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Passive Cooling Techniques in Historical Building Versus Contemporary Bio Mimic Concepts: An Overview

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Abstract Passive cooling techniques have been a problem in design and construction, due to climatic factors, fossil fuel usage, and other environmental issues that have been on the rise. This review paper is aimed at revisiting various passive cooling techniques that have been applied in the past and contemporary techniques that are being applied now. Research in passive cooling techniques has been proposed throughout the world. This research will focus on the use of the bio-mimic concept approaches that have been adopted in the design and construction of buildings around the world. Case studies of biomimicry design approaches like the East Gate Office building in Harare used the concept of termite mounds, natural techniques, and sustainable materials to cool the building. Rooftop garden construction techniques have created a balance in the temperature of indoor spaces in buildings, as seen in the Vancouver Convention Center in Canada. This review paper is limited to bio-mimic design approaches to passive cooling techniques, and it is seen to have significant solutions to energy efficiency in buildings. Further studies can also be carried out in search of alternative methods or approaches that can be adopted for sustainable design techniques.

Keywords: *Passive cooling, biomimicry, building efficiency, climatic buildings, sustainable materials.*

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1. Introduction

Passive design techniques have been the primary design approaches in both low-energy architecture and vernacular architecture, particularly in areas where climatic conditions are harsh and human comfort is compromised. Buildings were designed and built to acclimate to the environment's bioclimatic conditions as well as harness the natural climatic elements of their surroundings to achieve year-round thermal comfort. However, since the discovery of fossil fuels and advancements in material technology, the construction industry has been less concerned about the environment and passive practices. Buildings have become reliant on energy to give thermal comfort to their occupants. The use of fossil fuels is increasing, resulting in increased environmental difficulties and health issues linked to greenhouse gas emissions. As a result of these issues, architectural, engineering, and construction (AEC) professionals’ attention has switched to environmental and climatic elements as fundamental drivers of building design to deliver essential thermal comfort while reducing energy usage [1]. In recent years, architectural design and construction have attempted to adopt methods to address human comfort in buildings, but they have all relied on mechanical and electrical means to achieve thermal balance, which consumes a lot of energy and has an impact on the environment.

2. Passive Cooling

The term "passive cooling" refers to a variety of tactics and solutions that result in more energy-efficient building design and improved occupant comfort. The concept stresses architectural design approaches that reduce a building's energy consumption by combining traditional energy-saving techniques such as building siting, an efficient envelope, appropriate levels of fenestration, increased daylighting design, and thermal mass [2]. Passive cooling methods and active cooling methods Passive cooling is a design or technology feature designed to provide cooling to buildings with or without requiring a minimum amount of `energy. It is used to improve the efficiency of energy [3]. Passive cooling can be accomplished through natural airflow or by emulating past natural cooling systems. This is based on differential pressure created by wind-induced pressure or buoyant ventilation at the vent or apertures. The facades and openings, and their closeness to the wind pressure, have a role in air circulation. The used or stale warm air rushes in from the leeward side, while fresh outdoor air enters from the windward side (highly pressurized) (low pressure). When the inside of a building is hotter than the outside, gravitational acceleration circulation occurs, causing the inside air to rise and exit via larger openings. The air is colder and denser outside [4]. Many aspects, such as the geometry of a building, its orientation, the placement of shading components in the building, the landscape and vegetation, the indoor or outdoor paint color, and the building's insulation, can all help to conserve energy. The lower the thermal gains, the smaller the building's surface area-to-volume ratio. As a result, a building with a spiral shape is more energy-efficient than a standard cubic structure in terms of heating and cooling requirements for a given volume. As a result, a dome home has a 30% lower contact area than just a comparable-sized box house, leading to one-third lower heat transfer to or from its environment and, on average, a 30% decrease in cooling and heating costs [4]. Natural cooling and ventilation processes are used to collect, store, distribute, and control energy flow in passive architecture. When natural energy is used to conserve conventional energy for thermal comfort, passive energy becomes very effective. Passive design solutions aim to reduce or even eliminate the need for active mechanical systems while preserving or even improving occupant comfort. The focus of this review study is to revisit various passing cooling approaches that have been used in the past as well as current techniques. Passive cooling systems have been proposed all over the world for research. And to provide a comprehensive review of the passive cooling techniques that have been used in heritage buildings in parts of North Africa with hot climates and contemporary bio-mimic buildings around the world, including their working principles, how they have been applied in design and construction, and an analysis of the significance of passive cooling techniques in building performance. This review will provide information on the ability of passive cooling systems to improve interior thermal comfort and energy efficiency.

