PROPOSED HEALTH RESORT, LAMINGO

AN APPLICATION OF PRINCIPLES OF BIOMIMICRY IN RESORT DESIGN

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NIGERIA.

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January, 2012.

DECLARATION

I declare that the work in the thesis entitled 'PROPOSED HEALTH RESORT, LAMINGO : AN APPLICATION OF PRINCIPLES OF BIOMIMICRY IN RESORT DESIGN' has been performed by me in the Department of Architecture under the supervision of Dr. M D Ahmed and Arc. M N Shenge

The information derived from the literature has duly been acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

Bandi Fiama, Barka		January, 2012
Name of student	Signature	Date

CERTIFICATION

This thesis entitled "PROPOSED HEALTH RESORT, LAMINGO : AN APPLICATION OF PRINCIPLES OF BIOMIMICRY IN RESORT DESIGN" by Bandi B Fiama meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

Chairman, Supervisory Committee Dr M. D Ahmed	Date
Member, Supervisory Committee Arc. M.N Shenge	Date
Head of Department Dr. M. Abdulkarim	Date
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DEDICATION

To My Parents

ABSTRACT

One of the main challenges of the twenty-first century will be to bring about more sustainable human communities. The broad and diverse field of sustainability has come to be known as it helps play a central role in meeting this goal. Biomimicry, a part of it addresses the nuts-and-bolts of how tourism attraction spots and its related products should be built and run, including how they relate to natural ecosystems. With proper planning, development and management, they (tourist products) can be used as tools for conserving and protecting the natural environment.

This research is aimed at looking into the problem of sustainability in resorts and how the principles of biomimicry can be used as a tool to solve these problems.

The model for the research is built upon the works of several environmental scientists and architects specialized in environmental sustainability. Their works, which explores Biomimicry, where flora, fauna or entire ecosystems are emulated as a basis for design, is a growing area of research in the fields of architecture and engineering. Through a resourceful literature review, and an examination of existing case studies where biomimetic technologies were explored, this thesis elaborates on distinct approaches to biomimetic design that have evolved.

The whole assertion developed in these concepts of biomimetic approaches identify considerations that move to the application of natural principles and strategies such as; adopting natural forms, regenerative site design, the harvesting of renewable energy for power generation, water management and bio inspired filtration methods and the efficient use of materials in adaptation to changing conditions in the environment. These concepts were adopted and explored in the design, which was s necessary for actualizing a more realistic sustainability in regard to both the natural and human made worlds.

The study has shown that a biomimetic approach to resort design involves an understanding of ecosystems, which when applied could become a vehicle for creating sustainable built environment. This would help create a viable tourism development in Nigeria

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO STUDY

Sustainable design is an idea whose time has come. All over the country, indeed around the world, architects, engineers, developers and builders are all clamouring to understand how to market their services to reflect a new way of building and a new approach to design with the environment in mind. (McLennan, 2004). McLennan (2005) also stated that despite the growing awareness and interest, few words in the design and construction industry have been so poorly used as that of sustainable design and green architecture. This could be seen in our tourism industry today. The need for sustainable design in the tourism industry arises due to the reason that tourism organizations are notorious for erecting buildings, such as, airports, hotels and tourist centres, which ruin the beauty and integrity of their surroundings (International Hotel and Restaurant Association, 2005). One could deduce that there is a need for a philosophical basis of individuals and organisations to literarily seek to redefine how buildings are designed, built and operated to be more responsible to the surrounding environment and to people. The sustainable design therefore, seeks to maximize the quality of the built environment, while eliminating the negative impact on the natural environment.

McLennan (2002), proposed a list of sustainable design principles, which included the Biomicry principle. The biomimetic idea evolved from the respect for natural systems. (Benyus, 2008). She further stated:

For a long time, we thought we were better than the living world, and now some of us tend to think we are worse; but neither perspective is healthy. We have to remember how it feels to

have equal standing in the world, to be ‘between the mountain and the ant... part and parcel of creation’

By taking a look around, designers can find inspiration everywhere – particularly in nature. **Nature** provides us with an amazing array of solutions for many complex problems that we face today – the quest to learn from nature in this way is “**biomimicry**”, and **architecture** can benefit from this kind of approach. At times what may seem as “simple” in nature can translate to better design solutions that are more efficient, sustainable and healthy. Yes, nature is inspirational but it is also a part of our world which we can study more deeply – extracting creative solutions that we can apply today.

Nature can teach us about systems, materials, processes, structures and aesthetics (just to name a few). By delving more deeply into how nature solves problems that we experience today, we can extract timely solutions and find new directions for our built environments. (Benyus, 2008).

As architects, we can benefit from biomimicry to make buildings better by pushing for more natural, integrated, efficient and healthy solutions. We also need to take a look at the role aesthetics plays in nature , with the way function and form so synergistically merge. Perhaps this is a way for buildings to harmonize with nature in renewed ways – making built environments more environmentally sound and healthy for occupants

1.2 STATEMENT OF PROBLEM

The built environment is increasingly held accountable for global environmental and social problems with vast proportions of waste, material and energy use and green house gas emissions attributed to the habitats humans have created for themselves (Mazria, 2003). It is becoming increasingly clear that a shift must be made in how the built environment is created

and maintained. Mimicking life, including the complex interactions between living organisms that make up ecosystems is both a readily available example for humans to learn from and an exciting prospect for future human habitats that may be able to be entwined with the habitats of other species in a mutually beneficial way.

Likewise, there is also a problem of unavailability of energy to sufficiently cater for these recreational facilities. Most of the existing institutions spend so much money to generate their own power on daily basis (Archibong, 2007) which are expensive and emit gases that deteriorate the quality of the environment. There are always heating, and treating activities which are always wielding high fluxes of energy that would never be tolerated in natural systems (Benyus, 2008). From these assertions, one could deduce that energy management has become an issue in the management of the natural environment.

With respect to the quality of the environment, there are practical reasons that suggest that the nature and quality of environmental resources in tourism destinations influence tourists' entering the market, as such assumptions have been validated in some empirical studies such as those of (Gartner 1986), and (Afolabi 1993). These highlighted problems thus give rise to the need to address them sustainably, being the basic tool for development which presents options for solving these problems. The underlying philosophy of biomimicry is that environmental problems must be approached and managed naturally, objectively and rationally as a concept once it is understood. Biomimetic architecture takes after nature, and so applying its principles would result in giving a product that is environmentally suitable, dictated by its natural immediate environment.

1.3 AIM AND OBJECTIVES

1.3.1 AIM

The aim of this research is to apply biomimetic sustainable design principles in the design of health resort as a means of safeguarding against the deterioration of the eco-system, and providing economically viable means of energy management.

1.3.2 OBJECTIVES

The objectives of this research thesis are;

I. To study biomimetic architecture, its principles, roots and concepts
II. To study ways in which these principles have been applied.
III. To demonstrate through design the suitability of the application of the principles and features of biomimicry sustainable design in health resort design.

1.4 SCOPE OF THE STUDY

The three paramount aspects of biomimetic architecture are aspects of 'nature as a mentor' nature as a model' and 'nature as a mentor'. Biomimetic architecture by all its definitions proposes that a building should be sustainable using tools,materials, techniques, technologies and this forms the bedrock of the study with respect to the physical and climatic characteristics of the site. Forms and mechanical aspects would be mimicked, with an exclusion of chemical processes without scientific collaboration.The vehicle to direct the research is a health resort in Lamingo, Jos. This facility is to have Deluxe accommodations, The Spa and health centre, Green space, Fitness centre, with all its amenities and related facilities.

1.5 SIGNIFICANCE OF THE STUDY

A biomimetic approach to architectural design incorporates that an understanding of ecosystems could become a vehicle for creating a built environment that goes beyond simply sustaining current conditions to a restorative practice, but that the built environment becomes a vital component in the integration and regeneration of the natural ecosystems. (Zari 2007). Thus, biomimicry suggests that we develop a high degree of awe, bordering on reverence for our natural processes which offer us a solution in sustaining it for now and the future.

Furthermore, the significance of this research is that it provides a design that will be integrated with its environment sustainably by advancing efficient alternative means of generating and saving energy. This is to cater for the issue of power, which has continuously had a onerous effect, not only on the the industrial sector of the economy but also on the tourism industry as well its effects on the economy.

A typical example of this is the Eastgate center Harare, Zimbabwe. In the Eastgate center the design eliminated the use of conventional air conditioning units through the employment of wind channels and extractor fans. The end effect is that the building has a cleaner environment and use less than 10% of the energy of a conventional building its size. Outside of being eco-efficient and better for the environment, these savings also trickle down to the tenants whose rents are 20% lower than those of occupants in the surrounding buildings (Doan, 2007).

1.6 DEFINITIONS OF KEY TERMS

1.6.1 SUSTAINABLE DEVELOPMENT

“Sustainable development can be defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

(Brundtland Commission,(1999)

Sustainable development means “improving the quality of human life while living within the carrying capacity of supporting ecosystems.”

World Conservation Union (1991)

Sustainable development implies using renewable natural resources in a manner which does not eliminate or degrade them, or otherwise diminish their usefulness for future generations.

1.6.2 SUSTAINABLE DESIGN

Sustainable design is a design philosophy that seeks to maximize the quality of the built environment, while minimizing or eliminating negative impact to the natural environment.

1.6.3 BIOMIMICRY

Biomimicry is from the Greek word bios, meaning life and mimesis meaning imitation. Benyus (1996) described it as a re-emerging science and philosophy of learning from nature. She further described the science as having three major components:

1. Nature as a model- taking inspirations from the design of nature
2. Nature as a measure- using an ecological standard to judge the rightness of our innovations
3. Nature as a mentor – valuing what we can learn versus what we can extract.

1.6.4 BUILDING INTEGRATED PHOTOVOLTAICS

These are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylight, or facades. They are increasingly being incorporated into the construction of new buildings as a principal or ancillary source of electrical power, although existing buildings may be retrofitted with Building Integrated Photovoltaic (BIPV) modules as well. The advantage of integrated photovoltaics over

common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labour that will normally be used to construct the part of the building that the BIPV modules replace (Murcott, 2008).

1.6.5 RENEWABLE ENERGY

Renewable energy is energy generated from natural resources such as sunlight, wind, rain, tides and geothermal heat which are renewable. Renewable energy technologies include solar power, wind power, hydroelectricity, micro hydro, biomass and bio fuels (Murcott, 2008).

1.6.6 SOLAR ENERGY

Solar energy is heat and light from the sun. This energy resource powers the climate and weather and sustains life on Earth. Solar radiation along with secondary solar resources such as; wind and wave power, hydroelectricity and biomass account for over 99.97% of the available flow of renewable energy on Earth. Solar energy technologies can provide day lighting and thermal comfort in passive buildings; potable water via distillation and disinfection; water and space heating; space cooling by absorption or vapour-compression refrigeration; high temperature process heat for industrial purposes; and electrical generation by thermal or photovoltaic means (Murcott, 2008).

CHAPTER TWO

LITERATURE REVIEW

2.1 SUSTAINABLE DESIGN

Sustainable design is one that takes into cognisance all social and environmental impacts of a product or building throughout the complete lifecycle whilst maintaining other important measures such as cost, quality and appearance (Loughborough University, 2004). Such a design essentially involves an integrated design process that does not just involve the identification and assembly of the latest sustainable technologies and products but one that involves a holistic approach to design: an approach that touches social, environmental and economical areas.

Sustainable design is viewed as a process in which every element of the design is first optimized and then the impact and interrelationship of various different elements and systems within the building and site are re-evaluated, integrated, and optimized as part of a whole building solution. For example, interrelationships between the building site, site features, the path of the sun, and the location and orientation of the building and elements such as windows and external shading devices have a significant impact on the quality and effectiveness of natural day lighting. These elements also affect direct solar loads and overall energy performance for the life of the building. Without considering these issues early in the design process, the design is not fully optimized and the result is likely to be a very inefficient building. This same emphasis on integrated and optimized design is inherent in nearly every aspect of the building from site planning and use of on-site storm water management strategies to envelope design and detailing and provisions for natural ventilation of the building. This integrated design process mandates that all of the design professionals work cooperatively towards common goals from day one.

Sustainable design suggests that technological fixes be applied after natural ones have been used to the full extent. Example of this would be to design a building to harness breezes for natural cooling when climate conditions are favourable, instead of ignoring orientation and relying on air conditioning (Cohen, 1996). With this approach, the design will have to take into account prevailing breezes and how they are affected by site features such as trees, adjacent structures and topography, and then locate intakes and outlets to further improve the natural cooling effect. Sustainable design requires learning what is unique about a given place and how those characteristics can be celebrated and protected. It relies substantially on the qualities of a place to inform the process of design itself (Cohen, 1996).

Architecture and landscape design maintains a dialogue with its surroundings, and teaches about the places we inhabit, enrich on its experiences on all levels (Cohen, 1996). The discourse between the site, climate and ecology elevates the design object itself to a higher plane. A sustainable designer treats all sites with respect and reverence, no matter how uninspiring or degraded it may seem to be. Even the most degraded site can be restored and repaired under skilful hands, it is our duty to do so (McHarg, Ian, 1992).

McLennan (2005), also described Sustainable design as an umbrella term to describe a set of strategies, components and technologies that lower environmental impact while in many cases improving comfort and overall quality. These categories include but are not limited to:

i. Daylighting
ii. Indoor air quality
iii. Passive solar heating
iv. Natural ventilation
v. Energy efficiency
vi. Embodied energy
vii. Construction waste minimization

viii. Water conservation

ix. Solid waste management

x. Renewable energy

xi. Xeriscaping /natural landscaping

xii. Site preservation.

He (McLennan 2005) further expounded that the six governing principles of sustainable design are:

i. Respect for the wisdom of natural systems- the Biomimicry principle

ii. Respect for people- the human vitality principle

iii. Respect for place- the ecosystem principle

iv. Respect for the cycle of life

v. Respect for energy and natural resources- the conservation principle

vi. Respect for process- the holistic thinking principle.

A design that is sustainable would have to address social and environmental impacts of a product throughout the complete lifecycle whilst maintaining other criteria (such as cost, quality and appearance.) (Loughborough University, 2004). The optimum design solution is one that effectively emulates all of the natural systems and conditions of the pre-developed site – after development is complete, and preserves and restores habitat that is vital for sustaining life and becomes a net producer and exporter of resources, materials, energy and water rather than being a net consumer. (Building green in Pennsylvania, 2007).

2.2 BIOMIMICRY AND SUSTAINABLE DESIGN

Reducing human impact on the environment becomes more critical as every day passes. The public, along with designers and clients, now realize the tremendous impact our buildings

have on the natural and built environment. As sustainable design becomes widely accepted, new approaches, like biomimicry, are advanced to achieve a sustainable future (Benyus, 2007, McLennan & Berkebile, 2004). Yet as sustainable design gains support, an increasing number of critics suggest many current sustainable practices, will ultimately be insufficient (Alexander, 2004; Kellert and Heerwagen, 2008). Lance Klein argues that solutions focused on calculative methods that ignore the complex relationship between people and the environment are not adequate for achieving a more realistic sustainability.

Biomimicry in architecture is defined as a movement for the design and construction of expressive buildings which taps nature's huge reservoir of structures, process optimizations and functional solutions in order to find technical applications of natural principles. (Vincent 2009).

Janine Benyus, a biologist, argues for the need to imitate nature to ensure a more sustainable future, she reviews research regarding how nature harnesses energy and makes things.

Focus was made on the application of this Life principles and strategies in sustainable building design.

2.3 A FRAMEWORK FOR UNDERSTANDING THE APPLICATION OF BIOMIMICRY

Within the two approaches discussed, three levels of biomimicry that may be applied to a design problem are typically given as form, process and ecosystem (Guild, 2007) In studying an organism or ecosystem, form and process are aspects of an organism or ecosystem that could be mimicked. Ecosystem however is what could be studied to look for specific aspects to mimic.

A framework for understanding the application of biomimicry was proposed by Biomimicry Guild, (2007) that redefines these different levels and also attempts to clarify the potential of

biomimicry as a tool to increase regenerative capacity of the built environment. By defining the kinds of biomimicry that have evolved, this framework may allow designers who wish to employ biomimicry as a methodology for improving the sustainability of the built environment to identify an effective approach to take. The framework that will be described here is applicable to both approaches (design looking to biology, and biology influencing design).

The first part of the framework determines which aspect of 'bio' has been 'mimicked'. This is referred to here as a *level*. Through an examination of existing biomimetic technologies it is apparent that there are three levels of mimicry; the organism, behavior and ecosystem. The organism level refers to a specific organism like a plant or animal and may involve mimicking part of or the whole organism.

The second level refers to mimicking behavior, and may include translating an aspect of how an organism behaves, or relates to a larger context.

The third level is the mimicking of whole ecosystems and the common principles that allow them to successfully function. Within each of these levels, a further five possible dimensions to the mimicry exist. The design may be biomimetic for example in terms of what it looks like (form), what it is made out of (material), how it is made (construction), how it works (process) or what it is able to do (function). The differences between each kind of biomimicry are described in Table 2.1 and are exemplified by looking at how different aspects of a termite, or ecosystem a termite is part of could be mimicked.

Level of Biomimicry		*Example - A building that mimics termites:*
Organism level (Mimicry of a specific organism)	*form*	The building looks like a termite.
	material	The building is made from the same material as a termite; a material that mimics termite exoskeleton / skin for example.
	construction	The building is made in the same way as a termite; it goes through various growth cycles for example.
	process	The building works in the same way as an individual termite; it produces hydrogen efficiently through meta-genomics for example.
	function	The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.
Behaviour level (Mimicry of how an organism behaves or relates to its larger context)	*form*	The building looks like it was made by a termite; a replica of a termite mound for example.
	material	The building is made from the same materials that a termite builds with; using digested fine soil as the primary material for example.
	construction	The building is made in the same way that a termite would build in; piling earth in certain places at certain times for example.
	process	The building works in the same way as a termite mound would; by careful orientation, shape, materials selection and natural ventilation for example, or it mimics how termites work together.
	function	The building functions in the same way that it would if made by termites; internal conditions are regulated to be optimal and thermally stable for example (fig. 6). It may also function in the same way that a termite mound does in a larger context.
Ecosystem level (Mimicry of an ecosystem)	*form*	The building looks like an ecosystem (a termite would live in).
	material	The building is made from the same kind of materials that (a termite) ecosystem is made of; it uses naturally occurring common compounds, and water as the primary chemical medium for example.
	construction	The building is assembled in the same way as a (termite) ecosystem; principles of succession and increasing complexity over time are used for example.
	process	The building works in the same way as a (termite) ecosystem; it captures and converts energy from the sun, and stores water for example.
	function	The building is able to function in the same way that a (termite) ecosystem would and forms part of a complex system by utilising the relationships between processes; it is able to participate in the hydrological, carbon, nitrogen cycles etc in a similar way to an ecosystem for example.

Table 2.1: A Framework for the Application of Biomimicry
Source: Zari, 2007

It is expected that some overlap between different kinds of biomimicry exists and that each kind of biomimicry is not mutually exclusive. For example, a series of systems that is able to interact like an ecosystem would be functioning at the ecosystem level of biomimicry. The individual details of such a system may be based upon a single organism or behaviour mimicry however, much like a biological ecosystem is made up of the complex relationships between multitudes of single organisms.

i. Organism level: Species of living organisms have typically been evolving for millions of years. Those organisms that remain on Earth now have the survival mechanisms that have

withstood and adapted to constant changes over time, as Baumeister (2007) points out *'the research and development has been done'*. Humans therefore have an extensive pool of examples to draw on to solve problems experienced by society that organisms may have already addressed, usually in energy and materials through effective ways. This is helpful for humans, particularly as access to resources changes, the climate changes and more is understood about the consequences of the negative environmental impact that current human activities have on many of the world's ecosystems (Alberti, 2003). An example is the mimicking of the Namibian desert beetle, s*tenocara*. The beetle lives in a desert with negligible rainfall. It is able to capture moisture however from the swift moving fog that moves over the desert by tilting its body into the wind. Droplets form on the alternating hydrophilic – hydrophobic rough surface of the beetle's back and wings and roll down into its mouth (Parker and Lawrence, 2001). Matthew Parkes of KSS Architects demonstrates the process biomimicry at the organism level inspired by the beetle, with his proposed fog-catcher design for the Hydrological Center for the University of Namibia (plate 2.1) (Killeen, 2002). Ravilious (2007) and Knight (2001) discuss a more specific material biomimicry at the organism level, where the surface of the beetle has been studied and mimicked to be used for other potential applications such as to clear fog from airport runways and improve dehumidification equipment for example.

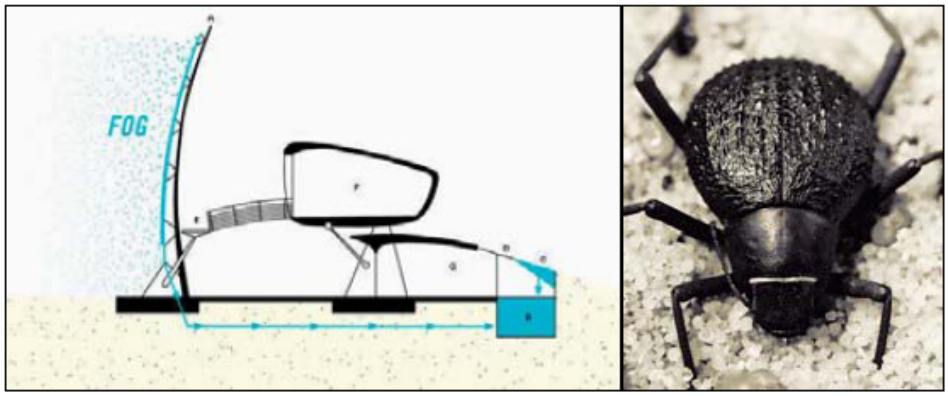


Plate 2.1: Matthew Parkes' Hydrological Center for the University of Namibia and the stenocara beetle. Source: Pedersen Zari, 2007

Nicholas Grimshaw & Partners' design for the Waterloo International Terminal demonstrates an example of form and process biomimicry at the organism level (Plate 2.2). The terminal needed to be able to respond to changes in air pressure as trains enter and depart the terminal. The glass panel fixings that make up the structure mimic the flexible scale arrangement of the Pangolin so they are able to move in response to the imposed air pressure forces (Williams, 2003).

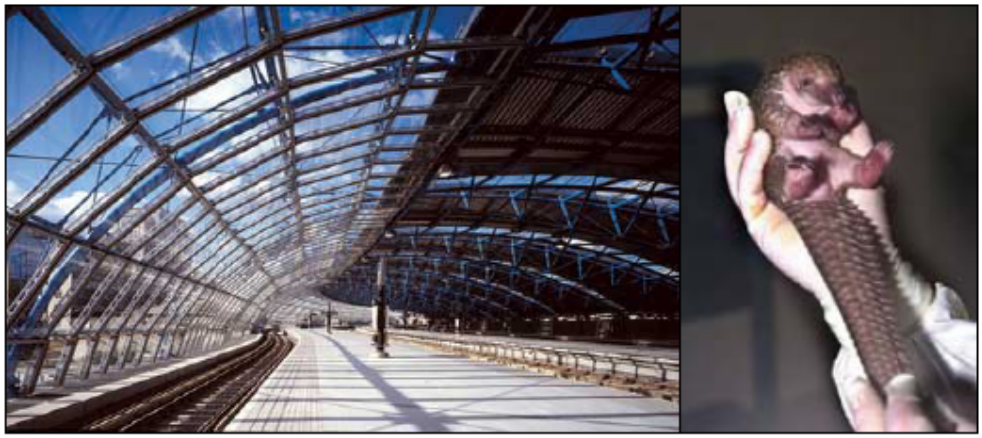


Plate 2.2: Nicholas Grimshaw & Partners' Waterloo International Terminal and the pangolin
Source: Pedersen Zari, 2007

Mimicking an organism alone however without also mimicking how it is able to participate in and contribute to the larger context of the ecosystem it is in, has the potential to produce designs that remain conventional or even below average in terms of environmental impact (Reap, 2005). This is because mimicking of organisms tends to be of a specific feature, rather than a whole system, the potential also remains that biomimicry becomes technology that is added onto buildings rather than being integral to them, particularly if designers have little biological knowledge and do not collaborate with biologists or ecologists during the early design stages. While this method may result in new and innovative building technologies or materials, methods to increase sustainability are not necessarily explored.

ii. Behaviour Level: A great number of organisms encounter the same environmental conditions that humans do and need to solve similar issues that humans face. As discussed,

these organisms tend to operate within environmental carrying capacity of a specific place and within limits of energy and material availability. These limits as well as pressures that create ecological niche adaptations in ecosystems mean not only well-adapted organisms continue to evolve, but also well-adapted organism behaviors and relationship patterns between organisms or species (Reap, 2005).

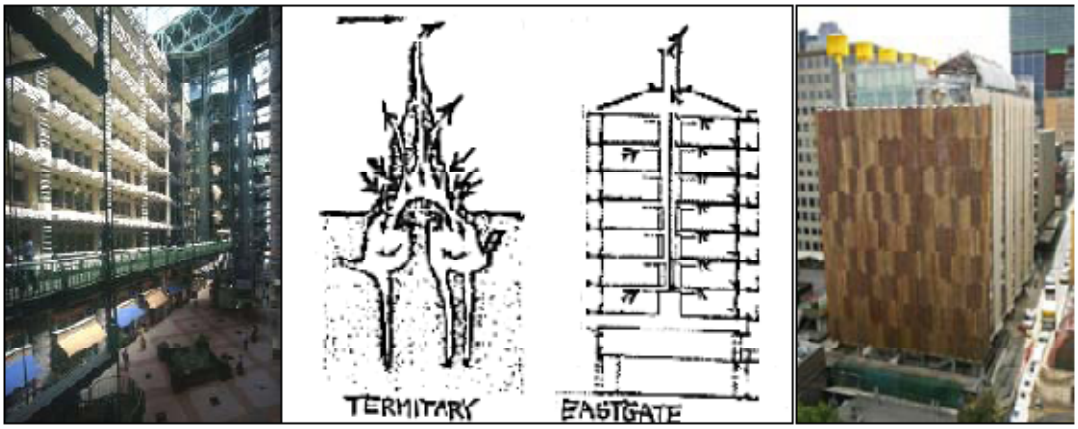


Plate 2.3: Eastgate Building in Harare, Zimbabwe and CH2 Building in Melbourne, Australia
Source: Zari, 2007

In behaviour level biomimicry, it is not the organism itself that is mimicked, but its behaviour. It may be possible to mimic the relationships between organisms or species in a similar way. An architectural example of process and function biomimicry at the behaviour level is demonstrated by Mick Pearce's Eastgate Building in Harare, Zimbabwe and the CH2 Building in Melbourne, Australia (plate 2.3). Both buildings are based in part on techniques of passive ventilation and temperature regulation observed in termite mounds, in order to create a thermally stable interior environment. Water which is mined (and cleaned) from the sewers beneath the CH2 Building is used in a similar manner to how certain termite species will use the proximity of aquifer water as an evaporative cooling mechanism.

iii. Ecosystem Level: The mimicking of ecosystems is an integral part of biomimicry as described by Benyus (1997) and Vincent (2007). The term ecomimicry has also been used to describe the mimicking of ecosystems in design (Lourenci, 2004, Russell, 2004), while Marshall (2007) uses the term to mean a sustainable form of biomimicry where the objective

is the wellbeing of ecosystems and people, rather than *'power, prestige or profit'*. Proponents of industrial, construction and building ecology advocate mimicking of ecosystems (Graham, 2003, Kibert et al., 2002, Korhonen, 2001) and the importance of architectural design based on an understanding of ecology is also discussed by researchers advocating a shift to regenerative design (Reed, 2006).

The most important advantage of such an approach to biomimetic design however may be the potential positive effects on overall environmental performance.

