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NATURE INSPIRED PRACTICES IN SUPER TALL BUILDING DESIGNS: SIMILARITIES OF FORM

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Abstract: Nowadays, competition between cities for super tall buildings is increasing. These buildings exceed the 300-meter height threshold, reaching enormous dimensions and playing a decisive role in the iconic character, visual impact, and prestige, and economic growth, technological and architectural progress of cities. In this context, the aim of the study is to formally analyze super tall buildings inspired by nature. In the study, which is evaluated according to two variables, super tall buildings are analyzed within the scope of the search for inspiration from nature in their form and interior formations. The study involves a content analysis of the ten tallest buildings in the Council on Tall Buildings and Urban Habitat (CTBUH) database. The formal analysis of the buildings revealed that the nature-inspired approach significantly influenced the design of the super tall buildings. This study emphasizes that combining super-tall designs with nature-inspired principles can create a new paradigm in architectural design. This combination improves the quality of life of individuals living in urban areas by enabling them to establish a closer relationship with nature. In this context, nature-inspired super tall buildings promote physical and mental well-being and create spaces that enhance indoor comfort.

Keywords: Super tall building, High-rise building, Nature inspired design, Formal analyses

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1. Introduction

There is no universally valid definition for tall buildings (Yıldız and Kalaycı, 2022). Definitions and height limits vary across countries, cities, specializations, regulations, relevant legislation and standards. The Council on Tall Buildings and Urban Habitat (CTBUH) has proposed a methodology and classification to establish a standard definition for tall buildings. According to this proposal, contextual data determines whether a building can be classified as a tall building.

A building is considered a tall building if it meets one or more of the criteria of context, proportion and technological sophistication (Figure 1). While the number of storeys is a poor indicator to identify a building due to varying height, a building over 14 storeys and 50 meters high is used as the threshold for a tall building. Furthermore, the CTBUH has created two categories for structures that reach significant heights: mega and super tall buildings. A super tall building is a structure with a height of 300 meters or more. A mega-tall building is used to characterize buildings with a height of 600 meters or more. In this context, since there are only four mega-tall buildings in the world (Burj Khalifa, Merdeka 118, Shanghai Tower and Mecca Royal Clock Tower) (CTBUH, 2023), the scope of the study is limited to super-tall buildings. The design of tall buildings draws inspiration from a variety of sources and processes. Nature-inspired approach is frequently preferred in tall building design. This is the process of transferring biological knowledge from nature to different disciplines through analysis, interpretation and abstraction (Mutlu Avinç, 2023). The systems in nature offer many strategies, systems and mechanisms that can be transferred to nature-inspired design (Badarnah and Kadri, 2015). This approach includes significant opportunities in terms of structural durability, high-quality indoor environment, resource-energy efficiency and morphology (Cruz et al., 2021).

The nature-inspired approach is applied in building design at three levels: organism, behavior and ecosystem. The organism level refers to imitating part or all of an organism/phenomenon such as an animal or plant. The behavior level involves being inspired by the behavior of an organism/phenomenon. Finally, the ecosystem level refers to transferring the ecosystem process and its logic as a solution to the problem. Each level has five possible imitation dimensions: form, material, construction, process and function (Zari, 2007). In this study, super tall buildings are analyzed in the context of form. In other words, the formal similarities with nature in the form formations and interior designs of the buildings were investigated. In this way, the study evaluates morphological approaches as well as natural elements such as plants, natural light and water in interior and exterior spaces.

