Understanding Biophilia and its integration with Architecture

Kaushal Modi, Sangramsinh Parmar

1. INTRODUCTION

The aim of this study is to understand the phenomena of 'biophilia' and understand how it has been integrated with architectural design – represented as 'biophilic design' in the current design and construction context. This study aims to deal with several questions, such as;

- What is 'biophilia'?
- To what extent is health and well-being influenced by built form?
- How can biophilia reduce building related illnesses?
- How does biophilic design affect health and well-being?
- How have different architects incorporated biophilia successfully into their building designs?

1.1 AFFILIATION BETWEEN NATURE AND BUILT FORM

Mankind is strongly connected with nature. This relationship has always played an important role in the evolution of humans. From the beginning of time, humans have depended on nature for food, clothing, shelter and all other necessities to be able to survive. Primitive humans had lived near sources of food and water. They chose naturally advantageous locations for habitation, which could save them from predators and rivals, as well as shield them from the harsh weather. The oldest shelters are caves and large trees. In the absence of caves or trees, bones of animals or branches of trees were used to create the inverted V-shape of natural tent. To hold that structure firmly, a ring of stones or a depression in the ground was used. The first reliable traces of human dwellings, found from as early as 30,000 years ago, follow such logical principles of built form creation, which was heavily reliant on nature.

Fig. 1.1 An illustration of early humans in cave (left) and natural tents from bones and branches (right)

Over time, humans developed more formal and sophisticated ways of living - through developing agriculture and trade. Thus, the story of architecture began. Permanent settlements became a factor of life and gradually more durable structures with straight walls and windows began to appear - made of clay, stone, timber and sun-dried bricks. These early human settlements were essentially rural. As surplus of production began to occur, rural societies transformed into urban ones and cities began to evolve. The earliest cities developed in around 3000 BC. These cities allowed for people to stay in one place in large communities, sustaining on each other. This was the turning point from where humans attempted to build habitats, away from the natural environment. The shift from rural areas to large cities (urbanization) was among the most significant changes over the centuries. Simultaneously, humans started manufacturing building materials such as concrete and different metals. While making those materials also, the dependency upon the nature was still there to varying degrees.

Fig. 1.2 An illustration of ancient city Lothal

During the 18th century population density of urban areas increased and hence the requirement for buildings also increased. Engineers began experimenting with huge structures. These structures were made of heavy stones with thick sturdy walls, but the inner environment of the building was very dark and cramped. During the 'Industrial revolution', successful experiments with new materials like steel and glass, started a whole new generation of very tall buildings. The ten storey 'Home Insurance Building' in Chicago was the first high-rise building to be supported by a steel skeleton of vertical columns and horizontal beams. Finally, in the 20th century, the era of enormous urban built forms like skyscrapers began as an outcome of several technological innovations and social developments [1].
The revolutionary construction techniques of these buildings set off a new phase of flat, reflective glass skins and massive skeletons of RCC and steel which looked like glass boxes with no real connection with their surrounding natural context. Additionally, in terms of resources and energy, this spurt in rapid construction was not so ideal because 40 - 45 % of total energy and raw materials in the world are consumed for building construction and most importantly their connection with their natural surroundings is generally not carefully conceived [2].
We depend on our surroundings for both natural resources and for enabling the establishment of community. As creatures of the earth, humans respond to its natural features, which can also be incorporated into constructed design rather than pushing nature aside.

1.2 SICK BUILDING SYNDROME

Human beings in general spend almost all their time in a building, whether at home, at work or busy with recreational activities. In the late 1970s, it was noted that non-specific symptoms were reported by tenants in newly constructed homes and offices. Which was largely known as 'office illnesses'. In 1984, a 'World Health Organization' (WHO) report suggested that up to 30% of new and re-modeled buildings worldwide may be having complaints related to poor indoor air quality. WHO used the term SBS - "Sick Building Syndrome" to describe these situations in which building occupants experiences acute health troubles and discomfort, but no specific illness or cause can be identified. In short, sick building syndrome is a condition in which people living in airtight building feel uneasy, unhealthy and stressed. Sick building syndrome (SBS) can be defined as a, "psychological and physical distress," which originates particularly in working environments [3], [4].
The following are some of the factors that might be primarily responsible for SBS [5].

- Chemical contaminants

From outdoor sources: Contaminants from outside, like pollutants from motor vehicle exhaust, plumbing vents and building exhausts (bathrooms and kitchens) can enter the building through poorly located air intake vents, windows and other openings. Combustion by-products can enter a building from a nearby garage. Formaldehyde, asbestos, dust and lead from paints can also enter enclosed interior spaces.
From indoor sources: The most common contaminant of indoor air includes the volatile organic compounds (VOC). The main sources of VOC are paints, polishes, adhesives, upholstery, carpeting, machines, manufactured wood products, pesticides, cleaning agents, etc. Environmental tobacco smoke, combustion by-products from stove, fireplace

and unvented space heater also increase the chemical contamination. Synthetic fragrances in personal care products or in cleaning and maintenance products also contribute to the contamination.

- Biological contaminants

The biological contaminants include pollen, bacteria, viruses, fungi, etc. These contaminants can breed in stagnant water that has accumulated in humidifiers, drain-pipes and ducts or where water / moisture has collected on ceiling tiles, insulation, carpets and upholstery. Biological contamination causes fever, chills, cough, chest tightness, muscle aches and allergic reactions. In places with a high density of occupancy, airborne diseases can spread rapidly from one occupant to another. Air-conditioning systems can recirculate pathogens and spread them throughout the building [6], [7].

- Inadequate ventilation

In 1970, the oil embargo to led designers making buildings more airtight, with less outdoor air ventilation, in order to reduce energy consumption [8]. The ventilation practices reduced actual airflow to 5 cfm/person. This reduced intake of fresh air was found to be inadequate to maintain the health and comfort of building occupants. Malfunctioning heating, ventilation and air-conditioning systems (HVAC systems) also increase the indoor air pollution. In order to have an acceptable indoor air quality (IAQ) with a minimum energy consumption, The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) recently revised ventilation standards to a minimum outdoor air flow rate of 15 cfm/person to avoid the problems related to inadequate ventilation. The standards specify 20 cfm/person in regular spaces and 60 cfm/person in smoking areas [5].

- Electromagnetic radiation

Gadgets like microwaves, televisions and computers emit electromagnetic radiation, which ionizes the air. Extensive wiring without proper grounding also creates high magnetic fields, which may lead to cancer.

- Psychological factors

Excessive work stress or dissatisfaction, fear of claustrophobic spaces, poor interpersonal relationships and poor communication are also sometimes seen to be associated with SBS.

In many cases, however, the removal or prevention of above mentioned causes doesn't solve the problem and there are several instances of occupants experiencing symptoms of sick building syndrome where none of the above causes could be found in the first place: air quality is good, the temperature is comfortable and the lighting is well-adjusted. So, still there was something which was needed to get rid of the syndromes.

1.3 OCCUPANT WELL-BEING IN ARCHITECTURE

Nature is an element of healing. Therefore, implementing it into design and everyday life would promote healthier living environments.
Alexander states that the physical environment affects an individual's life and the shape of a building affects one's ability to love, well-being and behaviour. Spaces and environments affect human well-being in a conscious and sub-conscious manner. Special gestures influence physical and mental state of mind. Vertical proportions draw us up, and the horizontals are calming. Spaces are designed to either influence your state of mind by inviting you to stop or allow you to move through freely [9].
Day, in his book defines health and well-being as "a state of renewal, development and balance relation to the world," which inform the basic balance of human needs (water, air and light) within a man's physical environment [10].
Butterworth talks about how people "prefer environments that support them with safety, food and shelter" [11].
When dealing with human well-being within a given space, one could refer to natural elements like light, water, wind, plants, stones etc. which are essential to human survival. These elements can be integrated within the architectural built form to improve wellbeing of the occupants.

Clean air is becoming scarce. Outdoor air gets polluted by industrial buildings and traffic while indoor air is polluted by recycled air, furniture and furnishings and building materials off-gassing. Most environmental hazards originate in the built environment. Headaches, eyestrain, depression, stress, anxiety and cancers can all be negative outcomes of poor quality of urban environments [11]. Natural materials could bring man closer to nature and, through living cycles and processes of nature, which is natural to every living thing, including humans [9]. Natural materials minimize

industrial processing when used locally, reducing transport pollution and re-establishes man with their surroundings [12].
A healthier way of design, results in a healthier way of living environment. Developing in broader holistic ways through thought and feelings of wellness and vitality would result in buildings as homes of the spirit. By designing with this kind of mind-set, different buildings would be built and old ones would be modified to support health and even healing [10].

Fig. 1.3 Schematic section of Khoo Teck Puat Hospital, Yishun, Singapore demonstrates achieving day lighting, plants, natural ventilation and good air quality through courtyard design

The health conditions associated with buildings are commonly classified as:

i. Sick Building Syndrome or Tight building syndrome.
ii. Building-related disease, when the symptoms of diagnosable illness are identified and attributed directly to airborne building contaminants.
iii. Building-associated symptoms [13].

People sometimes do not believe a building could be the cause of illness; there is level of disbelief with regards to its environmental and psychological effects. Yet, inhabitants are in agreement that physical factors like ventilating, heating systems and organic volatile compounds play an important role in the psychological, organizational and social impacts [3]. The psychological and experiential effects of the architectural form often take precedence over functional aspects. Stimulating the human senses and relaxation makes spaces pleasurable. Sensual delight is 'the satisfaction of order, variety, rhythm and contrast through the senses'. It can be achieved by a quality of space that is revitalized with colour, texture, shape and proportion. Visual sensation and movement in a space create enjoyment, through strong impressions in a space [14].

It seems that sick buildings have a long-lasting effect on their occupants who over time become unmanageable and irritable, affecting productivity and behaviour patterns. If buildings are healthy and pleasant to occupy, occupants are likely to be comfortable. Sick building syndrome is not only associated with the building in isolation. The people working in sick building syndrome buildings were known to have a much higher level of resentment, distrust, defensiveness, anxiety and confusion in comparison to those who worked in non-sick building syndrome buildings [3].

2. UNDERSTANDING 'BIOPHILIA'

At about the same time that the World Health Organization (WHO) described Sick Building Syndrome, the Pulitzer Prize winner American biologist and Harvard University professor - Edward O Wilson was developing theories on Biophilia, which he defined as...
"... the innate affiliation people seek with other organisms and especially the natural world."

Throughout our evolutionary history, humanity has depended on vegetation for food, fuel and shelter. Our very existence depends on being among vegetation and other natural elements. That dependence is so ingrained in our make-up that biologists now give the subconscious desire to be among vegetation a name: Biophilia. Wilson has also referred to studies which shows that, when given complete freedom to choose the settings of their homes and work places, people gravitate towards a location that combines three major features: positioned at height, overlooking the landscape; open terrain with scattered trees and proximity to open water, such as streams or lakes.

There have been many attempts to distil Wilson's theories into a set of design principles that can be incorporated into the built environment in an attempt to create restorative, or more naturalistic spaces. Many of these relate to the structure and architecture of buildings, and thus difficult to incorporate into existing structures, while others are easy to incorporate with very little cost - for instance, vegetation.
Numerous studies over the last few years have proven the positive impact of green spaces on the lives and work quality of every human being. Singapore's 'Gardens by the Bay' is a great example of "bringing a city into garden" instead of "garden into city". The vertical gardens of the Super tree Grove are 25 m high and spread in 101 hectares.

Fig. 1.4 An Ariel view of Singapore 'Gardens by the Bay' (left) and 'super tree grove' (right)

Biophilic design can reduce stress, anger, anxiety, improve productivity and creativity, improve our well-being and expedite healing; as the world population continues to urbanize, these qualities are ever more important [15], [16], [17], [18]. It is established that views of nature are linked to reducing sick building syndrome, increases performance and improves overall health and well-being [19].

Vegetation as an element of Biophilia

Hundreds of scientific papers have been published showing how plants can make a major contribution to the health and well-being of people, reduce energy costs and increase productivity and profitability. Complaints of Sick Building Syndrome are frequently reduced when interior plants are installed. Plants are credited with conferring many benefits to buildings and their occupants;

- Removing volatile organic compounds from the air
- Reducing the concentration of CO_2
- Reduce background noise
- Cooling the building

On the other hand, there are many benefits that scientists have found to be measurable but there are no complete explanations;

- Stress reduction
- Increased productivity at work.
- Reduction in complaints of symptoms associated with sick building syndrome.

As a result of increasing urbanization, people face the prospect of living in environments with few green spaces. There is increasing evidence for a positive relation between green space in peoples' living environment and self-reported indicators of physical and mental health. Live plants demonstrates natures' hearty resolve and process of cleaning surrounding air while exchanging it for fresh oxygen. Thus, a building with vegetation acts as an air purifier. It naturally cools the buildings in the summer and humidifies in the winter. The green skyscraper design theme is used extensively to promote a healthy lifestyle. Research has shown that atmospheric dust over wooded areas can be 75% lower than over relatively non-vegetated, populated areas [20].
Such research work related to occupants' health, should be one of the most important factors to focus for a building designer. If we try to integrate maximum natural environment for contemporary urban buildings, it could be helpful in many ways.

