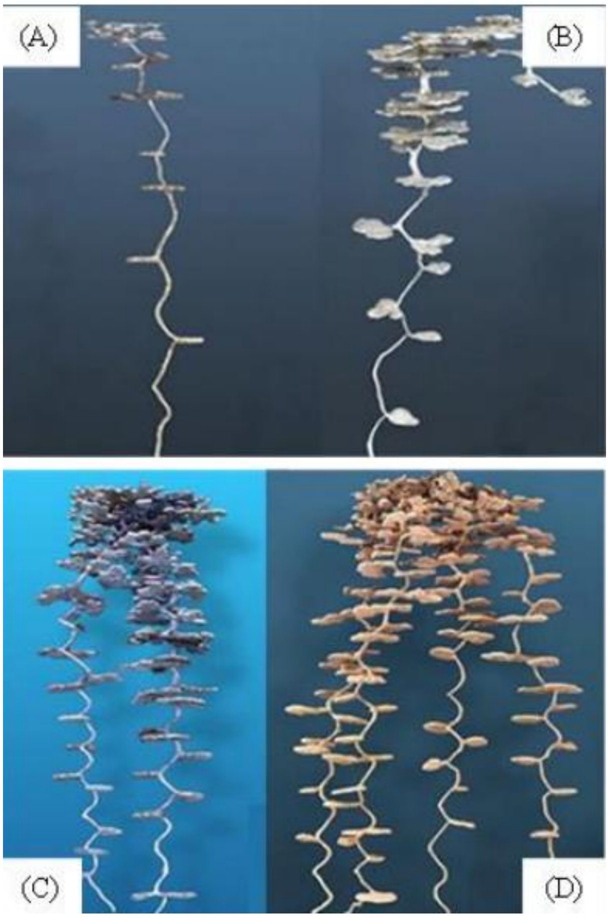

Figure 5: Casts of Pogonomyrmex badius nests of increasing size: (A) a very small nest with a single vertical chamber series and shaft; (B) a medium-small nest with the beginning of a second vertical series and shaft; (C) a medium size nest with 2 series of vertical shaft; (D) a large mature nest with 4 vertical series and shaft (Tschinkel, 2005).

2.4. Ant Nest architecture

The habitat of the ants is called the ant nests. It evolves as the ant colony grows in the population. The basic units of structure of the ant nest remains the same across all the underground nesting ant colonies. There may be a lot of variation in terms of the shape, size, number and arrangement of these basic elements. Thus, it gives rise to species-typical ant nest architecture. The basic elements that are found in the ant nest architecture are:

2.4.1. Vertical shafts:

Shafts are defined as elongated voids with a circular, oval or flattened-oval cross-section, with a long axis usually inclined from the vertical by 20° to 70°(rarely 90°) (Tschinkel, 2005). These shafts are used as transport systems and also the passages for natural ventilation inside the nest. The air passes through the shafts and then to all the other areas inside the nest. The shafts connect all the Nodes inside the nests.

2.4.1. Horizontal chambers:

Horizontal chambers are the spaces to be used for different activities like storage of food, laying of eggs, larva, residing, etc. The shape and size of the chamber varies depending on the use of that space. The chamber where the food is stored will be bigger than the chamber where the eggs are laid. The chambers have circular or lobed shape when seen in plan or top view. (Tschinkel, 2005).

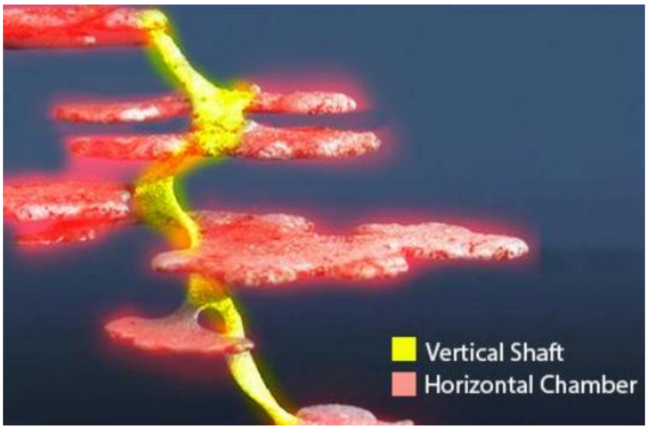

Figure 3: Graphical representation of a plaster cast of ant nest representing the vertical shafts and horizontal chambers (Tschinkel, 2003)