2.1. Passive Building Techniques

For building cooling, passive cooling strategies are the most crucial. Successful passive cooling designs in buildings necessitate a thorough understanding of airflow patterns around a structure as well as the impact of neighboring structures on it. Different forms of passive cooling technologies are generated based on internal heat gain, heat transfer in an envelope form, and heat transfer occurring in a mixture of outdoor and indoor air [3]. The solar passive technique is a building construction strategy that focuses on temperature acquisition and heat surplus control to maintain a steady interior temperature while utilizing less mechanical energy. The word vernacular can also apply to a term used in the household. Architectural vernacularism is an example of creating natural, long-lasting features in architecture. Commonly accessible resources include energy, materials, and natural resources. Vernacular methods are developed using locally accessible, readily worked, and natural construction materials such as timber, thatch, mud, and locally found trees such as Bahun, Kirir, and Loherro that are climate sensitive. Professionals construct vernacular architecture, which is based on the myths and rituals of their respective civilizations [5]. Natural qualities, climate, local building materials, and intellectual responses to physical elements give comfort and inspire shapes in vernacular architecture. Vernacular architecture is the most feasible for residential buildings. The system uses new techniques and reduces or prevents energy use.

2.2. Vernacular Passive Cooling Techniques

Courtyard: The courtyard acts as a storage room for cold air throughout the night, whenever the temperature decreases to its lowest point. After that, the chilly air is dispersed across the smallest feasible region. The cool air is then carried into the interior area during the hottest portions of the day. As a result, using nocturnal ventilation to cool high-mass structures and small courtyards is an effective strategy. Despite its capacity to act as a thermal regulator in hot desert climates, the land required for internal courtyards may be a major cause for this technique's rejection. One of the most crucial sites to produce effective shading is the courtyard. As a result, in traditional courtyard buildings in hot, dry regions, trees as interceptor mechanisms shelter buildings from straight sunrays and provide shaded regions within the courtyard as well as on the building walls. The courtyard is usually encircled by two levels within a traditional home, at a height that allows sunlight to reach sections of the courtyard floor for some time, as specified by the courtyard's design and the ratio of building height to courtyard width. Porticos: The portico is a typical vernacular architectural element that provides shade on at least two sides of the courtyard. The portico is particularly effective on the courtyard's south and north sides. Additionally, because the house surrounds the courtyard, a portion of the courtyard stays covered throughout the day, keeping the home cool until late in the afternoon. Cool air is created in the shaded area, and it flows through into ground-level rooms, replacing the rising heated air. This idea highlights the need for increasing ventilation systems in a structure with very few side openings and decreases reliance on outer wind conditions. Because of these advantages, several academics and architectural designers have been motivated to establish and develop a range of unique stack air conditioning systems, like cross ventilation options, in a variety of construction types. This includes advanced passive stack devices, solar-induced ventilation, wind-stack-driven systems, and sometimes even fan-induced stack ventilation solutions. The classic notion of ambient air circulation does not necessarily function in today's climate of higher temperatures and denser urbanized settings. Therefore, a functional outlet space at the top of the structure should be constructed, and vertical air circulation should be generated using a stack ventilation approach. In Kurdish vernacular architecture, aperture size and placement are considered. Small outside apertures are located at the top of the wall and are minimal in number [6]. Ewan: It's an enclosed hall having three main walls (among two rooms) as well as a fourth side that faces the inner entry hall and is exposed to clean air. It has a taller roof. The rest of the spots are occasionally on the floor and other times on the ceiling. The courtyard level is roughly a foot higher than the other neighboring rooms. one and a half meters to allow for cellar window opening, the patio provides lighting and ventilation. It is possible to combine two or more natural ventilation systems through the chimney. Ewan has a strong focus. To keep the heat out, the windows are typically oriented to the south or east of the house. This angle favors its use as a source of light in the afternoon. A place for people to sit, rest, and eat [6] Stack ventilation: Stack ventilation is the upward flow of air through openings in the fabric of a building caused by changing air pressures, with cooling air entering via the lower opening and hot air escaping through the upper opening. Temperature changes are typically caused by the tenants' heating, lighting, and other interior heat sources. The height of the building determines this. The ventilation area can be enhanced by adding the vertical displacement between the input and outflow. Water Pool and Fountains: A fountain is a crucial component that purifies and moisturizes the air while also boosting the courtyard's visual and aesthetic appeal. It is situated in the courtyard's middle. A typical house's areas are divided according to the seasons. Summer rest places are in the south of the courtyard, facing north to avoid as much sun excess heat, or on the bottom floor, but winter rest areas are in the north of the courtyard to take full advantage of the southern direction. In addition, to promote cooling, a fountain has been positioned in the center of the Ewan on occasion [6]. A windcatcher: The wind tower, which may be seen in traditional homes, draws air into the home. Wind towers are utilized to cool residences all around the Middle East by taking advantage of the constant, strong winds. Towers are typically square, with crossed transverse partitions dividing the tower chamber into four equal sections, allowing warm air to escape through the posterior division while fresh air is routed into the home. The void channel delivers air to the earth, where it is cooled by flowing through damp subterranean tunnels [6]. Shape and orientation of the structure: Shape and orientation are two of the most important passive design elements for reducing energy consumption and enhancing comfort conditions for building occupants. The quantity of sunlight hitting surfaces, natural lighting, and wind direction are all influenced. Design and orientation have a significant influence on a building's energy efficiency in the pursuit of net-zero energy objectives, enabling us to take advantage of solar energy and predominant winds. The structure's compact shape and orientation may aid in limiting the amount of heat absorbed via the surfaces of buildings' exposure to ultraviolet radiation [5].