International Journal of Scientific & Engineering Research Volume 11, Issue 5, May-2020
ISSN 2229-5518

2.1 THEORY OF BIOPHILIA

Biophilia is the inherent human inclination to affiliate with nature that even in the modern world continues to be critical to people's physical and mental health and wellbeing [21], [22], [23], [24].
The idea of biophilia originates in an understanding of human evolution, where for more than 99% of our species history biologically developed in adaptive response to natural and not artificial or human created forces. Most of what we regard as normal today is of relatively recent origin - raising food on a large-scale just in the last 12,000 years; the invention of the city - 6000 years old; the mass production of goods and services - beginning 400 years ago; and electronic technology is little over a hundred years old. The human body, mind, and senses evolved in a bio-centric not human engineered or invented world.

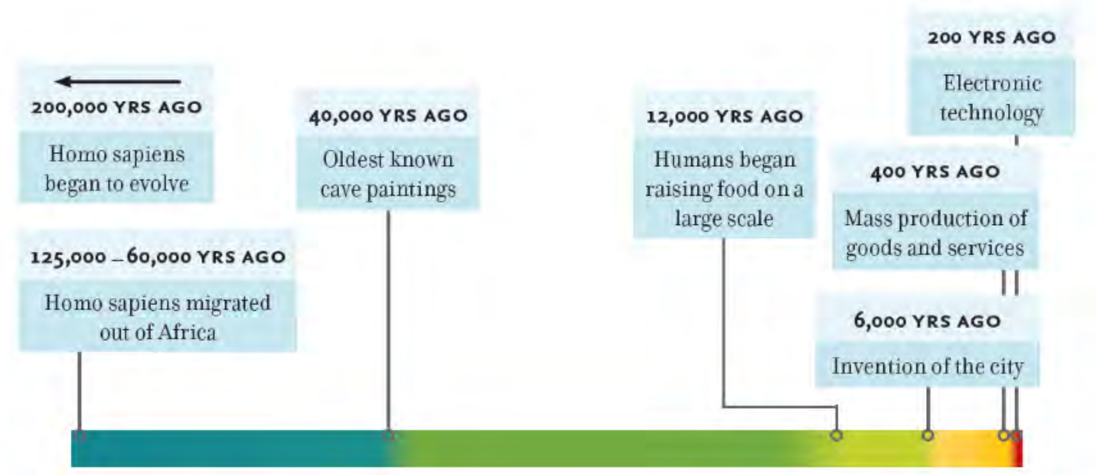


Fig. 2.1 The timeline of the evolutionary history of humankind

The German Social psychologist and psychoanalyst Eric Fromm first used the term '*Biophilia*' in his discussions of human nature in 1964, to describe a psychological orientation of humans of being attracted to life [25]. Biologist Edward O. Wilson later adopted the term and popularized it in his book in 1984 *'Biophilia'*.

2.1.1. Biophilia hypothesis proposed by Edward O. Wilson (1984) and Kellert (1996)

Biophilia (in Greek: 'bio' means life and 'philia' means love) literally translated it means love for life or anything that has life. Biophilia can be defined as "a biological inclination to affiliate with natural systems and processes instrumental in their health and productivity."
Wilson uses the term in the same sense when he suggests that biophilia describes "the connection that human beings subconsciously seek with the rest of life." He proposed the possibility that the deep affiliations humans have with nature are rooted in our biology. Unlike 'phobias', which are the aversions and fears that people have of things in the natural world, 'philias' are the attractions and positive feelings that people have toward certain habitats, activities and objects in their natural surroundings.
One of the central assumptions of biophilia is that human evolution took place in natural environments and that repeated contact with and dependence on natural elements influenced early human's subsistence. In essence, the biophilia hypothesis states that modern humans have

(1) An emotional affiliation with life and life like processes
(2) This affiliation is ingrained in our genetic makeup.

The hypothesis asserts the existence of biophilia a fundamental, genetically based human need and propensity to affiliate with other living organisms. It has been receiving increasing support from various fields, especially architecture. Genes that influence biophilia have not been identified and it is suspected that the increased dependence of the human species on technology has led to an attenuation in the human drive to connect with nature.
Wilson and others have argued that such declines in biophilia behaviour could remove meaning from nature, translating into a loss of human respect for the natural world. In fact the loss of desire to interact with the natural world, resulting in a decreased appreciation for the diversity of life-forms that support human survival has been cited as a potential factor contributing to environmental destruction and the rapid rate of species extinction. Thus, re-establishing the human connection with nature has become an important theme in conservation.

Biophilia is interpreted as a "positive emotional affiliation of human beings to other living organisms. Innate means hereditary and hence part of ultimate human nature" and must be strictly separated from negative or 'bio phobic' responses to natural entities [22]. When talking about Biophilic architecture as a general concept one starts to analyse the basic behaviour and values of human relationships with nature. Biophilic architecture could be the solution through a link of natural and physical environments, influencing human behaviour and well-being. Thinkers within the design community have adopted the idea of biophilia and have begun a discussion its application in environmental design, adopting the term biophilic design. [26].

2.1.2. Biophilia hypothesis proven by Kaplan & Kaplan (1982)

The concept of biophilia falls within a variety of disciplines, including the philosophy and psychology. Within psychology it falls most importantly and naturally under the umbrella of evolutionary psychology. Some evolutionary psychologists began to prove that Wilson has begun suggesting might be possible, namely the humans having instinctual preference towards certain environments. While refined through experience and culture are hypothetically the product of biological evolution. The hypothesis helps to explain why people care for and sometimes risk their lives to save domestic and wild animals and key plants and flowers in and around their homes. In other words, our natural love for life helps to sustain life.
Psychologist and sociologist have conducted various studies across many cultural and geographic groups and at various age levels which have consistently demonstrated not only that humans instinctively prefer a natural environment to the built environment but also that they inherently prefer specific types of natural environment with particular qualities that link back to human kinds primitive origins, instincts and habitats.
Psychologists Stephen and Rachel Kaplan have demonstrated a near universal preference among humans for pristine natural environments over built or cultivated environments.

Experiment 1: Subjects were shown images of pairs of environments and asked to choose which they preferred. In another study, subjects were asked to describe how images of different environments made them feel [26].
Findings - Subjects preferred images of a certain type: specifically, natural environments which included water bodies, high grounds overlooked and sparse trees with high canopies.

Experiment 2: The subjects were shown images of different manmade environments and were asked to choose which they preferred.
Findings - Subjects consistently preferred images which had more natural elements such as water, plants, sun light and views out to natural environments [26].

3. BIOPHILIC DESIGN

The successful application of biophilic design necessitates consistently adhering to certain basic principles. These principles represent fundamental conditions for the effective practice of biophilic design. They include:

Principle 1. Biophilic design requires repeated and sustained engagement with nature**.**
Principle 2. Biophilic design focuses on human adaptations to the natural world that over evolutionary time have advanced people's health, fitness and wellbeing.
Principle 3. Biophilic design encourages an emotional attachment to particular settings and places.
Principle 4. Biophilic design promotes positive interactions between people and nature that encourage an expanded sense of relationship and responsibility for the human and natural communities.
Principle 5. Biophilic design encourages mutual reinforcing, interconnected and integrated architectural solutions.

In the healthcare field, a wide range of studies have reported exposure to nature can reduce stress, provide pain relief, recover illness, accelerate healing, enhance staff morale and performance [27].
The successful application of biophilic design could also result in a wide spectrum of physical, mental and behavioural benefits. Physical outcomes include enhanced physical fitness, lower blood pressure, increased comfort and improved health. Mental benefits range from increased satisfaction and motivation, less stress and anxiety, to improved problem solving capacity and creativity. Positive behavioural changes include better coping and mastery skills, enhanced attention and concentration, improved social interaction and less hostility. The benefits of contact with nature often depend on repeated experience. People may possess an inherent inclination to affiliate with nature but like much of what makes us human, this biological tendency needs to be nurtured and developed to become functional [21], [24].

Fig. 2.2 The compression between the workplace without any natural connection and a workplace designed with biophilic principles

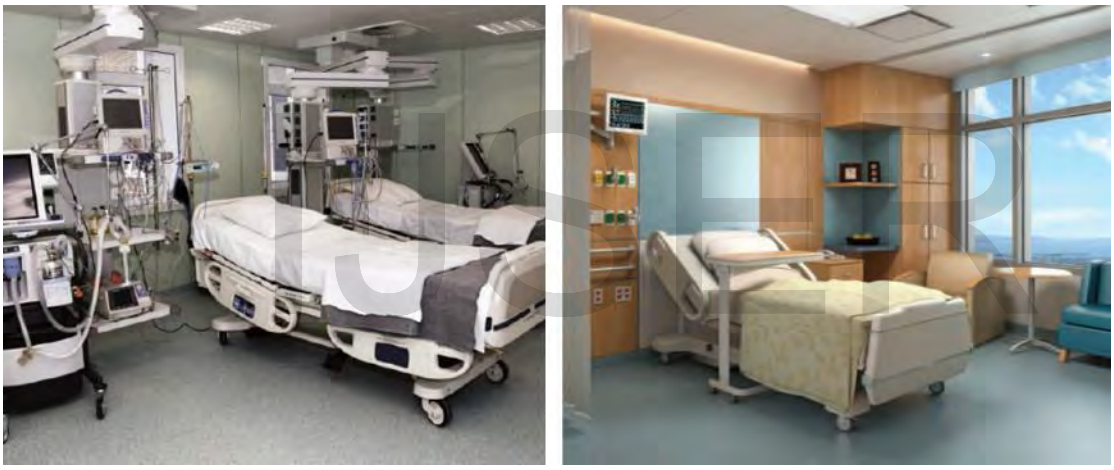


Fig. 2.3 The comparison between a hospital room dominated with technological equipment without any natural component and another hospital room designed with a natural view and natural light

3.1 EXPERIENCES AND ATTRIBUTES OF BIOPHILIC DESIGN

There are three basic type of experiences of biophilic design:

1) Direct Experience of Nature
2) Inderct Experience of Nature
3) Experience of Space and Place

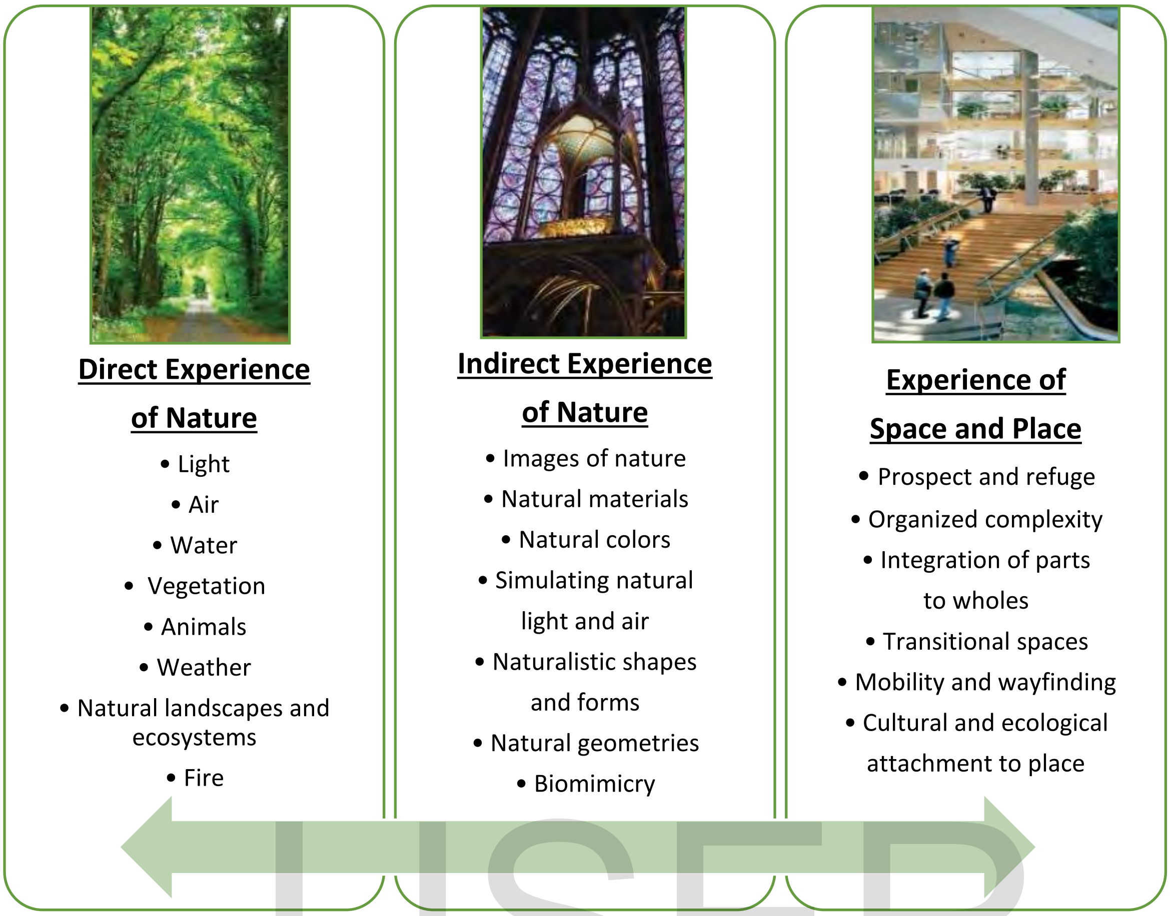


Fig 2.4 Three basic types of experiences of Biophilic design

Among all three types, 'Direct Experience of Nature' is the most fundamental and effective because as per Wilson's theory of bringing biophilia into the human environment. The other two are ancillary and contain man-made elements in it. It would be most effective to pick any Element of Direct Experience of nature for biophilic design in the built environment [28].