2.4 BIOMIMETIC ARCHITECTURE

Biomimetics (biomimicry) is a cross-disciplinary field of study based on the idea of taking inspiration from nature. Michael Fox (2007) further explained that Central to biomimicry within the context of Interactive Architecture is an understanding of the process by which organsims grow and develop. Again, Dave Oakey (2007) added that "nature rewards mistakes and learns from them"

According to Katharine Rhein (2006**),** Biomimetic Architecture is one that seeks to extract ideas from nature and applies them on buildings**.**How Nature Builds/ key ideas are:

i. Efficiency: optimisation, conservation, responsive buildings
ii. Environment: flows, waste, climate control, lighting, fringe living
iii. Envelope: adaptive, membranes, working envelope, defense
iv. Materials: composites, smart materials, coatings, and surface treaments
v. Structure: soft structure, interfaces and joints, efficiency and failure mechanisms
vi. Construction: self-assembly, replication and repair, and social building

2.5 PRINCIPLES OF BIOMIMETIC DESIGN

Biomimetic design, in addition to mimicking specific creatures, can also be the mimicry of general patterns and processes found in nature. These general patterns and processes are referred to as Life's Principles, (Benyus 2007)

2.5.1 USE OF NATURAL FORMS

Mainstream architecture is adopting and mimicking outward organic forms. The competition-winning elliptical dome for the Chinese national opera house and concert hall, Beijing (Paul Ardreau), is an example of a building that mimicked a natural form. The questions however is that are these projects motivated by the spirit of biomimetic design?



Plate 2.4: The 'Egg', China
(Source:http://www.guardian.co.uk/news/gallery/2007/sep/25/internationalnews2

Another example is New Zealand town Tirau's iconic dog building (form biomimicry at the organism level) (plate. 2.5). A building that is able to mimic natural processes and can function like an ecosystem in its creation, use and eventual end of life has greater potential to be part of a regenerative built environment.



Plate 2.5: Dog Building, Tirau, New Zealand
Source: Zari, 2007

Key principles

Patterns and forms in nature, such as the spiral and fractal, are products of internal laws of growth and of the action of external forces, such as sun, wind, and water. The use of natural forms are adopted from observing living structures: trees, bones, shells, wings, webs, eyes, petals, scales, rocks and microscopic creatures.

Key Strategies

i. Use of curves: The circle representing the path of the sun, moon, and stars, and the cycle of life and death, has been used since pre-historic times for the henges and barrows of sacred sites. Domes, arches, and vaults were used in religious architecture because of their power to evoke the sublime. They may also be sleek and streamlined to respond to the energy and force of wind and water, or sensual and erotic in suggesting the beauty of living forms. Curves are very strong and can reach optimum structural shapes as parabolic and hyperbolic arches and shells.

ii. Use of fractal geometry: Benoit Mandelbrot coined the term fractal, in 1970 in his groundbreaking book The Fractal Geometry of Nature; he fundamentally changed the way we look at the natural world. The attribute of self similarity is characteristic of fractals.

With Fractal geometry, one can describe natural shapes and rhythms such as snowflakes, leaves, tree branches, mountains, waves, and coastlines.

2.5.2 EXPLORING THE APPLICATION NATURAL PROCESSES

USE FREE ENERGY: Collective life can be seen as an unsustainable open system of energy, ultimately dependent on solar energy. Life over the years, has learnt to harvest energy from the Sun and to transform it for work without creating toxic by-products. The idea is to displace some of our conventional energy with a renewable source (Benyus 2006), as is demonstrated in a cornucopia of strategies as seen below.

Plant cells have been studied for solar energy absorption, an elegant, effective system that uses the earth's only perpetual source of energy.



Plate 2.6: Mangrove leaf spreads for photosynthesis
Source: Biology of Mangroves 2002.

Photosynthesis is the process by which plants convert carbon dioxide gas and water with the help of light energy into glucose (energy) and oxygen gas.

Key Principles:

i. Maximize passive design and renewable energy sources by alignment of energy flows with natural tendencies and use of solar sources of energy
ii. Minimization of adverse impacts on the environment (air, water, land, natural resources) through optimized building siting, optimized building design, material

selection, and aggressive use of energy conservation measures (Biomimicry Institute 2008).

Key Strategies and Technologies:

i. Use of high performance integrated photovoltaic façade systems
ii. Rain screens and stick systems
iii. Double skin façade systems
iv. Shading and Glazing systems
v. Atria and Canopies
vi. Use of high performance low-e glazing, which can result in significant year round energy savings. Window frames, sashes and curtain wall systems should be designed for optimum energy performance including the use of multiple thermal breaks to help reduce energy use.
vii. Energy Star certified energy efficient appliances, office equipment, lighting and HVAC systems should be used.
viii. If possible, small-scale wind, solar, and/or fuel cell based energy generation and co-generation. Environmentally preferable "green" power from certified renewable and sustainable sources can also be purchased.

USE MINIMAL ENERGY AND MATERIALS: Nature always tries to use energy and materials efficiently, successfully minimizing mass and energy use. Nature recycles everything; the natural skin reacts to changing conditions and influences of air pressure on the surface to perform a process of transpiration in plants. This system is created by a specific arrangement of a basic component, to utilize space and material in an efficient way. (Biomimicry Institute 2008)

Key Principles:

i. Minimizing the use of non-renewable construction materials and other resources such as energy and water through efficient engineering, design, planning and construction and effective recycling of construction debris.

ii. The use of smart materials to control solar radiation transmitting through the building envelope, control of conductive heat transfer through the building envelope, control of interior heat generation and **t**he use of secondary energy supply systems and optimization of lighting system

iii. Increased use of recycled content materials, modern resource efficient engineered materials, and resource efficient composite type structural systems wherever possible including the use of re-usable, renewable, sustainably managed, bio-based materials.

Key Strategies and Technologies:

i. The use of materials that are adaptable to hot Humid climate and environmentally responsive such as Thastyron and Polystrene Concrete Facade system with low thermal conductive property, energy efficient and recyclable. Thastyron also costs less to use and maintain than other materials when used for the building envelope design.

ii. The applying o smart materials like Photochromics, Liquid crystals to control solar radiation transmitting through the building envelope and phase change materials to control interior heat generation.

iii. The use of Secondary energy supply systems such as integrated photovoltaics and optimization of lighting system.

iv. Reduction in the amount of materials used and the amount of waste generated through the implementation of a construction waste reduction plan. A policy of “waste equals

food" whereby 75% or more of all construction waste is separated for recycling and used as feedstock for some future product rather than being land-filled.

v. Evaluation of all products and systems used for their ability to be recycled when they reach the end of their useful life. Preference should be given to products and systems that facilitate easy, non-energy intensive separation and recycling with minimal contamination by foreign debris.

ADAPTATION AND EVOLUTION: Nature evolves by responding to its environmental needs and finding solutions that work. The regenerative nature describes processes that restore, renew or revitalize their own sources of energy and materials, holistic frameworks that seek to create systems that are absolutely waste free.



Plate 2.7: Process of metamorphosis Lotus Flower Plant
Source : Biomimicry Guild 2009.

Key Principles:

i. Locally attuned and responsive, by using passive strategies to create a pleasant and comfortable environment for its occupants. For example, maximised use of daylighting, ventilation

ii. The use of process oriented regenerative approach to designs which describes processes that restore, renew or revitalize their own sources of energy and materials, creating sustainable systems

iii. The use of Feedback Loops and applying the integration of Cyclic processes in energy and material consumption

iv. Maximizing the use of renewable energy sources and alignment of energy flows with natural tendencies

Key Strategies and Technologies:

i. Environmental responses, Day lighting: the use of Skylights, full-height atrium with glass decks and Sky gardens

ii. Integrating human processes with natural processes by redesigning our processes to be aligned with natural processes, to protect, reinforce and strengthen them where possible. For example, rather than building seawalls to protect against erosion and flooding, it's far more effective to use natural vegetation to do the same work!

iii. Designing our systems to take advantage of share linkages that would provide mutual benefit and symbiosis between different elements.

2.5.3 LEARNING FROM THE ECOSYSTEM

ENHANCING THE BIOSPHERE : Nature uses and builds with life friendly processes and systems, considering the immediate environment is not depleted. Natural filtration environment filters out and absorbs components that would otherwise pollute the local ecosystem. (Biomimicry Guild, 2008). Many tropical forest leaves have a drip tip. These kinds of leaves have adapted to cope with exceptionally high rainforest. It is thought that these drip tips enable rain drops to run off quickly. This is because, plants need to shed water to avoid growth of fungus and bacteria in the warm, wet tropical rainforest.



Plate 2.8:Double drip tip, Bayan Fig tree leaf
Source : Biomimicry Guild 2009.

Key Principles:

i. Preservation of the existing natural water cycle and design site and building improvements such that they closely emulate the site's natural "pre-development" hydrological systems.

ii. Emphasis on retention of storm water and on-site infiltration and ground water recharge using methods that closely emulate natural systems.

iii. Minimization of unnecessary and inefficient use of potable water on the site while maximizing the recycling and reuse of water, including harvested rainwater, storm water, and grey water. (Biomimicry Institute 2008).

iv. Extensive use of native vegetation to improve microclimate (shading, breezes) Landscaping based on the original vegetation

v. Local community involvement in construction, maintenance, operations High-level support for the local community, crafts, artisans, staff and education

Key Strategies and Technologies:

i. Conduction of a thorough site assessment and strategically locate buildings and site

improvements so as to preserve key natural hydrological features. Special effort should be made to preserve areas of the site that serve as natural storm water retention and ground water infiltration and recharge systems. Preservation of existing forest and mature vegetation that play a vital role in the natural water cycle by absorbing and disbursing up to 30% of a site's rainwater through evapo-transpiration.

ii. Design and location of buildings and site improvements to optimize use of low-impact storm water technologies such as bio-retention, rain gardens, open grassy swales, pervious bituminous paving, pervious concrete paving and walkways, constructed wetlands, living/vegetated roofs, and other technologies that support on-site retention and ground water recharge or evapo-transpiration. Storm water that leaves the site should be filtered and processed naturally or mechanically to remove trash and debris, oil, grit and suspended solids.

iii. Establishment of a water budget for the building and implementation of a design that minimizes the use of portable water by using low-flow plumbing fixtures and toilets and waterless urinals. Harvesting, processing and recycling rainwater, site storm. Use of on-site treatment systems that enable use of rain water for hand washing, grey-water for toilet flushing, rain and storm water for site irrigation, and other uses.

2.6 BIOMIMETIC DESIGN FEATURES

The elements of biomimetic design would be discussed in the context of building materials, systems and methods that can be efficiently incorporated in a building to make it sustainable.

2.6.1 PHOTOVOLTAICS (SOLAR POWER)

Solar power is one of the most sustainable technologies that can be employed in a building. This owes especially to the abundant supply of sunlight in many regions of the world.

Photovoltaic technologies produce electricity directly from sunlight. When sunlight strikes a solar cell, its semiconductor materials absorb a portion of that light, if the energy from the absorbed light strikes electrons in the outer shell of an atom, these electrons are freed from their parent atoms. Free electrons can then travel into a circuit in the form of electricity.

The most common Photovoltaic device available today is made from rigid, crystalline silicon solar cells (although other materials can also be used). About 36 of these cells are typically combined to produce a flat module (see plate2.12), and about 10 of these modules are mounted to form a Photovoltaic array, which can measure up to several meters on a side. Photovoltaic arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight over the course of a day.



Plate 2.9: A typical photovoltaic module,
Source: (Roberts and Guariento 2009)

In a lay-on or additive solution, Photovoltaic modules are secured to a roof or unto a façade using a metal structure. The Photovoltaic system is an additional structural element with the sole function of generating energy. In contrast, Building Integrated Photovoltaics (BIPV) refers to the application of Photovoltaic in which the system as well as having the function of producing electricity, also takes on the role of a building element. More than just providing electrical energy, BIPV can enhance and satisfy a building image.(Roberts, Guariento 2009) Photovoltaic modules reduces the total cost of the building as compared to when the PV modules are not integrated into the building.

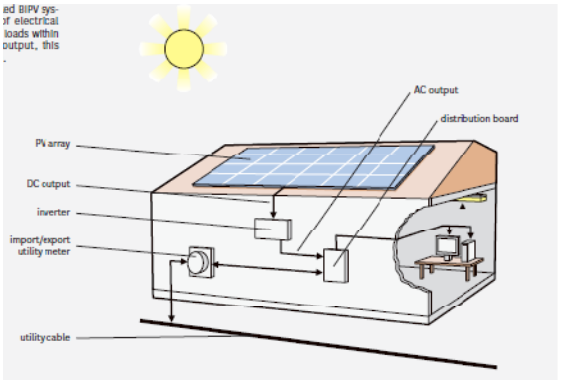


Fig 2.1: Basic parts of a grid-connected BIPV system showing the direction of flow of electrical energy. Source: Building integrated photovoltaics handbook

2.6.3 GREY WATER USE & WATER EFFICIENT FIXTURES

By collecting rainwater runoff from the roof, grey water can be used to supply many of the water needs of the facility such as landscape irrigation, toilet flushing, the mechanical systems and custodial uses. This minimizes the use of our dwindling potable water resources while decreasing storm water runoff. In addition, by utilizing high efficiency fixtures, water-saving faucets with occupant sensors, and waterless urinals, the overuse of our valuable clean water supply can be minimized. (www.churchville.net, 2008)

2.6.4 SOLAR HOT WATER SYSTEMS

Solar hot water is water heated by the use of solar energy. Solar water-heating systems use collectors, generally mounted on a south-facing roof, to heat either water or a nontoxic antifreeze that is circulated from the collector to the water storage tanks. The heated water is then stored in a water tank similar to one used in a conventional gas or electric water-heating system. The panels may use electricity for pumping the fluid, and have a reservoir or tank for heat storage and subsequent use. Hot water heated by the sun can be used to heat water (e.g. for showering, sanitary purposes and for heating swimming pools) and generate electricity

In order to heat water using solar energy, a collector is fastened to the roof of a building, or on a wall facing the sun. In some cases, the collector may be free-standing. The working fluid

is either pumped (active system) or driven by natural convection (passive system) through it. The collector could be made of a simple glass topped insulated box with a flat solar absorber made of sheet metal attached to copper pipes and painted black (see fig. 2.2).

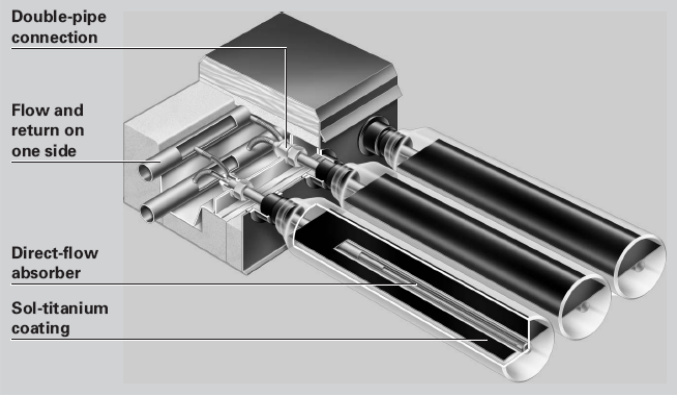


Figure 2.2: vacuum tube collector with sol-titanium coating,
Source: Veissmann, 2000

In some cases, before the solar energy is absorbed, a parabolic mirror is used to concentrate sunlight on the tube. Some systems are capable of converting light to heat and therefore are not as reliant on outside temperature. In sunny, warm locations, where freeze protection is not necessary, a batch type solar hot water heater can be extremely cost effective.



Plate 2.10: An installed compact solar hot water system in Australia
Source: Solarshop, 2000

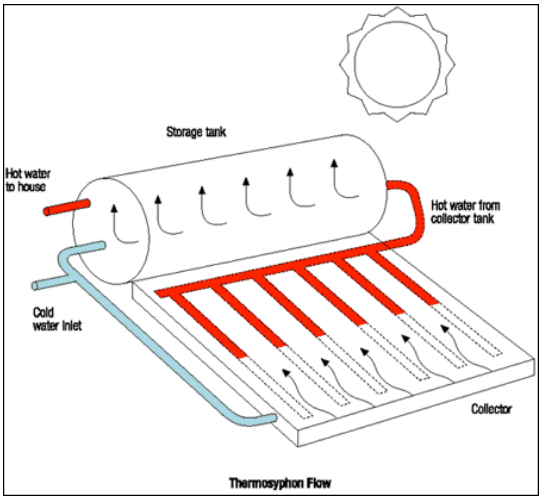


Fig 2.3: Schematic of a compact solar hot water system,
Source: Solarshop, 2000

2.6.5 RASTRA

Rastra is a concrete form system made of light weight material THASTYRON which provides a permanent framework for a grid of reinforced concrete to form load bearing walls and other building components.

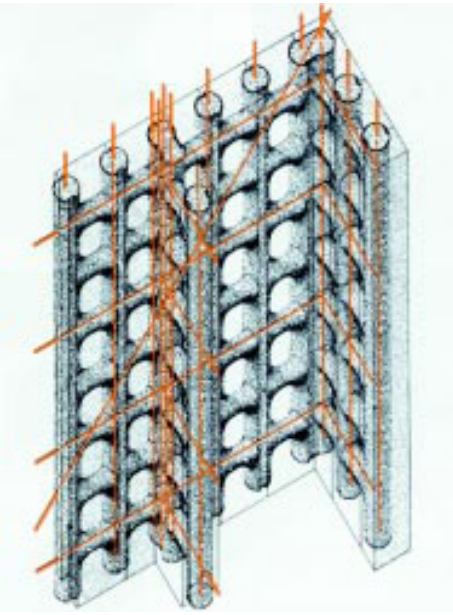


Fig 2.4: Honeycomb structure of Rastra panel
Source: www. rastra.com



Plate 2.11: Rastra elements at a job site
Source: www. rastra.com

"THASTYRON" (THermo-Accoustic-STYRo-cONcrete) is a lightweight, honeycomb like mixture of small Expanded Polystyrene beads completely covered with a skin of cement and it offers the best properties for a wall material. It has best heat/cold insulation, is resistant against fire, frost and other climate influence and takes plaster, stucco or any other type of wall covering very well. The cavities of the elements are filled with concrete after they have been set up on site, thus a rigid skeleton is formed inside.

The following properties are important for its applications as a construction material

i. Low thermal conductivity

Due to its closed air-filled cell structure that inhibits the passage of heat or cold, a high capacity for thermal Insulation is achieved which makes the building envelope energy efficient reducing the load for artificial cooling and heating

ii. Low water absorption

THASTYRON does not absorb moisture and its thermal and mechanical properties are unaffected by damp, humidity or moisture from the environment

iii. Chemical resistance

THASTYRON is completely compatible with other materials used in construction including cements, plasters, salt, fresh water and so on. The component styrene monomer is considered to have low oral toxicity, and is not classified in terms of carcinogenicity or mutagenicity

iv. Versatility

EPS can be cut into the shape or size required by the construction project. There are actually no limits for realizing even fancy architectural designs. Curved walls, for example, can be made by beveling off one flank of the element to achieve a desired radius. There are no limits to the ways the elements can be cut. Partition walls can be connected everywhere by cutting connection channels in order to make the concrete flow into the adjacent wall section.

2.6.6 STRUCTURAL INSULATED PANELS

Structural Insulated Panels (SIPs) are prefabricated insulated structural elements for use in building walls, ceilings, floors, and roofs. They provide superior and uniform insulation compared to more traditional construction methods (stud or "stick frame"), offering energy savings of 12%–14%. When installed properly, SIPs also provide a more airtight dwelling, which makes an interior more comfortable and quieter.

The most common types of SIPs use insulation made from expanded polystyrene or polyisocyanurate, a polyurethane derivative. The majority of Structural Insulated Panels are manufactured with expanded polystyrene (EPS) foam board or bead board insulation. There are two types: molded expanded polystyrene (MEPS) and extruded expanded polystyrene (XEPS) foam board. This type of SIP has a Nominal R-value of about 2.5 cm of thickness. Standard thicknesses for either type range from 89mm–190 mm for wall panels and 140mm – 292 mm for ceiling panels. They are available in almost any size; however, common wall panels are (1.04×1.06 meters). These panels are more fire and water vapor-diffusion resistant. In buildings constructed of SIPs, fire investigators have found that the panels held up well. For example, in one case where the structure exceeded 538°C in the ceiling areas 93°C near the floors, most wall panels and much of the ceiling remained intact.

CHAPTER THREE

3.1 TYPES OF RESORTS

Resorts range over many types, catering for different tourists requirements, they are as follows:-

Island resorts, Hotel resorts, Health resorts, Golf resorts, Luxury resorts, Ecotourism resorts, Mega resorts, Beach resorts, Spa resorts, Ski resorts, Diving resorts, Historical resorts, Lake resorts, Mountain resorts.

Resorts are categorized under vacation types:

3.1.1 BEACH RESORTS AND ISLAND RESORTS

These are resorts by the sea or oceans. These are located in countries that have shorelines by the sea, or ocean. These places attract many tourists all year around.

Visitors to island resorts are primarily beach and nature lovers, who seek a resort that is well integrated into the surrounding landscape. Island resorts typically developed in environmentally sensitive areas, and the success of the design is particularly dependent on the relationship of the resort building with the topographical, ecological, and climatic factors of the site.

The basic tourist facilities found in these resorts include extensive use of water resource in recreational or sports activities such as water skiing, swimming, sunbathing and others. (Huffadine, 2000)

3.1.2 GOLF RESORTS

Golf resorts have grown faster in popularity than any other type of resort in recent years. When golf is the major amenity, a resort usually takes the form of a country club, and groups of vacation and permanent residences form a second- home community. (Huffadine, 2000)

3.1.3 DIVING RESORTS

Diving resorts are located on or near the water and is primarily focused on providing lodging for guests interested in pursuing Scuba diving, snorkeling, or skin diving. A diving resort typically features a “dive shop” on or near the premises and offers diver support activities like guides, boats, and instructions. (Huffadine, 1999).

3.1.4 SKI RESORTS

Ski resorts are resorts which incorporate other seasonal activities in order to balance costs and increase revenues. The transformation from winter to all season operation has called for the construction of extra facilities, such as village shops, a playhouse and a variety of restaurants combined with suitable off-season sports such as hiking, golf, tennis, mountain bike trails, and hot-air ballooning. (McGraw-Hill, 1999)

3.1.5 ECOTOURISM RESORT

The concern with personal physical fitness and healthful outdoor activities is closely connected with an interest in wildlife and environment conservation issues. The “soft” activities of fishing, hiking, biking, and backpacking in nature parks have become enormously popular. The new concepts of Ecotourism and eco-resort have arisen from this interest. There are two associated objectives:

i. To provide a natural wildlife experience.

ii. To ensure minimum environmental damage.

3.1.6 HEALTH AND SPA RESORT

Health resorts are commercial establishments providing facilities devoted to health and body fitness. These facilities cater for health needs that is, to enjoy recreation and relaxation.

Health resorts are also places where people visit for recreation, healing, and cure, Health resorts can also be defined as health oriented recreational facilities where counseling, psychoanalysis, therapy, and recreation are combined with nature, water, landscaping, and architectural planning to refresh and rehabilitate the mind and the emotions as this will also have an interpretation on the physical well-being of the person. In such a place various methods are used for the treatment of many diseases some of which are hydrotherapy and aromatherapy. Hydrotherapy is the use of water for treatment of diseases and for relaxation. Hydrotherapy can be used to ease pains due to sprains and muscle-related injuries and speed up the repair process after a strenuous workout. Aromatherapy is the use of fragrance and hydrotherapy for relieve from certain ailments. It has been proven that the scent of particular plants in a garden can have therapeutic qualities. Other treatments include physiotherapy, reflexology, psychoanalysis, water exercise and massages. (McGraw-Hill,1999)

3.2 TYPES OF RESORT FACILITIES

Specific resort facilities are dependent on the type of resort; these facilities can be classified under three particular resort types which include:

3.2.1 MOUNTAIN RESORTS:

Mountain ski resorts cannot be developed in isolation, the resorts includes provisions for the regional development of lifts with inter-connections between potential neighboring resorts.

Specific facilities for mountain resorts are**:** The ski trail, the cable transporters and the Skating rink.

3.2.2 WATERFRONT RESORTS:

Waterfront resorts are resorts in which the primary interest is centered on water, such as lakeside resort, seaside resort, and riverside.

Specific facilities for waterfront resorts are: Lifeguard facilities, floating platforms and chains, security posts, first aid Center, kiosks, restaurant, sports and play areas, hiring facilities for boats, pedals, surfing equipment's, supervised protected area for children and play grounds.

3.2.3 SPAS AND HEALTH RESORTS:

Spas are resorts in which contact with landscaped nature and restfulness are found to be combined with cultural, recreational and sports facilities and a highly developed social life.

Specific facilities for Spas and Health resorts are: Fountains, collective pools, shower rooms, resting rooms, cloakrooms, sanitary accommodations, medical diagnostic and administrative buildings, therapy buildings, therapy gardens.

3.3 HEALING AND THERAPEUTIC GARDENS

Accodrding to Mitrione, (2005), he asserted that gardens are an integral part in the design of health resorts that general design guidelines have been developed and are generally accepted based on theories of stress reduction, encompassing six principles.

i. **Provide a sense of control by creating a variety of spaces.** Spaces within a garden should be easily accessible by all user groups, provide for privacy, and include a variety of spaces that allow individuals to seek out spaces that best suit them
ii. **Provide for social support.** Social support is associated with less stress than isolation, and has been linked with improved outcomes after heart attacks and cancer. Patient interviews highlight talking as a primary activity in garden settings. Gardens should provide spaces to accommodate various group sizes in a setting that encourages conversation.
iii. **Provide for physical movement and exercise.** Exercise is associated with reduced stress and alleviation of depression in almost all population groups, but especially those

with chronic illness. Gardens, because of their perceived pleasantness, can encourage exercise and movement.Theyshould thus offer easy wayfinding and provide destinations that encourage mild exercise.

iv. **Provide for access to nature and positive distractions.** Exposure to nature and natural scenes is associated with decreased physiological stress responses. This response is dose-related in that the greater the percentage of greenery, as opposed to hardscape, the more likely the relaxation response is to occur. This relaxation response is believed to be 'hardwired' into our nervous systems by evolutionary responses to environments that favored survival.

v. **Minimize ambiguity.** Stressed individuals respond negatively to ambiguity. Studies of inpatients recovering from surgery showed increased stress levels when exposed to abstract paintings as compared with natural scenes. This is believed to be due to the perception of ambiguous stimuli as negative in stressed individuals, congruent with their emotional state.

vi. **Minimize intrusive stimuli.** To exert their effect, therapeutic gardens need to minimize negative distractions such as noise, odor, and bright lights. Noise in particular can negate the positive effects associated with viewing nature.



Plate 3.1: A water feature can mask undesired noises.
Source: Mitrione, 2005

CHAPTER FOUR

The method of study of this research involved a qualitative analysis of case studies as well as a study of published and unpublished literature.

4.1 INSTRUMENT OF DATA COLLECTION.

The instruments of data collection used are listed below:

4.1.1 Photographs

Photographs were taken of relevant case studies to ascertain the features of bio mimicry in architecture they possess as well as the extent, to which they were applied, that is to say, if their extent of application was strong, weak or non-existent.

4.1.2 Sketches

Sketches were made of some parts of the selected case studies. These sketches showed the spatial organization of some of the case studies.

4.1.3 Notes

These notes where in form of field forms outlining the variables of bio mimicry in architecture as it relates to resorts and some other public building types.

4.2 PROCEDURES FOR DATA COLLECTION

The procedure for data collection involved visits to local and international case studies and taking a visual analysis of their architectural features. These buildings were then evaluated on the created field forms.

However, the foreign case studies were gotten through the internet and their features evaluated on the field forms as well.

4.2.1 Case Studies

The case studies selected for this thesis were sampled purposively on two bases:

i. As resorts with features denoting them as places for relaxation and therapeutic recreation.
ii. As buildings having biomimetic architectural design features.

4.3 CASE STUDY SELECTION CRITERIA

The case studies were purposely selected on the bases of being resorts on one hand and as buildings possessing features of bio mimicry in their design.

The case studies have been analyzed based on two aspects:

i. Descriptive analysis as resorts.
ii. Analysis as buildings with biomimetic design features.

4.4 ASSESSMENT OF APPLICATION OF PRINCIPLES OF BIO MIMICRY

PRINCIPLE 1: USE OF NATURAL FORMS

Dependent variables shall discuss the research area – biomimetic architecture and design. Here the variables used are extracted from the principles of natural form architecture.

i. Building form (form and flow) exterior:
    a) Symbolism,
    b) Geometry.
ii. Building's Relationship to site,
iii. Materials,
iv. Technology.