3. Methodology

This study adopts a qualitative methodology to explore how ant nests can inspire sustainable design in multi-story buildings. By conducting an in-depth review of existing literature and analyzing case study, the research establishes connections between natural ecosystems and human-made structures. The findings from both the literature review and case study are synthesized to offer suggestions for future architectural designs that draw inspiration from ant nests. These suggestions focus on improving sustainability in high-rise buildings by incorporating principles derived from nature into modern architectural approaches.

4. Results and Discussion

While designing a multi-storeyed building, many things are taken in to consideration like planning, structural system, daylighting, ventilation, firefighting, temperature control, etc. While designing the multi-storeyed buildings we can take inspiration from the ant nest architecture so as to improve our building designs from services perspective for better efficiency.

4.1 Proportions of base to height:

The base to depth proportion in an ant nest may vary in different species but one thing is common that deeper the nest wider is the base. According to Walter R. Tschinkel, if the base is 30cm then the depth of the nest is approximately 300cm in height ratio (Pogonomyrmex Badius species). Which is 1:3 proportion. In abstraction the form is near to triangular rather pyramidal in shape/ form. The pyramidal forms are the most stable and efficient in terms of load transfer. If the designer does not consider these proportions, then the structure will have to be provided with extra supports

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either horizontally or vertically to make the building form stable.

4.2 Ventilation systems

The vertical shafts inside the ant nest acts as the natural centralized ventilation system with the help of which the air flows naturally from positive pressure outside the ant nest to the negative pressure inside the nest. This is a typical feature in all the ant nest found all over the world. The man-made multi-storeyed buildings have mechanized heating and cooling systems installed. They are the centralized systems to maintain the ventilation and temperatures inside the building according to the requirement of the climate. Using these systems generates huge number of electrical loads and needs time to time maintenance of the heavy machinery. A system should be built where the air flow is maintained throughout the building naturally. We can design shafts which are centrally located which creates a negative pressure inside and having ventilation ducts on each floor. This will help the air with the positive pressure outside the building flow towards the shaft and then rising up and exiting the building allowing more fresh air to enter the building.

4.3 Vertical transport

As studied in the literature review, ants use the shafts as their vertical transport systems to reach out to their chambers. These shafts are centrally connected to all the Chambers of the nest like the lifts in our modern-day buildings. The express lifts in the sky lobby systems in skyscrapers or high-rise structures use a similar idea of connecting specific regions via a specific vertical transport system. This decreases the travel time and a person can be evacuated easily in terms of emergency.

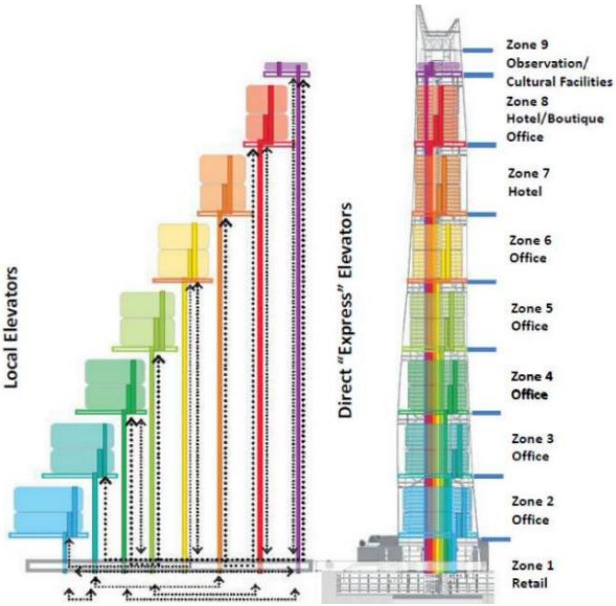

Figure 6: Section of the Shanghai Tower showing the Vertical Transport system of the building (Shanghai Tower / Gensler, 2016)