Following are the attributes of 'Direct Experience of Nature' as explained by Kellert and Finnegan [29]:

- **LIGHT**

The experience of natural light is fundamental to human health and well-being, enabling an orientation to the day, night and seasons in response to the sun's location and cycles. An awareness of natural light can also facilitate movement and way finding and contribute to comfort and satisfaction. Beyond simple exposure, natural light can assume aesthetically appealing shapes and forms through the creative interplay of light and shadow and the integration of light with spatial elements. Natural light can be brought deep into interior spaces by such means as glass walls and clerestories, the use of reflecting colours, materials and other design strategies. The experience of light in motion can be achieved through the contrast of lighter and darker areas and changes of daylight over time.

Fig 2.5 Use of Natural Light in Google INC. building, California

- **AIR**

Natural ventilation is important to human comfort and productivity. The experience of natural ventilation in the built environment can be enhanced by variations in airflow, temperature, humidity and barometric pressure. These conditions can be achieved through access to the outside by such simple means as operable windows or by more complex technological and engineering strategies.

- **WATER**

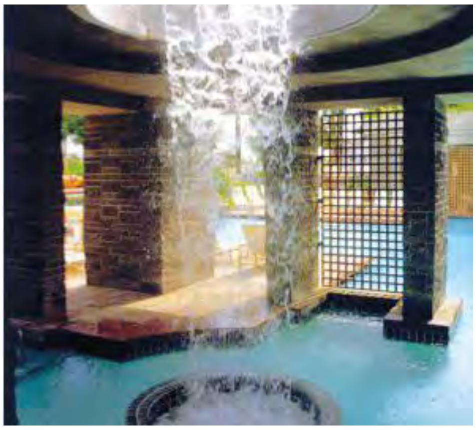


Fig 2.6 Water as a biophilic attribute used in a building

Water is essential to life and its positive experience in the built environment can relieve stress, promote satisfaction and enhance health and performance. The attraction to water can be especially pronounced when associated with the multiple senses of sight, sound, touch, taste and movement. Varying design strategies can satisfy the desire for contact with water including views of prominent water bodies, fountains, aquaria, constructed wetlands and others. Water in the built environment is often most pleasing when perceived as clean, in motion and experienced through multiple senses.

- **VEGETATION**

Vegetation is one of the most successful strategies for bringing the direct experience of nature into the built environment. The presence of plants can reduce stress, contribute to physical health, improve comfort and enhance performance and productivity. Vegetation in buildings and constructed landscapes should be abundant, ecologically connected and tending to focus on local rather than exotic and invasive species.

Fig. 2.7 Plants as a biophilic attribute used in building

- **WEATHER**

An awareness and response to weather has been an essential feature of people's experience of nature and critical to human fitness and survival. The perception of contact with weather in the built environment can be both satisfying and stimulating. This may occur through direct exposure to outside conditions, as well as by simulating weather-like qualities through manipulating airflow, temperature, barometric pressure and humidity. Design strategies include views to the outside, operable windows, porches, decks, balconies, colonnades, pavilions, gardens and more.

- **ANIMALS**

The presence of non-human animals has been an integral part of people's experience throughout human history. Yet, its integration in the built environment can be challenging. Contact with animal life can be achieved through such design strategies as feeders, green roofs, gardens, aquaria, aviaries etc. Isolated and infrequent contact with animal life tends to exert little impact. When feasible, contact with animal life should include a diversity of species and emphasize local rather than non-native species.

Fig. 2.8 Animals as a biophilic attribute used in building

- **NATURAL LANDSCAPES AND ECOSYSTEMS**

Natural landscapes and ecosystems consist of interconnected plants, animals, water, soils, rocks and geological forms. People tend to prefer landscapes with spreading trees, an open understory, the presence of water, forested edges and other features characteristic important in human evolution. Self-sustaining ecosystems in the built environment can be achieved through such design strategies as constructed wetlands, forest glades and grasslands, green roofs, simulated aquatic environments, and other means. Contact with natural systems can be fostered by views, observational platforms, direct interaction and even active participation.

- **FIRE**

One of humanity's greatest achievements has been the control of fire that allowed the harnessing of energy beyond animal life and facilitated the transformation of objects from one state to another. The experience of fire can be both a source of comfort and anxiety. The satisfying presence of fire in the built environment (especially in cold climates) may be achieved through the construction of fireplaces and hearths but also simulated by the creative use of light, colour, movement and materials of varying heat conductance.

3.2 INTEGRATION WITH ARCHITECTURE – VEGETATION

Green spaces, both interior and exterior are essential to architecture promoting a connection with nature. The green spaces soften the built environment, creating more inviting and relaxed places while reducing the risk of sick building syndrome and aid in a person's psychological well-being. Not only can plants physically improve the environment, but they have positive psychological impacts as well.
Plants are credited with conferring many benefits to buildings and their occupants. Studies performed by NASA have found that having few living plants per 100 square feet of floor space can help clean air in an office building. Some benefits are easy to explain in terms of the biological processes going on inside the plant, such as living plants can help combat sick building syndrome by purifying the air in indoor environments. As volatile organic substances (VOCs) are one of the causes of sick building syndrome, tropical plants are particularly good at removing these harmful VOCs from the air through natural processes like photosynthesis. By this process, concentration of CO_2 is reduced from surroundings and oxygen is released. Trees reduce greenhouse warming by fixing carbon dioxide during photosynthesis, provide shade to outdoor public areas and serve as a noise barrier.
Plants can reduce air temperatures and loads on air-conditioning systems during hot summer days, thus saving energy. On the other hand, there are many benefits that scientists have found to be measurable, but for which there is no complete explanation, such as stress reduction and increased productivity - studies have shown that people are less stressed when in the presence of plants.

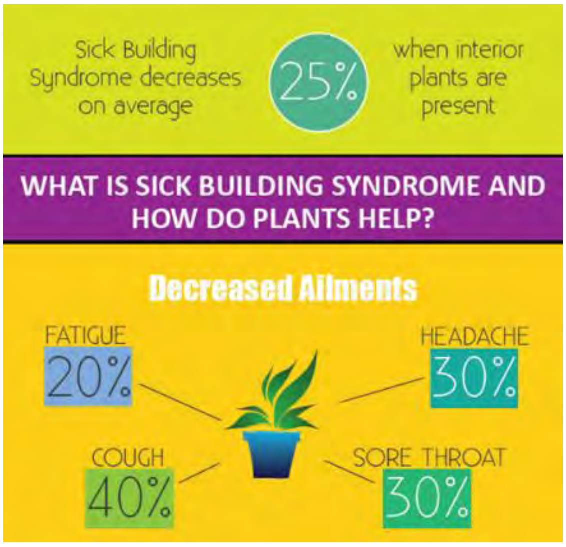


Fig. 3.1 Sick building syndrome eliminated by plants

Fig. 3.2 Greenery inside a building

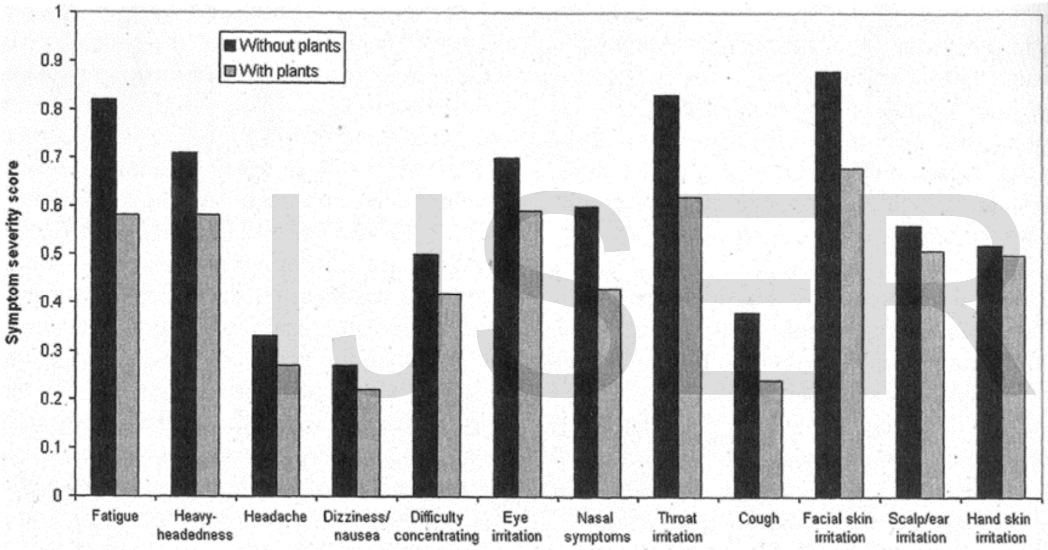


Fig. 3.3 Reported SBS symptoms Vs. presence or absence of indoor plants

Healthy air is vital for well-being of occupants and their overall well-being. Plants do not just photo-synthesize CO_2, giving out oxygen, but also clear air particles of unwanted chemicals. They improve air quality through re-oxygenation, humidity and temperature moderation, dust anchoring, pollution absorption and ion generation.

Research studies in work-spaces have compared typical lean spaces with those enriched with indoor plants. Such enrichment resulted in increased well-being and productivity by over 15%. Furthermore, research seems to show that the improvements in comfort and well-being attributed to plants in and around buildings are far greater than any physical change they make to the environment. Even limited amounts of vegetation such as grass and a few small trees is enough to enhance coping and adaptive behaviour [19].

A number of researchers have investigated the effects of plants on outcomes relevant to the effectiveness and well-being of office workers. Those outcomes include psycho-physiological stress responses, task performance, emotional states, and room assessments. In addition, some studies have investigated the effects of indoor plants on health and discomfort symptoms related to the sick building syndrome [30]. Outside the workplace, there is evidence that exposure to plants and natural settings can improve positive mood and reduce negative mood [17]. Findings also indicate that physiological stress is often lower after exposure to plants and nature as compared with harsh urban settings [17], [31]. Furthermore, increase in well-being have been shown to coincide with less mental distress among people living in urban areas interspersed with green spaces [15].

An obvious question is, why plants and green spaces might have these beneficial psychosocial benefits?
Currently, there are three classes of explanations for such findings.
According to the first, plants - as living organisms, exert a beneficial influence on the climate of the working and living environment. In particular, plants are thought to be healthy because they improve air quality. In this regard, when introduced in sufficient quantity, indoor potted plants have been shown to remove most types of air-borne pollutants arising from either outdoor or indoor sources. This has been studied within laboratories [32], as well as in naturally ventilated and air-conditioned office spaces. Air pollutants, even at imperceptible levels, can cause "building-related illness" and symptoms of headache, sore eyes, nose, and throat, or nausea. Where indoor plants have been installed, staff well-being is improved with reduced sick-leave absence [30]. In addition, plants can refresh the air by absorbing carbon dioxide (CO_2). The importance of this is suggested by studies which show that student performance declines with increasing CO_2, as does workplace productivity [33]. Studies found that students who worked in an environment that had been enriched with plants reported that air quality had improved. Such data thus suggest that enriching the workplace with plants should have a positive effect on the air quality within the working environment.
The second explanation of plants' beneficial effects centres on the evolutionary explanation that a green, planted environment reflects the natural world and thereby supports human physiology [34]. Proponents of attention restoration theory argue that natural environments restore people's capacity for directed attention, whereas built environments tend to deplete this capacity. The idea behind this theory is that the prolonged focus on a specific stimulus or task results in "directed attention fatigue." Natural environments exert less demand on directed attention and encourage more effortless brain functions, thereby allowing the capacity for attention to be restored. Thus, after an interaction with natural environments, one is able to perform better on tasks that rely on directed-attention abilities. According to this view, plants in the workplace should enhance employees' directed-attention capacity and therefore enhance their concentration and productivity levels.
The third class of explanations moves away from physiological responses and looks more closely at the relational and managerial consequences of enrichment. The basic idea here is that enrichment of the workspace signals that attempts are being made to enhance staff well-being and "environmental comfort". It also follows that if people are physically, cognitively and emotionally involved in their work there is a reduced risk of disengagement. In short, enriching the environment with plants should signal managerial care and hence result in increased engagement, attention and environmental satisfaction. More broadly, this should also result in perceived improvement to psychological well-being and productivity in the workspace.