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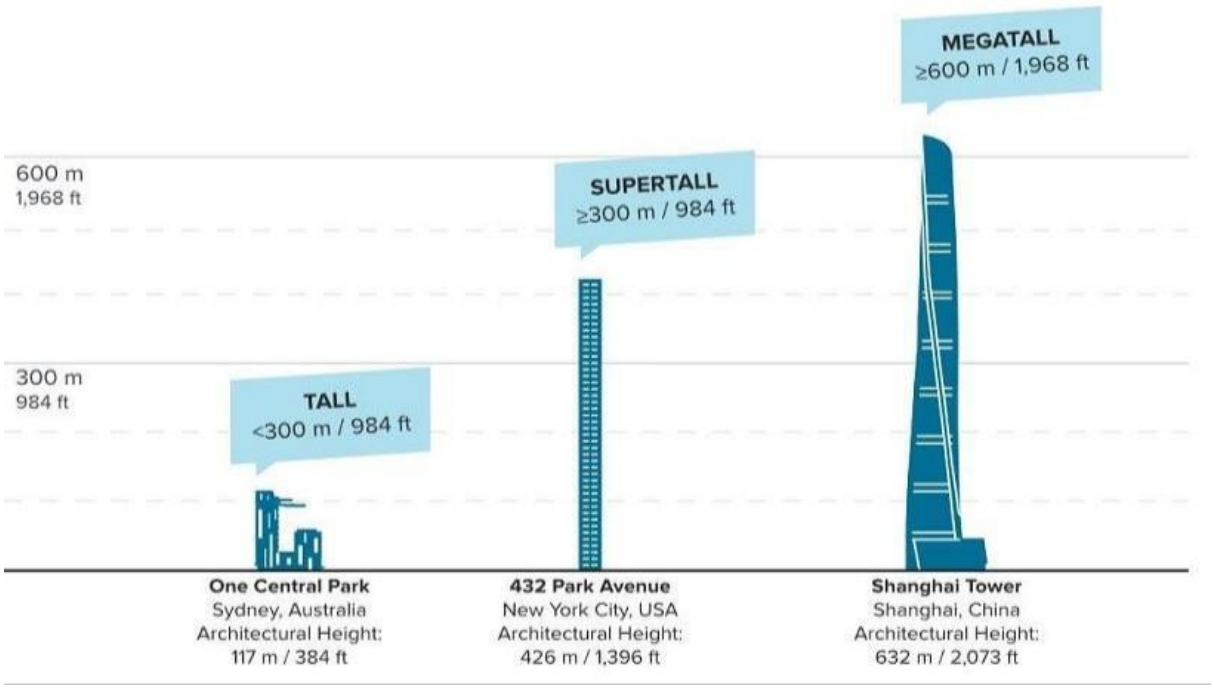

Figure 1. Types of tall buildings according to their height (CTBUH, 2023)

When the studies conducted so far with the keywords "tall building" and "nature-inspired building" are searched in the literature, it is seen that there is a limited number of studies on the subject. In the study by Altınöz et al. (2017), tall buildings designed with a biomimetic approach were analyzed. In the study, the energy consumption of the buildings was analyzed and the energy gains obtained were investigated (Altınöz et al., 2017). In Al-Sehail's (2017) study, "Biomimetic Structural Form" was developed as a sustainable paradigm. The design of a sustainable super high-rise building is examined as an application example of "Biomimetic Structural Form" (Al-Sehail, 2017). Mirniazmandan and Rahimianzarif (2018) examined different approaches and levels of biomimicry in tall buildings. In this study, it is discussed that the use of different biomimicry principles can lead to different results regarding the sustainability of tall buildings (Mirniazmandan & Rahinianzarif, 2018). In a study conducted in 2018, Al-Kodmany evaluated 30 tall buildings in different parts of the world in terms of sustainable design features and strategies (Al-Kodmany, 2018). The study identified design approaches that can bring sustainability and iconicity together. In the study conducted by Yetkin in 2020, the ecological gains provided by the biomimicry approach in architecture to tall buildings were classified (Yetkin, 2020). In another study by Contreras et al. (2023), the effects of biomimicry and biophilic design approaches in tall buildings were examined. It was determined that these concepts are very important in achieving a sustainable and healthy built environment (Contreras et al., 2023). Although there are many studies in the literature on the use of nature-inspired approaches in tall buildings, there is no research examining the relationship between nature-inspired design and super tall buildings. In this context, the study investigates the phenomenon of being inspired by nature in the form of super tall buildings. By their very nature, super-tall buildings stand out with their technological sophistication, construction systems, earthquake and wind resistance, and functionality. This study contributes to the related literature by evaluating super tall buildings in terms of their relationship with nature.