4.4 Volumetric changes

It is observed that each species of ants in their nest has developed different sizes of chambers for different purposes. For example, we can see that the chambers where eggs are laid in the ant nests of Pogonomyrmex badius are smaller in comparison to the chambers where the food is stored. As we can see in the figure 8 that as the nest goes deeper the chamber size also decreases because of the external factors of soils. In architecture we design volumes of spaces with relation to the use of that space. For example, a warehouse used for storage is bigger in volume than a residential unit.

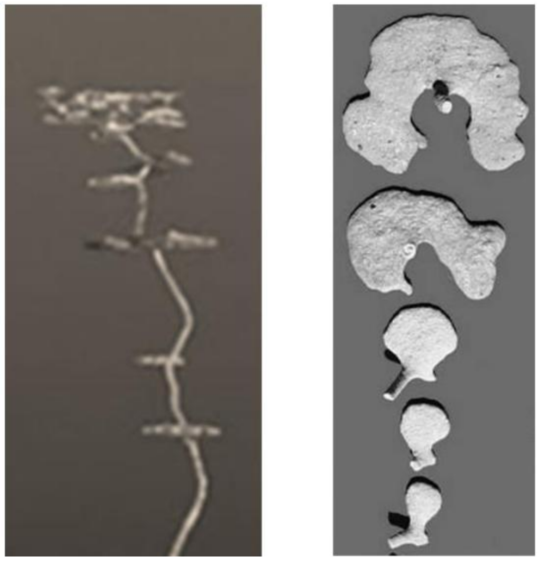

Figure 7: Decreasing Chamber sizes in Ant nests (a) Elevation (b) Plan (Tschinkel, 2005)

4.5 Multiple entry/exit locations

During the time of emergencies, like fires, earthquakes, etc. it is necessary to evacuate the building as soon as possible so as there are few numbers of casualties. During these times if there are a lesser number of exits then there are chances of people getting stuck inside the built form. In case of ants depending on the size of the colony the species decides whether there is a need of multiple entry/ exit points to evacuate the nest during the time of emergency. This can be imitated as a design requirement for any type of building where the population density within the building is very high so that the number of casualties is decreased.

4.6 Lobed walls:

This feature of the ant nest architecture is developed organically by the ants. As we can see in figure 7, the lobed walls benefits ant nest in multiple ways.

1) It increases the wall surface area
2) Naturally provides separation of use of space
3) It provides friction from lateral forces. (In case of ants it is the seismic waves)

4.7 Multi-storeyed building inspired by Ant's nest:

While there may not be any buildings that are exact replicas of underground ant nests, the principles by which they can be inspired are influencing architectural design, especially in the areas of ventilation, efficiency, and the use of underground space. One of the notable examples of such structure is explained below:

Tower of Time:

The Tower of Time is a conceptual skyscraper that draws direct inspiration from the architecture of ant nests, particularly their self-sustaining, well-ventilated, and adaptive underground structures. The building integrates biomimicry principles to enhance natural ventilation, energy efficiency, and space utilization, similar to how ant colonies function in nature. Crucially, it emphasizes both above-ground and underground exploration and excavation, directly mirroring the subterranean aspect of ant colonies. The building's subterranean portion serves as the foundation for exploration, excavation, and display of geological rocks, animal fossils, and burial legacy. In addition to maintaining the exhibits in their original, stable setting, this section enables visitors to learn about the important geological and human heritage facts by experiencing the relics excavation process and the preservation environment. In addition to a viewing area with a variety of research institutions, theme pavilions, theatres, catering, lodging, and recreational opportunities, the ground floor is intended for archaeological research and the display of cultural treasures. The concept also uses the idea of the excavated earth to be used as a primary building material. The "ant nest" structure also creates efficient internal transport channels. Therefore, while there isn't a physical "time tower" standing that's a perfect replica, this conceptual design powerfully demonstrates how ant nest architecture can inspire innovative building ideas.