2.3. Bio Mimics Passive Techniques

"The abstraction of good design from nature," according to the definition of biomimetics. As nature strives for maximum results with less effort, good design means optimal design. When God created all these creatures in various forms, some of these works are relevant and valuable to us, while others are not. They are distant from human habitats and from achieving any of their objectives. God appears to have targeted human wants, some of which have yet to be identified, by providing us with a diverse set of methods and processes that each species can use to live and put these strategies into practice to improve our quality of life on the planet. Environmental architecture is one of the many professions that may learn a lot from nature. According to Vincent, architecture can learn a lot from systems that exhibit high degrees of integration and functioning while developing with their environment [7]. The following list of principles comprises nine that Janine Benyus, author of "Biomimicry: Innovation Inspired by Nature," mentioned, but Onno Koelman found to be more basic. The last three concepts were not revealed by Janine, but they were presented as follows by several sources: natural designs:

- Powered by the sun and other "natural" energy sources.
- Only use the energy and resources that are required.
- Maintain proper form to work effectively.
- Everything should be recycled.
- Recognize and reward cooperation to foster symbiotic connections.
- Develop a wide range of options.
- Adapt to the present moment.
- Stay away from excesses and "overbuilding."
- Make use of the power of limitations.

2.4. The East Gate Harare

Another resource where we might look for improved materials and techniques is bio-mimic architecture. The African termite mound may be the ultimate example of complex animal building from a whole-systems perspective. It includes wonderful solutions to prevalent design issues that we confront as well (structural strength, elemental protection, ventilation, humidity control, and so on). So far, at least one structure has come close to replicating this sophisticated ventilation system. The termites' unique design is used to keep the Eastgate building cool during the hottest days in Harare, Zimbabwe. Using nature-inspired design to circulate fresh air into the building instead of noisy, energy-guzzling air conditioners and fans increases comfort while lowering energy costs. Building residents are happier as a result, and they pay less and are more likely to renew their lease agreements [8]. In 1992, Pearce Partnership was appointed to construct an office building in Harare, Zimbabwe, incorporating shops and parking. The objective was to cut the high costs of acquiring and sustaining hardware such as air conditioning while simultaneously employing local artisans and using less energy. Pearce Partnership put forth a lot of effort to design an office complex that didn't need air conditioning. Because of Zimbabwe's favorable climate, this was a perfect chance. As a result of these views, Mick Pearce got interested in Zimbabwean termites. The special techniques of their nests were used as a main source of inspiration while designing Eastgate. They may be found all over the place and build highly effective buildings to protect themselves from the weather. The nest's lungs are the termite tower. The heated air rises, whereas the cooler air enters the termite nest through small vents on the sides. This serves as a natural built-in cooling system. The wind and the sun determine the form of the termite tower [9]. The pheromones on the most exposed surfaces are evaporated by the southeasterly wind during the day, which indicates that Termites can only work in sheltered regions. The wind and the sun combine to generate a shape that maximizes the nest's efficiency in its specific position. Termites only use these structures as chimneys to vent heat from September to November. They're only there till the rains come, and there's no need for the towers because the climate is naturally cool. Throughout the year, the diurnal change in Harare is at least 10 degrees Celsius, falling evenly on both sides of the 20-degree comfort level. If the diurnal shift is exploited inside the structure's bones, it can save a lot of energy. The design challenge was to come up with new ways to turn the structure of the building into a heat exchanger. By making openings in the concrete structure for ventilation air to move through, they could turn the concrete building into thermal storage from night to day. The design was likewise influenced by termite structures, but we had to use electrically driven fans to move the air because our chimneys didn't provide enough buoyancy. Termites have a similar difficulty in the early summer. They build larger and taller chimneys with one of the most attractively curved tops to gather wind-driven electricity. Abigail Doan explains how Eastgate makes good use of this method. "Each of the two buildings has air," says the narrator. Fresh air replaces stale air that rises and leaves via exhaust holes in the roofs of each storey. Enter vertical ducts' exhaust portion before it's drained out of the structure's main drain chimneys at the end of the day [7]. The main street of the building goes through it and has always been available to the public. The Eastgate building's core houses all the services. Several platforms stretch over the courtyard from the surrounding structure, allowing for easy transit across the area while also ensuring safety. Because of the openness of the place and the perspectives from all sides, the maximum number of eyes may be always on it. Termite defences are comparable to this. Pearce Partnership used another method from the environment, this time fractal cooling, which they learned from cacti instead of termites. The prickliness of a cactus functions as a defence against predators and for temperature considerations. Silky surfaces are good at absorbing heat as well as poor emitters of heat into space at night. During the day, prickly bodies generally are poor heat absorbers, but at night, they are powerful heat transmitters. This configuration allows for continuous monitoring of the systems. Fortunately, the architect and engineers were among the first occupants. They employed a data recorder to keep track of key temperatures gathered from probes put into a building's construction. It seemed like I was fine-tuning a huge machine. Many things have gone wrong, but everything was well after that. The building began to respond to fine adjustments by the occupants and the microclimate Has been It’s all about discovering optimums and calculating storage capacity, as well as modifying timing and speed admirers both during the day and at night Using biomimicry concepts, such as heat fractal cooling, exchange, and the architecture of movement, the sun, and wind and defensible area, as well as a variety of sustainable options opportunity, presented themselves and were taken advantage of to work together to build a successful and straightforward Construction that is innovative.