PRINCIPLE 2: EXPLORING THE APPLICATION NATURAL PROCESSES

USE OF FREE ENERGY: Life learnt to harvest energy from the Sun and to transform it for work without creating toxic by-products This principle supports the use of available energy sources that do not degrade the environment from the point of generation up to the point of consumption by the final consumer and are renewable over time thus not posing as a risk to future generations in terms of exhaustion or ecological degradation (Pam Baldinger, 2006).

Variables:

Energy/power sources: This entails the use of renewable energy sources such as; use of high performance integrated photovoltaic façade systems

i. Rain screens and stick systems
ii. Shading and Glazing systems
iii. Courtyards
iv. Use of photovoltaic panels for power generation.
v. Employment of solar water heating.

Energy management methods: this entails the proper management of available power through the selection of appliances with energy star ratings and also the exploitation of passive climatic design methods like day lighting and cooling of building interiors. The methods that can be used include:

i. Use of high performance low e-glazing to minimize energy consumption.
ii. Use of sensors, controls and design circuits can be incorporated so that lighting fittings can be turned off independently when day lighting is sufficient.
iii. Use of solar water heating

USE MINIMAL ENERGY AND MATERIALS: Nature always tries to use energy and materials efficiently, successfully minimizing mass and energy use. This principle encourages the minimal use of non-renewable construction materials and other resources that are not recyclable. Consequently, it allows for the use of only recycled content materials, modern resource efficient engineered materials such as polystyrene and other composite type structural systems wherever possible (governor's green government council, 2007). These materials are to be designed such that they effectively provide for thermal efficiency so as to achieve thermal comfort for the users of the building.

Variables:

Adaptability and energy saving property of building materials to the environment

i. Use of low thermal conductive building envelope materials such as Rasta Thastyron panels
ii. Use of double or triple pane low e-glazing.

Use of building materials that are recyclable and biodegradable

i. Use of recycled or recyclable thermally efficient composite roof panels.
ii. The use of bio based materials and finishes such as various types of sheathing and insulating agriboards, these biodegradable materials do not contaminate the air or water with gases or hydro soluble substances.
iii. Use of recycled building materials such as Thastyron Rastra panels, the essence is to reduce waste pile up in landfills.

Application of Smart Materials

i. Control of conductive heat transfer through the building envelope.

ii. Control of interior heat generation using phase change materials.

iii. The use of Secondary energy supply systems and optimization of lighting system

ADAPT AND EVOLVE : Nature evolves by responding to its environmental needs and finding solutions that work.

Life is eternally regenerative describes processes that restore, renew or revitalize their own sources of energy and materials, holistic frameworks that seeks to create systems that are absolutely waste free.

Variables:

Locally attuned and responsive:

i. The use of courtyards to create a pleasant and comfortable environment for its occupants.
ii. Enhancing natural ventilation via stack effect using operable windows and provision of fresh air via sky gardens.

Resourceful and opportunistic:

i. The use of trees to control micro climate and applying natural vegetation to control soil erosion
ii. Applying the integration of Cyclic processes in energy and material consumption, creating sustainable systems
iii. Applying the use of photovoltaic façade systems and integrated wind turbines to maximize the available local renewable energy source

PRINCIPLE 3: LEARNING FROM THE ECOSYSTEM

ENHANCE THE BIOSPHERE: Natural filtration environment filters out and absorbs components that would otherwise pollute the local ecosystem .This principle stipulates the preservation of the existing natural water cycle and site design and building improvements such that they closely emulate the site's natural "pre-development" hydrological systems. The emphasis is on retention of storm water and on-site filtration and ground water recharge using methods that closely emulate natural systems as well minimization of unnecessary and inefficient use of portable water on the site while maximizing the recycling and re-use of water, including harvested rainwater, storm water and grey water (governor's green government council, 2007).

Variables:

Water harvesting, channeling and filtration technique

Harvesting, processing and recycling rainwater, site storm water, and building gray water and identification of appropriate uses within the building and site.

Natural hydrological systems

i. Minimal alteration of natural water cycle through building improvements that closely emulate the site's natural "pre-development" hydrological systems.
ii. Use of on-site treatment plants to enable recycles of grey water.
iii. Use of pervious ground cover to support on-site water retention and recharge.

Methods of water conservation

i. Use of on-site treatment systems that enable use of rain water for hand washing, grey-water for toilet flushing, rain and storm water for site irrigation, cooling tower make-up

and other uses.

ii. Design and location of buildings and site improvements to optimize use of low-impact storm water technologies such as bio-filtration ponds, rain gardens, open grassy swales, pervious bituminous paving, pervious concrete paving and walkways, constructed wetlands, living/vegetated roofs, and other technologies that support on-site retention and ground water recharge or evapo-transpiration.

CHAPTER FIVE

FINDINGS AND DISCUSSIONS FROM CASE STUDIES

5.1 CASE STUDY ONE: SHERATON MOOREA LAGOON RESORT & SPA, FRANCE

5.1.1 BACKGROUND

Sheraton Moorea Lagoon Resort & Spa is a full service resort ideally located in Papetoai, Moorea, France.. The property offers a pristine white sand beach, crystal blue lagoon and lush tropical gardens. (plate 5.1 and 5.2). At only 15 minutes from the airport, or 25 minutes from the ferry dock, wind your way along the scenic coast towards Papetoai. The garden and overwater bungalows are spacious, luxurious and are designed to provide maximum privacy. Double connecting bungalows are also available for larger parties travelling together or for families.

This resort was designed by Pierre Lacombe in 2001.Facilities in this resort include offices and reception, restaurant and kitchen, spa, pool and poolside bar, 150 m^2 meeting room, over-water bar, beach grill and bar, fitness gym, scuba centre, two tennis courts, 12 staff accommodation, five store rooms, maintenance shed,extensive network of walkways, helipad



Plate 5.1: Accommodation in over-water individual bungalows.
Source: Source: Zbigniew, 2009



Plate 5.2: Aerial View of the resort with the over-water individual bungalows in the foreground, and Moorea Island in the background

Source: Zbigniew, 2009

5.1.2 SITE PLANNING AND LANDSCAPING

The resort occupies a former hotel site of 7.5 acres and the area has been extensively recultivated and replanted in adaptation to its current use. Other major changes include establishing a swimming pool and a fish pond. (plate 5.3 and figure5.1)

Present on the site are 22 garden connected bungalows, 20 superior bungalows, 7 beach bungalows each covering spaces of 37.25 m^2, 35.25 m^2, 35.25 m^2respectively.



Plate 5.3: Open water ponds and pools cool the reception area and adjacent restaurant.
Source: Zbigniew, 2009

5.1.3 SPATIAL ORGANISATION AND DESIGN

The Sheraton Moorea Lagoon Resort & Spa has individual garden or twin bungalows. They are finely decorated in a Polynesian style and with exotic wood. They are located in the middle of luxuriant tropical gardens, and right next to the azure lagoon of the island of Moorea.

The bungalows are fully-equipped with modern comforts: individually-controlled air-conditioning, fan [and many other electrical appliances], private terrace. The bathroom includes a bathtub and separate shower, a hairdryer, a make-up mirror as well as American and European plugs.

The bungalows are equipped with individually controlled air-conditioning, fan, private terrace with outside shower [and a range of appliances, similar to the Garden bungalows].

The over-water bungalows and, to a lesser degree, beach bungalows take advantage of the moderating impact of the ocean on the resort's microclimate. They are elevated and fully exposed to cooling winds and breezes, and their lightweight structures quickly lose any heat gained during the day. Built to a design greatly influenced by the traditional Polynesian hut, with high cathedral ceilings, thatched roofs and thin walls woven from pandanus leaves, the bungalows are superbly suited for the climate.

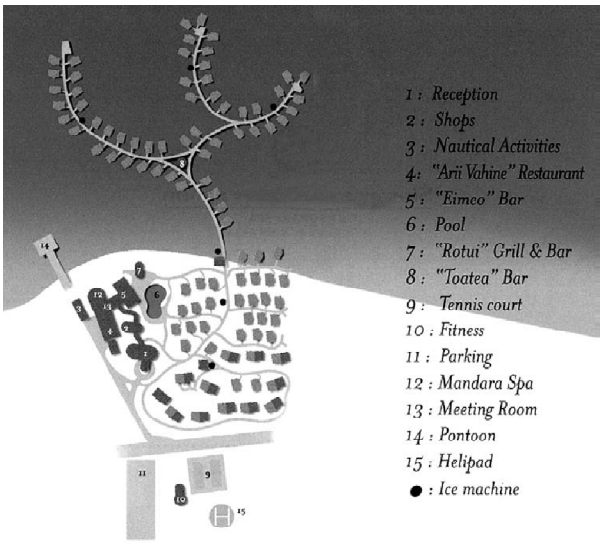


Figure 5.4: Plan of the resort
Source: Zbigniew, 2009



Plate 5.5: Open water ponds and pools cool the reception area and adjacent restaurant
Source: Zbigniew, 2009

Principal building materials used at Sheraton Moorea are timber, concrete (used for piling), maiao (pandanus) leaves replaced on a 5-year cycle, flagstone, and ceramic tiles, both on floors and walls (plates 5.6, 5.7)



Plate 5.6 Detail of bamboo wall cladding.
Source: Zbigniew, 2009



Plate 5.7: All bars and restaurants at the resort are open air to allow cooling sea breezes.
Source: Zbigniew, 2009

BIOMIMICRY PRINCIPLE 1: MIMICKING NATURAL FORMS			
Variables	**Features**	**Method of application**	**Remark**
Building form (form and flow) exterior	Symbolic a particular natural form or natural built form	Nil	Negative
	Geometry adopted to achieve the form	Nil	Negative
Building's Relationship to site	Use of materials indigenous to site	Bamboo,maiao (pandanus) leaves	Positive

TABLE 5.1: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE ONE AT SHERATON MOOREA LAGOON RESORT & SPA

Source: Field Survey, October 2010.

BIOMIMICRY PRINCIPLE 2: EXPLORING THE APPLICATION NATURAL PROCESSES			
Variables	**Features**	**Method of application**	**Remark**
Energy/power source	Integrated photovoltaic façade systems	Nil	Negative
	Building integrated wind turbines, wind tunnels and shafts.	Nil	Negative
Energy management methods	Automated operable windows	Nil	Negative

	Structural insulated panels and other high performance insulated concrete panels	Nil	Negative
Re-usability of Building materials	Use of recyclable or reusable building materials,	Use of timber, concrete (used for piling), maiao (pandanus) leaves replaced on a 5-year cycle, flagstone, and ceramic tiles, both on floors and walls	Positive
Use of building materials with high durability	Use of reinforced concrete, aluminium roofing sheets which are of high durability	Nil	Negative
Application of Smart Materials	Control of solar radiation transmitting through the building envelope and Control of interior heat generation	Use of ceilings, roof monitors for expelling hot air, wide shading eaves, polished floors that are cool to touch and many windows enabling adequate cross-ventilation.	Positive
	Secondary energy supply systems and optimization of lighting system	Nil	Negative
Environmental Response to design features	Day lighting, the use of Skylights.	Use of roof monitors, extensive curtain walls.	Positive
	Natural ventilation via stack effect.	The use operable windows and provision of ceilings and roof monitors for expelling hot air.	Positive

TABLE 5.2: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE TWO AT SHERATON MOOREA LAGOON RESORT & SPA

Source: Field Survey, October 2010.

BIOMIMICRY PRINCIPLE 3: LEARNING FROM THE ECOSYSTEM			
Variables	**Features**	**Method of application**	**remark**
Source of water	Source of water is a bore hole drilled on site.	Borehole is present on site	Positive
	Effort at harvesting, processing and recycling rainwater.	Rainwater is harvested and recycled.	Positive
	Use of on-site storm water treatment and ground water recharge	Grey water from washing is recycled in an irrigation system	Positive
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.	Most of the native plants were retained	Positive
	Construction of structures to follow the topography of the site	Minimal cut and fill of the site.	Positive
Regenerative site, design	The use of trees to control micro climate	The use of trees to control micro climate	Positive
	Use natural vegetation to control soil erosion	The use of trees and grasses to control soil erosion	Positive
Minimal alteration of natural hydrological systems	Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge.	More than 90% of total site area is pervious to rain water.	Positive
Applying Integrated Cyclic processes & Feedback Loops	Use of water management and waste recycling	Use of water management and waste recycling	Positive
Water conservation methods	On-site treatment plants	There is an on-site water treatment plant for the recycle of grey water.	Positive

TABLE 5.3: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE FOUR AT SHERATON MOOREA LAGOON RESORT & SPA

Source: Field Survey, October 2010.

5.2 CASE STUDY TWO: BORA BORA NUI RESORT & SPA, FRANCE

5.2.1 BACKGROUND

Located on a volcanic islet, southeast of the main island of Bora Bora in French Polynesia, Bora Bora Nui Resort & Spa is the most exclusive luxury resort in French Polynesia. With 84 bungalows set over a magnificent crystal clear lagoon, the resort sets a new benchmark for elegance and service, meeting the demands of even the most discerning traveler. This resort was designed by Pierre Lacombe in 2003 with other facilities which include restaurant and kitchen, spa, meeting room, 750 m^2 pool and poolside grill and bar, beach bar, fitness gym, water sports centre,several gazebos, staff accommodation, store rooms, maintenance shed extensive network of walkways, helipad.

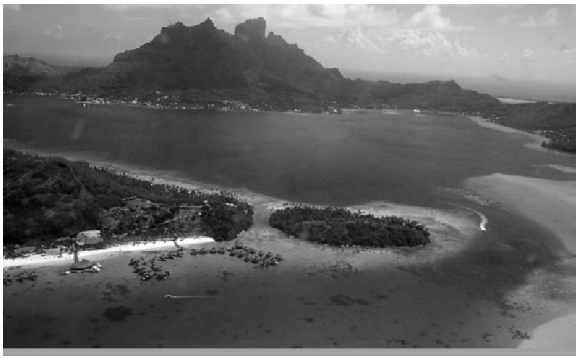


Plate 5.8: Aerial view of the Bora Bora Nui resort with the main island of the atoll in the background.
Source: Zbigniew, 2009

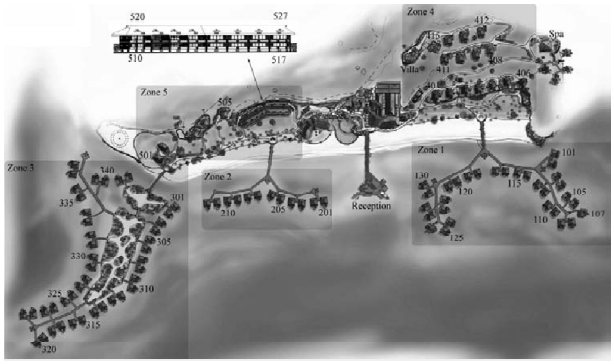


Figure 5.5: Plan of the resort
Source: Zbigniew, 2009

5.2.2 SITE PLANNING AND LANDSCAPING

The resort occupies a site that has been extensively recultivated and replanted in adaptation to its current use. The 120 luxury suites or villas at [the Resort] are located on 16 acres of lush, terraced hillside and on the water of a private, protected cove. The 600 m long beach was created by pumping in sand from dredging operations in the atoll's shipping channel. Two small

artificial islets linked by bridges have also been built. The hillside has been terraced and 600 coconut trees have been planted together with hundreds of other palms, ornamental trees and bushes (plates 5.10, 5.11, 5.12).



Plate 5.10: Pathways and boardwalks are used by both pedestrians and light maintenance vehicles.
Source: Zbigniew, 2009



Plate 5.11: The 600 m long artificial beach was built with sand dredged from the atoll's shipping channel.
Source: Zbigniew, 2009



Plate 5.12: Aerial View of the atoll
Source: http://media-cdn.tripadvisor.com

5.2.3 SPATIAL ORGANISATION AND DESIGN

The spa resort features 82 Horizon Over-water Villas (94 sq. meters), 2 Horizon Over-water Royal Villas (135 sq. meters), 12 Beach Villas (85 sq. meters), Hillside Lagoon View Villas (85 sq. meters), 1 Hillside Lagoon View Royal Villa (135 sq. meters), 16 Lagoon View Suites (95 sq. meters), convenience, with breathtaking views of the pristine lagoon. All villas and suites feature a very spacious bedroom and living room, separated by Japanese panels.

The resort spa offers an extensive menu of spa treatments and services as well as four exquisite private bungalows each with its own jacuzzi, bathroom and massage table and a

breathtaking view of Bora Bora. Other features in the resort are; Fully equipped fitness center, swimming pool, Private meeting room for up to 80 seated persons, Over-water reception set above a natural aquarium, Laundry.



Plate 5.13: Details of roof structures suggest their inspirational origins.
Source: Zbigniew, 2009



Plate 5.14: view of interiors restaurants
Source: Zbigniew, 2009

Principal building materials used at Bora Bora Nui Resort & Spa are balau, marumaru, kahia, coconut, teak and mahogany timber, concrete (for piling and hillside construction), maiao (pandanus) leaves (replaced on a 5-year cycle) flagstone, and ceramic tiles, both floor and wall ones (plate5.13).



Plate 5.15: view of interiors restaurants
Source: Zbigniew, 2009



Plate 5.16: All resort restaurants and bars offer al fresco dining both during the day and at night

The bungalows have very low thermal mass, cathedral ceilings, roof monitors for expelling hot air, wide shading eaves, polished floors that are cool to touch and many louvred windows enabling adequate cross-ventilation. They are sited over water or near the crest of a low hill with both positions well exposed to air movement all year round. They are built from mostly local materials and blend well with the landscape.



Plate 5.17: View of multi-level inland pool with surrounding buildings shaded by towering palms
Source:http://media-cdn.tripadvisor.com



Plate 5.18: View of bedroom with local finishes and glass opening in the floor to observe colourful underwater life
Source: http://media-cdn.tripadvisor.com



Plate 5.19: View of deep end of the reef with an approaching launch
Source: http://media-cdn.tripadvisor.com



Plate 5.20: View of beachside with a pagola surrounded by towering palms
Source: http://media-cdn.tripadvisor.com

BIOMIMICRY PRINCIPLE 1: MIMICKING NATURAL FORMS			
Variables	**Features**	**Method of application**	**remark**
Building form (form and flow) exterior	Symbolic a particular natural form or natural built form	Nil	Negative
	Geometry adopted to achieve the form	Nil	Negative
Building's Relationship to site	Use of materials indigenous to site	Balau, marumaru, kahia, coconut, teak and mahogany timber.	Positive

TABLE 5.4: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE ONE AT BORA BORA NUI RESORT AND SPA

Source: Field Survey, October 2010.

BIOMIMICRY PRINCIPLE 2: EXPLORING THE APPLICATION NATURAL PROCESSES			
Variables	**Features**	**Method of application**	**Remark**
Energy/power source	Integrated photovoltaic façade systems	Nil	Negative
	Building integrated wind turbines, wind tunnels and shafts.	Nil	Negative
Energy management methods	Automated operable windows	Nil	Negative
	Structural insulated panels and other high performance insulated concrete panels	Nil	Negative
`	Use of recyclable or reusable building materials,	Use of concrete, marumaru, kahia, coconut, teak and mahogany timber	Positive
Use of building materials with high durability	Use of reinforced concrete, aluminum roofing sheets which are of high durability	Use of reinforced concrete, which is of high durability	Positive
Application of Smart Materials	Control of solar radiation transmitting through the building envelope and Control of interior heat generation	Use of ceilings, roof monitors for expelling hot air, wide shading eaves, polished floors that	Positive

		are cool to touch and many windows enabling adequate cross-ventilation.	
	Secondary energy supply systems and optimization of lighting system	Photovoltaics	Positive
Environmental Response to design features	Day lighting, the use of Skylights.	Nil	Pegative
	Natural ventilation via stack effect.	The use operable windows and provision of ceilings and roof monitors for expelling hot air.	Positive

TABLE 5.5: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE TWO AT BORA BORA NUI RESORT AND SPA

Source: Field Survey, October 2010.

BIOMIMICRY PRINCIPLE 3: LEARNING FROM THE ECOSYSTEM			
Variables	**Features**	**Method of application**	**Remark**
Source of water	Source of water is a bore hole drilled on site.	Nil	Negative
	Effort at harvesting, processing and recycling rainwater.	Main source of water is from town mains supplementing it with rainwater from its own storage when available.	Positive
	Use of on-site storm water treatment and ground water recharge	Grey water from washing is recycled in an irrigation system	Positive
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.	Most of the native plants such as oil palm were retained	Positive
	Construction of structures to follow the topography of the site	Minimal cut and fill of the site.	Positive
Regenerative site, design	The use of trees to control micro climate	The use of trees to control micro climate	Positive

	Use natural vegetation to control soil erosion	The use of trees and grasses to control soil erosion	Positive
Minimal alteration of natural hydrological systems	Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge.	More than 90% of total site area is pervious to rain water.	Positive
Applying Integrated Cyclic processes & Feedback Loops	Use of water management and waste recycling	Use of water management and waste recycling	Positive
Water conservation methods	On-site treatment plants	There is an on-site water treatment plant for the recycle of grey water.	Positive

TABLE 5.6: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE THREE AT BORA BORA NUI RESORT AND SPA

Source: Field Survey, October 2010.

5.3 CASE STUDY THREE: MEZZANINE RESORT, MEXICO

5.3.1 BACKGROUND

The resort is located in the hotel zone of Tulum, one of the most popular tourist destinations on the Yucatan peninsula, in a suburban neighbourhoodwhich has been extensively modified for a number of years. Designed by Brendon Leach with Katrina Taylor and completed in 2004, the resort has Principal attractions in the area which include archaeological sites, the lagoon and beach, nature reserves: cenotes, caves, Sian Ka'an World Biosphere Reserve, nature and culture tours, dining. Facilities present include restaurant and kitchen, bar, mezzanine lounge, toilet block, office, caretaker accommodation, storage, battery room, pool

5.3.2 SITE PLANNING AND LANDSCAPING

The site covers a total area of 0.2 acres (0.08 ha) which was totally transformed in the process of development. Some trees were removed, walkways were paved and an in-ground pool was built. Admittedly, some modifications followed repairs done after past hurricane damage as the site is very exposed. The escarpment occupied by the resort had to be reinforced with a retaining wall to stop erosion. The resort building is located right next to and above the

beach, with its broad side turned east towards the ocean. Its two parts – the largely independent restaurant and the accommodation block – are separated with a 3 m wide gap. This helps to avoid late night noise from the restaurant penetrating into the residential part (Plate 5.21 and 5.22).



Plate 5.21: The freshwater pool in the guest unit deck stays in the shade for most of the time.
Source: Zbigniew, 2009



Plate 5.22: Generous mezzanine space directly under the restaurant's roof doubles as a resort lounge.
Source: Zbigniew, 2009

5.3.3 SPATIAL ORGANISATION AND DESIGN

The resort's architecture is a variation of traditional Mexican themes with its white slightly sloping walls and small grilled openings. The heavyweight structure performs remarkably well in cooler conditions but it should respond equally well to the hot weather due to its unique double-storey open interior. The openness allows the warm air to move up beyond occupied height. A dominating colour scheme of white and blue, together with smooth tiled floors, psychologically reinforces the cooling effect achieved in this free-running building. Prudent energy and water management is also commendable (plate 5.24)



Plate 5.23: The two parts of the resort – the guest unit one (on the left) and restaurant/office (on the right)
Source: Zbigniew, 2009



Plate 5.24: View of the resort from its mezzanine; the relatively narrow room is well cross-ventilated and naturally lit during the daytime.
Source: Zbigniew, 2009

The resort building is one of a few examples of passive design that is very dependent on the use of thermal mass. Local stone, concrete and ceramic tiles are extensively used in thick walls and floors. These materials require minimal maintenance but their principal advantage is their ability to slow down heat flows. This maintains temperatures within a fairly narrow range and makes for a building that is quite warm in winter and relatively cool in summer. Its summer performance gets a boost from stack effect – guest rooms have very high (almost 8 m) ceilings in a mezzanine arrangement of floors. There is also ample cross-ventilation with windows on the ocean side having louvred openings at a bed height and on the well shaded western side permanently open (unglazed and secured with grills only) (Plate 5.24).

The resort is, in terms of power supply, practically autonomous. Twenty 28 amp photovoltaic panels, 0.5 by 1.5 m each, provide the source of electricity. The daily gains are stored in a bank of 16 batteries for night-time use. There is also a wind turbine and propane back-up power generator. Efficient low-voltage lighting and gas appliances help to save energy. The management appeals to guests to save energy in order to limit demand (plate 5.25).

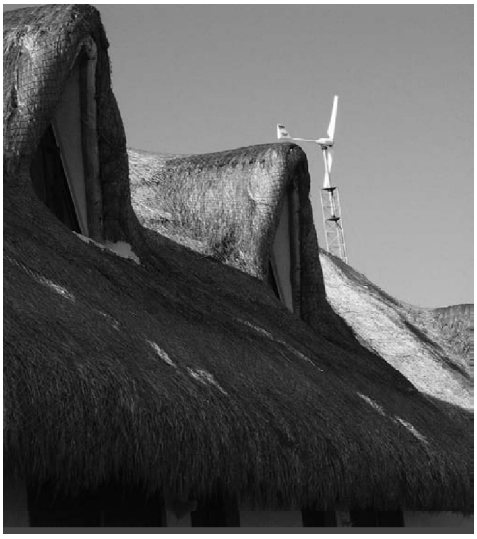


Plate 5.25: The wind turbine
Source: Zbigniew, 2009



Plate 5.26: The principal source of power is a set of 20 photovoltaic panels above the roofs of guest units
Source: Zbigniew, 2009



Plate 5.27: Guest rooms rely chiefly on natural airflows through cross-ventilation; louvred openings
Source: Zbigniew, 2009



Plate 5.28: Room height allows for vertical air movement and sensible cooling through stack effect ventilation making the indoor environment thermally comfortable.
Source: Zbigniew, 2009

BIOMIMICRY PRINCIPLE 1: MIMICKING NATURAL FORMS			
Variables	**Features**	**Method of application**	**Remark**
Building form (form and flow) exterior	Symbolic a particular natural form or natural built form	Nil	Negative
	Geometry adopted to achieve the form	Nil	Negative
Building's Relationship to site	Use of materials indigenous to site	Local stone was widely used.	Positive

TABLE 5.7: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE ONE AT MEZZANINE RESORT
Source: Field Survey, October 2010.

BIOMIMICRY PRINCIPLE 2: EXPLORING THE APPLICATION NATURAL PROCESSES			
Variables	**Features**	**Method of application**	**Remark**
Energy/power source	Integrated photovoltaic façade systems	Twenty 28 amp photovoltaic panels, 0.5 by 1.5 m each on roofs of structures	Positive
	Building integrated wind turbines, wind tunnels and shafts.	There are wind turbines and propane back-up power generator	Positive
Energy management methods	Automated operable windows	Nil	Negative
	integrated photovoltaic façade systems	Twenty 28 amp photovoltaic panels, 0.5 by 1.5 m each on roofs of structures	Positive
`	Building integrated wind turbines, wind tunnels and shafts.	There are wind turbines and propane back-up power generator	Positive
Use of building materials with high durability	Use of reinforced concrete, aluminum roofing sheets which are of high durability	Use of reinforced concrete, which is of high durability	Positive

Application of Smart Materials	Control of solar radiation transmitting through the building envelope and Control of interior heat generation	Use of ceilings, roof monitors for expelling hot air, wide shading eaves, polished floors that are cool to touch and many windows enabling adequate cross-ventilation.	Positive
	Secondary energy supply systems and optimization of lighting system	Use of photovoltaics in which the gains are saved in batteries	Positive
Environmental Response to design features	Day lighting, the use of Skylights.	Use of roof monitors, extensive curtain walls.	Positive
	Natural ventilation via stack effect.	The use operable windows and provision of ceilings and roof monitors for expelling hot air.	Positive

TABLE 5.8: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE TWO AT MEZZANINE RESORT
Source: Field Survey, October 2010.