Figure 8: Tower of Time (Tower of Time. (2018))

Following are the various elements of the building inspired by Ants' nest, explained in detail:

4.7.1 Structural Form & Layout:

In order to create the "ant nest" structure, parametric design is used at the building's epidermal. The idea of "ant nest" is also reminiscent of the subterranean mining operation. The Time Tower's "ant nest" has organized effective internal transport pathways, and the excavated earthwork has been used as the primary building material. Green plants cover the epidermis in this parameter, and the "ant nest" epidermal structure can expand the area of plant coverage from many dimensions, hence increasing the air purifying effect of the plants. Ant's nests consist of complex networks of interconnected chambers, each designated for specific functions like nurseries, food storage, and ventilation. The Tower of Time is divided into multiple zones, each serving different purposes (residential, commercial, and green spaces), just like ants segregate functions within their colonies. Instead of a conventional vertical design, internal voids and interconnected levels create a layered habitat, much like how ant tunnels connect different chambers underground.

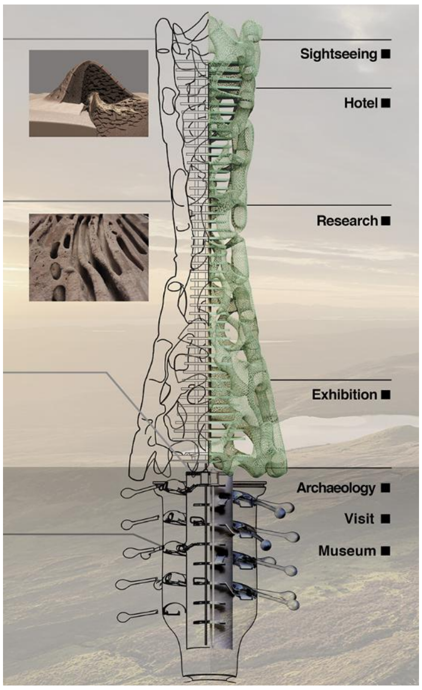

Figure 9: Section of Tower of Time
(Tower of Time. (2018))

4.7.2 Natural Ventilation system:

Ants use a system of air shafts and tunnels to regulate temperature and airflow underground, maintaining stable conditions regardless of external temperatures. The Tower of Time, has a passive ventilation system with a central air shaft that acts like a "lung," constantly circulating fresh air and removing hot air. Porous façade elements mimic the small holes found in ant nests that allow controlled air exchange. This design minimizes the need for air conditioning, significantly reducing energy consumption.

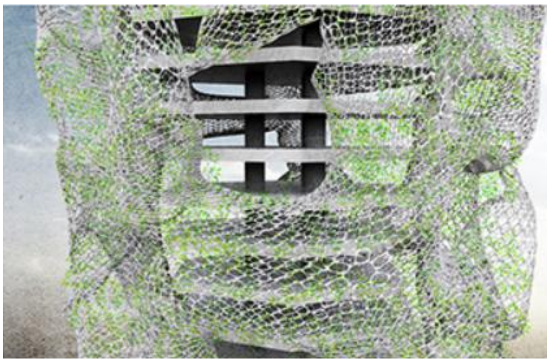

Figure 9: Porous Façade elements in the Tower of Time
(Tower of Time. (2018))

4.7.3 Energy efficiency (resource optimization):

Ants optimize their energy use by harvesting heat, moisture, and nutrients from the environment efficiently. Their colonies are designed to be self-sustaining, reducing external dependence. In the Tower of Time, solar panels and wind

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turbines are integrated into the exterior to generate renewable energy. Heat recovery systems capture waste heat from different zones of the building and repurpose it for temperature regulation. Water collection systems harvest rainwater, similar to how ants optimize underground moisture retention.