2.5. Vancouver Convention Center West (Vancouver, Canada)

Since the building is so close to nature, we are especially concerned about our impact on the environment. First, from the design of its double LEED® Platinum-certified buildings to the installation of cutting-edge green technology and the adoption of green operational practices, the Vancouver Convention Centre is committed to being as ecologically friendly as possible. The convention center is the first LEED® Platinum-certified facility in the world. Here are some reasons why we've made it our duty to design everything to be green.

- North America is home to over 400,000 native plants and grasses and boasts the world's biggest non-industrial living roof. The West building's six-acre living roof is the biggest in Canada.
- Lowering summer and winter heat gains and losses. The roof is built to be an insulator.
- Plants on the living roof's top offer honey for our "homemade" kitchen. On the roof, four beehives are containing European honeybees. The pollination of the blooms is aided by the bees.
- The water quality in the region has greatly improved because of the influx of a varied range of sea life. The base of the West building features a restored marine habitat.
- During the warmer months, our revolutionary black water treatment process recycles grey and black water, which can then be used for flushing toilets and rooftop gardening.
- To offer cooling in the summer and warmth in the winter, our seawater heating and cooling system makes use of the neighboring seawater.
- Natural sunlight and circulation are enhanced throughout the space.
- Native BC timbers from sustainably managed forests are used throughout the facility.
- Natural ventilation in the pre-function rooms on the west side. The roof has no open entrances, enabling it to develop into a perfectly functioning ecosystem for migrating species, and the landforms fold to enable views of the rich flora from within and without the structure. In the Burrard Inlet viewpoint, the roof's sloping contours mimic the topography of the area, providing a formal and ecological relationship to surrounding Stanley Park as well as the North Shore Mountains. The slopes provide natural drainage and seedling migratory patterns for the roof's ecology [10].

3. Analysis

EASTGATE CENTRE: inspired by termite mounds.

The Eastgate Centre, which opened in 1996, is a 55,000-square-meter office and retail structure in Harare, Zimbabwe's capital. The construction was contracted in 1991 by Old Mutual's property firm, the country's largest pension fund, which stipulated that it be "climate-appropriate" and have "acceptable" management and operating expenses. Air conditioning is common in modern office buildings in southern Africa, which comes at a high cost, accounting for 15-20% of the building cost, and adds a significant running cost over time. Furthermore, HVAC systems are hard to correct or replace due to the scarcity of components. The customer advised adopting passive cooling techniques since Harare's environment was tropical, with an eight-month dry season, cold nights, and scorching days [11]. Mick Pearce of Pearce Partnership was chosen as the project's architect, which was a good choice because Pearce's work is based on the premise that structures in tropical climates are typically based on temperature concepts and that instead, a structure should "draw" the environment. nature as a source of inspiration" He found inspiration in African termite mounds. In their underground nests, termites, especially those of the species M. Michaelseni employs fungus to transform wood into digestible nutrition. To do so, it was established that the nest needed to be kept at a constant temperature (87 degrees Fahrenheit), which was accomplished using an extensive circulation system of air channels in the climate-controlled, self-cooling mound [11].

Termite nest construction principles:

The termite tower acts as the nest's lungs. Cool air enters through tiny holes on the termite nest edges, while heated air rises. Mound ventilation is thought to be the result of two distinct processes. In the Martin Luscher paradigm of thermosiphon circulation for mounds that are capped or sealed at the top, the air circulates cyclically. Due to the heat that the nest generates, the air rises to the top of the mound, where water vapor entering the porous mound walls augments it. The air becomes denser and descends to the nest, where the process is repeated. If the mounds are open at the top, the stack effect forces air to travel in a single direction. The summits of the mounds, which have been estimated to be up to thirty feet tall, were commonly considered to breach the surface boundary layer, exposing them to increased wind speeds. Air is drawn into channels towards the lowest part of the mound and out through the top like a chimney by the wind current [12].