4. CASE-STUDIES

This study has explored the concept and theory of biophilia and benefits of vegetation as a vital element for biophilic design in urban areas. This influences on physical and psychological wellbeing of occupants. Now, some case studies are chosen to explicate virtuous examples of integrating vegetation with built form by different techniques and consequent benefits as discussed in previous chapters.
The buildings chosen for case studies are of different location, climatic condition, surrounding context and purpose of incorporating vegetation. These buildings are serving as appropriate examples of architectural responses to prove the symbolic relationship between man and nature.
These case studies are selected and evaluated by comparison with each other on the basis of following criteria.

- Nature of the surroundings
- Use of building
- Types of client
- Ideology of architect
- Aim of the project
- Vegetation Incorporation Intention
- Effects Achieved from vegetation

There are some limitations in the study of these case-studies. The buildings have not been visited by author in person, but comprehensively studied from the vast resource of materials available from books and internet. There is no formal quantitative base for evaluating if maximum vegetation has been incorporated in the building or not. Architects of respective buildings are highly inspired by nature and therefore have some inherent features in their buildings.
The study is a search for evaluating the qualities integrated into these buildings and not a comparison between the works of these architects.

4.1 '25 VERDE', TURIN, ITALY

See Annexure 'A' for project drawings and visuals

Fig. 4.1.0 Exterior view of building and terrace of a residential unit

Introduction

Turin is an ancient metropolitan city and an important Centre for business and cultural activities in northern Italy, located on the left bank of the 'Po' River. The Average temperature during the months of summer is around 28 ºC and in the months of winter the average temperature is about -2 ºC. It remains mostly dry during winters and often receives heavy rainfall during summer.

25 Verde (25 Green) is one of the most unique and beautifully designed modern apartment buildings in the world. This eco-friendly design makes the building stand out with its beauty as every part of it is integrated with nature. 25 Verde brings plants up off the ground in an attempt to evade Turin's homogeneous urban scene and integrate life into the facade of the residential building.

The load-bearing structure is made of steel and columns shaped like tree trunks. This metal structures look like trees and they "grow" from the ground floor to the roof while holding up the wooden planking of the terraces, they become entwined with the vegetation to form a unique façade. The structure helps to support the 63 residential lofts that is covered in larch wood shingles. The wainscot in larch shingles is a sort of soft and vibrant surface. The residential lofts are all different, fitted with irregular terraces that wrap around the trees with the top floor having its own green roof.

A five-storey building mix of lush trees and steel girders that let urban residents feel like they live in a giant urban tree-house. The trees' seasonal progression creates the ideal microclimate inside the building, steadying temperature extremes during the cold and warmer months. The plants' full foliage block rays of sun during the summer while letting in warm light during the winter.

Fig. 4.1.1 Irregular shaped terraces and Lynch wood shingles cladded Façade of the building

Key features of 25 Verde

- '25 Verde' apartment is a fantastic 'tree house' right in the middle of a densely populated urban area.
- Every step in the building's design was taken with natural integration in mind.
- The building considered as alive because it grows, breaths and changes since 150 trees with tall trunks cover its terraces, together with 50 trees planted in the courtyard garden.
- The organic and asymmetric shape of its terraces allow potted trees to "sprout" out from the building at random intervals.
- The ponds in the courtyard provide residents with a refreshing place to relax in the summer.

- The healthy amount of greenery provides environmental benefits by way of producing 150,000 liters of oxygen each hour, while absorbing 200,000 liters of carbon dioxide an hour at night.
- When all the green is fully blooming it gives the feeling of living in a tree house.

Philosophy of architect and aim of project

The fundamental idea of the architect Luciano Pia, was to create an urban "tree house". He had a vision for how people and nature can live together even in a thoroughly urban landscape. The concept of the scheme was to create a space with a transition between the interior and exterior, by the prominent use of foliage.

The aim of the project is both the construction of the block perimeter with a continuous façade and the making of a filter between the internal inhabited space and the streets. In such a way

The project wants to create a flowing and smooth transition space to soften the passage from the inside to the outside where the space is always enjoyable. The smooth and changeable transition is emphasized by a targeted use of the green and the building materials as to create a structure which is compact and distinct but also transparent, mutable and enjoyable.

By utilizing geothermal energy for heating and cooling, harvesting rainwater to water the plants and a natural flow of ventilation. Overtime, the building and surrounding vegetation will grow and age, side by side, establishing its own microclimate and when the plant life is fully in bloom, give its occupants a real tang of living in a tree house.

Fig. 4.1.2 Building like an 'Urban Tree House

Integration of Vegetation in the Design

Here vegetation incorporation is illustrated in diverse ways such as green walls, potted plantation in big vases, courtyard garden and roof gardens, altogether seamlessly coherently carried through the entire building. The building holds 63 units, each benefiting through vegetation just beyond their windows and walls.

There are over 150 deciduous trees incorporated in the building and each and every one of them has an important function. Among them 50 trees are planted only in the courtyard garden itself. In the vases there are trees or shrubs of different heights from 2.5 m. to 8 m. The asymmetric shape of the terraces on the building allow the trees to grow out of it at random intervals. The last floor is covered with private green roofs. This combination of a large number of trees, steel girders and asymmetric shape makes it feel like one of the biggest tree houses in the world.

Fig. 4.1.3 Inner courtyard where 50 trees have been planted

Each species of plant has been chosen purposefully from deciduous plants in Turin to provide the highest variety of color, foliage, and blooming. During summer, the lush trees prevent sunlight from reaching to apartment while during winter, as these are deciduous trees, they do the opposite.

Studies have shown that trees are quite effective in acting as natural barriers that can mitigate noise levels from the adjacent trees. They produce oxygen, absorb carbonic anhydride, cut down air pollution, follow the natural cycle of seasons, grow day after day and create a perfect microclimate inside the building so diminishing the fall and rise in temperature in summertime and wintertime. They are also helpful in pollution protection to its residents, helping to eliminate harmful gasses caused by cars and harsh sounds from the bustling streets outside.

Fig. 4.1.4 Potted plants of various sizes and 'Tree' shaped columns

4.2 ACROS FUKUOKA PREFECTURAL INTERNATIONAL HALL, FUKUOKA, JAPAN

See Annexure 'B' for project drawings and visuals

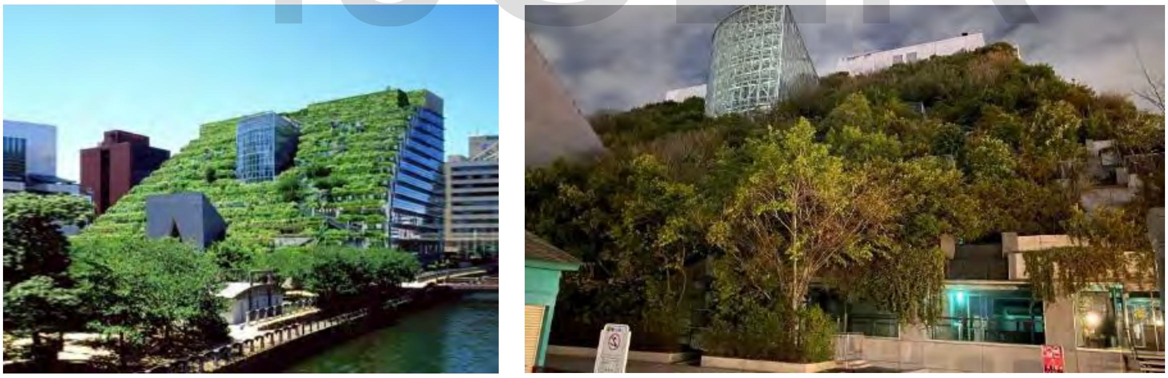


Fig. 4.2.0 Exterior views of the project

Introduction

Fukuoka is the fastest growing city of Japan and best example of a city becoming a National Economic Zone on its own. It is having moderate climate, characterized by hot summer and mild winter. The average temperature during the months of summer is around 30° C and in the months of winter the average temperature is about 5° C.

The site 'Tenjin' Central Park was owned by the city and the last large remaining green space in central Fukuoka. Eventually the city of Fukuoka had decided to develop the vacant site in a joint venture with a commercial developer. In the scheme, a commercial developer was able to lease the land for sixty years and construct a building. A portion of the building's space was supposed to be devoted to public and municipal operations both; the remaining allowable space was kept for revenue producing. Thus, the site and conditions were demanding for a structure which could fulfil all the needs of city. Keeping this in mind, the architect had designed the building in such a way that its north face presents an elegant urban facade with a formal entrance appropriate to a building on the most prestigious street in Fukuoka's financial district. The south side of the Hall extends an existing park through its series of terraced gardens that climb the full height of the building, culminating at a magnificent belvedere that offers a breath-taking view of the city's harbour.

This design has made the park and the building inseparable. The building gives back to the city the very land it would have taken away and allows a major urban structure to exist symbiotically with the invaluable resource of open public space.

Key features of Fukuoka Prefectural International Hall

- ACROS Fukuoka - Prefectural International Hall is a most powerful synthesis of urban commercial necessity and a park.
- The structure is made of steel-frame and reinforced concrete. It is having 14 floors above ground and 4 floors below ground. This provides 1, 00,000 m2 of total floor space area.
- The building is containing an exhibition hall, museum, 2000-seat proscenium theater, conference facilities, 600,000 square feet of government and private offices, as well as large underground parking and retail spaces.
- A huge semi-circular atrium and a triangular lobby in contrast with the greenery which contains symphony hall, offices and shops.
- There are water pools upon the every stepped terrace which are connected upwardly and pressurized by spraying jets, to create a ladder-like climbing waterfall.
- The waterfall lies directly above the central glass atrium within the building helping to diffuse the light coming from the glass atrium and also cool the building from inside.
- Outside the stepped garden terraces become an inviting outdoor amphitheatre for the entire city.

Philosophy of architect and aim of project

The architects Emilio Ambasz & Associates created a design to preserve the green space as much as possible, while still fitting in a large office building. Emilio was concerned about the effect of the development on the only green open space in the central city. He wanted to give back all the land the building would subtract to Fukuoka's citizens at maximum extent possible.

The primary idea was to create a green roof system, integrating the adjacent Tenjin Park into the design and increasing the area of green spaces, while providing sufficient office area for municipal operation. The architect has successfully achieved two opposite goals of expanding the size of the green spaces at the same time providing the city of Fukuoka with a powerful symbolic structure as its centre.

Integration of Vegetation in the Design

The architect has tried to emphasize on the continuity of the planting zone of Tenjin Central Park. Therefore, a staircase-shaped rooftop garden is proposed with the adjoining building surface which could easily merge with the park. As a result of this, the building steps up floor-by-floor along the edge of the park, in a stratification of low, landscaped 14 terraces which are generating an effect of a green mountain of 60m height instead of low heighted vegetation. This green mountain comes in the vicinity from almost every area of the city and changes its looks four times in a year according to the seasons.

Fig. 4.2.1 Views of the landscaped terrace from inside and outside of the building

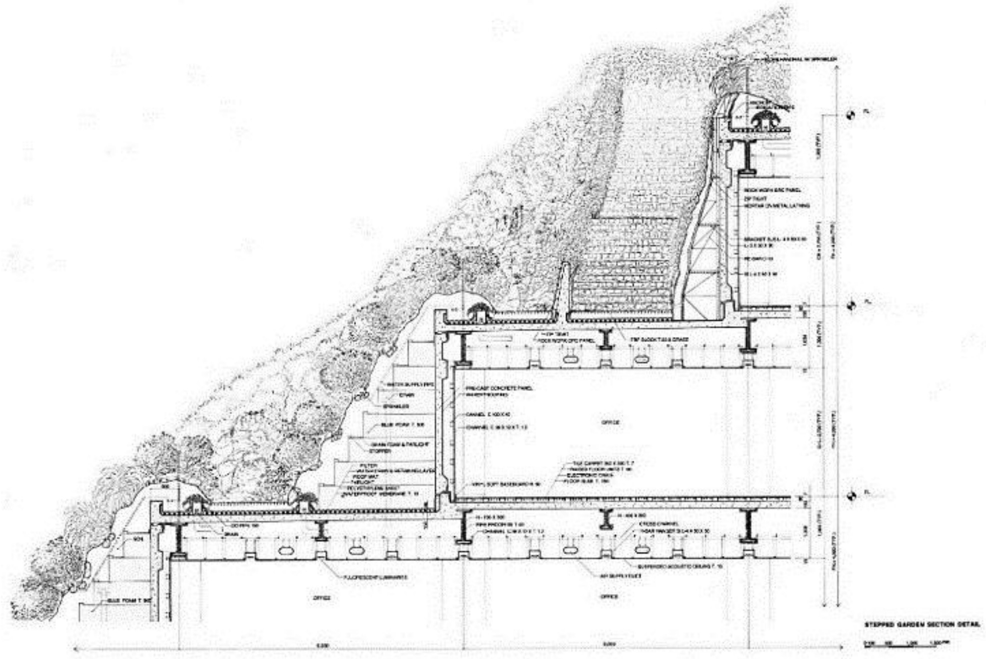


Fig. 4.2.2 Detail of the Landscaped terraces

The total area of the green terraces is 13,000 m² which is fully covered with vegetation in all seasons. This area is actually bigger than the original area of the green space of Tenjin Park. There are more than 35,000 plants on the terraces of the building which are representing 76 different local species. Every terrace is having the depth of two to three feet to accommodate the growing medium and irrigation system. All these plants are irrigated using 'drip irrigation system' which utilizes waste-water of the building.