BIOMIMICRY PRINCIPLE 3: LEARNING FROM THE ECOSYSTEM			
Variables	**Features**	**Method of application**	**Remark**
Source of water	Source of water is a bore hole drilled on site.	Nil	Negative
	Effort at harvesting, processing and recycling rainwater.	Main source of water is from town mains supplementing it with rainwater from its own storage when available.	Positive
	Use of on-site storm water treatment and ground water recharge	Grey water from washing is recycled in an irrigation system	Positive
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.	Most of the native plants such as oil palm were retained	Positive

	Construction of structures to follow the topography of the site	Minimal cut and fill of the site.	Positive
Regenerative site, design	The use of trees to control micro climate	The use of trees to control micro climate	Positive
	Use natural vegetation to control soil erosion	The use of trees and grasses to control soil erosion	Positive
Minimal alteration of natural hydrological systems	Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge.	More than 90% of total site area is pervious to rain water.	Positive
Applying Integrated Cyclic processes & Feedback Loops	Use of water management and waste recycling	Use of water management and waste recycling	Positive
Water conservation methods	On-site treatment plants	There is an on-site water treatment plant for the recycle of grey water.	Positive

TABLE 5.9: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE THREE AT MEZZANINE RESORT

Source: Field Survey, October 2010.

5.4 CASE STUDY FOUR: LA CHAMPAGNE TROPICANA BEACH RESORT, LAGOS

5.4.1 BACKGROUND

La Champagne Tropicana beach resort is an enchantingly peaceful and quiet resort. The resort policy is to showcase the very best in rich and vied culture and cuisine of Nigeria. The idea of this resort was conceived by the owner Mr. Wonle Akinboboye. It was developed as a resort in 1995.

The resort is located on the lekki peninsula of Lagos state on the coast of Nigeria, facing the Atlantic Ocean. It can be accessed by road from Lagos on a well maintained highway in a 50 minute road drive from Victoria Island to Ikegun, the site of the resort.

5.4.2 SITE PLANNING / LANDSCAPE

The resort has a reception situated close to the parking area at the entrance gate. The chalets are well linked together in a linear arrangement and are centralized in the resort which gives room to a clear view of the beach and the ocean. The furnished bungalows spread out over 60 square meters of virgin green tropical lands on the banks of the lagoon.

The social facilities such as the restaurant, swimming pools are located around the chalets, other spots such as the spa and massage room are located on the beach area.

The resort is endowed with an open superb white sandy beach stretching along the warm equatorial seas of the Atlantic Ocean bordered by the multitude of towering coconut trees and the green fields beyond. The beach gives the resort a paradise image having the waves moving to and fro, and depositing beautiful sea shells on it. Safe and clearly defined pathways have been carefully plotted through the green vegetation and waters of the tropical forest and lagoon.



Plate 5.29:View of the resorts reception
Source: Adekeye, 2009

5.4.3 SPATIAL ORGANISATION AND DESIGN

The chalets are circular and are raised on silts. They are made up of a combination of red mud bricks used for walls, wood and glass used for the window sills. Bamboo was used for as

walls and columns in some structures such as the massage room, open stages. Tiles are used for floors, while the roofs are conical in shape and are made of well treated thatch; the buildings are well linked with other functional spaces with soft water permeable landscape of a combination of white beach sand, carpet grass shaded by towering coconut trees in an attempt to blend in with the natural environment.

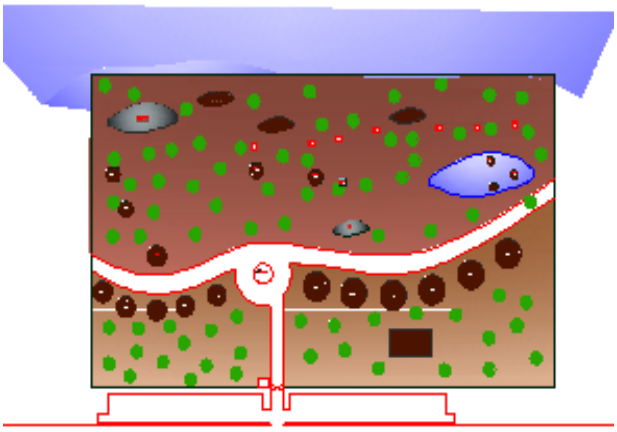


Figure 5.6: View of Resort site plan
Source: Adekeye, 2009



Plate5.31: Exterior view of Labalaba (butterfly) chalet
Source: Adekeye, 2009

Accommodation is provided in village clusters of five buildings, having bungalows with two floors each. One village 'Labalaba'-meaning butterfly- is furnished in Yoruba style, the 'Obieze' is furnished in Igbo style while the 'Kodi' –meaning shell- shows the traditional Hausa décor of the north.



Plate 5.32: View of Guest Living space
Source: Adekeye, 2009



Plate 5.33: View of Kitchenette/bar area
Source: Adekeye, 2009

Each bungalow is fully furnished with a comfort table sleeping area upstairs, (the Kodi village is better suited for families) a sitting area downstairs, a bathroom with shower, and all other modern conveniences such as air conditioning or electric fans, color TV with DVD player and films, CD player with radio, refrigerator and coffee-tea making facilities. Olufunke camp-tents are for day visits and relaxation.



Plate 5.34: Exterior view of Kodi (shell)chalet

Source: Adekeye, 2009



Plate 5.35: Interior view of Kodi chalet

Source: Adekeye, 2009

The resort has two open stages used for cultural dances and other live performances. Open stage one (see plates 5.35. 5.36) is a small stage located close to the chalets. The mega open stage is located at the beach front looking over the ocean.



Plate 5.36: View of Open stage one
Source: Adekeye, 2009



Plate 5.37: View of Mega open Stage
Source: Adekeye, 2009

BIOMIMICRY PRINCIPLE 1: MIMICKING NATURAL FORMS			
Variables	**Features**	**Method of application**	**Remark**
Building form (form and flow) exterior	Symbolic a particular natural form or natural built form	Nil	Negative
	Geometry adopted to achieve the form	Nil	Negative
Building's Relationship to site	Use of materials indigenous to site	Bamboo, thatch widely used.	Positive

TABLE 5.10: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE ONE AT LA CHAMPAGNE TROPICANA BEACH RESORT, LAGOS

SOURCE: FIELD SURVEY, OCTOBER 2010.

BIOMIMICRY PRINCIPLE 2: EXPLORING THE APPLICATION NATURAL PROCESSES			
Variables	**Features**	**Method of application**	**Remark**
Energy/power source	Integrated photovoltaic façade systems	Nil	Negative
	Building integrated wind turbines, wind tunnels and shafts.	Nil	Negative
Energy management methods	Automated operable windows	Nil	Negative
	Low e-glazing or double pane glazing	Nil	Negative
Use of building materials with high durability	Use of reinforced concrete, aluminium roofing sheets which are of high durability	Nil	Negative
Application of Smart Materials	Control of solar radiation transmitting through the building envelope and Control of interior heat generation	Use of Photochromics, Suspended particle panels, Louver control systems	Positive
	Secondary energy supply systems and optimization of lighting system	Energy from a wind turbine	Positive
Environmental Response to design features	Day lighting, the use of Skylights.	Use of roof monitors, extensive curtain walls.	Positive
	Natural ventilation via stack	Nil	Negative

	effect.		

TABLE 5.11: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE TWO AT LA CHAMPAGNE TROPICANA BEACH RESORT, LAGOS

SOURCE: FIELD SURVEY, OCTOBER 2010.

BIOMIMICRY PRINCIPLE 3: LEARNING FROM THE ECOSYSTEM			
Variables	**Features**	**Method of application**	**Remark**
Source of water	Source of water is a bore hole drilled on site.	Borehole is present on site	Positive
	Effort at harvesting, processing and recycling rainwater.	Rainwater is harvested and recycled.	Positive
	Use of on-site storm water treatment and ground water recharge	Grey water from washing is recycled in an irrigation system	Positive
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.	Most of the native plants such as oil palm were retained	Positive
	Construction of structures to follow the topography of the site	Minimal cut and fill of the site.	Positive
Regenerative site, design	The use of trees to control micro climate	The use of trees to control micro climate	Positive
	Use natural vegetation to control soil erosion	the use of trees and grasses to control soil erosion	positive
Minimal alteration of natural hydrological systems	Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge.	More than 90% of total site area is pervious to rain water.	Positive
Applying Integrated Cyclic processes & Feedback Loops	Use of water management and waste recycling	Use of water management and waste recycling	Positive
Water conservation methods	On-site treatment plants	There is an on-site water treatment plant for the recycle of grey water.	Positive

TABLE 5.12: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE THREEO AT LA CHAMPAGNE TROPICANA BEACH RESORT, LAGOS

SOURCE: FIELD SURVEY, OCTOBER 2010.

5.5 CASE STUDY FIVE: EASTGATE CENTRE, HARARE

5.5.1 BACKGROUND

The Eastgate Centre in Harare, Zimbabwe, typifies the best of green architecture and ecologically sensitive adaptation. The country's largest office and shopping complex is an architectural marvel in its use of biomimicry principles. The mid-rise building, designed by architect Mick Pearce in 1996, in conjunction with engineers at Arup Associates, has no conventional air-conditioning or heating, yet stays regulated year round with dramatically less energy consumption using design methods inspired by indigenous Zimbabwean masonry and the self-cooling mounds of African termites!



Plate 5.38: Eastgate Center in Harare, Zimbabwe.
Source:Pearce, 2006

5.5.2 PLANNING / LANDSCAPE

The complex also consists of two buildings side by side that are separated by an open space that is covered by glass and open to the local breezes. It and provides 5,600 m² of retail space, 26,000 m² of office space and parking for 450 cars

5.5.3 SPATIAL ORGANISATION AND DESIGN

The Eastgate Centre, largely made of concrete, has a ventilation system which operates in a similar way as in the termite mound. Outside air that is drawn in is either warmed or cooled by the building mass depending on which is hotter, the building concrete or the air. It is then vented into the building's floors and offices before exiting via chimneys at the top.

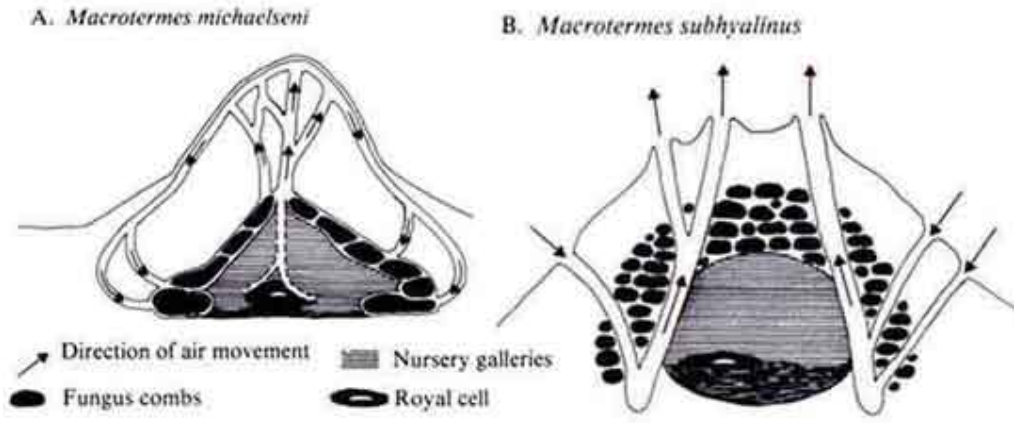


Fig 5.7: Air movement in termite mound
Source:Pearce, 2006

Air is continuously drawn from this open space by fans on the first floor. It is then pushed up vertical supply sections of ducts that are located in the central spine of each of the two buildings. The fresh air replaces stale air that rises and exits through exhaust ports in the ceilings of each floor. Ultimately it enters the exhaust section of the vertical ducts before it is flushed out of the building through chimneys.

BIOMIMICRY PRINCIPLE 1: MIMICKING NATURAL FORMS			
Variables	**Features**	**Method of application**	**Remark**
Building form (form and flow) exterior	Symbolic a particular natural form or natural built form	The building looks like a termite mound	Positive
	Geometry adopted to achieve the form	Use of curves	Positive
Building's Relationship to site	Materials used	nil	negative

TABLE 5.13: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE ONE AT EASTGATE CENTRE, HARARE

SOURCE: FIELD SURVEY, OCTOBER 2010.

BIOMIMICRY PRINCIPLE 2: EXPLORING THE APPLICATION NATURAL PROCESSES			
Variables	**Features**	**Method of application**	**Remark**

Energy/power source	Integrated photovoltaic façade systems	Nil	Negative
	Building integrated wind turbines, wind tunnels and shafts.	Nil	Negative
Energy management methods	Automated operable windows	Nil	Negative
	Integrated photovoltaic façade systems	Nil	Negative
Use of building materials with high durability	Use of reinforced concrete, aluminium roofing sheets which are of high durability	Nil	Negative
Application of Smart Materials	Control of solar radiation transmitting through the building envelope and Control of interior heat generation	Use of ceilings, roof monitors for expelling hot air, wide shading eaves, polished floors that are cool to touch and many windows enabling adequate cross-ventilation.	Positive
	Secondary energy supply systems and optimization of lighting system	Energy from a wind turbine and a propane 11 kW backup generator.	Positive
Environmental Response to design features	Day lighting, the use of Skylights.	Use of roof monitors, extensive curtain walls.	Positive
	Natural ventilation via stack effect.	The use operable windows and provision of ceilings and roof monitors for expelling hot air.	Positive

TABLE 5.14: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE ONE AT EASTGATE CENTRE, HARARE

SOURCE: FIELD SURVEY, OCTOBER 2010

BIOMIMICRY PRINCIPLE 3: LEARNING FROM THE ECOSYSTEM			
Variables	**Features**	**Method of application**	**Remark**
Source of water	Source of water is a bore hole drilled on site.	Nil	Negative
	Effort at harvesting, processing and recycling rainwater.	Main source of water is from town mains	Positive

		supplementing it with rainwater from its own storage when available.	
	Use of on-site storm water treatment and ground water recharge	Grey water from washing is recycled in an irrigation system	Positive
Working with site topography and native landscape elements	Retention of plants native to location as landscape elements.	Most of the native plants such as oil palm were retained	Positive
	Construction of structures to follow the topography of the site	Minimal cut and fill of the site.	Positive
Regenerative site, design	The use of trees to control micro climate	The use of trees to control micro climate	Positive
	Use natural vegetation to control soil erosion	the use of trees and grasses to control soil erosion	Positive
Minimal alteration of natural hydrological systems	Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge.	More than 90% of total site area is pervious to rain water.	Positive
Applying Integrated Cyclic processes & Feedback Loops	Use of water management and waste recycling	Use of water management and waste recycling	Positive
Water conservation methods	On-site treatment plants	There is an on-site water treatment plant for the recycle of grey water.	Positive

TABLE 5.15: ASSESSMENT OF APPLICATION OF BIOMIMICRY PRINCIPLE ONE AT EASTGATE CENTRE, HARARE

SOURCE: FIELD SURVEY, OCTOBER 2010

CHAPTER SIX

THE SITE

6.1 SITE LOCATION.

The proposed location for the Lamingo resort is Jos the Plateau state capital north-central Nigeria. Plateau State is located in the Middle Belt tourism area of Nigeria, with an area of 26,899 square kilometers; the State has an estimated population of about three million people (see plate 6.1). It is located between latitude 80°24'N and longitude 80°32' and 100°38' east.

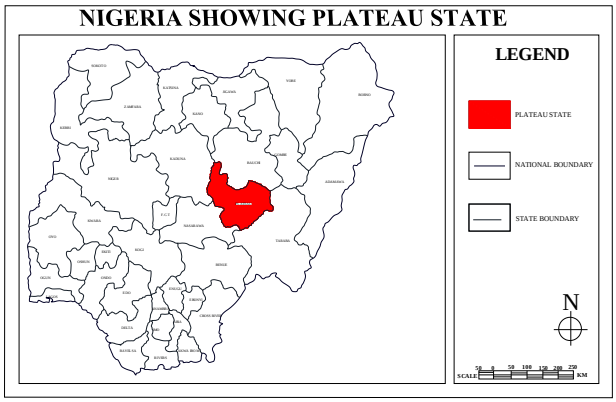


Fig 6.1: Map of Nigeria showing plateau state and neighbouring states.
Source: Golesh, 2009.

The state is named after the picturesque Jos Plateau, a mountainous area in the north of the state with captivating rock formations (see plate 6.2). Bare rocks are scattered across the grasslands, which cover the plateau. The altitude ranges from around 1,200 meters (about 4000 feet) to a peak of 1,829 metres above sea level in the Shere Hills range near Jos (Awarintefe, 2007). It is conducive for both culture, and adventure/landform tourism. Annual visitor's rate for both domestic and foreign tourists is 18,451 visitors per annum (Awarintefe, 2007). These visitors are mostly new experience seekers with a bias for eco-tourism.

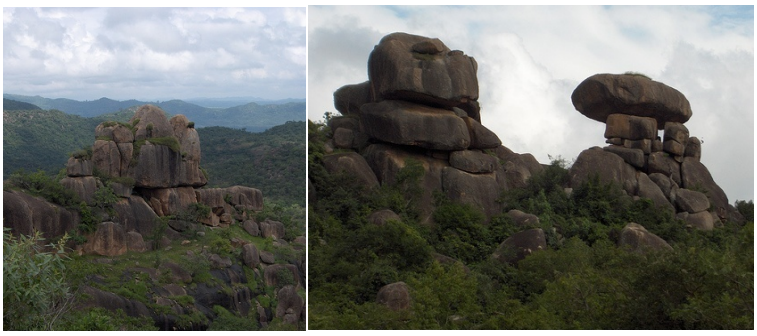


Plate 6.1 A view of some of the rock formation at the shere hill range near Jos.
Source: Author, 2010.

Potential sites need to be considered in relation to the main tourist and service attractions, in a resort area, views, distance and frontage to water fronts and surroundings are key factors (Fred Lawson, 1995). These factors influenced the choice of the site .The site is located at the heart of the Shere hill range beside the old lamingo dam (see plate 6.3). The Shere Hills include some of the Plateau's highest peaks. They are a scenic range of hills to the east of Jos which offer a prime view of the city below. They offer fantastic opportunities to mountain climbers and hill walkers alike. Plates 6.3, 6.4 and 6.5 show satellite images of the proposed Lamingo resort site and surrounding hills.



Plate 6.2: A satellite image of the proposed Lamingo resort l site and surrounding hills.

Source: google earth, 2008.

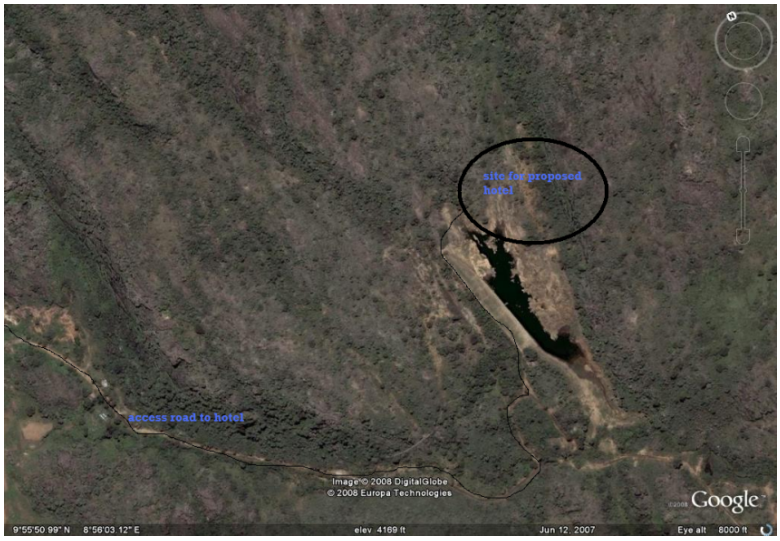


Plate 6.3: A magnified satellite image of the proposed Lamingo resort site and the old lamingo dam.

Source: google earth, 2008.

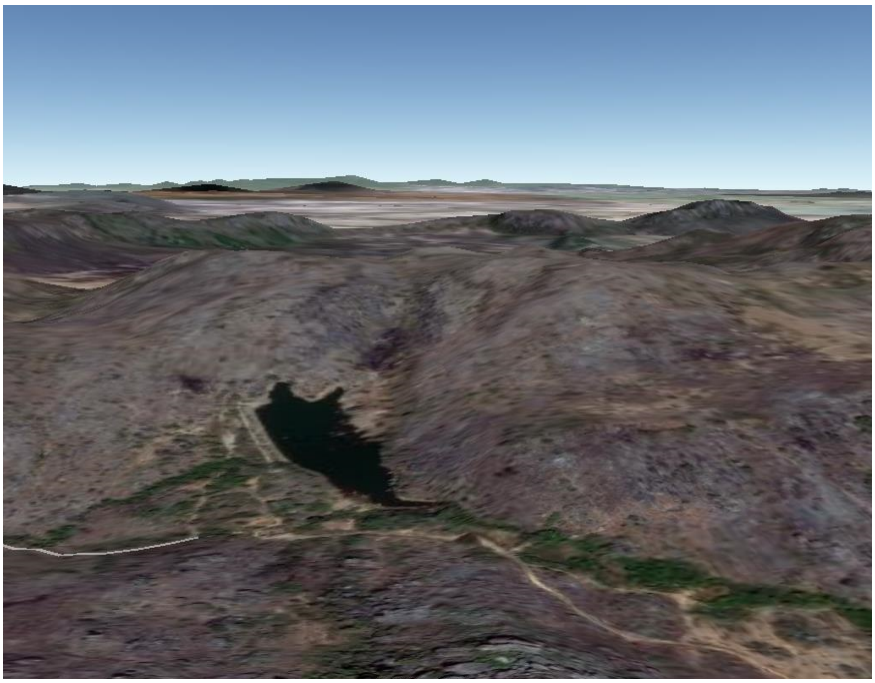


Plate 6.4 A 3D View of the site

Source: google earth, 2008.

6.1.1 CLIMATIC DATA OF THE SITE.

Though situated in the tropical zone, a higher altitude means that Plateau State has a near temperate climate with an average temperature of between 18 and 22°C. Harmattan winds cause the coldest weather between December and February. The warmest temperatures usually occur in the dry season months of March and April. The mean annual rainfall varies from 131.75 cm (52 in) in the southern part to 146 cm (57 in) on the Plateau (http//www.tutiempo.com, 2009). The highest rainfall is recorded during the wet season months of July and August. The average lower temperatures Plateau State has led to a reduced incidence of some tropical diseases such as malaria. The Jos Plateau, makes it the source of water from many rivers in northern Nigeria including the Kaduna, Gongola, Hadejia and Yobe rivers.



Figure 6.2: Jos mean monthly rainfall 1997-2007.
Source: http://www.tutiempo.com.at/

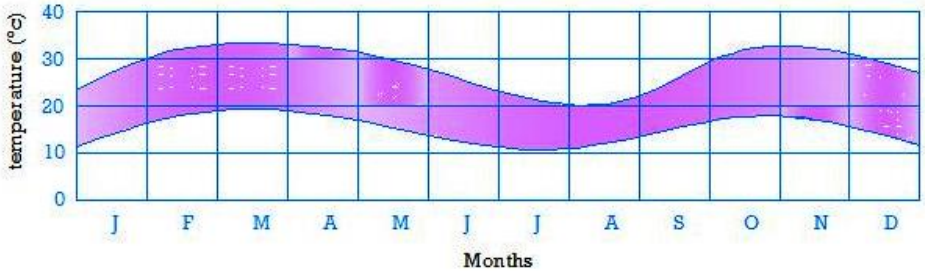


Figure 6.3: Jos mean monthly temperature ranges 1997-2007.
Source: Source: http://www.tutiempo.com.at/

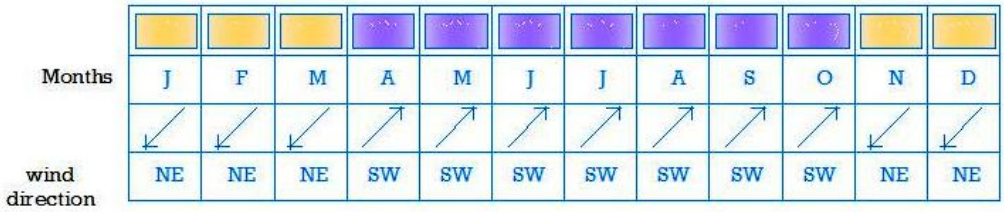


Figure 6.4 Jos prevailing wind directions 1997-2007.
Source: Source: http://www.tutiempo.com.at/

6.1.2 GEOLOGY OF THE SITE.

The Jos Plateau is thought to be an area of younger granite which was intruded through an area of older granite rock, making up the surrounding states. These "younger" granites are thought to be about 160 million years old. This creates the unusual scenery of the Jos Plateau. There are numerous hillocks with gentle slopes emerging from the ground like mushrooms scattered with huge boulders (Wikipedia, 2009). Also volcanic activity 50 million years ago created numerous volcanoes and vast basaltic plateaus created from lava flows. This also produces regions of mainly narrow and deep valleys and pediments (surfaces made smooth by erosion) from the middle of rounded hills with sheer rock faces. The phases of volcanic activities involved in the formation of Plateau State have made it one of the mineral rich states in the country. Tin is still mined and processed on the plateau.

The resort site is in the Shere hills range. The ground around the proposed site is predominantly covered with granite outcrops forming an interesting vista of undulating hills. Plates 6.3 show some the hills adjoining the site while plates 6.5-6 show a magnification of the type of boulders to be found in and around the site.



Plate 6.5: A view of hills adjoining the site.
Source: Author,2010



Plate 6.6: a view of granite boulders on the site.
Source: Author,2010.

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Plate 6.7: a view of granite boulders on the site.
Source: Author,2010.

6.2 SITE SELECTION CRITERIA

Two (2) alternative sites were chosen for this research, based on purposive sampling

The following criteria were considered in the site selection.

i. The ecological characteristics of the site.

This check implies the need to carry out hydrological and geological tests to ascertain the suitability of the bearing strength of the soil to carry the proposed building project. It is also

important to ascertain whether the proposed development will adversely affect the biodiversity of the soil and water bodies on the site.

ii. The site's nearness to existing infrastructure such as roads, power lines, water supply and waste disposal sites.

This question is crucial to determine the multiplier impacts if the site is remote from existing infrastructure and if the proposed development will contribute to the expansion of urban sprawl. Another important consideration under this site consideration check is if the proposed development can be built as a self-contained unit in terms of water, energy and waste disposal.

iii. The state of the environment of the site.

The state of the environment of the site can eventually be the deciding factor in choosing or not choosing a site for a resort since it is expected that visitors will use the buildings and the surrounding landscape for leisure and recreation. The factors to be considered are; if the site has been used for industrial purposes which might have contaminated the soil and the water, if there are strong electromagnetic fields present, if the vegetation on the site shows any signs of stress and also the potential of the site for passive solar design and renewable energy. This is especially important if the site is far from the grid.

iv. Reuse of existing structures.

The professionals involved in the development of the resort should check for the possibility of the reuse of existing structures or an upgrading of the existing structures so that they can be part of the development. But if the structures are beyond repair, some building materials may be recovered and reused for the new development.

v. The influence of future land-use plans for the areas surrounding the site.

The developers should ensure that the proposed development conforms to existing land use plans and there will be no industrial and commercial developments planned for surrounding areas which will decrease the value and Aesthetics of the site. The future developments should in no way adversely affect the site's access to sunlight, water or power.

vi. Easy access to the destination

The ease of access to the site determines the likelihood of guests patronizing the resort since holiday makers are less likely to succumb to strenuous demands in an effort to make leisure travels.

vii. Cost of living at the destination

Jaume Garau-taberner considered relevant with the argument that tourists and holiday makers have financial wherewithal as the main determining factor in choosing holiday locations, as such they are more willing to spend their holidays in places where affordability is not a delimiting factor.

viii. The potential of the site to support recreational activities.

For most young vacationers, studies have shown that the potential of a resort destination to support recreational activities such as hiking and swimming determines their choice.

ix. The scenery or exotic atmosphere of the destination.

The potential of the site to present a new experience to holiday seekers also determines their choice of the holiday location.