2. Materials and Methods

In this study, super tall buildings in the CTBUH (2023) database are analyzed within the scope of nature-inspired design approaches. The study was limited to 10 buildings whose construction was completed until 2024. General information about the buildings (building name, city, and year of construction, height, number of floors, material and function) is presented in Table 1.

The super tall buildings are evaluated according to the relationships they establish with nature in their building form and interior design. The design inputs of the buildings were obtained from literature studies and websites sharing information about the buildings and the formal similarities with nature were analyzed. Formal similarities consist of plant and animal morphologies as well as various sources of inspiration that can be associated with nature. In the interiors, the use of natural elements such as materials, plants, trees and water, as well as the use of parameters such as color, texture and form that emulate nature were also taken into consideration. In this way, it has been revealed how the buildings establish a connection with nature both in their form shaping and interior design. Figure 2 shows the flow chart of the study.

Phytomorphic approach means having or being

represented by the qualities of a plant that give information about its anatomy, forms and structure (Merriam-Webster, 2023). While the zoormorphic approach is the transfer of animal characteristics to inanimate beings, the anthropomorphic approach is the transfer of human characteristics to inanimate beings (Suyabatmaz and Sever, 2023). Abiotic embodiment, on the other hand, is defined as being influenced by non-living features that are part of the physical or chemical environment that affect the functioning of living things and ecosystems (Chapin, et al., 2002). Therefore, ten super-high structures with zoomorphic, anthropomorphic, phytomorphic and abiotic morphology were analyzed in this study.

Table 1. List of super tall buildings

Building Name	City	Year	Height	Floor	Malzeme	Function
Burj Khalifa	Dubai	2010	828 m	163	Steel + Concrete	Office+Residence+ Hotel
Merdeka 118	Kuala Lumpur	2023	678 m	118	Concrete+Steel+Co mposite	Office+Residence+ Hotel
Shanghai Tower	Shanghai	2015	632 m	128	Concrete+Steel+Co mposite	Office+Hotel
Ping An IFC	Shenkron	2017	599 m	115	Concrete+Steel+Co mposite	Office
Tianjin CTF	Tianjin	2019	530 m	97	Concrete+Steel+Co mposite	Office+Residence+ Hotel
Taipei 101	Taipei	2004	508 m	101	Composite	Office
Laktha Center	St. Petersburg	2019	462 m	87	Concrete+Steel+Co mposite	Office
Vincom Landmark 81	Ho Chi Minh	2018	461 m	81	Concrete+Steel+Co mposite	Hotel+Residence
Suzhou IFS	Suzhou	2019	450 m	95	Concrete+Steel+Co mposite	Office+Residence+ Hotel
Al Hamra Tower	Kuveyt	2011	413 m	80	Concrete	Office