These landscaped terraces are used for meditation, relaxation and escape from the congestion of the city, while the top terrace becomes a grand belvedere, providing an incomparable view of the bay of Fukuoka and the cityscapes. In Fukuoka city, the average annual temperature had increased by 3°C before the building was not existed. The increased vegetation of the area have helped to keep the temperature down in the surrounding area, improved the air quality and also support the life of insects and birds.

4.3 CONSORCIO BUILDING (CONSORTIUM BUILDING), SANTIAGO, CHILE

See Annexure 'C' for project drawings and visuals

Fig. 4.3.0 Exterior views of the project and inside view showing typical planter at various levels

Introduction

Santiago is the capital of Chile and one of the most prosperous South American cities. The average temperature during the months of summer is around 32° C and in the months of winter the average temperature is about 18° C.

The 'Consorcio' (Consortium) Building is bounded by Forest Avenue along with busy road of 'Ell Bosque Sur' and two small streets. It has a boat shaped plan and zoned vertically. The building is designed in four parts, two of them are set aside for a gallery and main entrance, then 4 floors are reserved for the 'Consorcio' Company, above that the main volume of the building has been established which is rented to different entities for revenue generation. Whole building is 17 stories high and 75 m long.

Key features of 'Consorcio' Building

- The main façade overlooking east is glazed and offers nice views of the Andes River.
- The façade overlooking west is built in such a way to avoid heat problems.

Philosophy of architect and aim of project

Architect's intention was to create a façade which saves the building from heating and create a live façade which adds value to the neighbourhood's environmental context.

Integration of Vegetation in the Design

The facade of the 'Consorcio' Building is developed with special attention. According to climatic condition of Santiago, western facade produces serious heat problems during the summer season. To avoid heating problems, the architect has used vegetation very systematically in this building. The west façade is designed in two layers, which has a thermo-plastic inner and outer panels with green vegetation. While the East Façade is fully glazed and overlooking views of the Andes river and cityscapes.

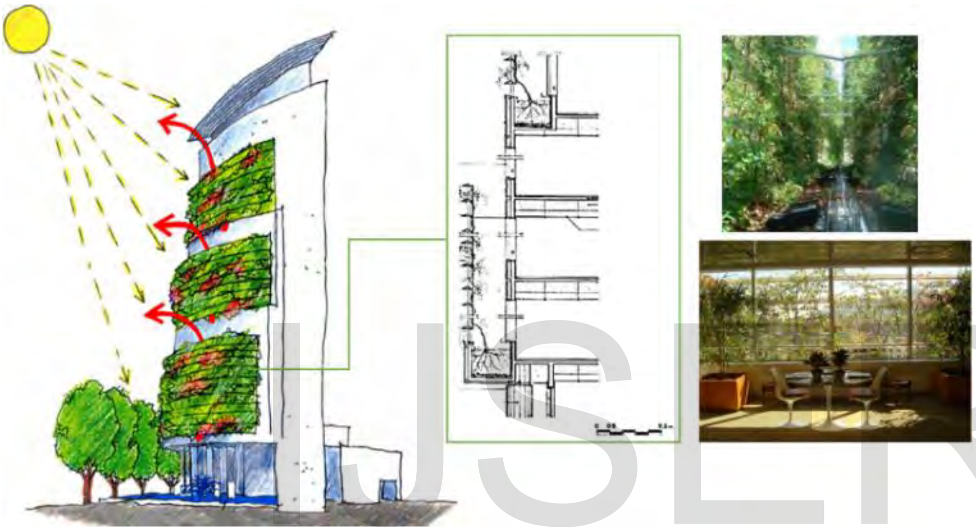


Fig. 4.3.1 Concept of double layered façade along with its detail in 'Consorcio' Building

This "double vegetal facade" reduces the solar radiation. In addition, it transforms the building into a vertical garden of about 3,200m^2, equivalent to the gardens which were on site before the 'Consorcio' building was erected. Thus, one can say that, metaphorically the greenery which was in existence earlier, was now raised vertically. The building is trying to recover the vegetation which was taken away from the city. By doing that, it is also trying to please the neighborhood and mitigate the air pollution. In addition, 17 stories tall vegetated façade changes its colours naturally in every season which makes the surroundings vibrant. For this, locally available species of deciduous vines like Star Jasmine, Plumbago, Parthenocissus and Bougainvillea are chosen.

Fig. 5.38 External view of 'Consorcio' building in different seasons

4.4 KHOO TECK PUAT HOSPITAL, YISHUN, SINGAPORE

See Annexure 'D' for project drawings and visuals

Fig. 4.4.0 Exterior view and courtyard view of hospital

Introduction

Singapore is one of the world's major commercial hubs, the fourth largest financial centre and one of the busiest city. Singapore has a tropical rain forest climate with no distinctive seasons and high humidity and abundant rainfall. The average temperature during the months of summer is around 36° C and in the months of winter the average temperature is about 22° C.

Khoo Teck Puat Hospital is Singapores' first green hospital, located on a 3.4 hectare site at Yishun in Singapore. With its decidedly non-clinical environment and innovative eco-friendly features, KTPH is well positioned as a premier hospital of the future, both regionally and internationally.

The three block KTPH wards allow for maximum transparency and views of forest like plantation, through an open facade design, connecting man with the surrounding natural setting. "The design concepts are underpinned by the desire to create a healing environment" which is central to the design idea that "nature would nurture".

Every opportunity has been maximized for the creation of therapeutic green spaces. KTPH has landscape footprints at every floor to ensure patients and staff is constantly treated to garden views from different angles, and to provide for a calming surrounding that soothes and rejuvenates.

Philosophy of Architect and Aim of the project

Khoo Teck Puat Hospital (KTPH) sets a new benchmark in healthcare design with its "hospital in a garden, garden in a hospital" concept. With a mission given by Singapore's minister of health to provide a well benefits and convenient healthcare hub in the heart of the north Singapore, this project had completed this challenging task by building a high quality and affordable hospital to the community.

Innumerable species of plants, birds, butterflies and fish were to be sustained by creating the proper garden environment and ecology. This would in turn create more interest for patients, staff and guests to find something unique as the gardens' flora and fauna are constantly and dynamically evolving. The endeavour of the creators was carrying the visions to provide not only quality healthcare, but also maintaining garden spaces that help in patient's well-being and healing. The gardens of KTPH is derived from following three principles:

1. Establishing the gardens in practical and self-sustaining ways
2. Creating gardens with nature and people in mind
3. Implementing energy and resource efficient landscape features.

Key features of KTPH Building

- KTPH does not look like a typical hospital but a therapeutic green spaces.
- 550-bed public hospital serves the needs of 700,000 residents.
- It consists of a seven story tower for specialists of clinical service, 8 story private ward tower and a 10 story subsidized ward tower adjacent to 8 roof gardens, 5 levels of corridor planters and 81 balconies planter boxes.
- The hospital opens up to its adjacent lake, which becomes the catchment for harvested rainwater from the whole site.
- Central courtyard helps to bring plenty of daylight at the very bottom of the basement.

- 70% of the floor area is naturally ventilated and illuminated with the help of aluminum sunshades and light shelves.
- Up to 50% of cost has been brought down from the total energy consumption cost by using roof gardens, green courtyard and natural ventilation.

Integration of Vegetation in the Design

- Courtyard

The garden courtyard is the heart of the KTPH hospital. One can see the whole hospital from the courtyard and enjoy the views of the Yishun Pond, serving as a catchment for rainwater that is subsequently used to irrigate the hospital gardens. The courtyard plays an important role to illuminate and ventilate the spaces of the building naturally. It filters the air and offers views of vegetation from the each part of the building. The courtyard accommodates pathways and bridges connecting the building blocks. So, while traveling from one block to the other courtyard offers a seamless feel where 'hardscape' and 'softscape' blend together which generates a unique experience.

Fig. 4.4.1 Bringing greenery into the building through courtyard

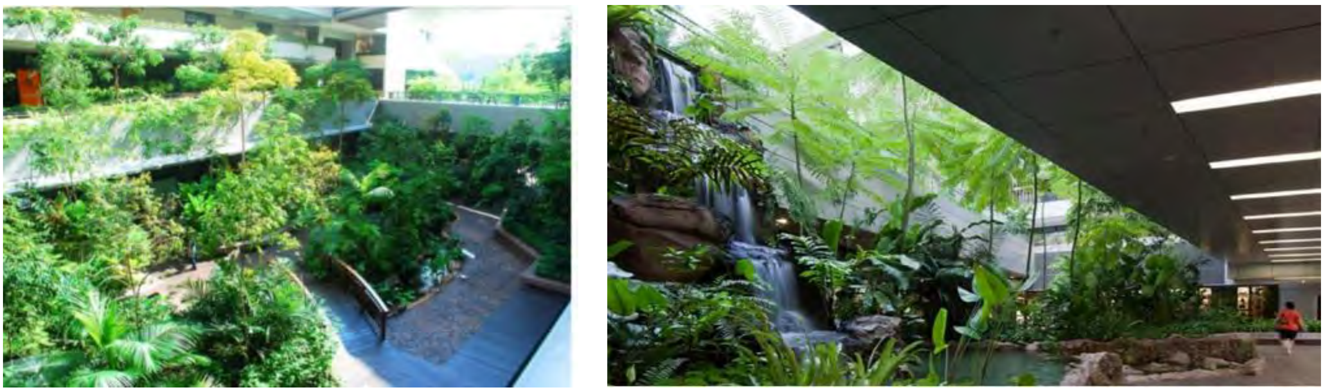


Fig. 4.4.2 Courtyard and connecting pathways of the building

- Planter boxes

At several places vertical green walls filled with plants. In the whole complex, there are 5 levels of corridor planters, 81 balconies' planter boxes, and vertical green walls. These vertical greenery helps to reduce the indoor temperature and mitigate urban heat island effect in the building.

Fig. 4.4.3 Drawings and photographs showing the Planters

- Roof garden

Every floor of the KTPH have some amount of greenery. It has been achieved by 8 roof gardens and community gardens. Each roof garden was created to address certain themes to keep them interesting, engaging and educating. On the roof top, certain gardens are considered only for the plantation of edible vegetables and fruits. All the citrus plants are at level 4 podium roof decks and other fruit bearing trees are at level 8 and level 10 roof garden. Other roof gardens are reserved to grow certain specific medicinal plants. These gardens are nurtured and maintained together by patients, qualified hospital staff and surrounding residential communities to ensure a seamless interaction between indoor and outdoor. The organic rooftop garden has over 130 fruit trees and vegetable plots with over 50 varieties of edibles and others specific patient needs. These fruits and vegetables offer a wide range of flavours for the hospital kitchen. Most importantly, these roof gardens replace 70% of the building footprint with greenery.

Fig. 4.4.4 Analytical key plans showing foot-print of greenery at every level of KTPH

Fig. 4.4.5 Different views of Roof garden and Terrace planters

- Plant species

In KTPH, over 70% of the total plant species are indigenous, including many rare endangered species. South-east asian and tropical plants are mainly considered while choosing plants in order to create a sustainable environment and a healthy eco-system that suits the local weather. The proper selection of the right combination of trees, shrubs and ground covers encourage the creation of natural habitats to attract wide variety of species. In addition, the fruits, vegetables and plants offer a diversity of flavours, scents and colours for the hospital kitchen. Some majorly grown plants and trees in KTPH are Pygmy date palm, Cabbage tree, Coral beans, Chinese evergreens, Nest fern, Copper leaf, Brazil rain tree, Manila grass, Hongkong orchid tree, Japanese Honeysuckle, Paper flower, Mouse-tail plant, Fox tail, Milkwood, Philippine Orchid, Lady's fingers, sweet potato, lychee, Tomatoes, Corn and Java tea.

5. OBSERVATIONS & CONCLUSION

The present study was undertaken to identify the phenomena of biophilia and evaluate the potential of incorporation of vegetation as one of the vital elements of biophilic design in built environment. In this chapter some reflections that emerged throughout the dissertation is well explained.

5.1 COMPARATIVE EVALUATION

See Annexure 'E'.