These site selection checks are summarized in table 6.1 and have been used to compare and evaluate the appropriateness of the old Lamingo dam area and the liberty dam area for the siting of the resort.

S/N	CRITERIA	Old lamingo dam site	Liberty dam site
1.	Potential of the site to be utilized for sustainable site design.	The site has the capacity to cater for the buildings water requirements	The site has the capacity to cater for the buildings water requirements
2.	The site's nearness to existing infrastructure such as roads, power lines, water supply and waste disposal sites.	The site is easily accessible via existing roads leading to the dam.	The site is easily accessible via existing roads leading to the dam.
3.	Potential of the site for passive solar design and renewable energy.	The site has the potential for passive solar design and renewable energy such wind power due to its high altitude.	The site has a lower potential to support passive solar design and renewable energy such wind power due to its lower altitude.
4.	Inherent attractions on the surrounding landscape for leisure and recreation.	The site has an interesting landscape that can provide a means for recreation for mountain climbers (plate 6.2) and water sports can be had on the lake.	The site has a less interesting landscape.

Table 6.1 Site selection criteria.
Source: author's survey

From the above comparison it is obvious that the lamingo area will better support the development of a resort.

6.3 SITE ANALYSIS

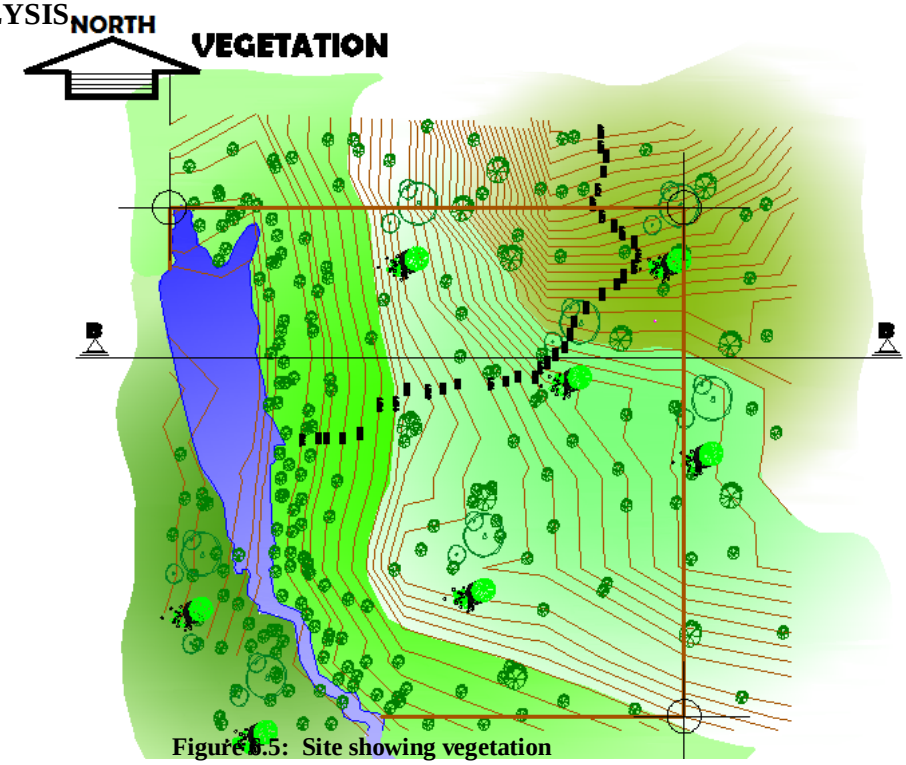


Figure 6.5: Site showing vegetation
Source: author's survey

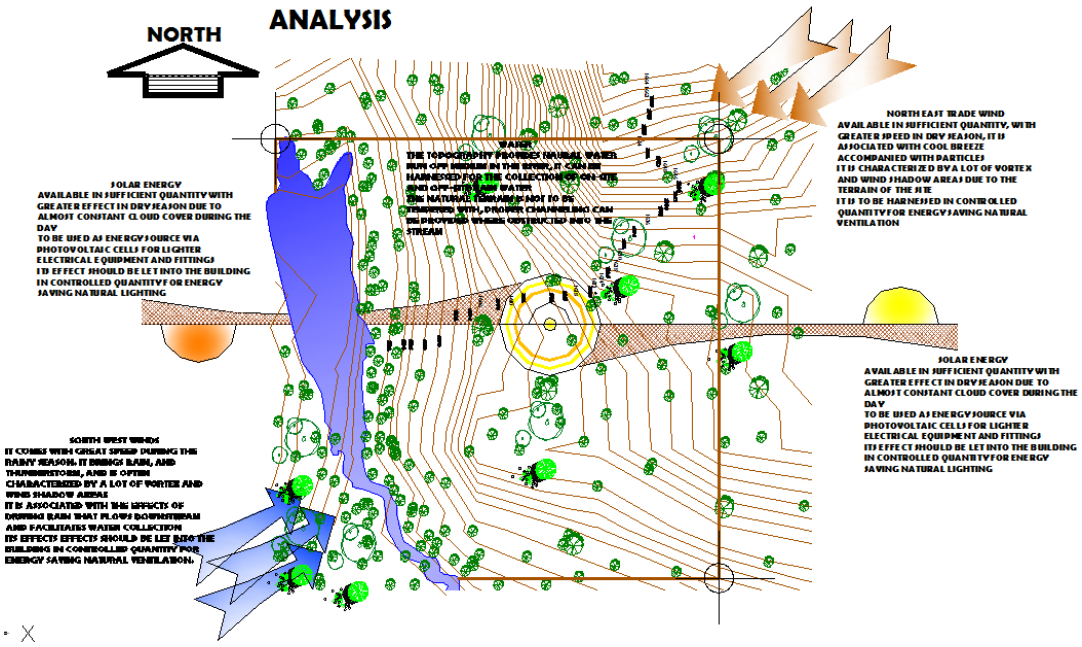


Figure 6.6: Site Analysis
Source: author's survey

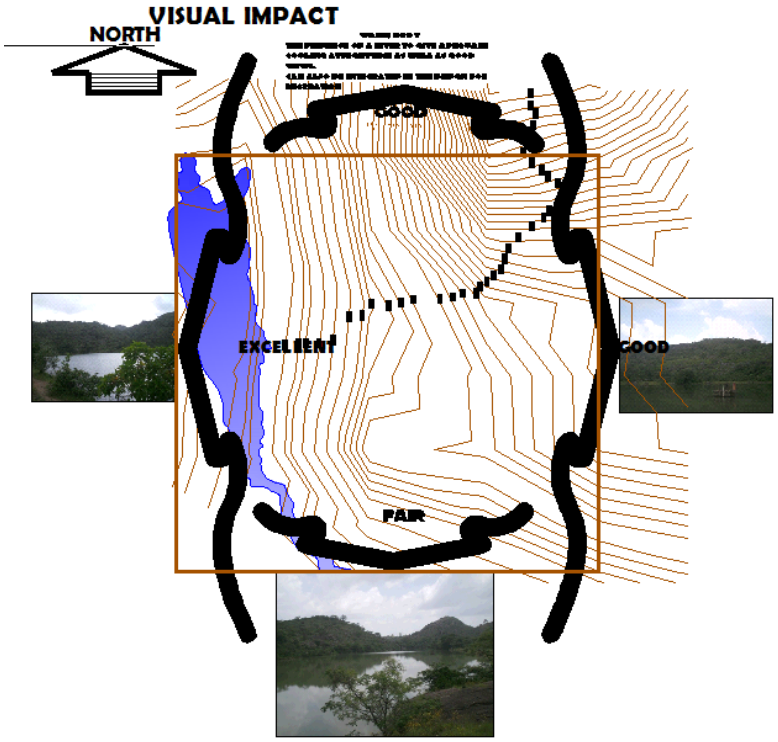


Figure 6.7: Visual impact
Source: author's survey

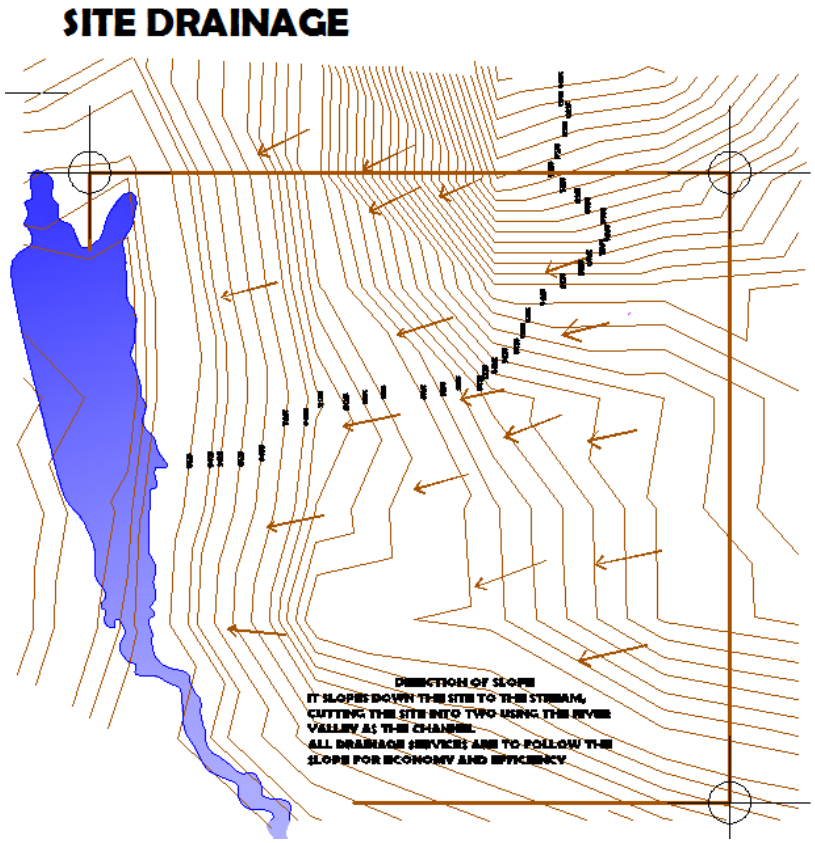


Figure 6.8: Topography
Source: author's survey

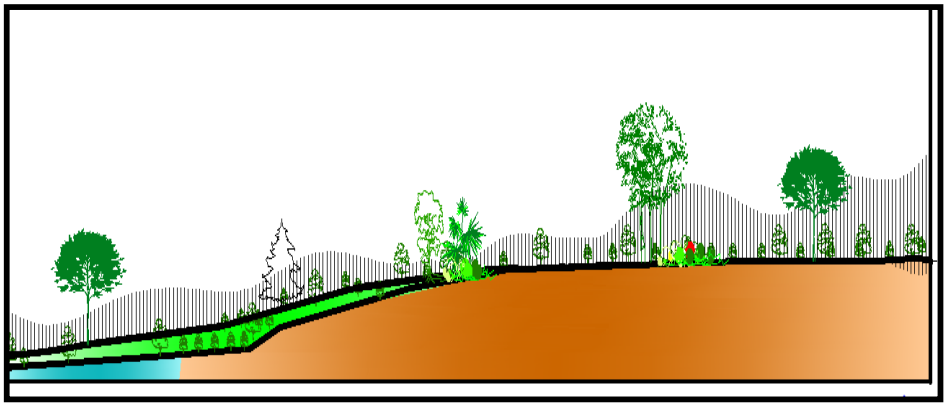


Figure 6.9: site section (section B-B).
Source: author's survey

DEVELOPMENT POTENTIAL

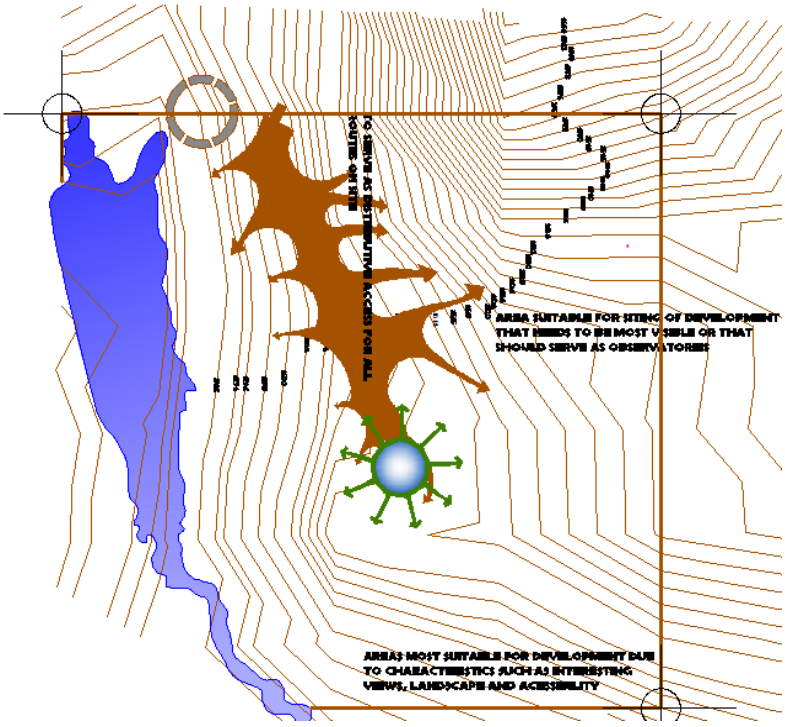


Figure 6.10: Development potential
Source: author's survey

CHAPTER SEVEN

DESIGN REPORT

7.1 DESIGN CONCEPT

Concept and architecture development is a process that creates a system solution which satisfies users' needs. This process is repeated at each level of solution decomposition. It includes the application of properly weighted decision criteria to get a feasible design.

The great 19th century architect of skyscrapers, Louis Sullivan, promoted an overriding precept to architectural design: "Form follows function".

The lamingo plains of Jos is characterized by visual scale, created by the bare rocks which are scattered across the grasslands, covering the plateau. The form of the structures that were resemble rocks protruding on the site. See plate below



Plate 7.1: A view of some of the rock formation at the shere hill range near Jos.
Source: author's survey, 2010.

7.2 SITE PLANNING CONCEPT

A dual roadway leads into the site for visitors. From the site plan, the road layout was designed with respect to the site contours. The parking spaces of each facility spread out on a larger curve radiating along the axis in a fractal pattern of textural progression heading towards the building in front of it.

7.3 BUILDING FORMS

The plan arrangement of the buildings evolve as knoll shaped structures, evolving from different levels of bases, overlapping one another,as if to say a contours of knolls, sitting side by side. The oval shaped (conical) forms for the administration building, health centre and fitness centre are all reminiscent of 'inselberg' forms of the Lamingo plains of Jos.

The whole arrangement thus speaks of a 'hill range structure' on the sloping base, with each 'knoll' protruding as a distinct form, each self similar, but affine - following from fractal principles.

Summarily the design concept harnesses the following aspects:

i. Harmony of building to site and surrounding, in terms of forms and materials, giving it a uniform identity with the site features: the hilly range;
ii. The exploration of the curvilinear, typified by the dominance of curved lines over the straight;
iii. Fractal principles applied the textural progressive design of the parking spaces and the self similar shapes of the different buildings.

Stone masonry shall largely be employed for the floors, a sustainable and site-available material. Stone is also used extensively for walkways, roadways, floor finish; the aggregate of the concrete' that will be employed for construction. The introduction of courtyard design is for improved natural lighting and ventilation.

Geometry: (2d context)

The use of a “seed shape” lays emphasis on fractal self similarity, unity and variety.

Basic two dimensional shapes: Circle, and the elipse.

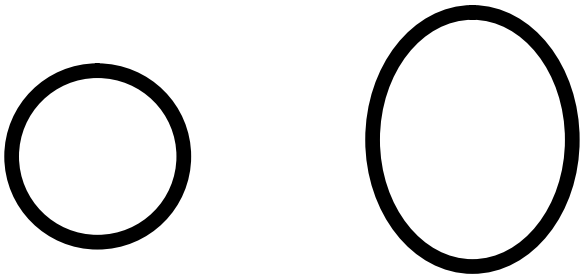


Fig 7.1: Forms for concept development
Source: author's survey.

The ellipse is stretched circle, and more organic. It is thus used as the seed shape. The inselbergs of the hills are best described as elliptical on plan.

Indoor hydrotherapy and Health Centre: The plan form of the three main structures are ellipses on overlapping each other as illustrated in figures below.

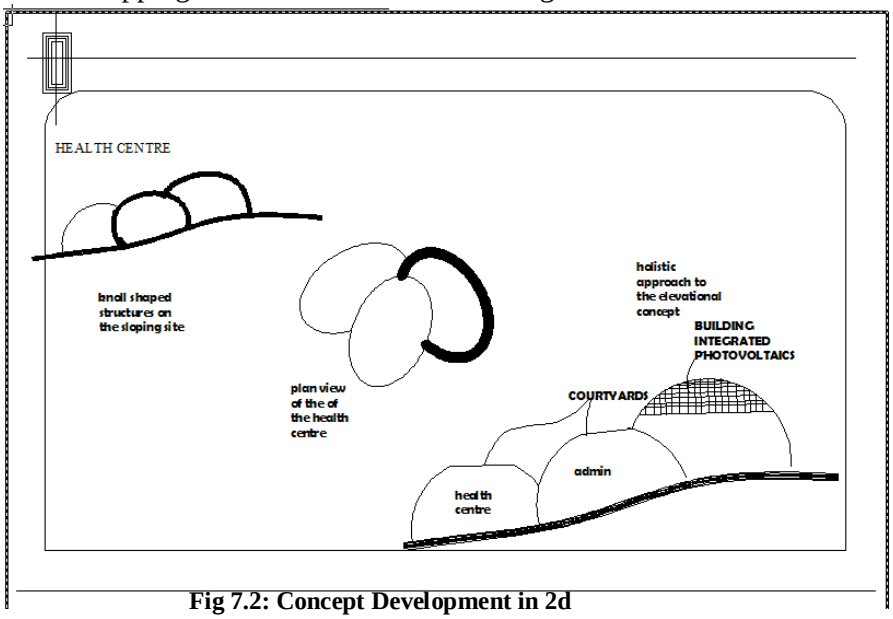


Fig 7.2: Concept Development in 2d
Source: Author

The forms of the buildings are inspired by the terrain of the site features. The outcrops of inselbergs are a common prominent geographical feature. Thus the building resembles inselbergs, three knolls overlapping themselves on the sloping terrain. The use of courtyards was employed to promote the light and ventilation qualities of the buildings.

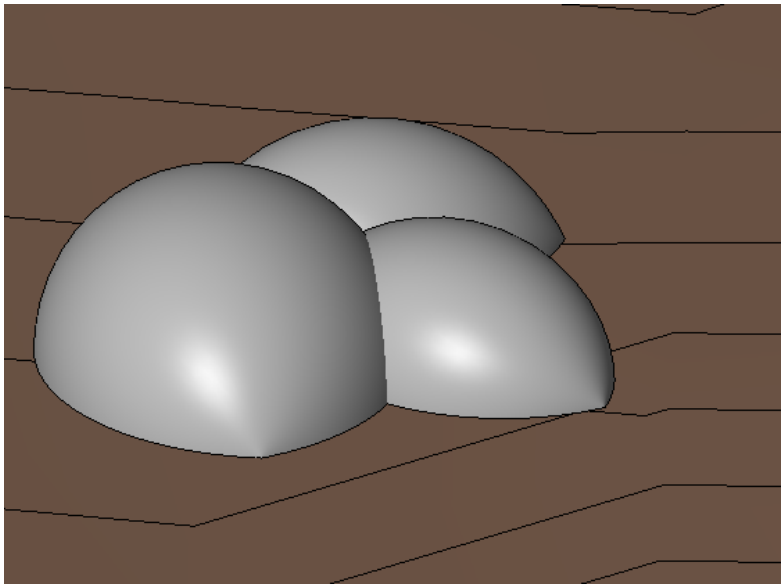


Fig 7.3: Concept Development in 3d
Source: Author

Multi Purpose Hall, Fitness centre: The took after the elliptical and circular shapes in plan cropping out of the site like the boulders that characterize the site. The ground was raked along the slope of the site

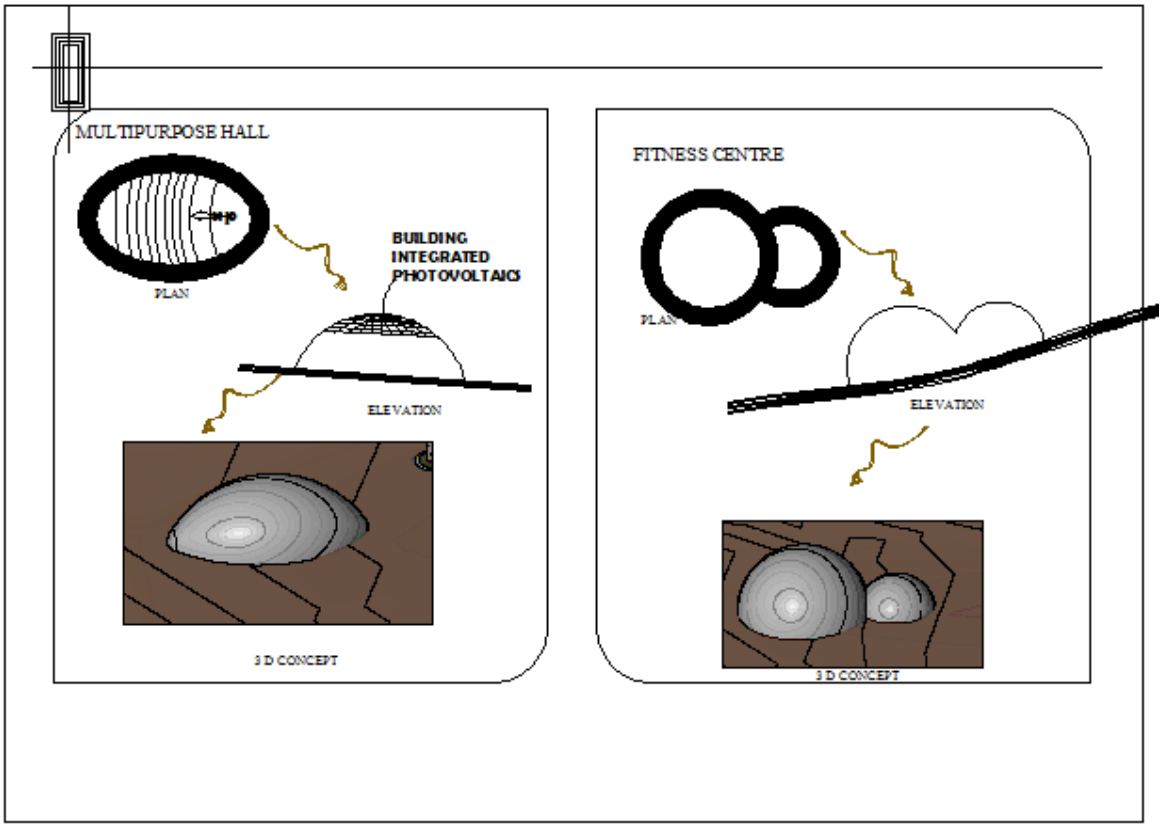


Fig 7.4: Concept Development
Source: Author

Restaurant: The restaurant design took after the leaf form hanging on its stem. The leaf as a concept was chosen being that it is the 'nutritional house' of a plant. The Building was situated at raised area to an appreciable height above the ground to take advantage of sea-breezes, scenic views and to avoid the negative effects of moisture seepage and flooding.

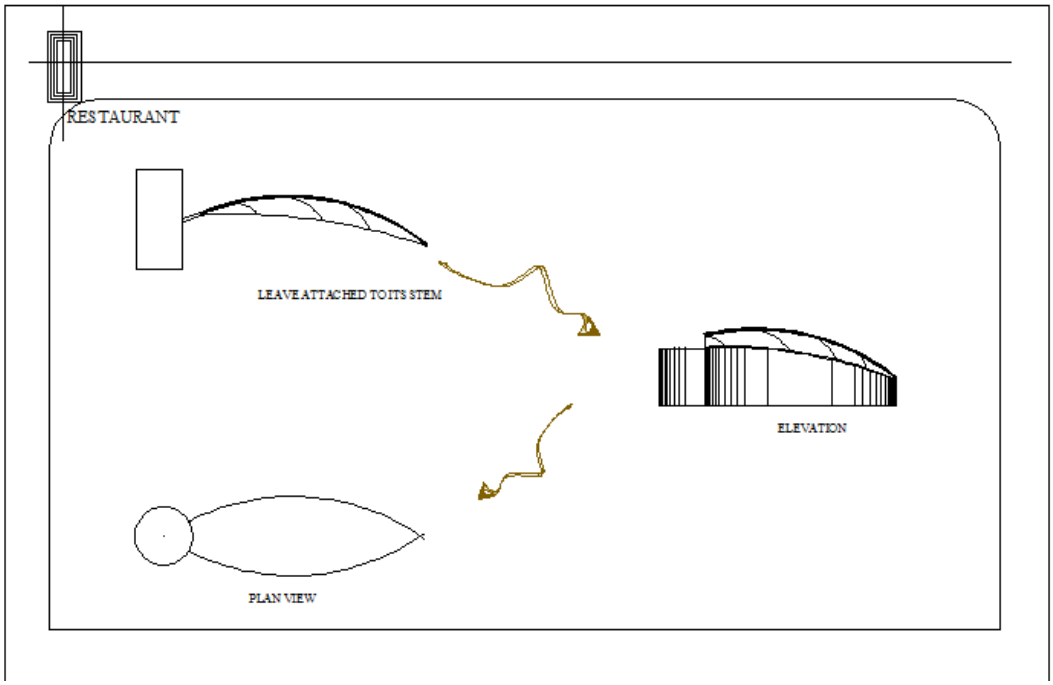


Fig 7.5: Concept Development for restaurant
Source: Author

7.4 DESIGN CONSIDERATIONS

7.4.1 Site Planning and Landscaping

Site planning as an integral part of the design content was put into consideration. Existing conditions on the site such as rocks, stony soil conditions and steep slopes were considered in the general layout of the site, spatial arrangement and landscaping. The road layout was designed to follow the contours of the site in order to check for minimal cutting and filing. Stone paving was used for the walkways, to emphasis use of natural materials. Paramount to a health resort is the availability of gardens which was strategically centrally, to demarcate the public and private spaces.

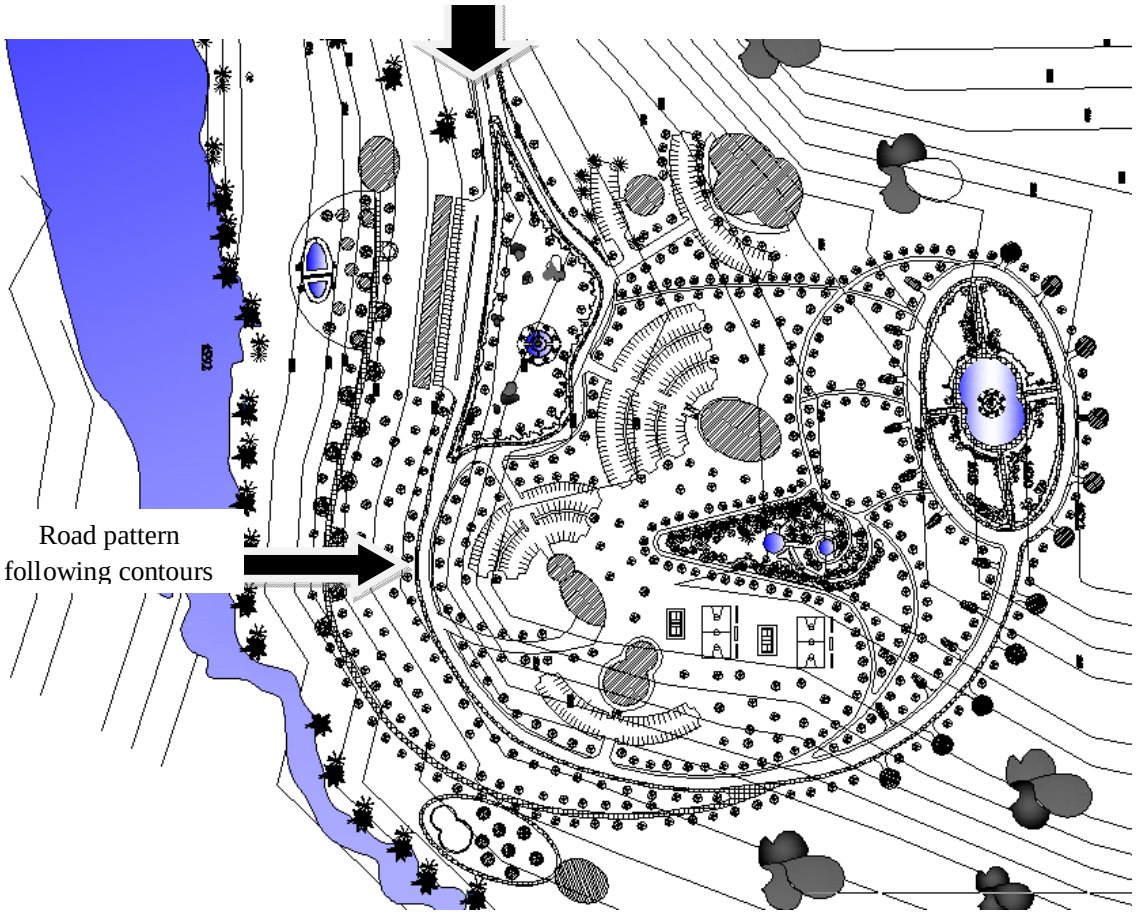


Fig 7.6: Site planning
Source: Author

7.4.2. Circulation

Conscious design efforts to separate pedestrian and vehicular traffic were made. The layout of the circulation was designed to allow for guests to drive or walk within the site and experience the scenic views, provides the guest an opportunity to be exposed to nature and the natural scenes of the hills, landscape and water body, see fig 7.6.