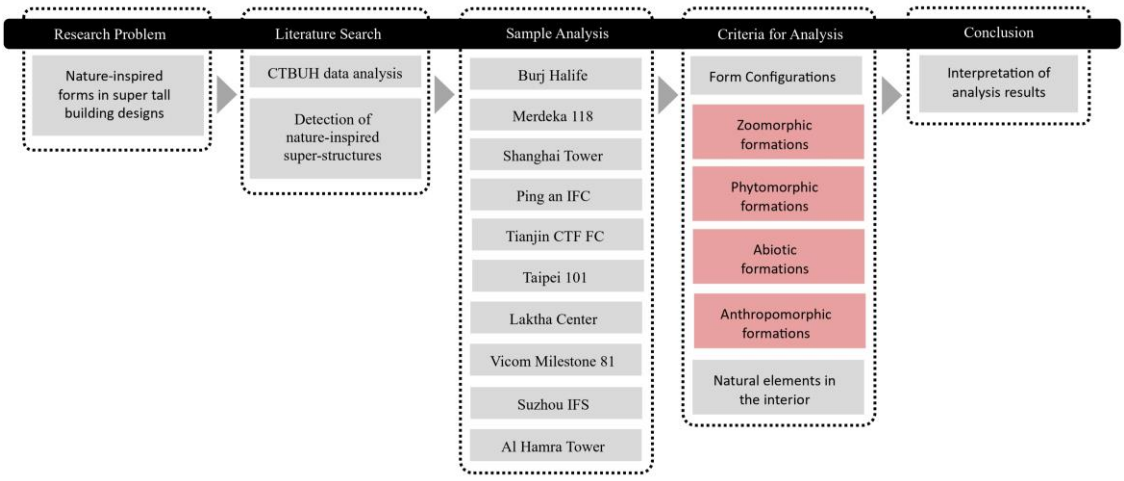

Figure 2. Method flowchart

3. Results

In this part of the study, descriptive information about each building is presented regarding the interiors' nature-inspired design approach and biophilic features. The buildings were analyzed from the highest to the least high building.

3.1. Burj Khalifa

The building, completed in 2010, is 828 meters high with 163 floors and currently holds the title of the tallest

building in the world. The architectural and structural design of the building in Dubai was carried out by Skidmore Owings and Merrill. The structure generally consists of a hexagonal core in the center and units connected to it. The starting point of the design is the Spider Lily (Hymenocallis), a flower that grows in the desert. The flower's tri-axial structure and spiral growth pattern have been crucial in shaping the tower's form. In addition, traditional Islamic forms and intertwined geometries are other references used to enrich the design. As the building gets higher, its narrower form both emphasizes the height effect of the building and reduces the effect of wind loads. The building's facades are intentionally designed with non-planar surfaces, specifically avoiding flat surfaces and employing circular corners to minimize wind loads on the building's exterior (Figure 3) (Ilgın and Günel, 2008).

This desert flower-shaped triaxial plan has many advantages for the building. The first advantage is that it offers an ideal solution for residential units. It provides both privacy and access to the panorama between the units. Another advantage is that it allows the building to be designed with a buttressed core system. The decreasing profile of the building's plan section along its height accentuates the tower's ascent to the sky, giving the impression of a structure perpetually rising with increasing momentum. This phenomenon highlights the tower's height, simultaneously reducing the wind load on the upper levels of the building. As the tower ascends, the variation in the plan section minimizes the impact of wind forces. The distinct design of each new layer prevents the formation of wind vortices (Weismantle et al., 2007).

Biophilic elements are also included in the interior design of the building. More bright and spacious interiors were obtained with perennial trees in the lobby spaces. Natural elements were used in the offices to comfort the employees, especially in the resting areas (Figure 4).

Figure 3. Burj Khalifa design (URL-1), Hymenocallis flower (URL-2).

Figure 4. Burj Khalifa office designs (URL-3); (URL-4)

3.2. Merdeka 118

The building, completed in 2023, is 678 meters high and has 118 floors. The civil and structural engineer of this building is Arup. The building serves as a hotel, residence, and office. It is the tallest building in Malaysia and Southeast Asia and the second tallest in the world. The form of the building is based on the posture of Tunku Abdul Rahman's speech on 31 August 1957 when he declared Malaysia's independence (Arup, 2023) (Figure 5).

The design of the building incorporates biophilic elements in its overall design and interior spatial composition. In order to break the cold and hard appearance of concrete curtain walls and beams in semi-open spaces, the spaces are enriched with soft floors and landscape elements that emulate nature (Figure 6). In the landscape design of the building, interaction with nature is strengthened with water and green elements.

3.3. Shanghai Tower

The building, completed in 2015, is 632 meters high and has 128 floors. The building serves as a hotel and office. Shanghai Tower is located in Pudong, the business and commercial center along the east bank of the Huangpu River on the Lujiazui peninsula, the financial center of Shanghai. It is the second-tallest building in the world and the tallest building in China. The decisive factors in the design of the structure include its location in an area with strong air flows, its positioning in an active seismic zone, its foundation on weak soil, and its candidacy for LEED Gold certification. The spiral transparent form of the tower serves as a showcase for the latest technologies and exemplifies targeted sustainability

strategies and emerging standards in public spaces (Xia et al., 2010). Additionally, rainwater harvesting has been considered in the Shanghai Tower (Lau, 2015).