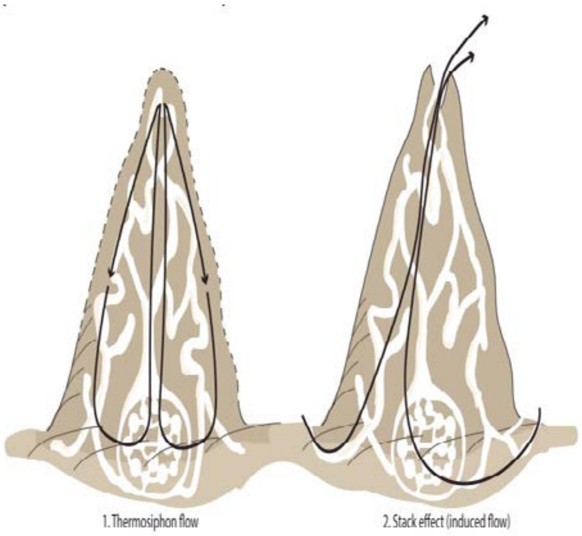

Figure 1. Two models of termite mound airflow. Source (Jacobson, 2014).

Fractal Cooling

At night, smooth bodies absorb the heat better but radiate it less effectively. During the day, prickly bodies are poor heat collectors, but at night, they are powerful heat transmitters. Its form allows for more rapid heat diffusion, which is great in hotter climates [9].

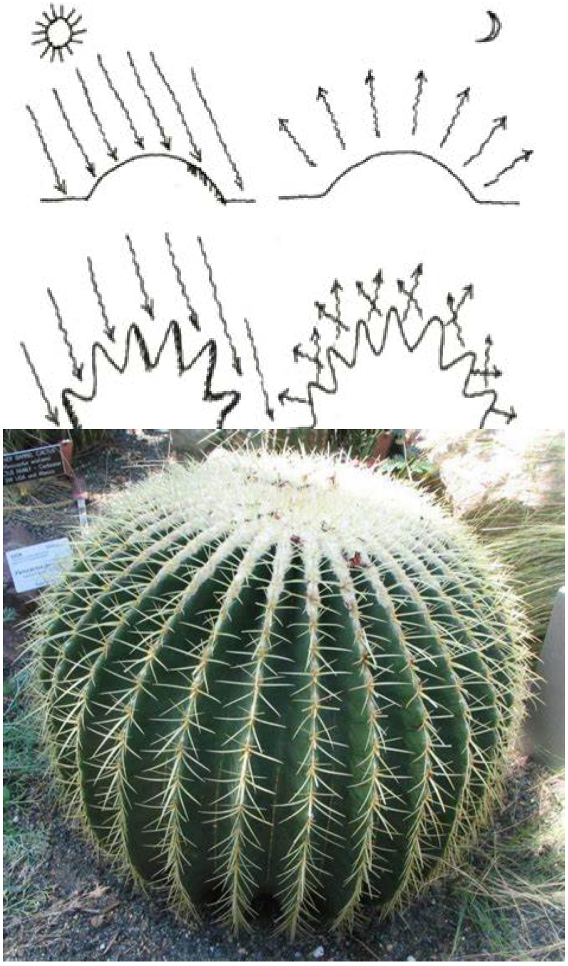

Figure 2. Smooth surface vs. prickly surface and cactus plant. source (Greenfield, project; East Gate Biomimicry-presentation).

The East Gate Design:

The complex is made up of two massive yet narrow office buildings that stretch east to west and are nine stories tall. A municipal street runs through the middle of the two structures, as does a second-story promenade "skywalk," and a glass canopy spans the top. The concrete structure of the building is coated in brickwork and precast concrete, which has a great ability to store heat inside its thermal mass. The buildings incorporate thirty-two vertical ventilation ducts that reach enormous air spaces that pervade the building. The heat generated inside the structure through people, machines, and lighting and the heat retained in the structure's heat capacity drive the thermosiphon effect from the inner offices to the roof. The heated air is discharged through huge chimney stacks on the roof, providing the stimulated flow that directs the stack effect [12].