7.4.3 Ventilation

One of the main considerations during the design stage was finding a way of ventilating the buildings naturally especially the health centre which has a suspended floor. As a solution, stack effect was used to circulate air through a courtyard in the middle of the offices.

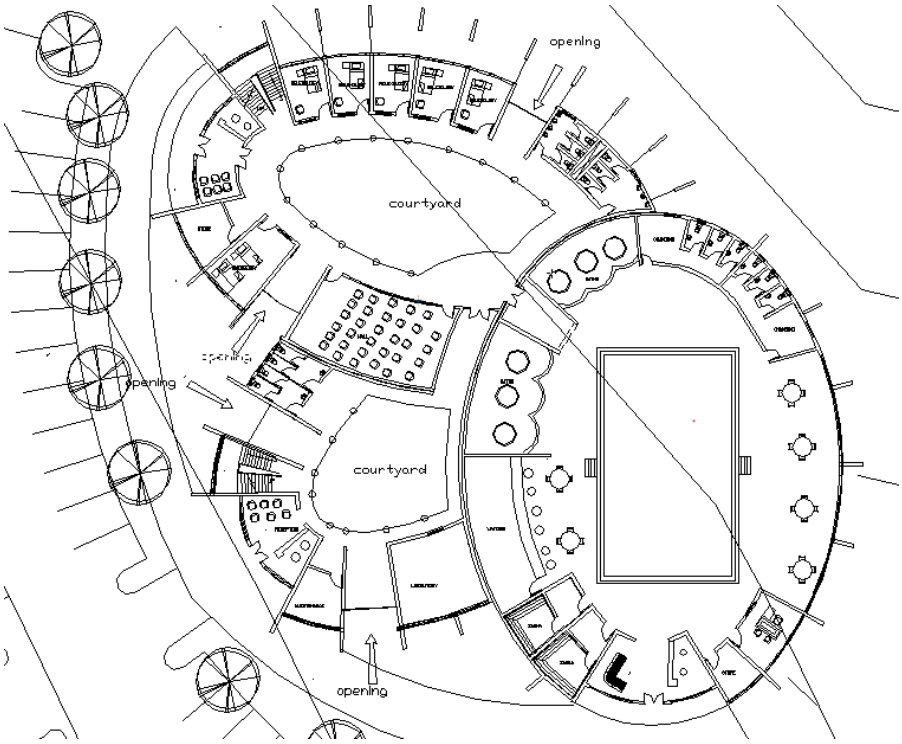


Fig 7.7: Floor plan of health centre showing courtyards and openings
Source: Author

Stack effect: is the movement of air into and out of buildings, chimneys, flue gas stacks, or other containers, and is driven by buoyancy. Buoyancy occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture differences. The result is either a positive or negative buoyancy force.

Stack effect in buildings since buildings are not totally sealed (at the very minimum, there is always a ground level entrance), the stack effect will cause air infiltration. During the heating season, the warmer indoor air rises up through the building and escapes at the top either through open windows, ventilation openings, or other forms of leakage. The rising warm air reduces the pressure in the base of the building, drawing cold air in through either open doors, windows, or other openings and leakage. During the cooling season, the stack effect is reversed, but is typically weaker due to lower temperature differences.

7.4.3 Spatial organization

Generally, the buildings were fully exposed to cooling winds. In order to ensure free movement of air through the site, resort buildings were located a fair distance from each other; this also avoids obstructing breezes.

Another consideration was the zoning of the facilities according to usage. The public spaces such as the shops, multipurpose halls, and health center and relaxation spots were placed respectively as a visitor approaches the resort. Private spaces, basically the therapeutic gardens and guest chalets were located deep into the site for control of noise, and to provide privacy to the guests.

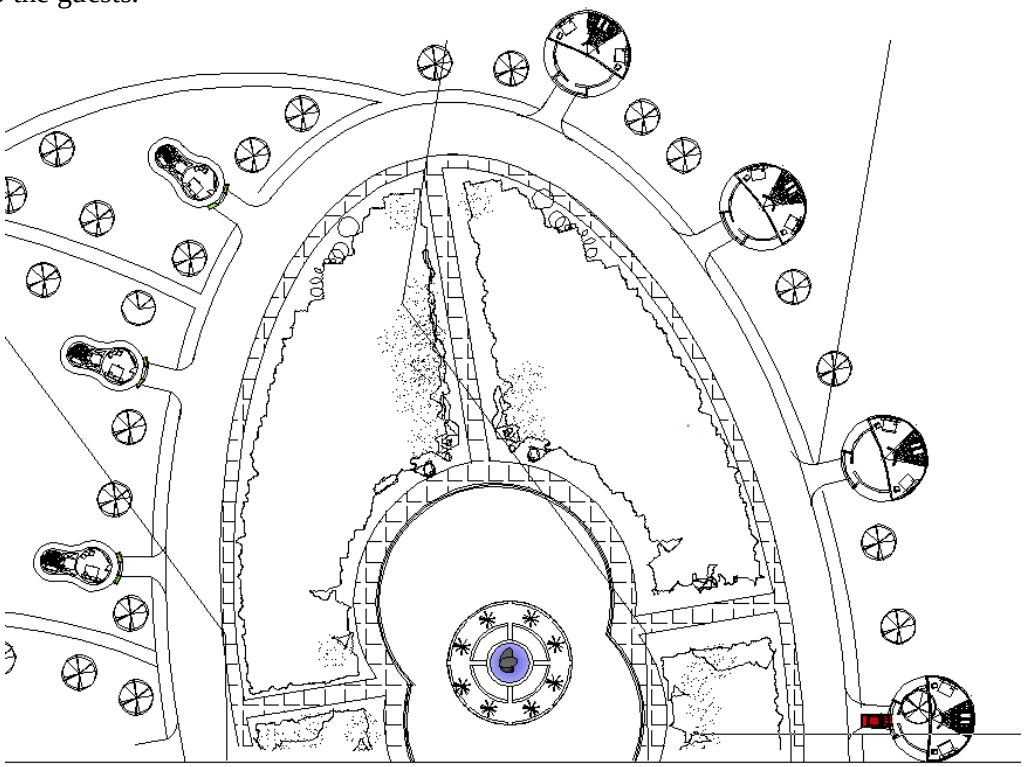


Fig 7.8: Spatial arrangement of chalets
Source: Author

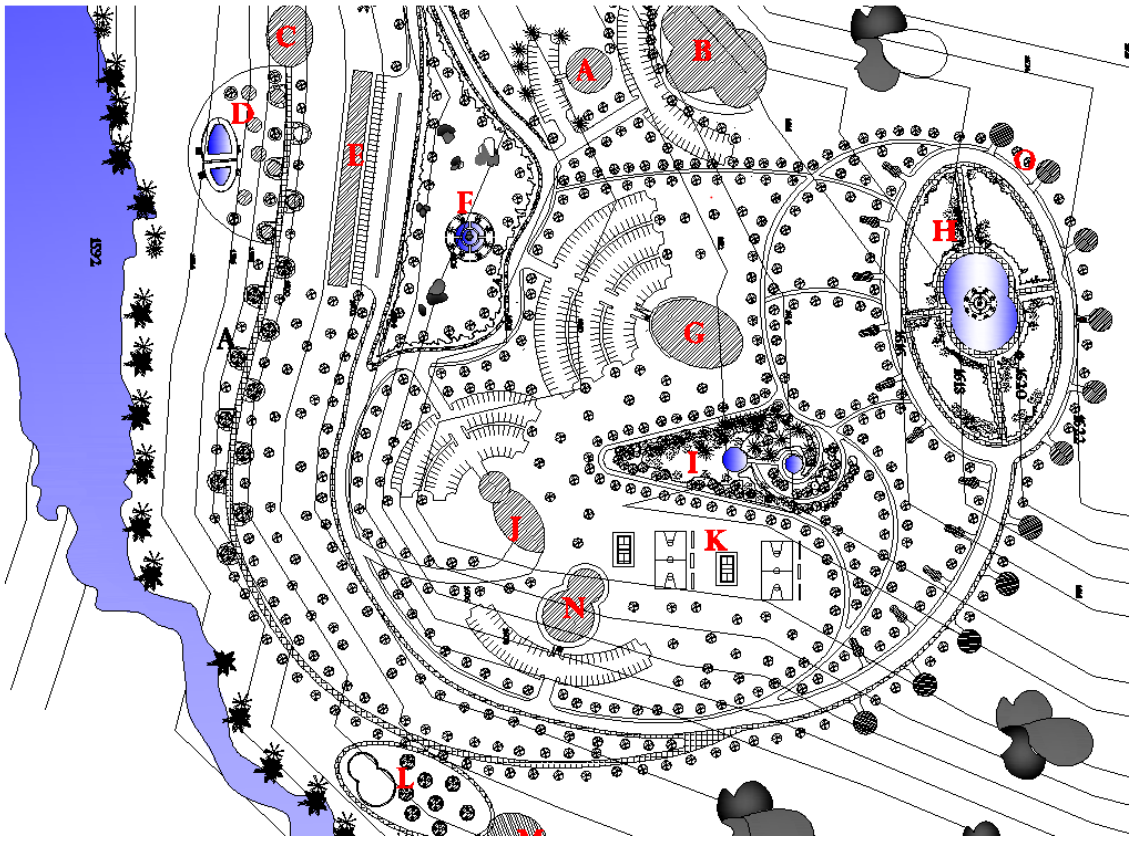


Fig 7.9: Spatial arrangement of chalets
Source: Author

A. - Administrative Building

B. – Health centre

C. – Pool bar

D. – Outdoor relaxation with swimming pool

E. – Shops

F. – Fountain

G. – Multipurpose Hall

H. – Outdoor relaxation for guest chalets with pool

I. – Garden

J. – Restaurant

K. – Outdoor games

L. – Children's relaxation spots with swimming pool

M. –Fast foods, snacks and ice cream shops

N. – Fitness centre

O. –Guests' chalets

7.7.4 Rainwater harvesting

Rainwater harvesting was provided for in the design. Rainwater collected from the roofs of the charlets, can make an important contribution to the availability of water for domestic purposes.

Roof rainwater collected cannot be of good quality and may require treatment before consumption or domestic usage. It can be useful in flushing toilets, washing clothes, watering the garden and washing cars. Household rainfall catchment systems are appropriate in an area like the site as aserted by Cotton, (1992), that for areas with an average rainfall greater than 200 mm (7.9 in) per year, the use of these catchment systems are advised. Overflow from rainwater harvesting tank systems will be used to refill aquifers in a process called groundwater recharge.

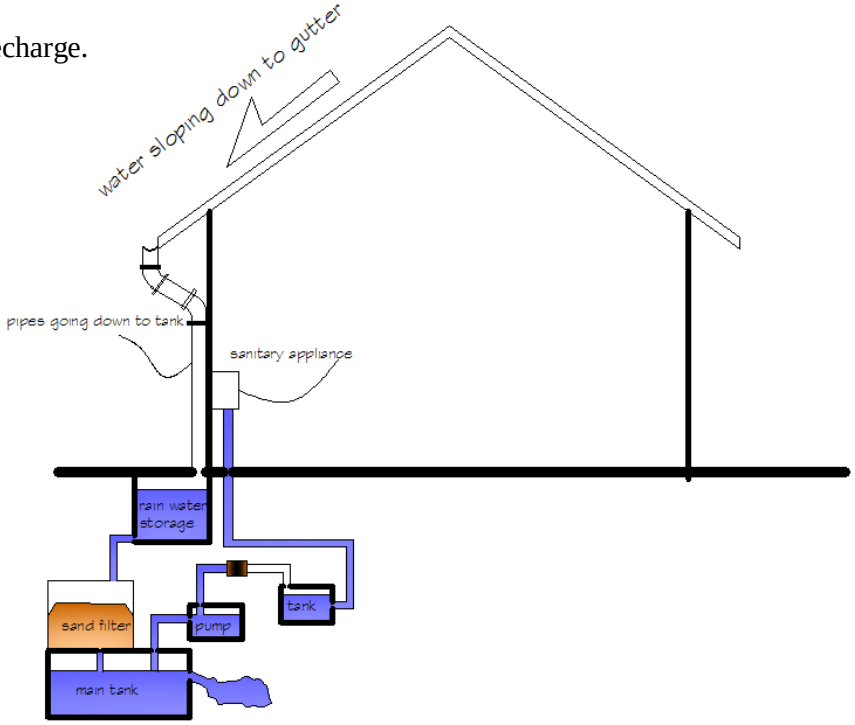


Fig 7.10: Schematic diagram of water harvesting from the chalet buildings
Source: Author

7.4.5 Energy harvesting

Building integrated Photovoltaics were used in the roofs of the structutres. These are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylight, or facades. They were being incorporated into the construction of buildings as a principal or ancillary source of electrical power. The advantage of integrated photovoltaics over common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labour that will normally be used to construct the part of the building that the BIPV modules replace.

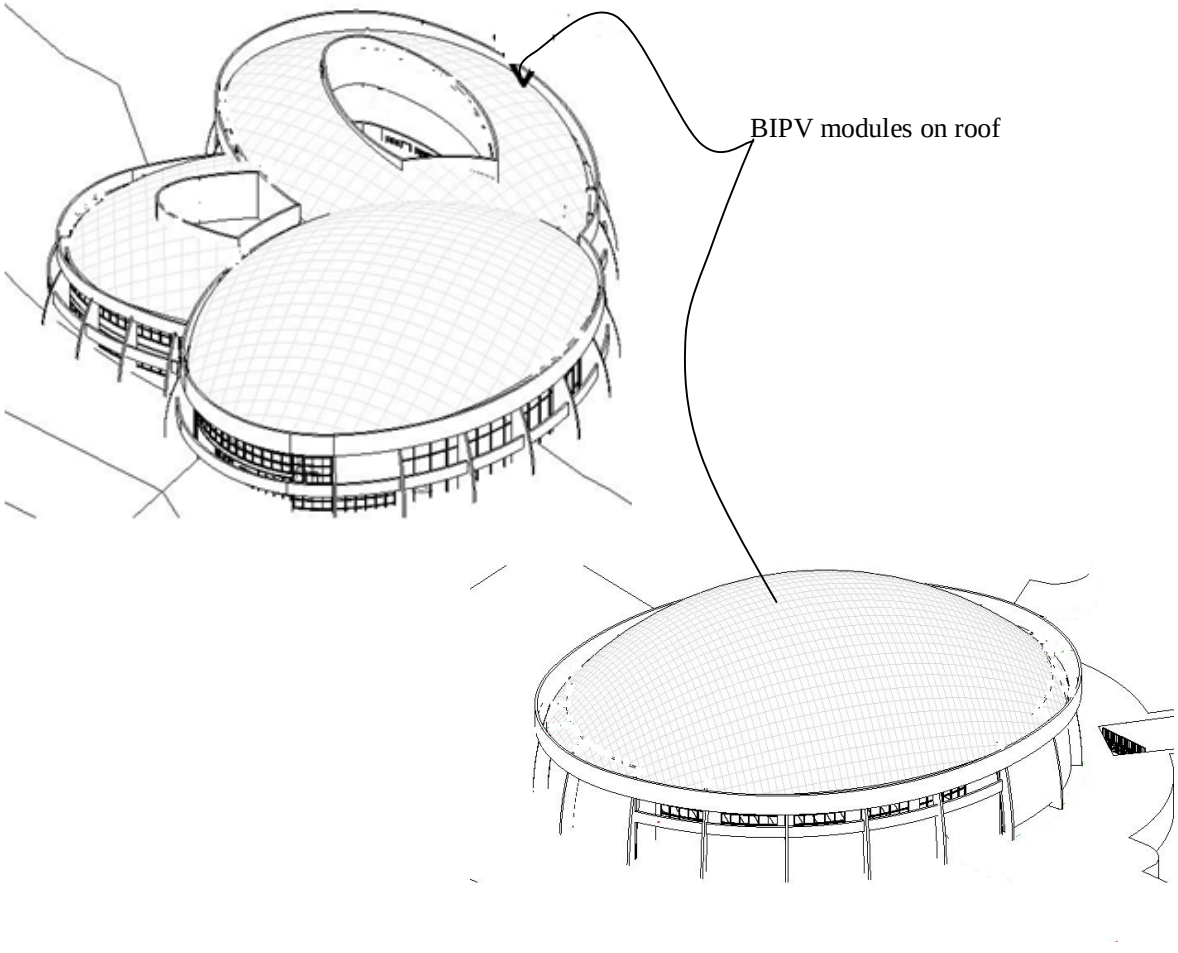


Fig 7.11: BIPV modules on roofs of health centre and multipurpose hall
Source: Author

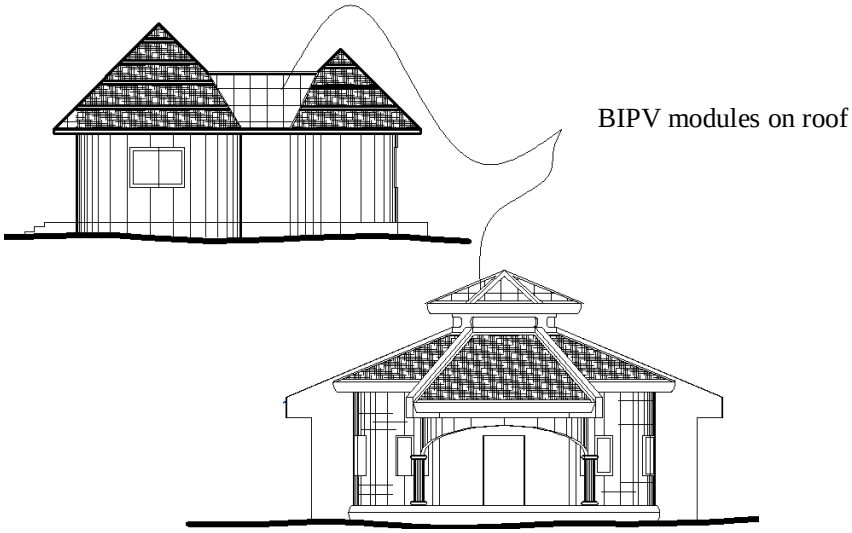


Fig 7.12: BIPV modules on roofs of guests' chalets
Source: Author



Plate 7.2: A view detail of the BIPV module on the roof.
Source: author's survey, 2010.

7.4.6 Multipurpose hall design

The multipurpose hall is targeted to attract people who have events and conferences of a large number of persons around the location. The building was designed with all the necessary requirement a hall should have. The form adopted is from the knoll shaped concept, with its building integrated photovoltaic façade to harvest and provide energy to the building. Ramps for the disabled and steps were provided.

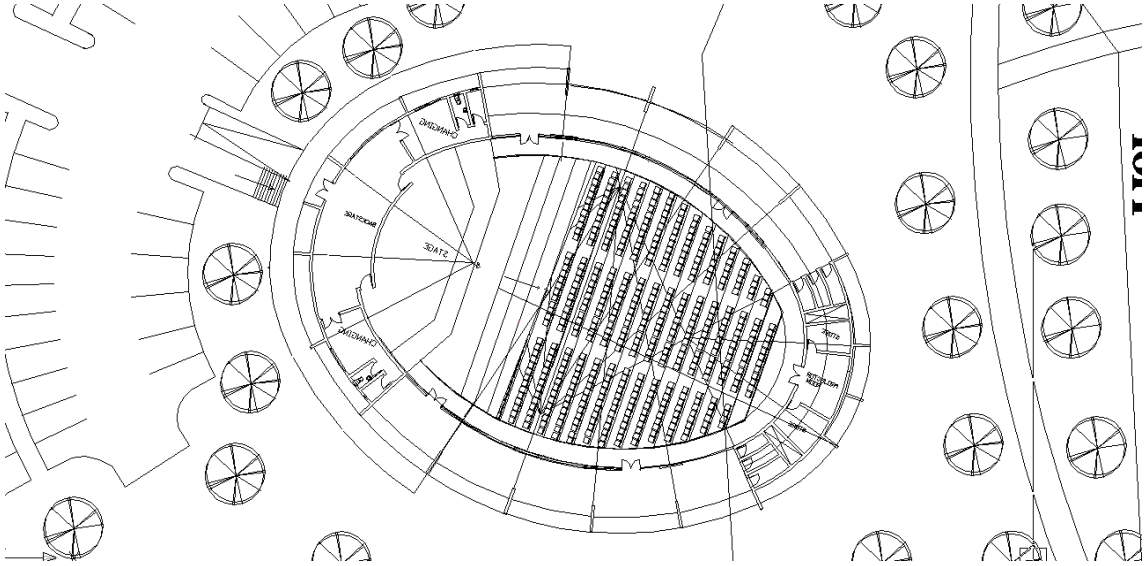


Fig 7.13: Hall design of floor plan
Source: Author

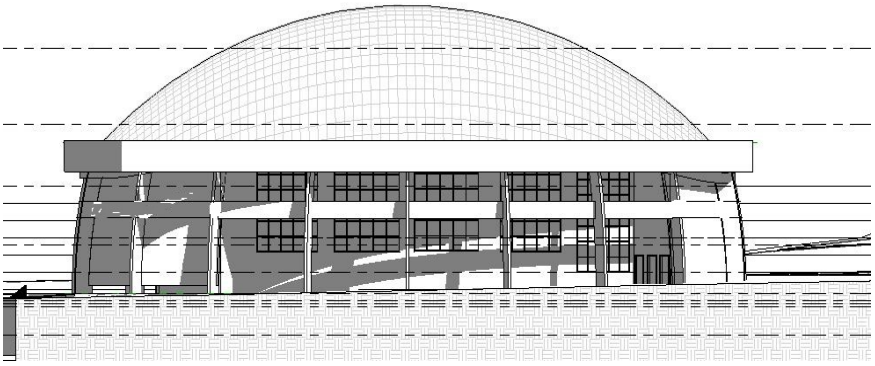


Fig 7.14: Hall design of elevations
Source: Author

7.4.7 Health centre design

The health was divided into two parts: the main health centre, and hydrotherapy centre. All of these are linked with passages and serviced with staircases to adjoining floors. The use of a courtyard with lower inlets maximizes the use of stack effect for cooling.

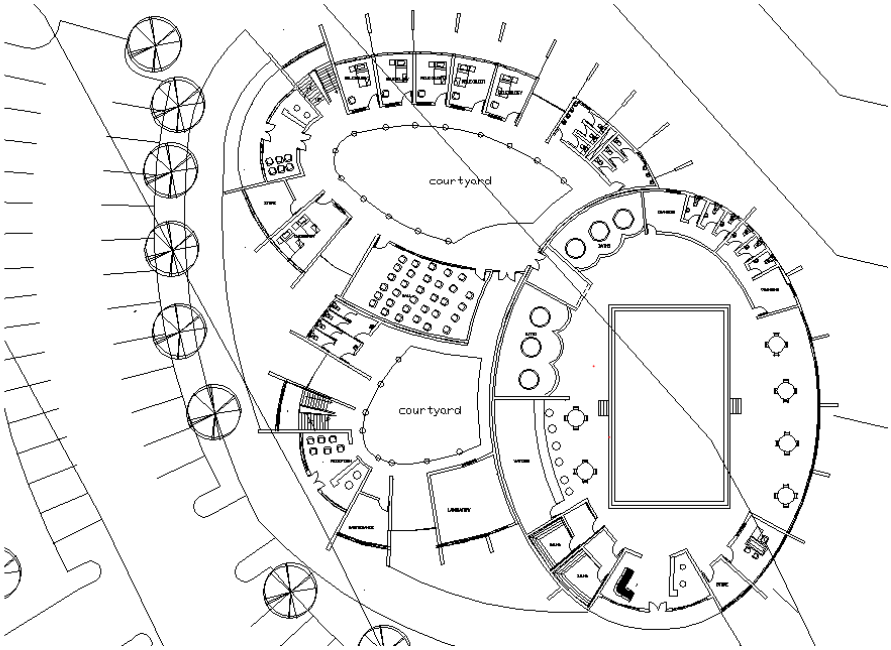


Fig 7.15: Ground floor health centre
Source: Author, 2010

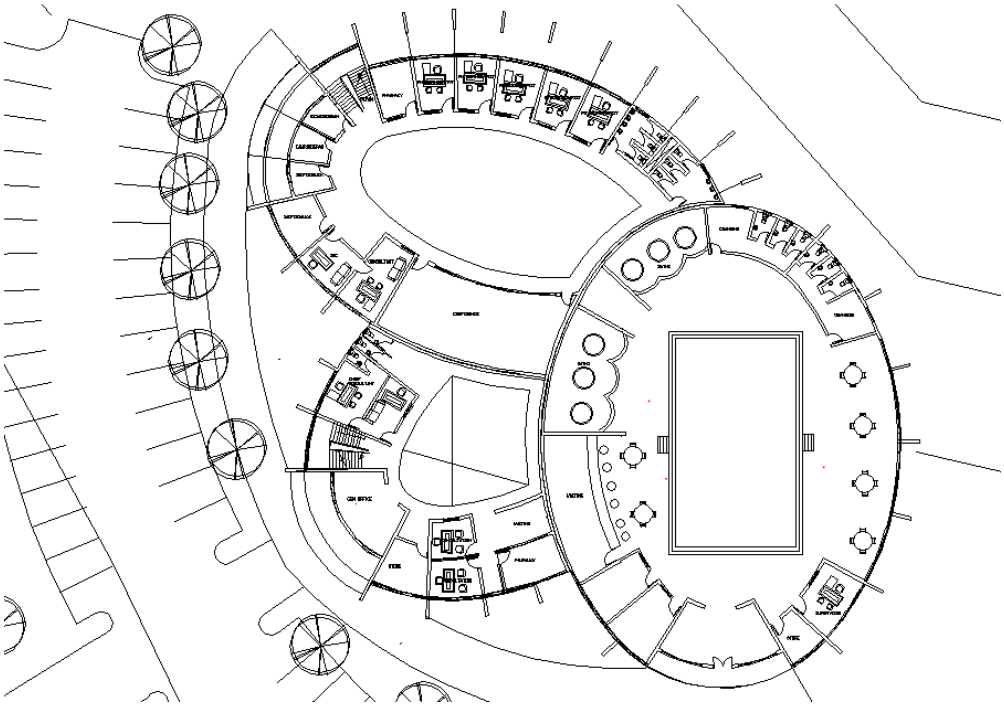


Fig 7.16: 1st floor plan, health centre
Source: Author

7.4.8 Fitness centre design

Planning principles were centered on creating a comfortable Environment through the use of natural endowments created by God, thus, the building was sited on the natural slopes of the

of the site. The Atriums helps to create vertical circulation of air and enhances the penetration of natural day lighting into the building. Some parts of the interior features natural elements such as pools and flowers to create a natural habitat like that of the surrounding Environment.