The building's form was inspired by the spiral movement of the wind, and the form was shaped with vertically displaced sky gardens (Xia et al., 2010; Ali and Kodmany, 2012). Analyses conducted on wind and airflow patterns led to the preference for a form that offers optimal resilience and resistance against the prevailing winds (Figure 7).

Biophilic elements are included in the interior landscape designs of the building. The building, which consists of two shell surfaces, is enriched with natural landscape elements to break the cold and soulless effect between the glass spaces (Figure 8).

Figure 5. Merdeka 118 Design Concept (URL-5).

Figure 6. Merdeka 118 interior and exterior designs (URL-6), (URL-7).

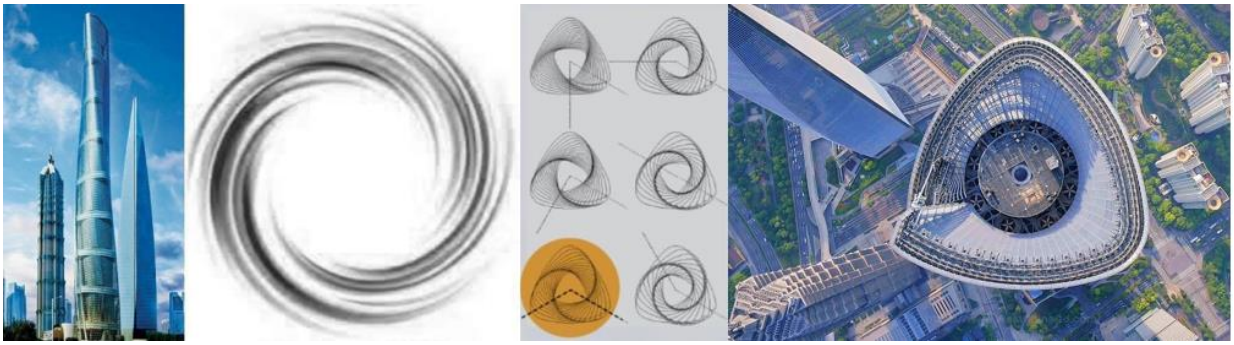

Figure 7. Shanghai Tower Design Concept (URL-8), (URL-9), (URL-10).

Figure 8. Shanghai Tower interior design (URL-11).

3.4. Ping An International Finance Centre

The building, completed in 2017, is 599 meters high and has 115 floors. Designed by Kohn Pedersen Fox, the building serves as offices. The tower has a distinctive, futuristic design that combines various sustainable features such as a double skin facade, rainwater harvesting system, and energy-efficient HVAC system. The building has a square plan and is designed considering earthquake and wind loads (Poon et al., 2011). The building form resembles a stretched cable. With its sharp corner lines and pointed endpoint design, the building resembles precious stones (diamonds, etc.) that are rare in nature (Figure 9).

Biophilic elements are included in the interior design of the building. Nature-inspired design elements are frequently used in the shared areas of the building to enrich the interiors. The roof gardens of the building also feature natural elements (Figure 10).

3.5. Tianjin CTF Finance Centre

The building, completed in 2019, is 530 meters high and has 97 floors. The convex and concave surfaces of the structure, along with its conical form, are designed to reduce wind loads. The architectural form of the building exhibits biomorphic characteristics, resembling the pistils of greenhouse flowers. The building combines residence, office, and hotel programs under a single roof and is an important center at the intersection of transportation axes (Lee et al., 2016) (Figure 11).

Green elements are included in the interior design of the building. More interesting and spacious interiors have been obtained by breaking the monotony of the corridor spaces with live plant walls. Natural wood surfaces and wave-shaped lighting elements in the corridor spaces have a biophilic character (Figure 12). In addition to the interior spaces, the building establishes a visual connection with the natural landscape in the exterior spaces.

Figure 9. Ping An IFC design concept (URL-12) https://thetowerinfo.com/visit-ping-an-finance-center-observatory/.