5.2 CLOSING THOUGHTS

Like all species, humans are also evolved in adaptive response to nature rather than artificial forces. We are always connected with nature, directly or indirectly. However, due to rampant urbanization and huge amount of building construction worldwide, our rapport with natural surrounding is diminishing - which is eventually affecting our health and well-being.

The theory of 'Biophilia' emphasizes the relationship between people and natural surroundings. According to this theory, man has the innate desire to affiliate with nature as an escape because nature has immense potential to revitalize us at all scales, individually and socially. If given a choice, people habitually prefer to live within a natural surrounding and shows great affection towards the natural elements. Principles of biophilia refers people as a 'biological organisms' and prescribes to create more natural habitats with the extensive use of single or multiple natural elements. By doing so, these principles advocate integrating nature in our buildings and cities for better physical and mental health and fitness.

Vegetation is considered as one of the vital elements of biophilic design. This study understands it's evolution and highlights the importance and beneficial effects of vegetation and studies some successful examples of how it has been integrated into architectural design. Green spaces, both interior and exterior are essential to architecture promoting a connection with nature. Incorporating greenery in urban built form itself, is one of the ways to bridge this gap between people and nature.

It is evident that architects can make bigger impact by designing buildings incorporating vegetation, for a healthier built environment. However, lack of knowledge, unwillingness to pay extra initial cost, additional operational care for maintenance and ignorance are some probable reasons which prevent many people from actively pursuing biophilic architecture and construction. Moreover, in most cities and countries, there is a lack of specific building rules and regulations regarding integration and nurturing of greenery in built forms. The more it is implemented, the further its drawbacks will be eliminated, and its benefits will be highlighted to all people. Proper utilization of the techniques and more public awareness regarding this can improve our environment within near future.

REFERENCES

[1]. Landau, Sarah Bradford, and Carl W. Condit. *Rise of the New York Skyscraper*, 1865-1913. New Haven: Yale UP. 1996. Print.

[2]. Gottmann, Jean. *"'Why the Skyscraper?" Geographical Review* 56.2.190-212. 1966. JSTOR. Web. 27 Apr. 2015.

[3]. Baker, D.B. "*Social and Organizational Factors in Office Building-associated Illness"* Occupational Medicine: State of the Art Reviews 4, 607-24. 1989. Print.

[4]. Joshi, Sumedham. "*The Sick Building Syndrome*." Indian Journal of Occupational and Environmental Medicine 12.2: 61-64. 2008. Web.

[5]. *Indoor Air Facts No. 4 (revised) Sick Building Syndrome*, Research and Development (MD 56), 1991. PDF file.

[6]. Breiman, R. F., and D. W. Fraser. *Public Health and Preventive Medicine*. 13th ed. New Jersy: Prentice Hall International, 181-182. 1992. Print.

[7]. Phoon WO. *Practical occupational health*. Singapore: PG Publishing, 326-327. 1988. PDF File.

[8]. Nsc.org,. IAQ Fact Sheet, 2015. Web. 3 Apr. 2015.

[9]. Alexander, C. *The Phenomenon of Life- Book One.* 4th ed. California: The Centre for Environmental Structure 184-197, 2002. PDF File.

[10]. Day, C. *'Spirit Ad Place'*. Architectural Press, United Kingdom: 187-190, 2002. PDF File.

[11]. Butterworth, I. *'The Relationship Between The Built Environment And Well Being: A Literature Review'*. Ph.D. Melbourne University, Australia, 2000. PDF File.

[12]. Tuan, Y.F. *'Space and Place: The Perspective Of Experience'*. Leonardo 12.3: 251. 1979. Web.

[13]. Purushottam, K. *'The Sick Building Syndrome'*. Indian Journal occupants Health 44: 36-40. 2001. Print.

[14]. Lynch, K. *'A Theory Of Good City Form'*. Cambridge: MIT Press. 1982. PDF File.

[15]. Alcock, I., M.P. White, B.W. Wheeler, L.E. Fleming, & M.H. Depledge. *Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas*. Environmental Science &Technology, *48* (2), 1247-1255. 2013. PDF file.

[16]. Barton, J. & J. Pretty. *What Is the Best Dose of Nature and Green Exercise for Improving Mental Health?* Environmental Science & Technology, *44*, 3947 - 3955. 2010. PDF file.

[17]. Hartig, T., G.W. Evans, L.D. Jamner, D.S. Davis, & T. Garling. *Tracking Restoration in Natural and Urban Field Settings*. Journal of Environmental Psychology, 23, 109-123. 2003. PDF file.

[18]. Hartig, T., M. Mang, & G. W. Evans. *Restorative Effects of Natural Environment Experience.* Environment and Behavior, *23*, 3 - 26. 1991. PDF file.

[19]. Kellert, Stephen R, Judith Heerwagen, and Martin Mador. *'Biophilic Design'*. Hoboken, N.J.: Wiley, 2008. Print.

[20]. Rotschke M. *Untersuchungen uber die Meteorologie der Staubatmosphare*. Veroff. Geoph. I. Leipzig 11, 1-78. 1937. PDF file.

[21]. Wilson, E.O. *Biophilia: the Human Bond with Other Species*. Cambridge: Harvard University 1986. Press.

[22]. Kellert, Stephen R, and Edward O Wilson. '*The Biophilia Hypothesis*'. Washington, D.C. Island Press, 1993. Print.

[23]. Kellert, S. *Kinship to Mastery: Biophilia in Human Evolution and Development*. Washington, DC: Island Press. 1997. PDF File

[24]. Kellert, S. *Birthright: People and Nature in the Modern World*. New Haven: Yale University Press. 2012. Print.

[25]. Fromm, E. *The Heart of Man,* New York: Harper and Row. 1964. Print.

[26]. Kaplan S. and Kaplan R., *Humanscape: Environments for People*. University of Michigan., 1982. Print.

[27]. Wells, N. and K. Rollings. *The natural environment: influences on human health and function*. In Clayton, S., 2012. Print.

[28]. Lenchner, N. *Heating, Cooling, Lighting – Sustainable Design Methods for Architects*. 3rd Edition. Hoboken: John Wiley and Sons, Inc. 2009. Print.

[29]. Kellert, S. and B. Finnegan. *Biophilic Design: the Architecture of Life*. A 60 minute video. 2011 Retrieved on April 20, 2015 from www.bullfrogfilms.com. Web.

[30]. Fjeld, Tove et al. 'The Effect Of Indoor Foliage Plants On Health And Discomfort Symptoms Among Office Workers'. *Indoor Built Environ* 7.4 (1998): 204-209. Web. 4 May 2015.

[31]. Laumann, Karin, Tommy GÃ¤rling, and Kjell Morten Stormark. 'Selective Attention and Hear Rate Responses To Natural And Urban Environments'. *Journal of Environmental Psychology* 23.2 (2003): 125-134. Web.

[32]. Orwell, Ralph L. et al. 'Removal Of Benzene By The Indoor Plant/Substrate Microcosm And Implications For Air Quality'. *Water, Air, & Soil Pollution* 157.1-4. 193-207. 2004. Web. 1 May 2015.

[33]. Seppanen, O., W. J. Fisk, and Q. H. Lei. '*Ventilation and Performance In Office Work*'. Indoor Air 16.1: 28-36. 2006. Web 21 March 2015.

[34]. Reynolds, Peggy, and George A. Kaplan. *'Social Connections And Risk For Cancer: Prospective Evidence From The Alameda County Study'*. Behavioral Medicine 16.3: 101-110. 1990. Web.

ILLUSTRATION CREDITS

Fig 1.1 - Bearder, S. K., and Richard Passingham. 'The Human Primate.'. Man 18.2 (1983): 407. Web.

Fig 1.2 - Newberry, John. Indus Inscriptions From Ancient Lothal. [Victoria, B.C.?]: John Newberry, 1982. Print.

Fig. 1.3 - Guenther, R. *'Sustainable Architecture For Health: A Mindset Shift'*. HERD: Health Environments Research & Design Journal 2.4: 3-9. 2009. Web.

Fig. 1.4 - Spencer-Jones, Rae, and Elizabeth Scholtz. *1001 Gardens You Must See Before You Die*. Happauge, NY: Barron's Educational Series, Inc., 2012. Print.

Fig. 2.1, 2.2, 2.3 - Kellert, 2012 Kellert, S. *Birthright: People and Nature in the Modern World*. New Haven: Yale University Press. 2012. Print.

Fig. 2.4 - Author

Fig. 2.5, 2.6, 2.7, 2.8 - Terrapin Bright Green,. 'Terrapin Home - Terrapin Bright Green'. N. p., 2015. Web. 17 Feb 2015.

Fig. 3.1, 3.3 - http://www.nhs.uk/conditions/sick-building syndrome/Pages/Introduction.aspx [Accessed 3 Mar. 2015]

Fig. 3.2 - National Library Board, S. (2015). Cecil Street | Infopedia. [online]

Fig. 4.1.0 - https://www.archdaily.com/609260/25-green-luciano-pia [accessed 15th May, 2020]

Fig. 4.1.1 to 4.1.4 - Architect Luciano Pia, Italy

Fig. 4.2.0 – https://www.cosasdearquitectos.com/2010/07/acros-fukuoka-international-hall-emilio-ambasz/ [accessed 15th May, 2020] and https://www.tripadvisor.in/Attraction_Review-g14135106-d3349447-Reviews-Acros_Fukuoka-Tenjin_Chuo_Fukuoka_Fukuoka_Prefecture_Kyushu.html#photos;aggregationId=101&albumid=101&filter=7&ff=451391805 [accessed 15th May, 2020]

Fig. 4.2.1, 4.2.2 - 'Greenroofs.Com' Projects - ACROS Fukuoka Prefectural International Hall'. N. p., 2015. Web. 22 March 2015.

Fig. 4.3.0 – https://www.plataformaarquitectura.cl/cl/02-14392/edificio-consorcio-sede-santiago-enrique-browne-borja-huidobro [accessed 15th May, 2020] and https://www.e-architect.co.uk/chile/consorcio-santiago-building [accessed 15th May, 2020]

Fig. 4.3.1 - Labarca, Claudia – 'Identity and Institutionalization as trust-building strategies: the Sino-Chilean case'. Rev. cienc. polít. (Santiago) 33.2 (2013): 489-511. Web.

Fig. 4.3.2 - ArchDaily,. 'Consorcio Building Concepcion / Enrique Browne'. N. p., 2015. Web. 23 June 2015.

Fig. 4.4.0 – https://development.asia/case-study/turning-public-hospital-site-healing-biodiversity-and-urban-green-space [accessed 15th May, 2020] and https://living-future.org/biophilic/case-studies/award-winner-khoo-teck-puat-hospital/ [accessed 15th May, 2020]

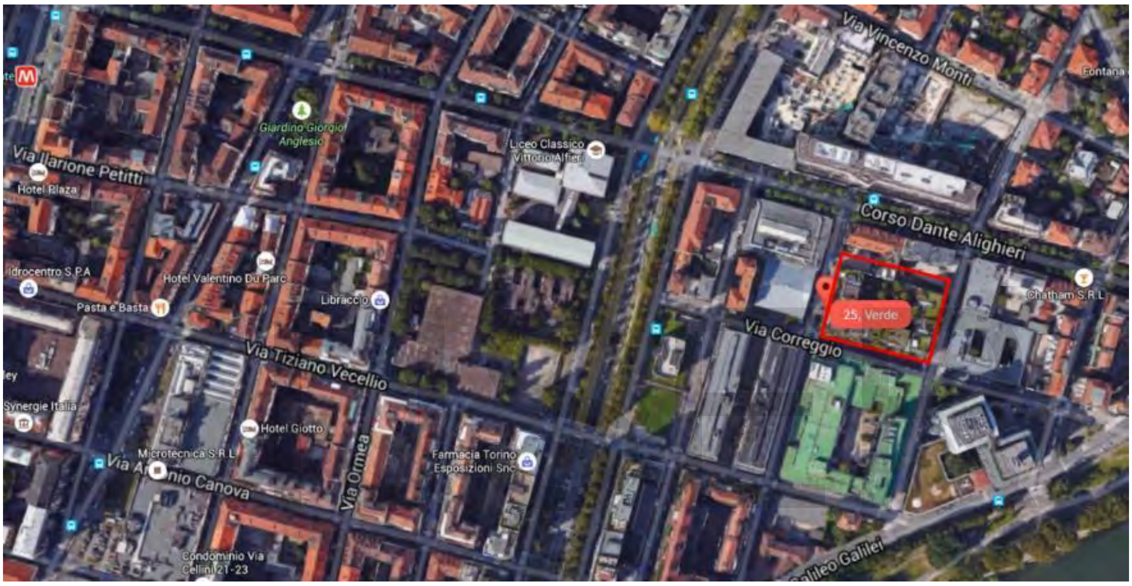
Fig. 4.4.1, 4.4.2 - Cpgcorp.com.sg,. N. p., 2015. Web. 16 April 2015.