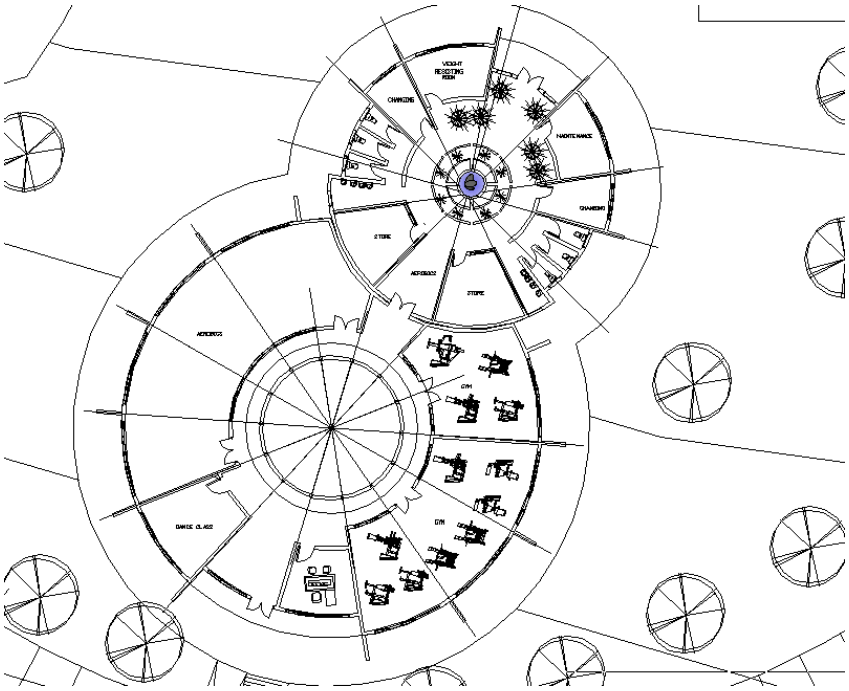
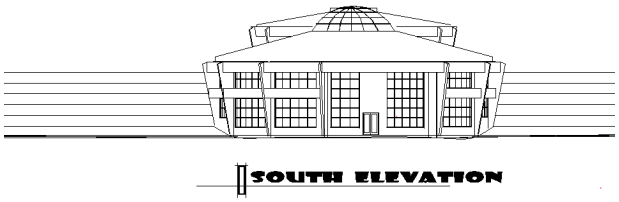


Fig 7.17: Fitness centre design, floor plan
Source: Author



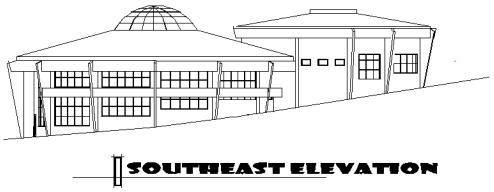


Fig 7.18: Front and side Elevations fitness centre
Source: Author

7.5 SCHEDULE OF ACCOMMODATION

HEALTH CENTRE		
Space	**units**	**Floor area/unit(m^2)**
Reception	1	9.0
Waiting	1	18.
Offices for physiotherapists	4	10.0
Reflexology- male	4	6.0
Reflexology- female	4	6.0
Emergency	1	9.0
Electrocardiogram exercise rooms	2	21.0
Biofeedback rooms	2	21.0
Herb and drug stores	2	21.0
Public toilets	6	1.8.0
Stress Clinic.	1	12.0
Program Consultant Office.	1	9.0
Conference	1	82.0
Hall	1	85.0
HYDROTHERAPY CENTRE		
Space	**units**	**Floor area/unit(m^2)**
Reception	1	18.0
Waiting	1	18.0
First aid	1	19.0
Public toilets	6	2.0
Aquatic Exercise Pool	1	175.0
Changing Room for Gents.	1	11.5
Changing Room for Ladies.	1	11.5
Plunge For Ladies.	4	12.0
Plunge for Gents.	4	12.0
Sauna for Ladies.	1	12.0
Sauna for Gents.	1	12.0
Steam bath Room for Gents	1	15.0
Steam bath Room for Ladies	1	15.0
Pool Bar.	1	42.0
Male Changing Room.	3	2.0
Female Changing Room.	3	2.0

MULTIPURPOSE HALL		
Space	**units**	**Floor area(m^2)**
Audience seating	1	450.0
Thrust stage	1	93.0
Public toilets	6	2.0
lower lobby	1	
Power switch room/HVAC control	1	7.5
Maintenance/store/security offices	1	7.5
Backstage	1	37.0
Changing	2	14.2

FITNESS CENTRE		
Space	**units**	**Floor area(m^2)**
Reception	1	6.0
Waiting	1	12.0
Gymnasium male	1	76.0
Gymnasium female	1	52.0
Stores	2	16.6
Toilets- male	3	2.2
Toilets-female	3	2.3
Changing Room for Gents.	1	9.0
Changing Room for Ladies.	1	9.0
Maintenance	1	15.0
Dance Class.	1	48.0
Aerobics Studio.	1	76.0
Gymnasium Supervisor's Office.	1	9.0
Program Consultant Office.	1	9.0
Machine and Weight Resisting Room.	1	15.0

ADMINISTRATION		
Space	**units**	**Floor area(m^2)**
Reception	1	12.0
Public toilets	6	2.0
conference	1	62.0
Staff lounge	1	
Staff Training Room For Management.	1	62.0
General Managers Office.	1	18.0
Secretary to General manager.	1	11.0
Accountant Office	1	12.0

General Office.	1	27.0
Purchasing Manager's Office.	1	12.0
Security Maintenance Section.	1	18.5
GUEST CHALETS		
Space	**units**	**Floor area(m^2)**
Guest chalets- semi detached	12	
Single unit guest chalets	12	
RESTAURANT		
Space	**units**	**Floor area(m^2)**
Reception.	1	11.5
Dining	2	380.0
Family dining	1	270.0
Lounge.	4	12.0
Outdoor dining	1	
Kitchen.	2	70.0
Open kitchen	1	
Dry Store.	1	9.0
Space	**units**	**Floor area(m^2)**
LAUNDRY		
Service counter	1	10
Washing area	1	20
Drying area	1	50
Dry cleaning	1	15
Office	1	4

Table 7.1: Schedule of accommodation
Source: Author, 2010

7.6 SITE EXTERNAL WORKS

The location of this resort is on a site of advantageous interest and as described in the selection criteria. Therefore, its potentials were fully exploited to generate more revenue and create an environment that will be soothing to its guests.

7.6.1 GUEST CAR PARKING

The concept of the car parking lot of this resort was chosen to achieve separate parking

spaces for all the separate units on the site.

The advantages are:

i. This minimizes trekking distances.

ii. It reduces congestion of cars in a spot.

iii. The zoning of some of the parking spaces, for conference guests, shoppers would allow for an effective use of these facilities without necessarily congesting the main entrance to the resort.

7.6.2 LANDSCAPING AND GARDENS

Gardens, adequately located and shaded from the western sun were provided. Users of this garden are protected from the effects of the harmattan wind by the location of trees in the path of the wind. These gardens, were strategically located where users may appreciate the beauty, provide for social support, access to nature and some form of exercise. They are equipped with the following garden furniture; garden seats, lighting, green lawns and litter cans fixed to the lighting poles.

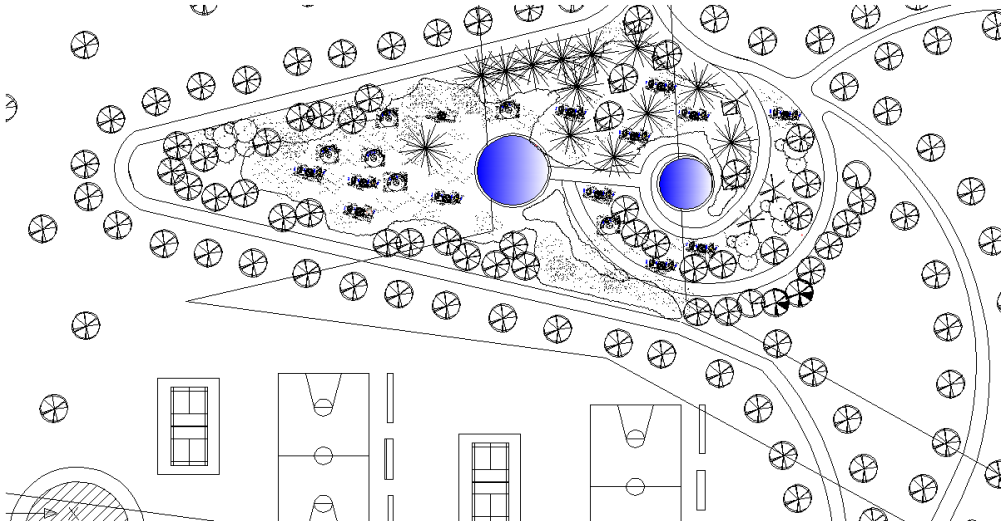


Fig 7.19: Floor plan garden and outdoor games
Source: Author

7.6.3 SWIMMING POOLS

Indoor swimming pools, plunge pools, outdoor adult and the children's pools were provided within a paved area. These pools were located in the part of the site which offers guests the best view of the beautiful lake. Users of the pool were offered a pool bar with the bar stools offering users snacks and non-alcoholic drinks. They are also offered a good view of the lake and surrounding mountains, the intention being to create environment of "total recreation and relaxation" for the users.

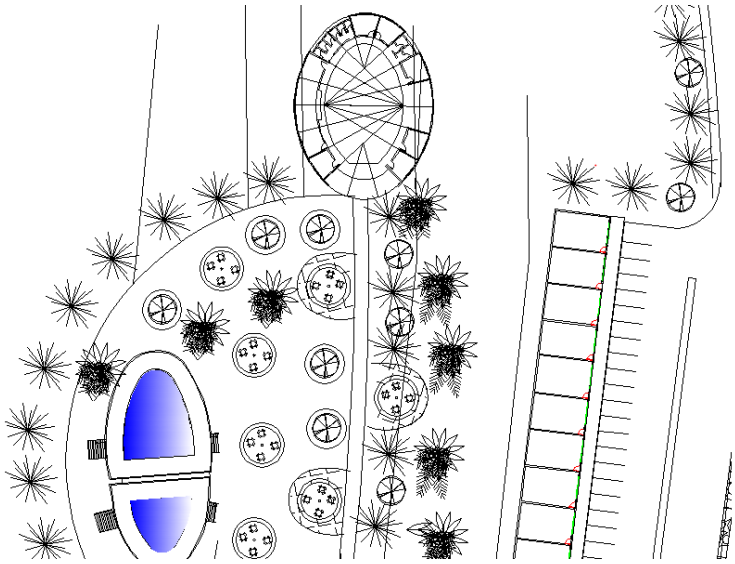


Fig 7. 20: Floor plan relaxation area,swimming pool and shops
Source: Author

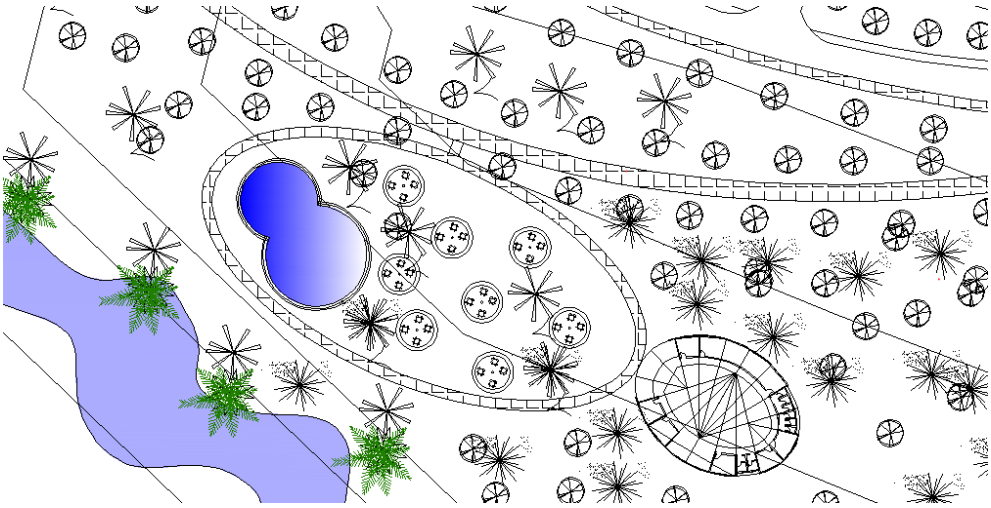


Fig 7. 21: Floor plan relaxation area,swimming pool and shops Source: Author

7.7 SERVICES

7.7.1 Mechanical Engineering Services and Equipment

i. Water Supply

This resort complex is linked with the mains of water supply of the neighbouring city for supply of water for such needs as, food preparation, cleaning and general domestic purposes, firefighting, coo1ing and softening plant, boilers, laundries and swimming pools.

ii. Water Harvesting and Water Conservation Technique

Harvesting, processing and recycling rainwater, site storm water, and grey-water and identification of appropriate uses within the building and site.

Use of on-site treatment systems that enable use of rain water for hand washing, grey-water for toilet flushing, rain and storm water for site irrigation, and other uses.

Design and location of buildings and site improvements to optimize use of low-impact storm water technologies such as, rain gardens, open grassy swales, pervious bituminous paving, pervious concrete paving and walkways that support on-site retention and ground water recharge or evapo-transpiration

iii. Water Storage, Distribution and Pressure

Sufficient water equal to at least 100% of the daily requirement is stored in tanks, to ensure continuity of supply and a suitable constant pressure. All pumping equipment is duplicated with provision for isolation, drainage and repairs.

To avoid the complexity of water supply and distribution systems which resorts are noted for, the following pipe networks were provided for in this design;

a. Cold water supply for drinking (may be chilled)

b. Cold and hot water distribution to bathroom fittings

c. Supplies to water closet flushing values

d. Hot and cold water distribution to toilets

e. Supplies to sprinklers located in gardens hedges and lawns.

f. Domestic hot water is supplied at 50^0C

g. Chilled water for drinking is supplied at 10^0C.

iv. Waste And Sewage Disposal

Most solid waste is to be disposed of at the communal tipon. Most plastic, glass and metal waste is sorted out and recycled, and organic waste is composted on site. The liquid waste is to be initially stored in septic tanks and later pumped and processed at a sewage plant.

7.7.2 ELECTRICAL ENGINEERING SERVICES

i. Primary and Emergency Supplies

Energy sources include the use of renewable energy sources such Building Integrated Photovoltaic Panels (BIPVs) and Building Integrated Wind Turbines to maximize energy efficiency within the building

The total output of the generator is a minimum of 30% of the normal maximum, covering the following services;

a. Lighting: all bollards in walkways, and 10-29% of lighting all public areas.

b. All sewage pumps and water pumps to main hot and cold water supplies and partial heating or cooling.

c. Partial services to kitchens

d. Food refrigerators and cold rooms.

ii. Maintenance Services

Access for maintenance services was provided to:

a. Chalets for locating heating, circulation and control equipment (pumps, valves, boiler room equipment and electrical switchgear).

b. Ceiling housed engineering services and equipment A/C ductwork, lighting fittings, control and relay equipment.

c. Wall mounted equipment, socket outlets, vacuum connections, light switches.

CHAPTER EIGHT

CONCLUSION.

8.1 SUMMARY OF FINDINGS

The introduction to the research began by establishing the natural principles and approaches to biomimicry and its relevance in architecture, further discussing how this vocabulary can be translated appropriately to find technical applications of these principles in the built form.

The objective of this study was to explore the principles of biomimicry,and apply it as a design concept in the design of resorts. Exploring these principles serve as a means of safeguarding against the deterioration of the ecology and providing economically viable means of energy generation. The studies carried out in the course of this research have shown that buildings account for up to 50% of total energy consumption with heating and cooling accounting for most of the energy demands in buildings. The effect on resorts and other related tourism accommodation in Nigeria is that energy has to be generated privately to sufficiently cater for the energy demands of such institutions.

The inferences drawn from these findings are the application of some of the mentioned principles of biomimicry design features in resort designs in Nigeria , it is possible that the tourism industry will become more viable since it will enhance the comfortable accommodation of tourists while not compromising the quality of the environment. It is also important that buildings are designed with the thought of reducing energy consumption by optimized building siting, orientation and proper material selection to reduce total energy consumption and the need for air conditioning.

8.2 RECOMMENDATION

After exploring the use of biomimicry as a design concept, the following recommendations have been made.

i. Harvesting of renewable solar energy using Building Integrated Photovoltaics should be encouraged. This can help achieve high energy efficient buildings and provide economically viable means of energy generation.

ii. Application of concepts and techniques which are naturally derived for water management and reuse, thus safe guarding against the deterioration of the ecology of the immediate environment.

iii. Designs should be done in such a way that buildings can be ordered within the site to flow in and with the existing environment.

8.3 CONCLUSION

In view of the probable adverse impact Tourism and its related products have on the environment, reducing human impact on the environment becomes more critical as every day passes. The public, along with designers and clients, now realize the tremendous impact our buildings have on the natural and built environment. However, architects have to continually work towards providing congenial environment for the occupants of these buildings, let's encourage the use of architectural solutions based on the observation of natural principles that can reliably supplant artificial or mechanical means of energy generation and water management.

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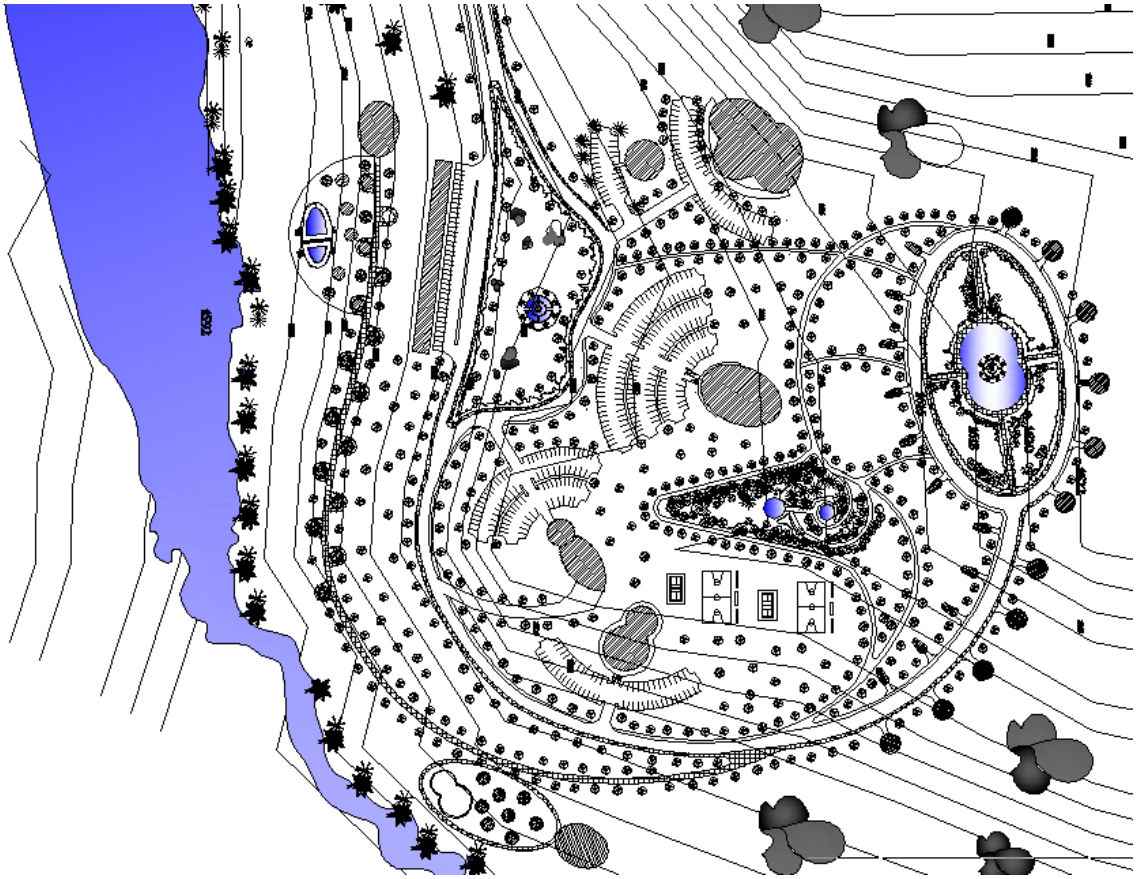
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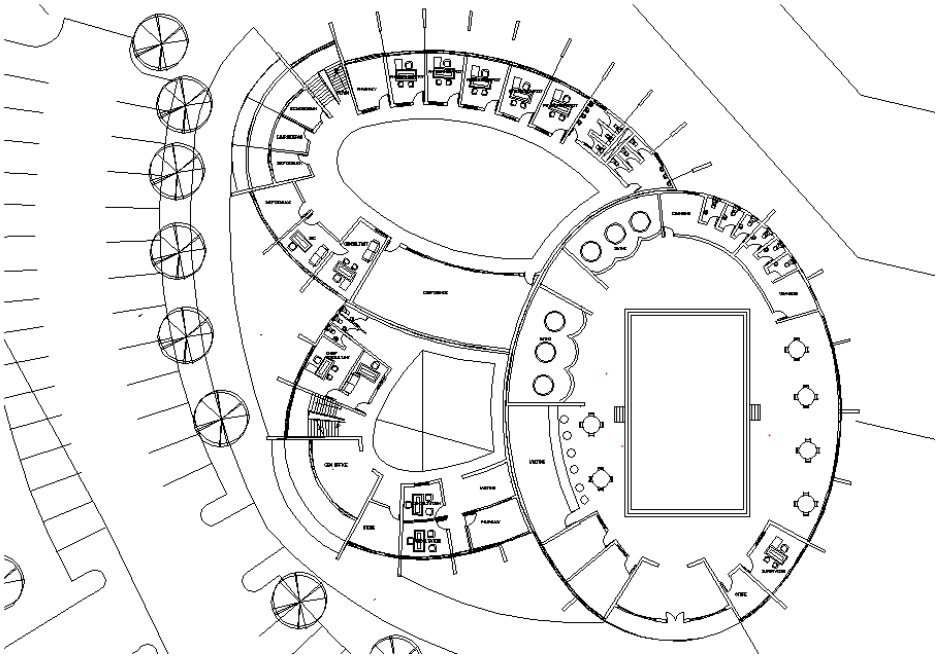
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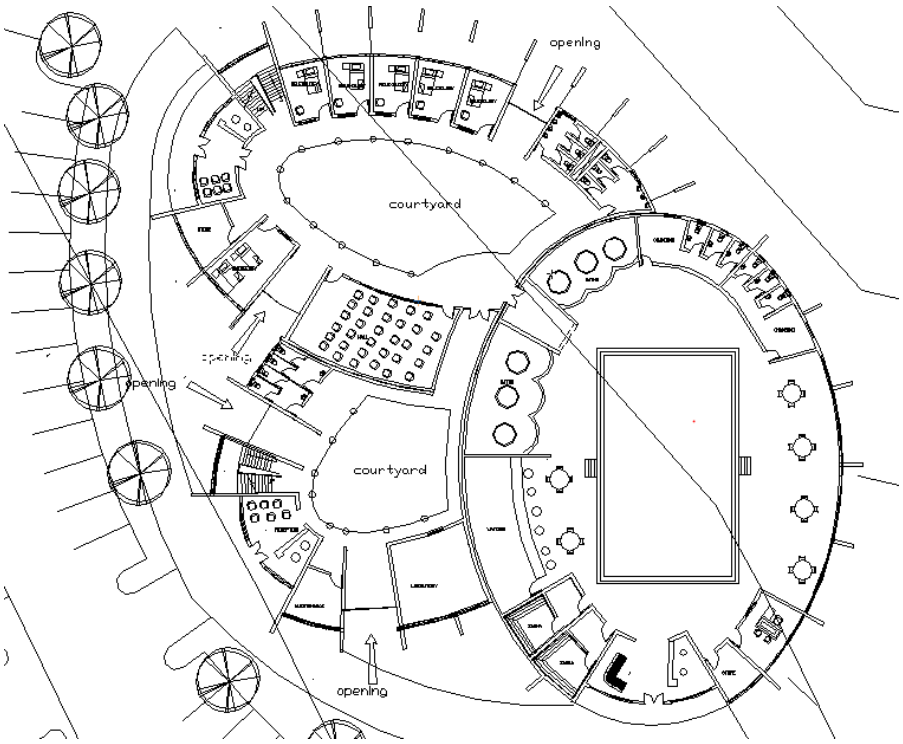
APPENDIX



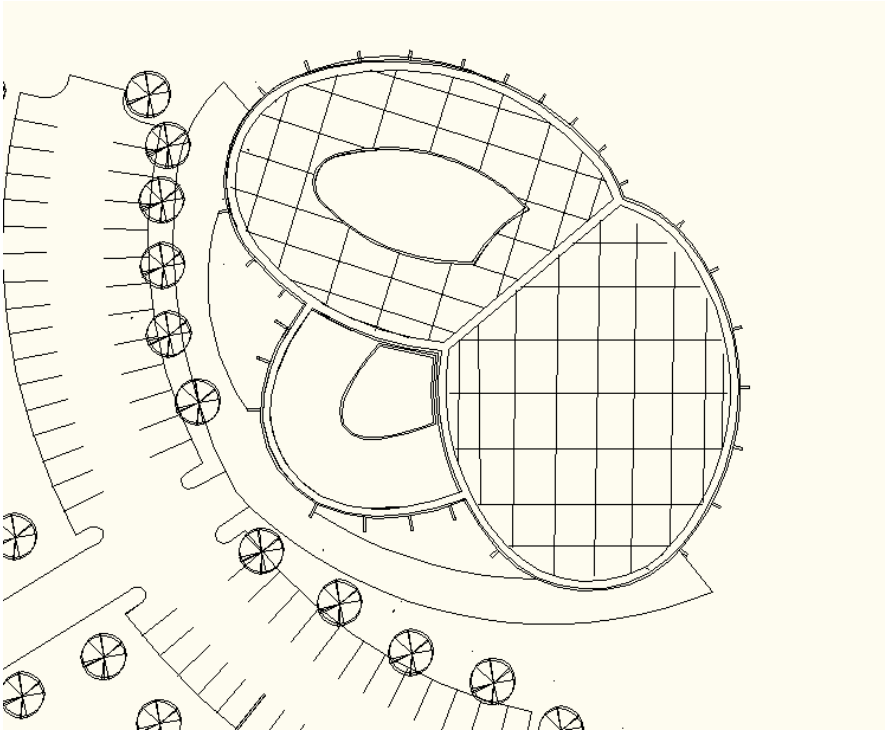
Appendix 1 SITE PLAN



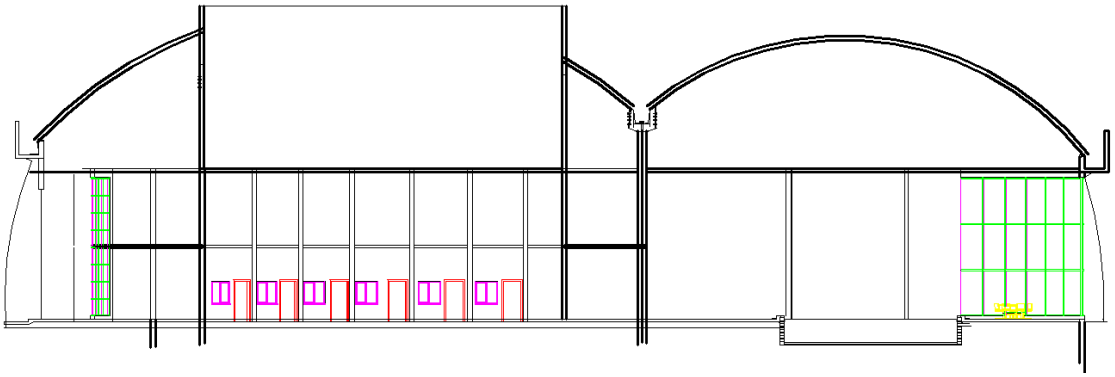
Appendix 2 HEALTH CENTRE GROUND FLOOR PLAN