Figure 10. Ping An IFC Indoor and Outdoor Spaces (URL-13), (URL-14)

Figure 11. Tianjin CTF Design Concept (URL-15), (URL-16)

Figure 12. Tianjin CTF Indoor and Outdoor Spaces (URL-17), (URL-18), (URL-19)

3.6. Taipei 101

The building, completed in 2004, is 508 meters high, 101 stories, and is used as offices. The design of the building is based on wind and earthquake loads. It is risky to build high-rise buildings in the Taipei region, which is shaken by earthquakes twice a year. Therefore, the building has a flexible design (Chang, 2012). From the main façade, the eight-section building resembles a Chinese or Japanese Pagoda (Buddhist temple). The form of the pagoda, inspired by the pagoda flower, and the thin and delicate cross-section of the bamboo plant have shaped the design of the building. The division of the structure into eight segments is rooted in the Chinese belief that the number 8 brings good luck. The windows of the building are blue-green, and motifs found in Chinese temples are placed at all corners of the façade. The building forms an inverted cone by narrowing 5 degrees in the first 25 stories. Afterward, it widens by 7 degrees in every nine stories upwards. The mobility in the form and the high rate of delicacy reveal the elegance of the building (Figure 13).

The building overlooks the natural landscape of Taipei City and has Biophilic features in its interior design. Artificial and natural landscape elements and water pools in the atrium spaces create warmer and more spacious interiors (Figure 14).

3.7. Laktha Center

Lakhta Centre is 462 meters high and has a total rotation angle of 90 degrees. The rotation angle for each floor is 1 degree. A circular form at the center and five additional conical volumes surrounds this central form in a spiral movement. Built-in 2019, the building has 87 floors and is used as an office. It has a five-pointed star-like floor arrangement and a conical twisted form. While the conical form contributes positively to its aerodynamic performance, the twisted form reduces the wind load on the structure (Askarinejad, 2014). The form of the Lakhta Centre is inspired by the geometry of the ice crystal (Figure 15).

The building is located on the shore of the Baltic Sea, and biophilic elements are prominent in landscape and interior design. The atrium spaces are enriched with perennial trees, shrubs, and grasses. In addition to landscape elements, flexible and fluid spaces were achieved with natural and organic forms (Figure 16).

Figure 13. Taipei 101 Design Concept (URL-20), (URL-21).

Figure 14. Taipei 101 indoor and outdoor spaces (URL-22).

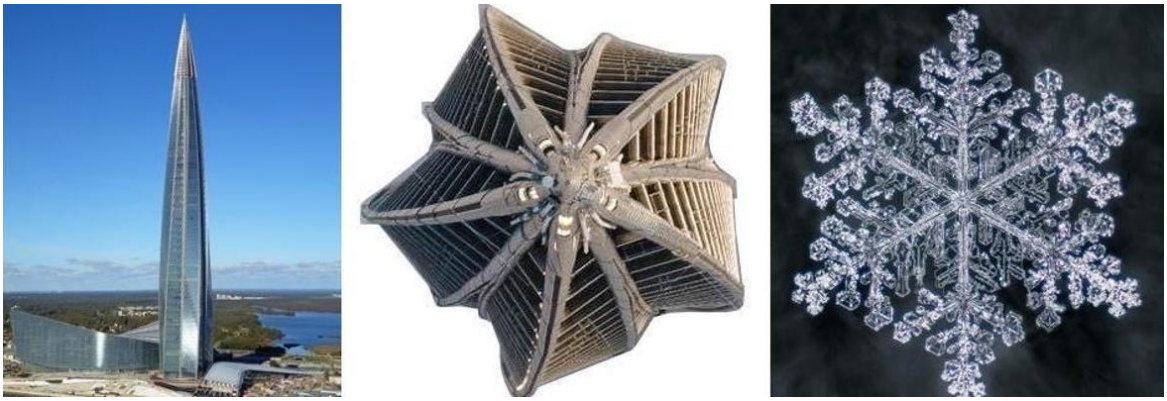

Figure 15. Laktha Center design concept (URL-23).

Figure 16. Laktha Center indoor and outdoor spaces (URL-24; URL-25; URL-26).