Vancouver Convention Centre West (Vancouver, Canada)

The LEED Canada Platinum-certified project combines architecture, interior architecture, with urban design to create a unified whole that functions as a living element of both the city and the port. At the intersection of a dynamic city center and one of North America's most stunning natural ecosystems, the new Vancouver Convention Centre West design provides a chance to fully embrace the urban environment. The key architectural task was to construct and integrate a 22-acre development program at the crossroads of the urban and seaside settings, more than tripling the existing convention district's area. Each environmental encounter is carefully considered and categorized into three groups: landscape habitat, marine habitat, and human habitat. The project creates an urban area that serves as the focal point of the downtown waterfront in a community with a high degree of civic involvement and environmental concern.

Figure 3. The East Gate Design

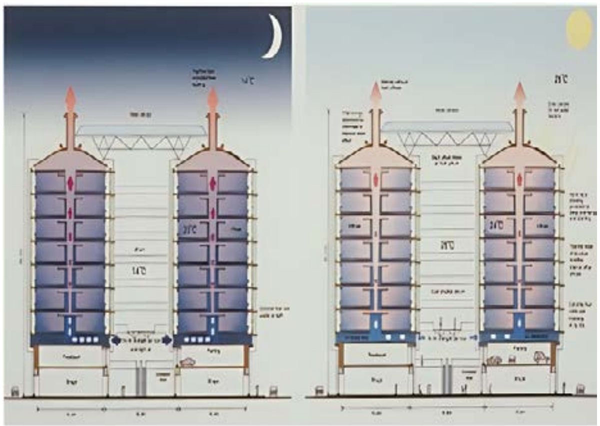

Figure 4. Stack ventilation

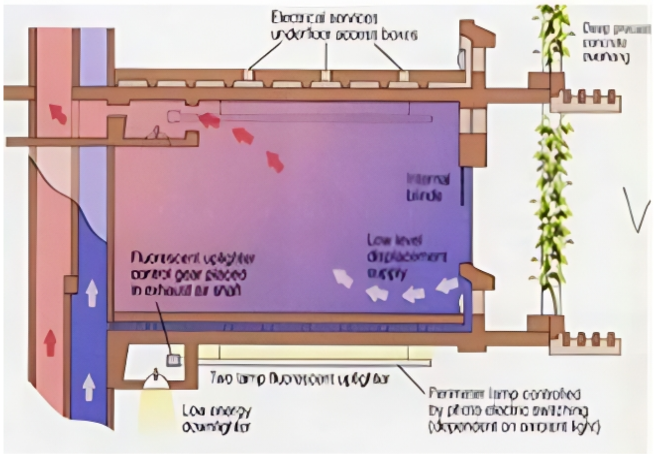

Figure 5. Ventilation diagram.

The LEED Platinum accreditation for the building is the result of a determined commitment to seek out sustainable design solutions at every level of the construction phase. One of the project's early requirements, which determined the angles of the roof boundary and the public plaza, was the preservation of view corridors to the lake from important downtown streets. The salmon migratory path, which runs all along the downtown coastline, played a significant role. Because salmon seem unable to pass through large, dark regions, an artificial reef was built to assist migration all around foundational piers [13].

Bioclimatic Design

The climate in Vancouver is mild, and the project is situated above the port, giving cool air, and is largely shaded on the south side by tall structures. The solar challenges are the sun in the early morning and late afternoon. The conference room levels have extensive glass on all façades for views and are covered on the east and west by inside motorized shutters. In the winter, radiant pipework in the floor collects solar energy and delivers heating to improve comfort. For low-occupancy hours when floatplane noise is not an issue, natural ventilation is given on the west façade. Despite the glazed meeting levels, the exhibition halls and meeting rooms dominate the convention center's interior load. Free cooling economizers can keep the conference center cool during most of the busy seasons. Very high-efficiency seawater heat pumps fueled by renewable hydroelectricity provide heating and cooling [13]. CO_2, VOC, and humidity sensors are deployed throughout the building and may be utilized in combination with circulation, temperature, and lighting controls to enhance the air quality in individual rooms. These elements may be controlled using hand-held devices, which in many areas enable control over individual fluorescent fixtures and come with several presents for a variety of event types. The bulk of the program areas feature infrared flooring that allows for improved air circulation while using less energy. The function rooms benefit from a complex system of air diffusers interwoven in an air swirl arrangement above the ceiling members.

Figure 6. Vancouver Convention Centre West (Vancouver, Canada)

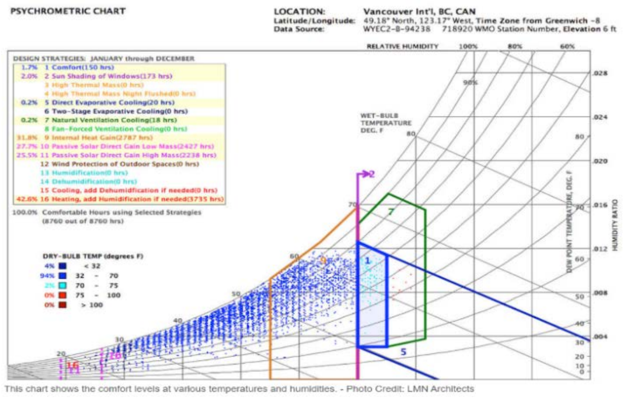

Figure 7. Chart showing comfort levels in various temperatures and humidity, source LMN architects