Fig. 4.4.3, 4.4.4, 4.4.5 - 'The Practice Of Integrated Design: The Case Study Of Khoo Teck Puat Hospital, Singapore'.*Academia.edu*. N. p., 2015. Web. 24 May 2015.

ANNEXURE 'A' - '25 VERDE' (25 GREEN), TURIN, ITALY

(All drawings, diagrams, photographs courtesy project owners and designers)

- Architect – Ar. Luciano Pia
- Client - Armour group,
  Mania construction
- Completion Year - 2012
- Purpose/use of building - Residential apartment building
- Area of Site - 7,500 m^2
- Ground Coverage – 3,570 m^2
- Height of building - 5-story



Ariel view showing location and urban context of the project

Exterior view of the project

Illustrative plan of the Ground level

Illustrative plan of the Typical apartment floor

Illustrative plan of the Terrace

Cross-sections of the building

Elevations of the building: with and without full grown vegetation

ANNEXURE 'B' - ACROS FUKUOKA PREFECTURAL INTERNATIONAL HALL, FUKUOKA, JAPAN

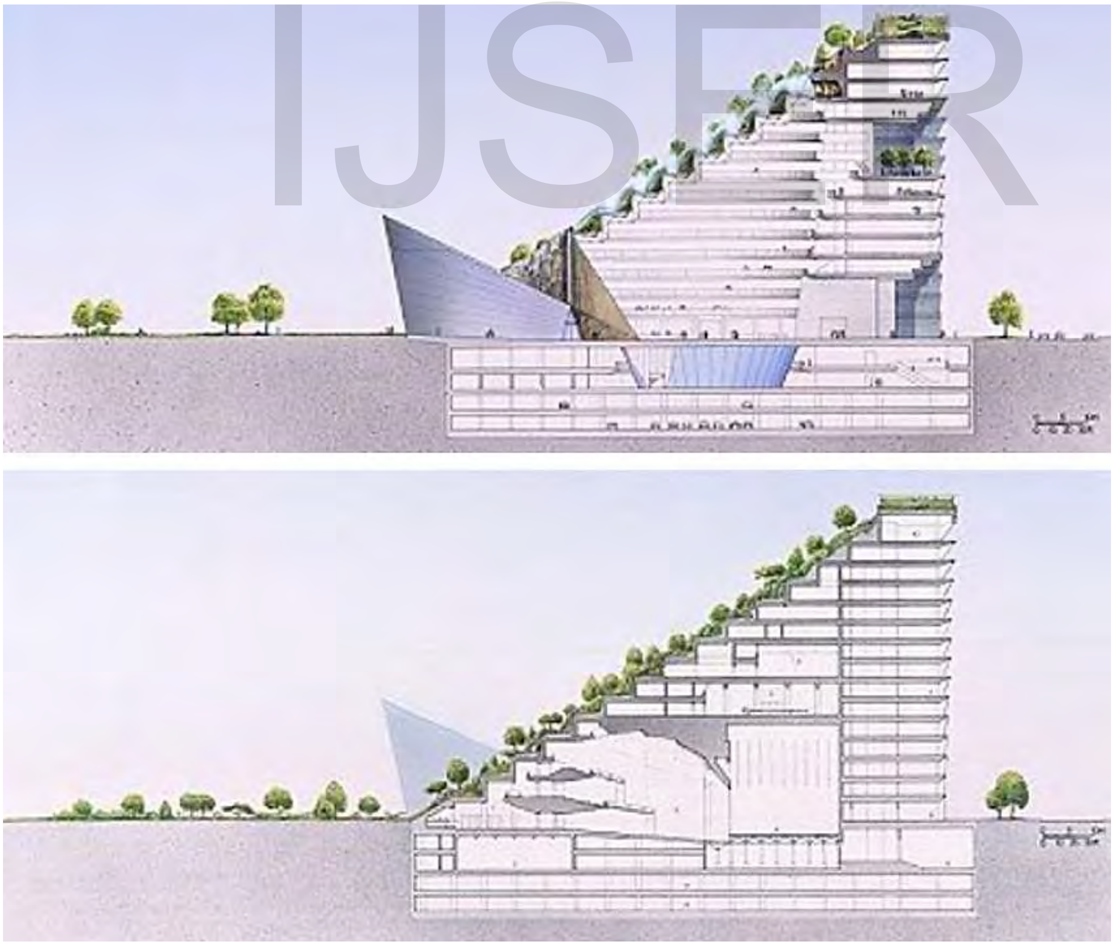
(All drawings, diagrams, photographs courtesy project owners and designers)

- Architect – Emilio Ambasz & Associates
- Client - Dai-ichi Mutual Life Insurance Co.
- Completion Year - 1993
- Purpose/use of building - Commercial + Institutional building
- Built up Area – 1,00,000 m²
- Height of building – 60m, 15 storeys

Ariel view showing location and urban context of the project

External Views of ACROS Fukuoka Prefectural International Hall

Ground floor plan of the project



Sectional drawings of the project

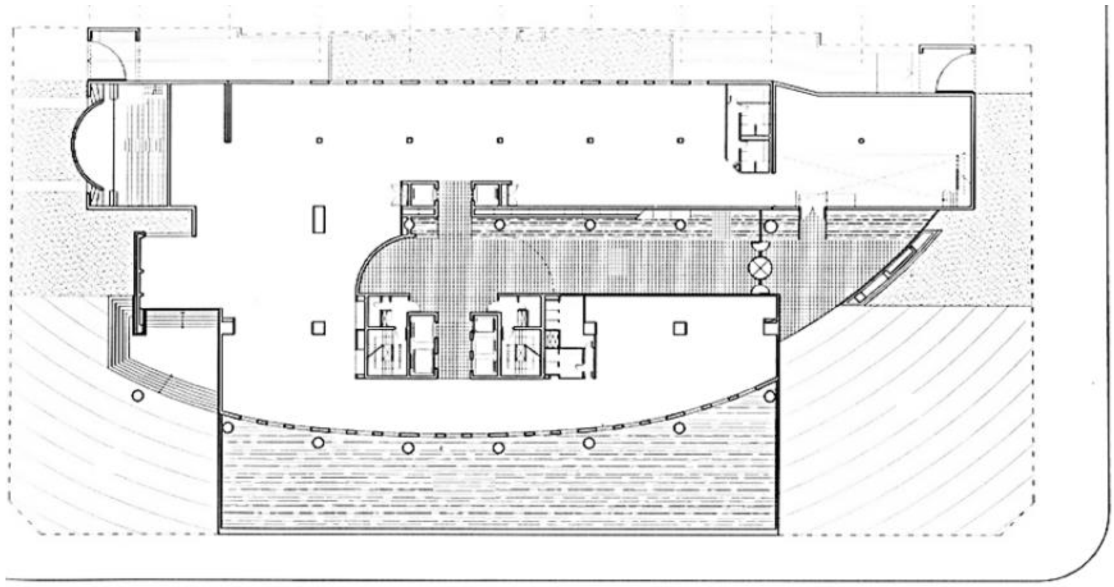
ANNEXURE 'C' - CONSORCIO BUILDING, SANTIAGO, CHILE

(All drawings, diagrams, photographs courtesy project owners and designers)

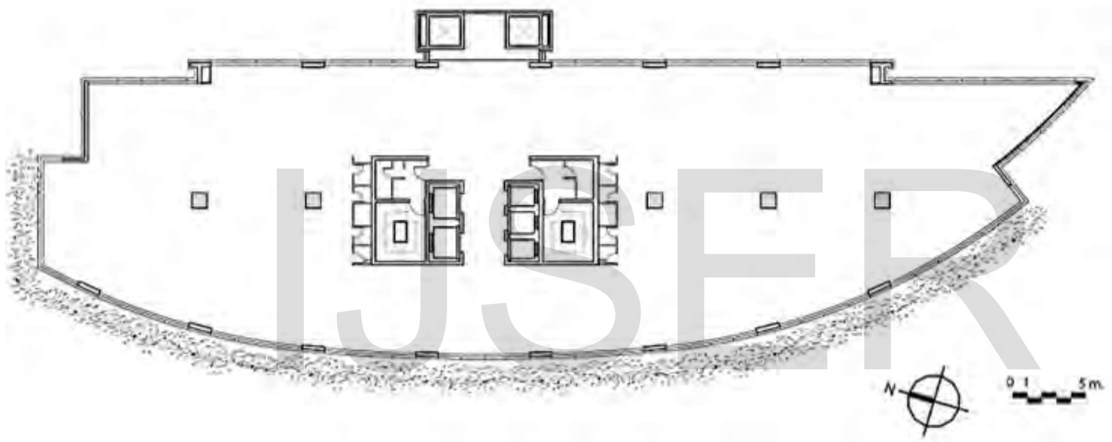
- Architect - Enrique Browne and Borja Huidobro
- Client - National Consortium of Life Insurance
- Completion Year - 2013
- Purpose/use of building - Commercial Building
- Surface Area - 3,781 m²
- Built up Area - 26,720 m²
- Height of Building - 40m (17 floors)

Ariel view showing location and urban context of the project

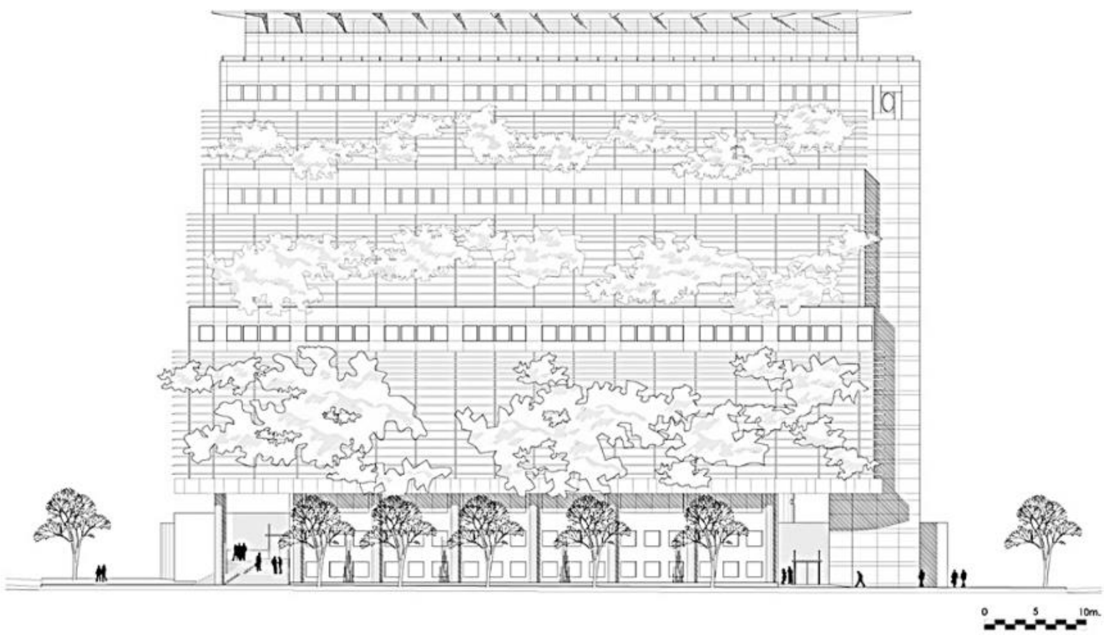
External views of 'Consorcio' building in day and night time