3.8. Vincom Landmark 81

Completed in 2018 in Ho Chi Minh City, Vietnam, the 461m high Vincom Landmark 81 is a hotel and residential building. It is the tallest building in Vietnam. The shape of the building is inspired by the traditional bamboo bundle, representing strength and unity in Vietnamese culture (Truong et al., 2020). The blue glass façade of the building is covered with colored lights to make it stand out both day and night (Figure 17).

Figure 17. Vincom Landmark 81 design concept (URL-27).

Located on the periphery of Vinhomes Central Park, the building establishes a panoramic visual connection with the Saigon River. The building has biophilic features in its interior and landscape designs. Natural elements are frequently used in the interiors, semi-open, and open spaces to break the hard and cold glass-steel material effect. The use of water and plant elements together in the landscape design of the building emphasizes the integrity of natural and built elements (Figure 18).

3.9. Suzhou IFS

Suzhou IFS is 450 meters high and functions as a hotel, office, and apartment building. The form of the tower is designed inspired by a fish. The tower is planned to interact with the surrounding bodies of water. The tower form and orientation reduce heat and glare while bringing more natural daylight into the interior spaces (Bao et al., 2015) (Figure 19).

The tower moves towards Lake Jinji, opening up towards the water. More than a mere architectural ornament, it maximizes the water view for the serviced apartments within the expanded base. Natural elements and vegetal forms are indirectly included in the interior design of the building. Natural materials and textures are preferred in the living areas, and warmer, more comfortable spaces have been created (Figure 20).

3.10. Al Hamra Tower

The building, also known as Firdous Tower, is the tallest in Kuwait. The building, completed in 2011, was designed by Skidmore, Owings and Merrill (SOM). The 80-storey, 413m (371m used) tall Al Hamra Tower is an example of a helix-shaped super-tall building with an office function. Since the office tenants wanted to see the golf view, the architects designed the building so that they could see the golf as they went up to the upper floors. The north, west, and east sides of the building form are transparent, while the south side is opaque against the harsh desert sun. The building form resembles a curved metal plate as a source of inspiration (Figure 21).

Biophilic elements such as natural landscapes, geometric patterns, and plants are used in the interior design of the

building. Nature-inspired elements are frequently used in workspaces and offices to create spacious and comfortable spaces for employees. The building also has a natural sea view. The large glass windows provide a direct visual connection with the sea view. The natural light coming in through the large glass windows creates a dynamic and diffused light effect (Figure 22).

The nature-inspired approaches seen in the form and interior design of ten (10) super tall buildings are presented in Table 2. Accordingly, formal similarities are established with biotic and abiotic natural concepts such as desert flower, human pose, wind vortex, precious stones, greenhouse flower, bamboo plant, snow crystal, and fish. In addition, in the interior spaces of these buildings, recreation areas, visual connection with the landscape, the use of live plants and trees in the atrium and corridor spaces, and the use of natural materials are observed.

Figure 18. Vincom Landmark 81 design concept (URL-28; URL-29).

Figure 19. Suzhou IFS concept design (URL-30).

Figure 20. Suzhou IFS indoor and outdoor spaces (URL-31; URL-32; URL-33).

Figure 21. Al Hamra Tower (URL-34; URL-35).

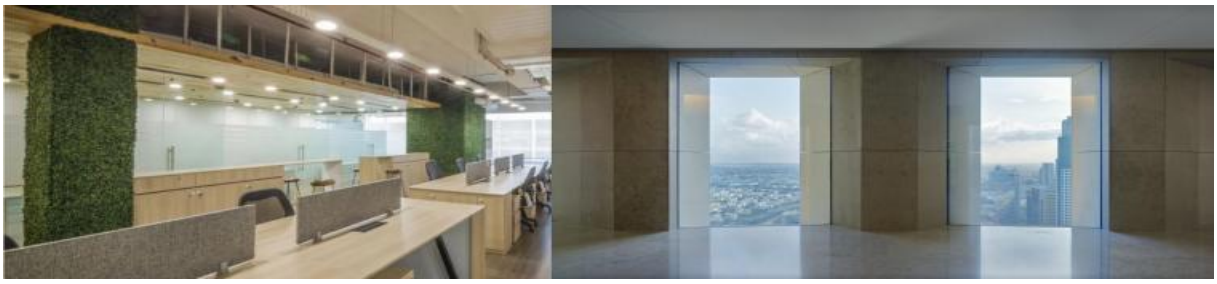

Figure 22. Al Hamra Tower indoor and outdoor spaces (URL-36; URL-37).