For nine months of the year, the recovered water, approximated at 60,000 liters per day, fulfills the whole building's lavatory flushing and landscaping watering requirements. Reclaimed water is utilized for agriculture throughout the summer, with freshwater added for toilet flushing. Low-volume flushes and low-flow fixtures save potable water usage by 73 percent, and no potable water is used for irrigation. Zenon Environmental Inc. provided the on-site wastewater treatment facility, which processes all of the gray and blackwater to secondary standards. Deferred scheduling ensures that all irrigation demands are met as quickly as possible during droughts. The 28,000 m2 of vegetation and rooftop garden screen collect storm water for 60% of the site area [13].

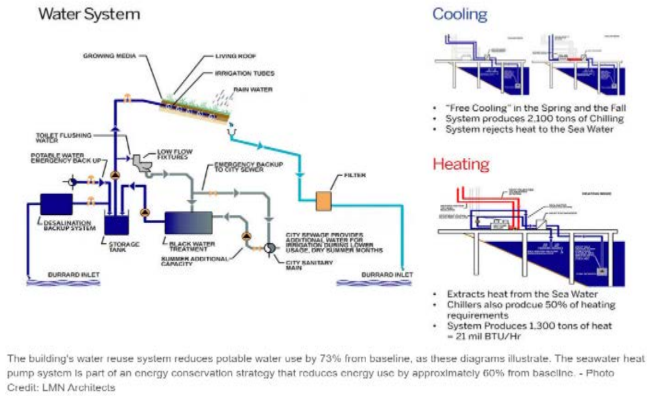

Figure 8. Diagram illustrating the seawater heat pumps. source LMN Architects

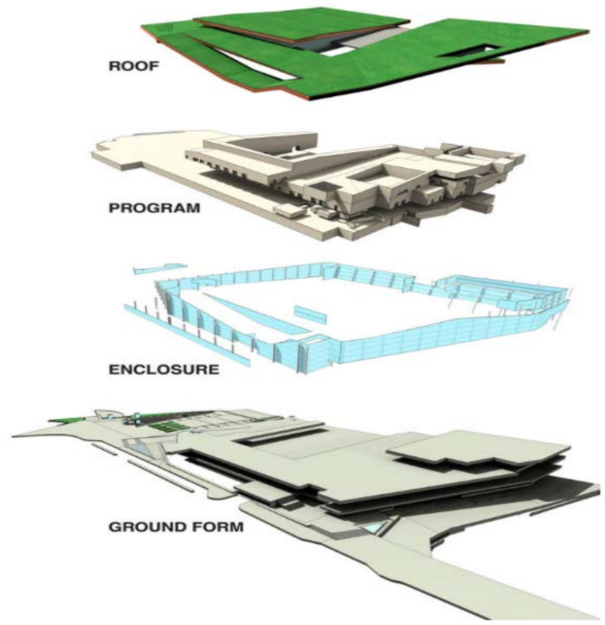

Figure 9. The layout of Vancouver Convention Centre West (Vancouver, Canada) at various levels.

Material and Construction

The major interior expression is the use of naturally occurring materials unique to British Columbia. Interior finishes were carefully selected to optimize recycled material, recycled content, durability, the use of renewable resources, and local harvesting and extraction. The creative ceiling and wall designs highlighted the importance of using BC-harvested and manufactured wood. The ballroom and conference room programs that make up the structure's internal bulk are encased in a wooden sheathing method that replicates the texture and positional accuracy of a stack of logs. The internal spaces' orthogonal massing contrasts with the roof's organic geometry and the outside shell's organic shape. To create the look, long, striking, continuous lines of wooden ceiling panels are linked with the orthogonal building up of the internal spaces.

- 16.1 percent of the product is made from recycled materials.

- 20.7 percent of the content is from the region.
- Construction trash was diverted from the landfill by 86.4 percent.

The convention center has established a green housekeeping program, which is an extension of the previously effective program in place at the east (older) building. This aims to reduce occupant and maintenance personnel exposure to potentially harmful chemical contaminants that have a dangerous impact on air quality, occupant health, and the environment [13].