4.7.4 Underground Expansion & Longevity (inspired by ants colony growth):

Ant colonies expand gradually, with new tunnels and chambers being added over time based on population and resource availability. In the Tower of Time, instead of being a static structure, the building is designed to adapt over time, allowing additional sections or underground extensions to be constructed based on future needs. The foundation mimics the deep, stable underground chambers of ant nests, providing resilience against environmental changes.

4.7.5 Community & Social Interaction (Inspired by Ant Colony Behavior):

Ants communicate and collaborate seamlessly within their structured colonies, ensuring efficiency in resource distribution and survival. In the Tower of Time, the building features shared community spaces, such as co-living zones, gardens, and multi-use areas to encourage social interaction and collaboration among residents. Smart infrastructure is integrated to enhance communication between different sections of the building, much like ants' pheromone-based navigation systems.

The Tower of Time is not just a skyscraper; it’s a self-sustaining, intelligent, and efficient habitat modelled after millions of years of evolution in ant colony design. It proves that biomimicry can revolutionize architecture, making it more adaptable, energy-efficient, and environmentally friendly.

5. Conclusion

The study of ants’ nest architecture offers a compelling avenue for enhancing sustainability in multistorey building design. While direct replication of complex underground networks presents challenges, the underlying principles of natural ventilation, thermal regulation, and efficient spatial organization provide invaluable inspiration. The conceptual "Tower of Time" illustrates the potential for integrating ant nest principles into innovative skyscraper designs, emphasizing both above-ground and subterranean functionality. The ongoing research of scientists like Walter R. Tschinkel continues to illuminate the intricacies of ant nest construction, providing a deeper understanding of these natural systems. As architects and engineers increasingly prioritize sustainable solutions, the exploration of ant nest architecture holds immense promise for developing buildings that are not only environmentally responsible but also resilient and adaptable to future challenges. By embracing the lessons learned from nature's efficient designs, we can pave the way for a more sustainable and harmonious built environment.

References

[1] Aldersey-Williams, H. (2003). Zoomorphic: New Animal Architecture. Laurence King Publishing.

[2] Bharti, H., Guénard, B., Bharti, M., & Economo, E. P. (2016). An updated checklist of the ants of India with their specific distributions in Indian states (Hymenoptera, Formicidae). Zookeys. doi:10.3897/zookeys.551.6767

[3] Charest, S. (2007). Ecosystem Principles Research. In M. P. Zari, Biomimetic Approaches to Architectural Design for Increased Sustainability. Auckland: Sustainable Buildings Conference.

[4] El Ahmar, S. S. (2011). Biomimicry as a tool for sustainable architectural design. Alexandria University, Master of Science Thesis. Alexandria: Unpublished.

[5] Shanghai Tower / Gensler. (2016). Retrieved February 2020, from Arch Daily: www.archdaily.com/783216/shanghai-tower-gensler

[6] Singh, A., & Nayyar, N. (2015). Biomimicry-An Alternative Solution to Sustainable Buildings. Journal of Civil Engineering and Environmental Technology, 2, 96 -101.

[7] Tschinkel, W. R. (2003, march 15). Subterranean ant nests: trace fossils past and future? Paleogeography, Palaeoclimatology, Paleoecology, 192(1-4), 321-333.

[8] Tschinkel, W. R. (2005). Nest architecture of the Florida harvester ant, Pogonomyrmex badius. Journal of Insect Science, 5-9.

[9] Tschinkel, W. R. (2005). The nest architecture of the ant, Camponotus socius. Journal of Insect Science.

[10] Zari, M. P. (2007). An ecosystem based biomimetic theory for a regenerative built environment. Lisbon Sustainable Building Conference (SB07). Lisbon.

[11] Tower of Time. (2018). Retrieved January 2025, from Evolo: https://www.evolo.us/tower-of-time-based-on-ant-nest-architecture/