4. Discussion

In super tall buildings, design inspirations are partially in the background compared to low-rise buildings due to structural system requirements and height limits. In the examples, the focus is on super tall buildings that are inspired by nature. In this way, the potentials of super tall buildings in terms of design are revealed. The search for inspiration from nature has been identified in both the interior design and the form shaping of the buildings. At the same time, while the examples have natural inspirations in terms of form, there are also forms of learning from nature such as collecting rainwater, shaping the form against wind and earthquake loads.

Integrating nature-inspired elements into tall building designs has positive effects on the physical and mental well-being of the occupants. The buildings analysed in this study have integrated principles and elements from nature into their design. In the analysed examples, organic and inorganic natural forms such as bamboo plant and bundle, wind vortex, diamond, desert flower, human posture, ice crystal, pagoda flower, greenhouse flower and fish were found to be the inspiration for super tall building designs. In addition, it has been found that all the buildings analysed have given elements such as landscape, plant and water elements, natural patterns in their interior and exterior designs. In general, common areas such as atriums, lobbies, corridors, seating and resting areas are the spaces where nature-inspired approaches come to the fore. These spaces create larger, spacious and comfortable areas for the building users.

5. Conclusion

In conclusion, super tall buildings by their very nature are characterised by technological sophistication, construction systems, earthquake and wind resistance, and functionality. This study contributes to the related literature by evaluating super tall buildings in terms of their relationship with nature, which is often ignored. As super tall buildings get higher, their connection with nature and the ground decrease. On the other hand, in order to re-establish interaction with nature, natural elements are used more in the interior spaces. Analogical inspirations from nature are widely used in the interior and exterior designs of the super tall buildings. This study is limited only to the form and interior design of the buildings in their relationship with nature. However, nature-inspired design is also used as a data source in many aspects such as structural lightness, durability, responsiveness, adaptability and sustainability. In future studies, the scope of the study can be expanded by adding these criteria.

Table 2. Nature-inspired approaches to super tall buildings

No	Image	Connection with nature in the formation of the building	Connection with nature in the interior	No	Image	Connection with nature in the formation of the building	Connection with nature in the interior
1		Inspired by the desert flower Phytomorphic formations	Use of nature-inspired elements in offices, recreation areas, and outdoor spaces Visual connection with the view/ landscape	6		Inspired by the bamboo plant Phytomorphic formations	Use of nature-inspired elements in atrium spaces and outdoor spaces Visual connection with the view/landscape
2		Inspired by human posture Anthropomorphic formations	Use of nature-inspired elements in semi-open spaces and outdoor areas Visual connection with the view/ landscape	7		Inspired by snowflakes Abiotic formations	Use of nature-inspired elements in atrium spaces and outdoor spaces Visual connection with the view/landscape
3		Inspired by the wind vortex Abiotic formations	The use of nature-inspired elements in atrium spaces on the floors and outdoor spaces Visual connection with the view/ landscape	8		Inspired by the bamboo bunch Phytomorphic formations	Use of nature-inspired elements in semi-open spaces and outdoor areas Visual connection with the view/landscape
4		Inspired by precious stones in nature Abiotic formations	Use of nature-inspired elements in shared areas and outdoor spaces Visual connection with the view/ landscape	9		Inspired by the fish figure Zoomorphic formations	Use of nature-inspired elements in living spaces and outdoor areas Visual connection with the view/landscape
5		Influenced by greenhouse flowers Phytomorphic formations	Use of nature-inspired elements in the corridor areas on the floors and outdoor spaces Visual connection with the view/ landscape	10		Inspired by curled metal plate or paper Abiotic formations	Use of nature-inspired elements in offices, workspaces, and outdoor spaces Visual connection with the view/landscape

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	A.Y.	G.M.A.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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