4. Summary Findings

Pearce Partnership was charged with developing an office building with stores and parking in central Harare, Zimbabwe. The challenge at hand was to reduce the exorbitant cost of imports as well as the maintenance of materials and equipment. For items like air conditioning, hire local artisans. Also, limit your energy use to a minimum. The collaboration's purpose was to construct an office building. Zimbabwe is a calm nation when air conditioning is not used. Because of the weather, this was a perfect opportunity. Mick Pearce became obsessed with Zimbabwean termites. The natural systems of their nests were a major inspiration for Eastgate. They may be found throughout the place and build incredibly effective buildings to protect themselves from the weather. The termite tower acts as the lungs of the mound. The heated air rises, while cold air enters through small vents on the edges of the termite colony. This essentially serves as natural, built-in cooling. The wind and sun influence the design of the termite mound. The pheromones on the most exposed surfaces are dissipated during the day by the south-easterly breeze; thus, termites only operate in protected areas. The sun and wind work together to create a form that enhances the effectiveness of the nest in its precise location. From September through November, termites are using these mounds as chimneys to release heat. They're just there till the rains arrive, and the towers are unnecessary because the environment is naturally cold. "Fans on the first level continually suck air from this open space," Eastgate says. The material is then driven up vertical supply parts of ducts in both structures' central spines. Stale air rises and exits via exhaust holes in each story's ceiling, to be replenished by fresh air. It finally reaches the exhaust port of the vertical ducts before being drained out of the structure by chimneys. Pearce Partnership used another natural method, fractal cooling, this time using cacti rather than termites. The prickliness of a cactus functions as a defense against predators and a temperature barrier. During the night, smooth surfaces absorb more heat and radiate less heat into space. Prickly bodies are inefficient heat collectors during the day and efficient heat emitters at night. This form promotes quicker heat transfer, making it perfect for hotter climates. The design process did not end after the building was finished. It lasted three years after the occupation, and the systems were checked during that period. Fortunately, the architect and engineers were among the first occupants. They were using a data logger to capture the crucial temperatures from probes implanted into the building's structure. They appeared to be adjusting a big instrument. Most things went wrong, but after some fine-tuning, the structure began to adapt to the microclimate and its residents. Finding optimums, assessing storage capacity, and adjusting the timing and velocity of the day and night blowers were all part of the procedure. The massive West Building of the Vancouver Convention Centre, which sits on downtown Vancouver's Central Waterfront, is one of the city's most striking architectural expressions of urban, environmental, and interior design. The design team was fully aware of the difficulties involved in offering the program as a participant in those earlier techniques. With over 400,000 native plants and grasses, the six-acre living roof atop the West building is the biggest in Canada and the largest non-industrial living roof in North America. Our roof is built to be an insulator, reducing heat gains and losses in the summer and winter. The roof is home to four beehives carrying European honeybees. Bees are responsible for the plants on our living rooftop and supply honey for our home kitchen. The base of the West building has a reconstructed marine habitat. The quality of water in the region has greatly improved because of the increased diversity of sea life. During the warmer months, the revolutionary black water treatment process reuses gray and black water, which is then utilized for toilet flushing and rooftop irrigation. Seawater air conditioning is mainly used to control the surrounding seawater to offer cooling in the summer and warmth in the winter. Natural daylight and circulation are utilized throughout the space. Local BC wood resources from responsibly managed forests are used in the facility.

5. Conclusion

The study's findings have highlighted passive cooling methods' amazing effectiveness in old structures. These techniques have not only produced remarkable thermal comfort inside enclosed environments but have also done so with little energy use. These architectural wonders have been created using locally accessible resources, methods, and bioclimatic conditions.

In addition, the study investigated the idea of adapting bio-mimetic design as a workable method for approaching passive cooling and bioclimatic design. This strategy incorporates elements of the creative adaptations found in plants and animals into architectural design. We can dramatically lower the energy requirements of contemporary buildings by combining these measures in a synergistic way, which will eventually minimize our reliance on mechanical ventilation systems.

The study has shown a range of sustainable alternatives that can be used to build creative, environmentally responsive constructions. These possibilities include heat exchangers, fractal cooling theories, solar and wind energy harvesting architectural considerations, the incorporation of natural movement dynamics, and the creation of fortified areas. These ideas have already been successfully implemented in well-known projects like the Eastgate and Vancouver Conference Centre, where efficient passive and natural cooling systems have been produced, as the review of several articles indicates.

However, it is crucial to recognize that nature cannot be perfectly imitated, as shown by the times when our efforts did not go as planned. Only a small portion of the complexity and adaptability found in nature can be recreated. This, however, should not discourage us but rather act as inspiration for additional study and investigation in this area. With further research and development, we may work to develop a design strategy that more closely resembles nature, enabling the best possible use of passive cooling methods without the use of mechanical ventilation.

The findings inspire academics, architects, and designers to adopt a more holistic and sustainable approach to building design in a larger environment. We can design ecologically responsible structures that prioritize occupant comfort and make a substantial contribution to cutting energy use and decreasing the effects of climate change by fusing the lessons of the past with the advancements of the present. Let's continue to take cues from nature and work toward a healthy cohabitation of the natural and constructed environments as we move forward.

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