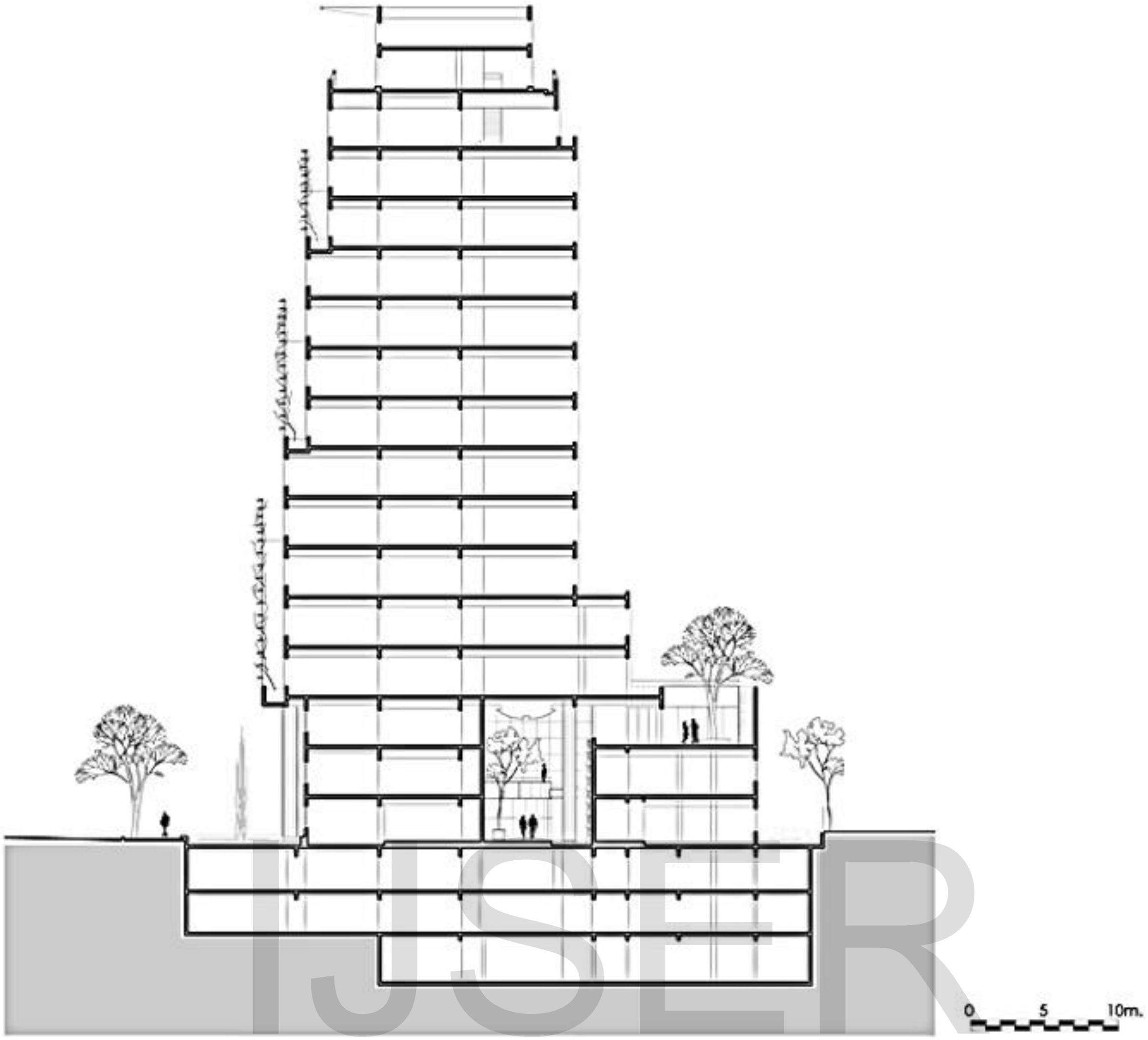
Ground floor plan of the project



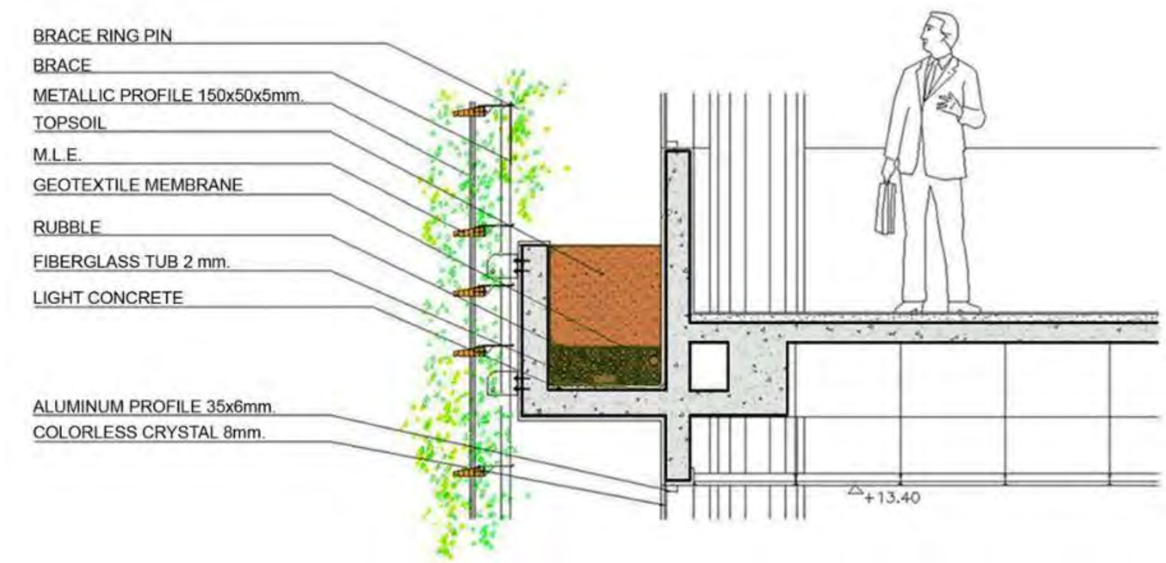
Typical floor plan of the project



West facing elevation of the building



Section through the building

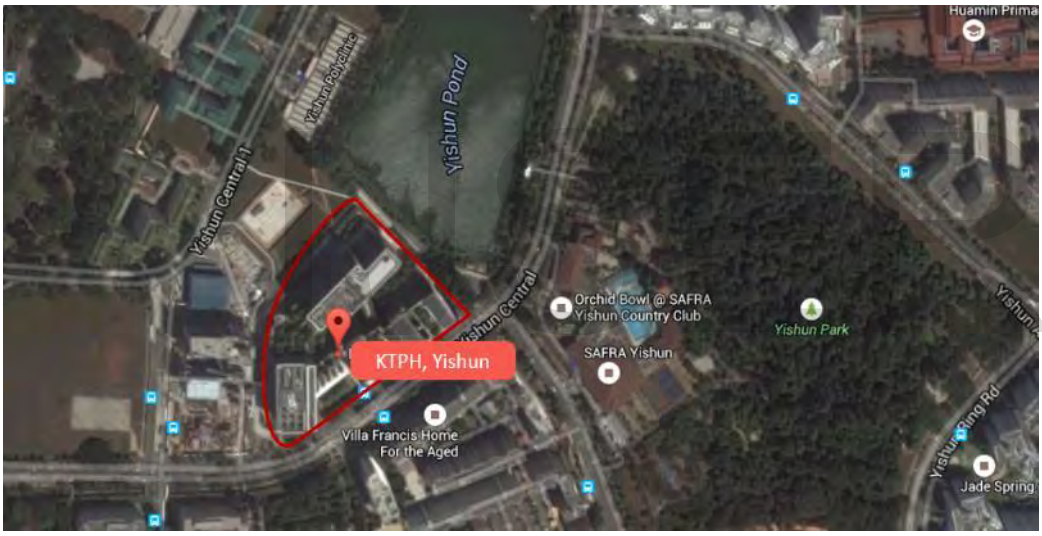


Typical detail of planter and screen

ANNEXURE 'D' – KHOO TECK PUAT HOSPITAL, YISHUN, SINGAPORE

(All drawings, diagrams, photographs courtesy project owners and designers)

- Architects – CPG Consultants in collaboration with RMJM Architects
- Client- Alexandra Hospital and Health ministry of Singapore
- Completion Year- 2010
- Purpose/ Use of Building– Hospital and Healthcare Centre
- Area of Site– 3.4 Hectare
- Total floor area- 1,05,000 m^2
- Height of Building– 55m (10-11 floors)

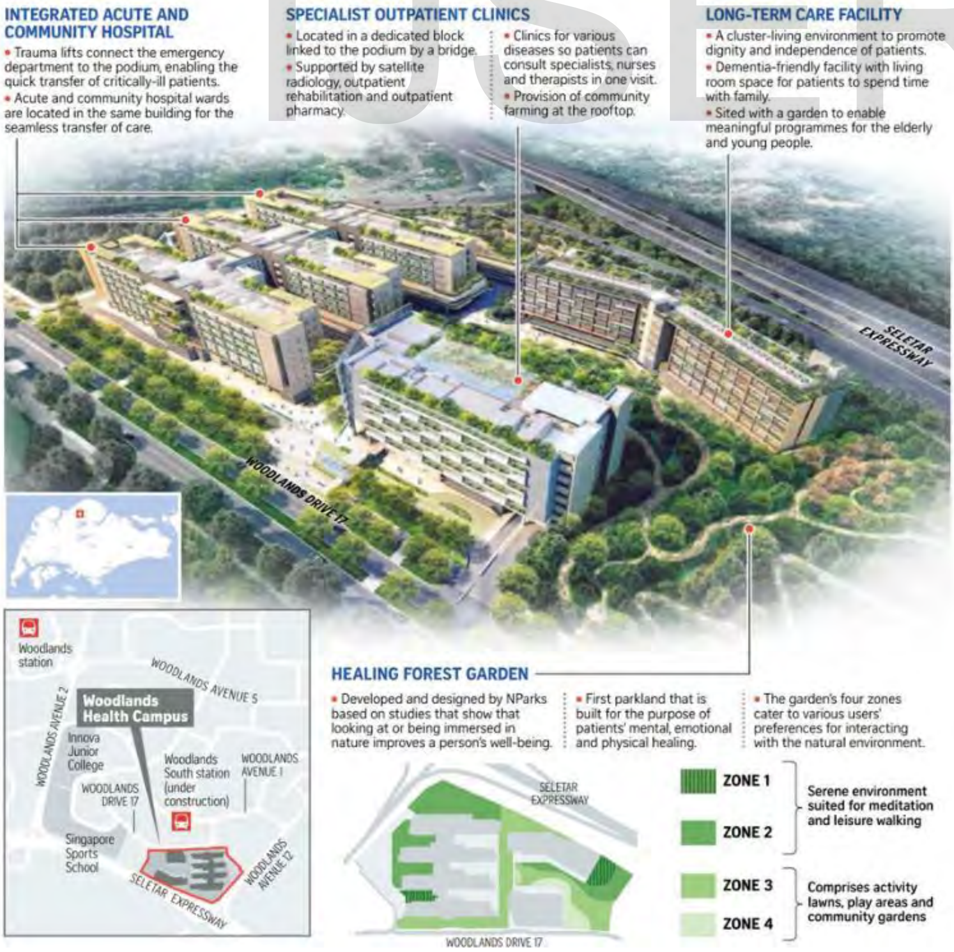


Ariel view showing location and urban context of the project

'Hospital in a Garden' – exterior view of the project from across the Yishun lake

Building footprint plan with landscape elements

Schematic section of the building showing greenery at every level and floors



Illustrative renderings and diagrams from the Hospital's website, explaining the zoning of activities and green areas

International Journal of Scientific & Engineering Research Volume 11, Issue 5, May-2020
ISSN 2229-5518

ANNEXURE 'E'

COMPARATIVE EVALUATION OF BIOPHILIC FEATURES OF THE CASE STUDIES

Parameters	Case Studies			
	ACROS Fukuoka Prefectural International Hall	Khoo tech Puat Hospital	25 Verde (25 green)	Consorcio Building (Consortium Building)
Location	Fukuoka, Japan Asia (Far East)	Yishun, Singapore Asia	Turin, Italy Europe	Santiago, Chile South America
Surrounding Context	Very dense urban fabric	loose dense urban fabric	Dense urban fabric	Dense urban fabric
Climatic Conditions	Summer 30° C, Winter 5° C	Summer 36° C, Winter 22° C	Summer 28° C, Winter -2° C	Summer 32° C, Winter 18° C
Completion Year	1993	2010	2012	2013
Height of Building	15 story (60 m)	10-11 story	5 Story (about 16 m)	17 story
Total Floor Area	1,00,000 m^2	1,05,000 m^2	7,500 m^2	3,781 m^2
Type of Client	Dai – Ichi Mutual Life Insurance Co.	Alexandra Hospital and Health ministry of Singapore	Armour group, Mania construction	National Consortium of Life Insurance
Use of Building	Multipurpose space containing exhibition hall, museum, theater, conference hall, offices	Hospital and Health Care Centre	Residential Apartment Building	Commercial offices and company headquarter
Purpose of Incorporation of Vegetation	To double up the greenery of central park through an 'Agro-Urban Model'	To create healing gardens for the patients and staff.	To facilitate people live with nature	To save the building from harsh sun light and create vibrant façade
Philosophy of Architect	'Green over gray'	'Hospital in a garden, Garden in a Hospital'	To build a natural habitat which behave like an 'Urban Tree House'	To make a vibrant façade which enrich the area as well as keeps the building cooler
Vegetation Indoor-Outdoor Techniques Used	Outdoor Stepped terrace gardens	Indoor and outdoor both Terrace farming, green courtyard and vertical green walls	Indoor- outdoor both Huge Potted plants and Green facades	Outdoor and visual only People can feel the beauty of it but cannot touch it
Occupants contact	Occupants use it as an extension of Park. Visual and touchable	From every level. They can also nurture join the process of nurturing greenery. Visual, touchable, edible	Each and every spaces of the building is filled with greenery. Visual and touchable	A single green façade which starts at the height 3rd floor and reaches up to 17th floor . Visual only
Effects & Benefits	The total area of the greenery increased rather than decrease, Temperature decreased of surrounding area up to 3°C	Lesser stress full atmosphere for staff, speedy recovery for patients and a unique community space for surrounding people	The building works as a huge urban tree for the surrounding area which filters the polluted air	With a 17 story high green façade helps to keep the building cooler and reduce the load on air conditioning system.