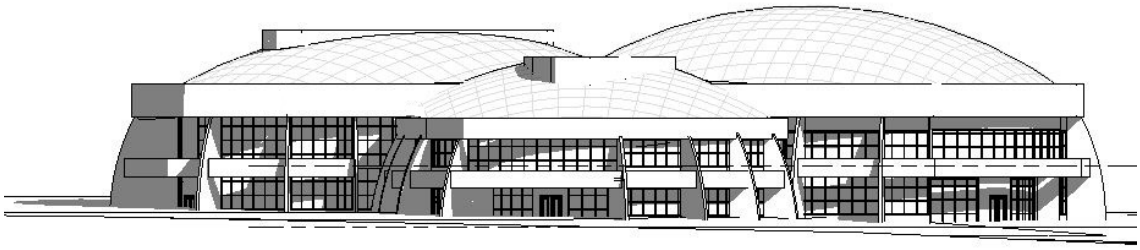
Appendix 3 HEALTH CENTRE 1ST FLOOR PLAN



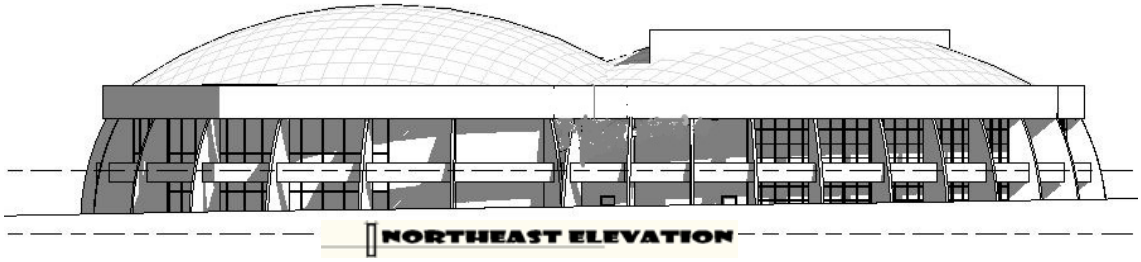
Appendix 4 HEALTH CENTRE ROOF PLAN



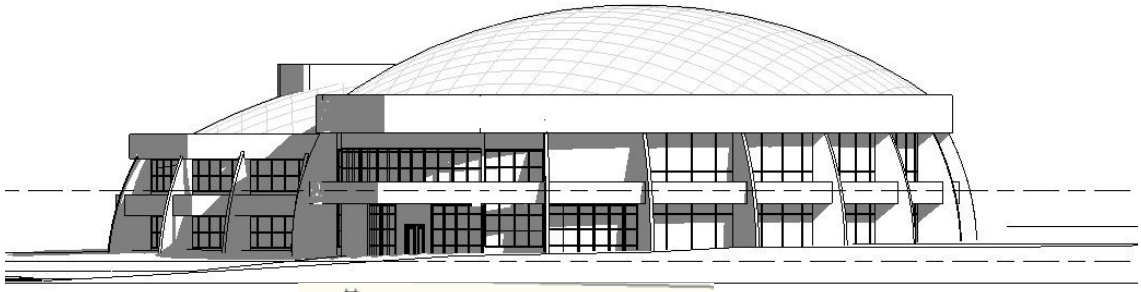
Appendix 5 SECTION A-A



SOUTHWEST ELEVATION



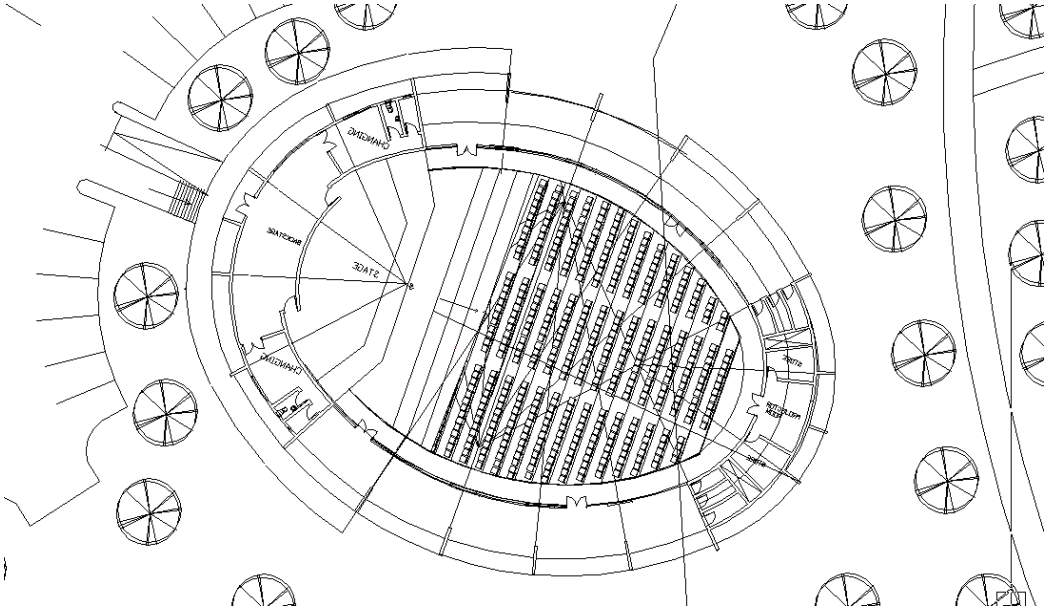
NORTHEAST ELEVATION



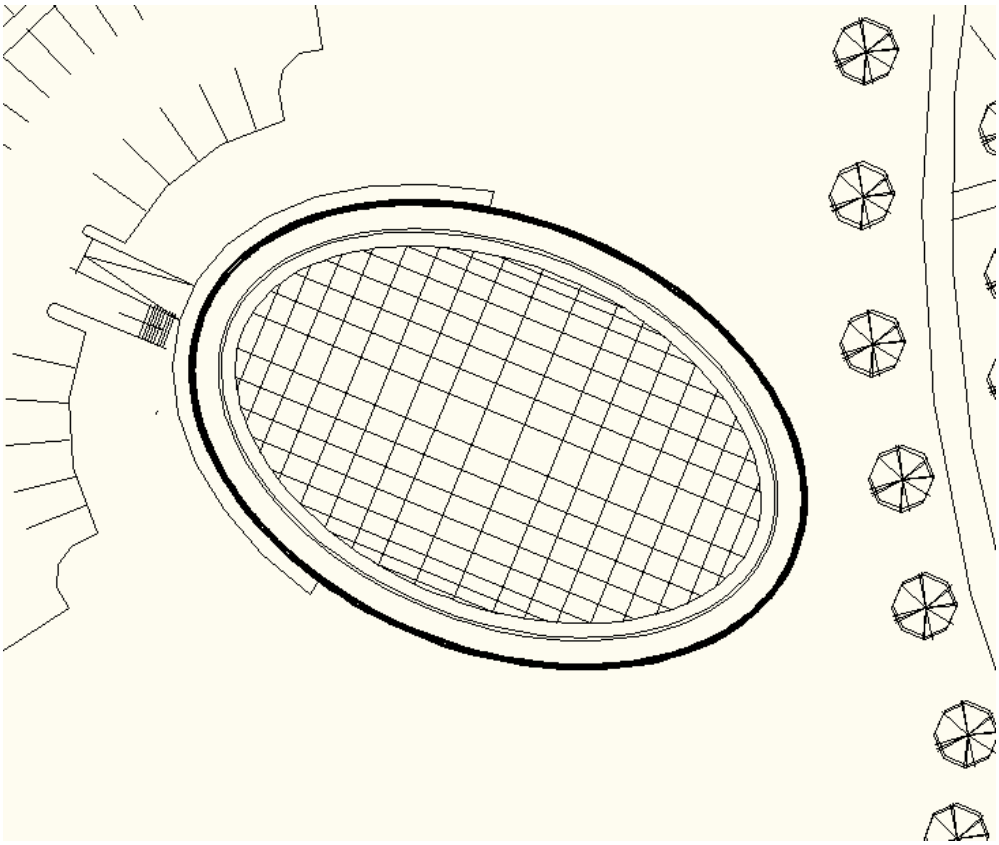
SOUTHEAST ELEVATION



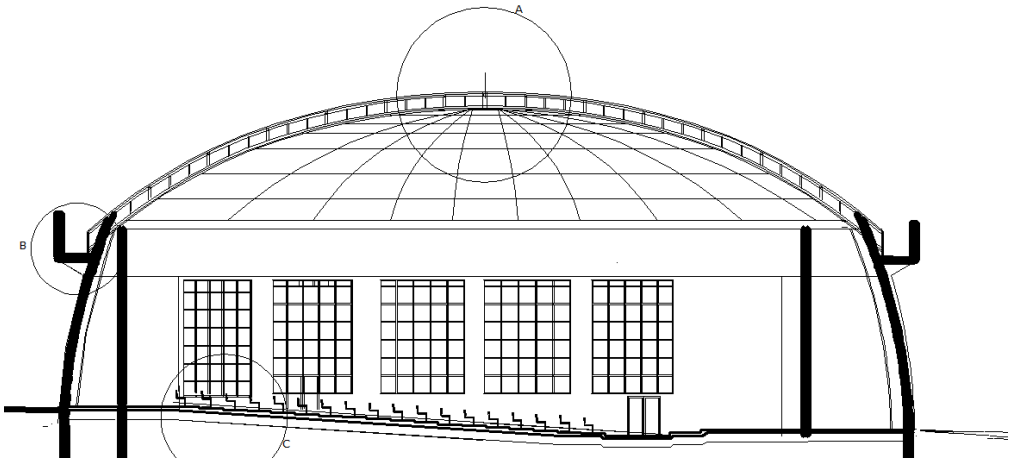
Appendix 6 ELEVATIONSOF HEALTH CENTRE



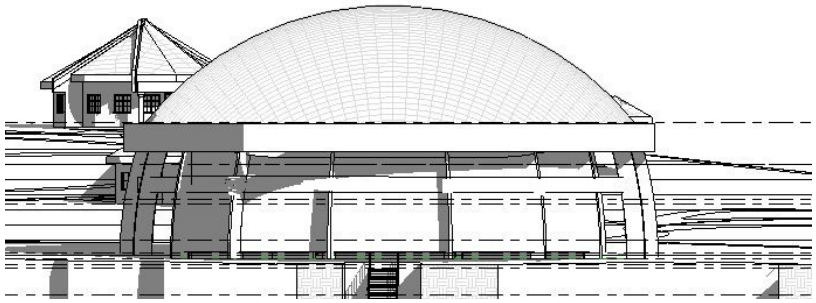
Appendix 7 FLOOR PLAN HALL



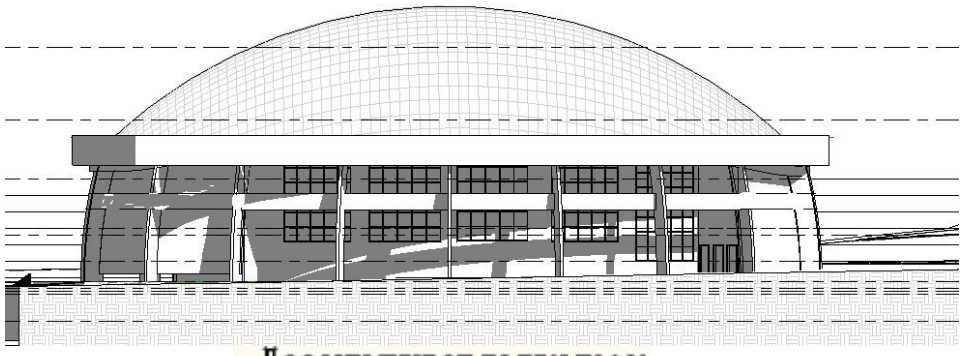
Appendix 8 ROOF PLAN HALL



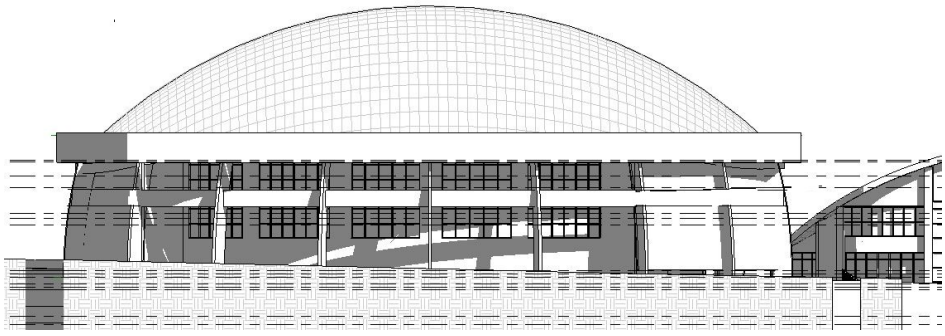
Appendix 9 SECTION THROUGH MULTIPURPOSE HALL



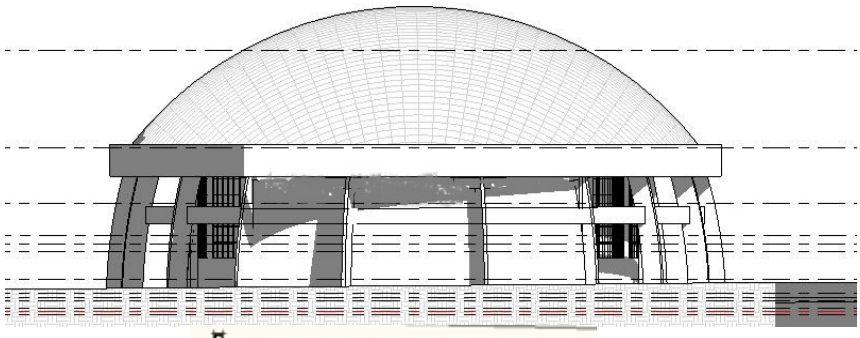
NORTHWEST ELEVATION



SOUTHWEST ELEVATION

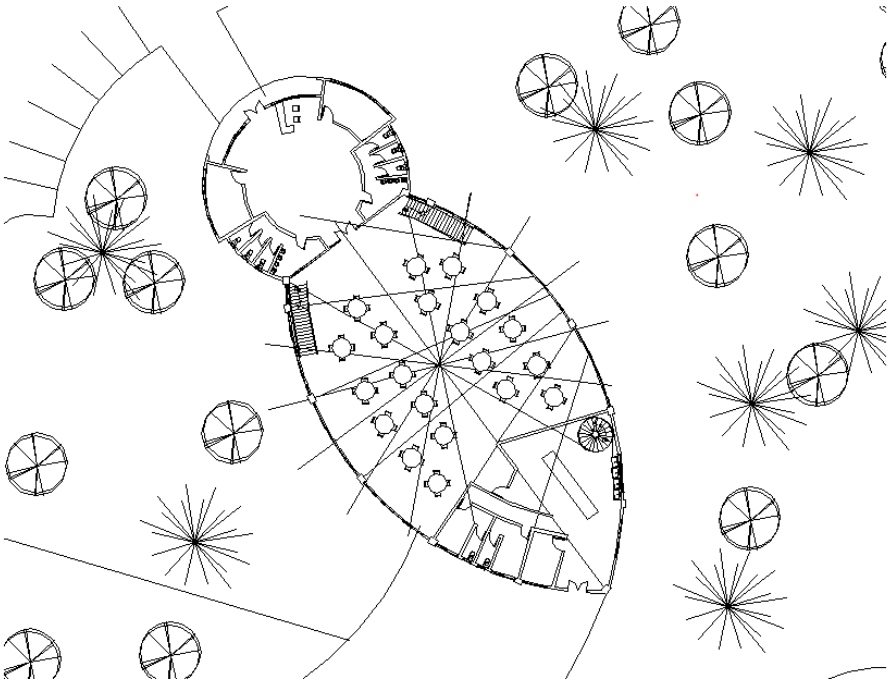


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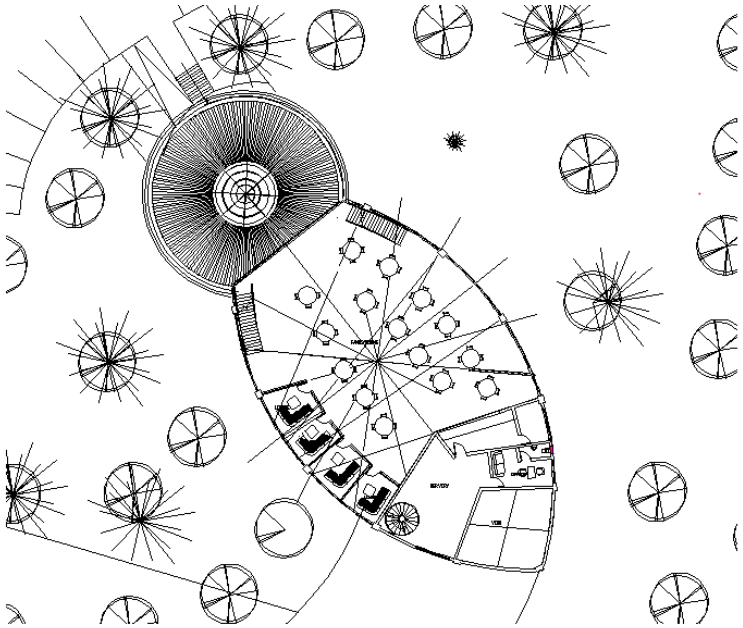


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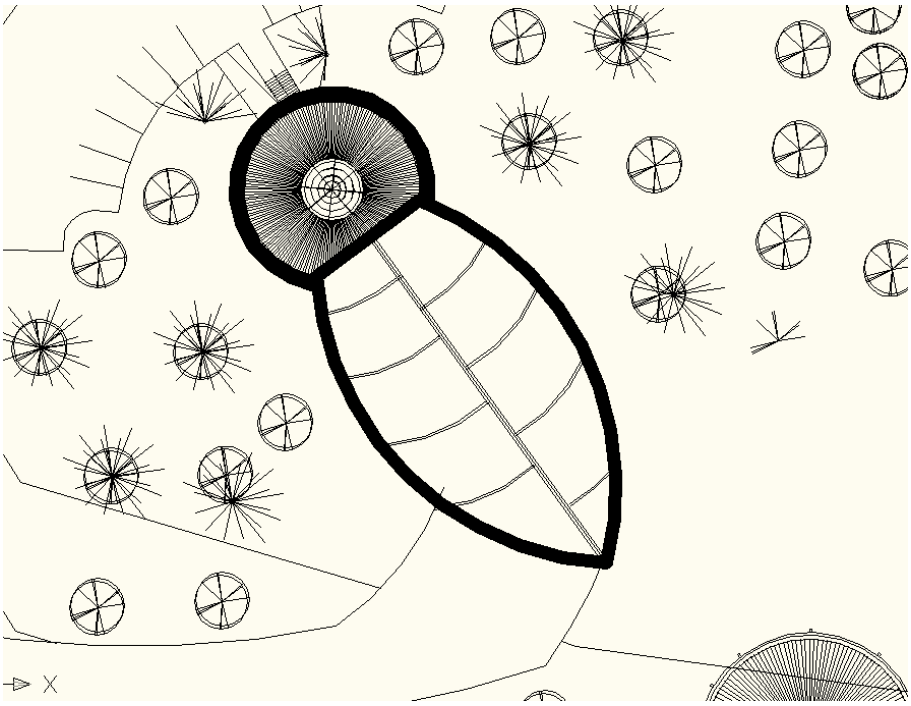
Appendix 10 ELEVATIONS-MULTIPURPOSE HALL



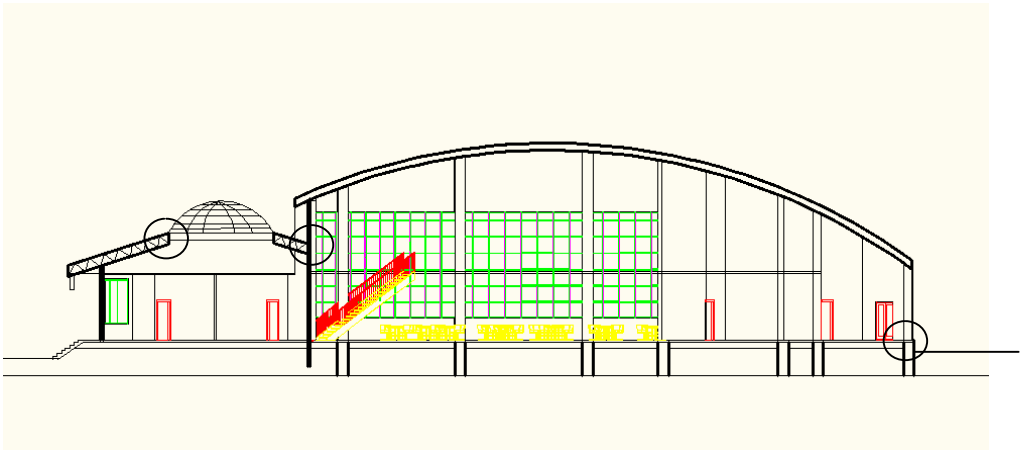
Appendix 11 GROUND FLOOR PLAN RESTAURANT



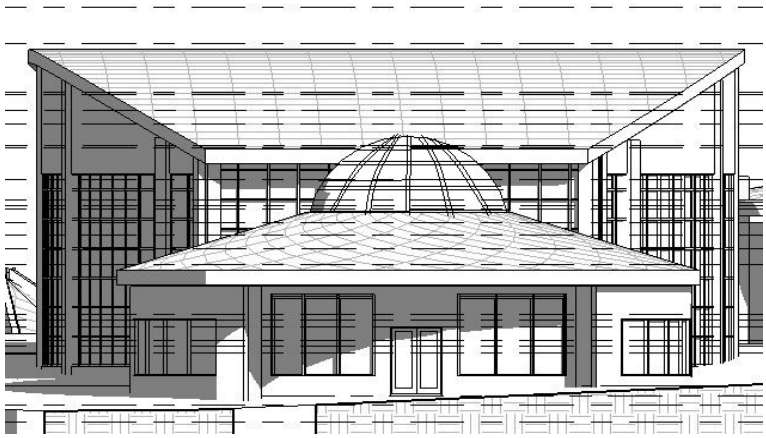
Appendix 12 1ST FLOOR PLAN RESTAURANT



Appendix 13 ROOF PLAN RESTAURANT



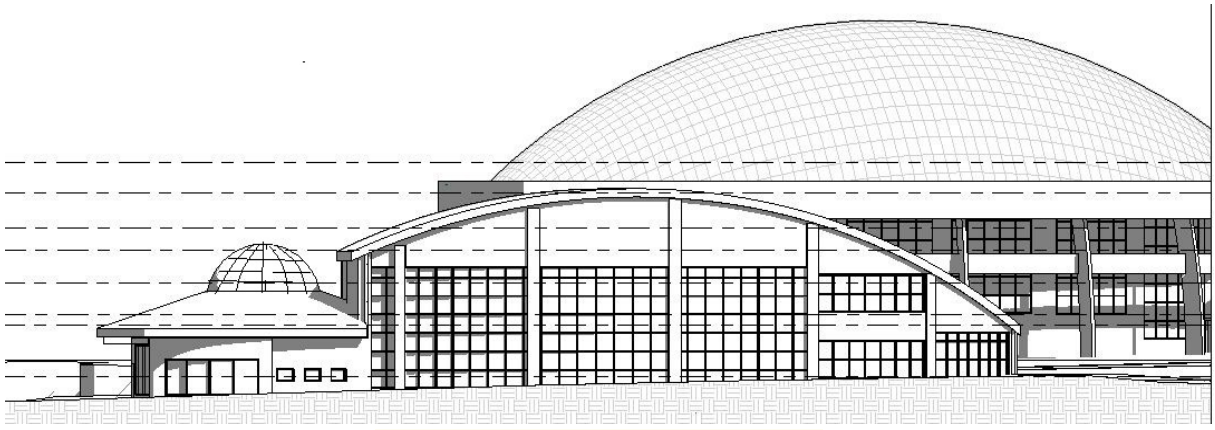
Appendix 14 SECTION RESTAURANT



NORTHWEST ELEVATION

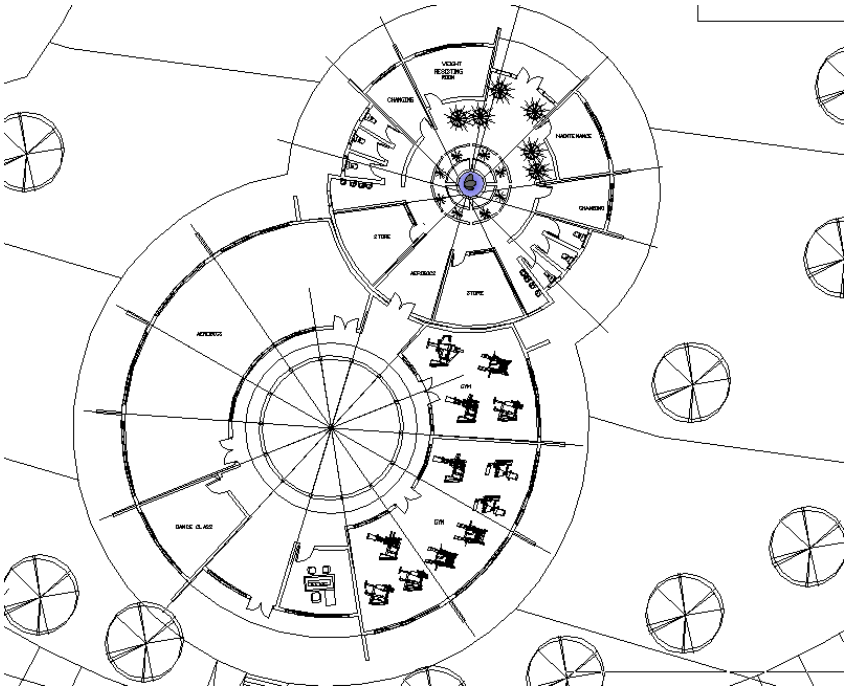


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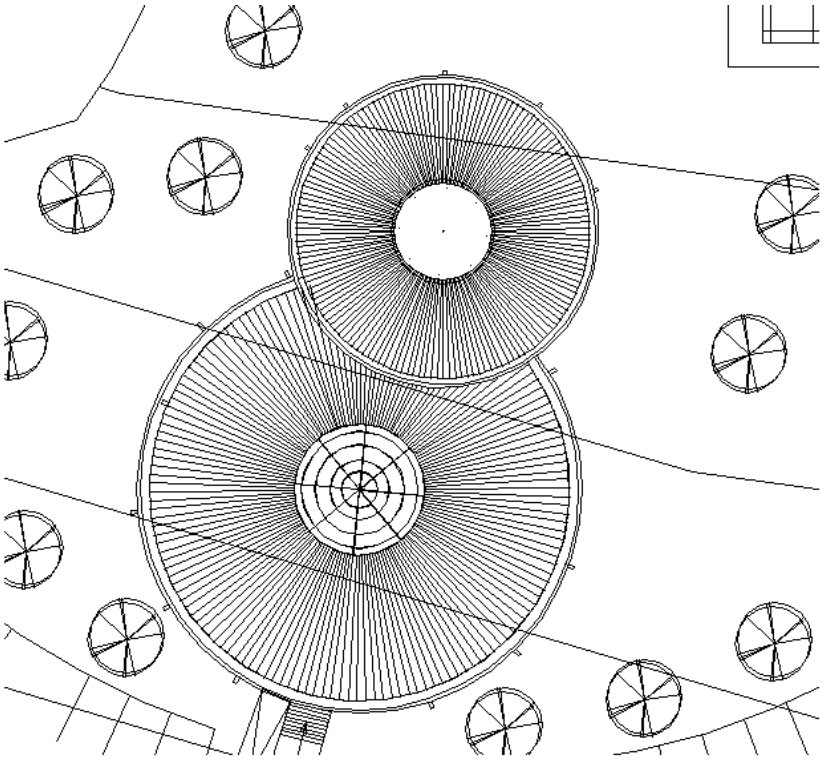


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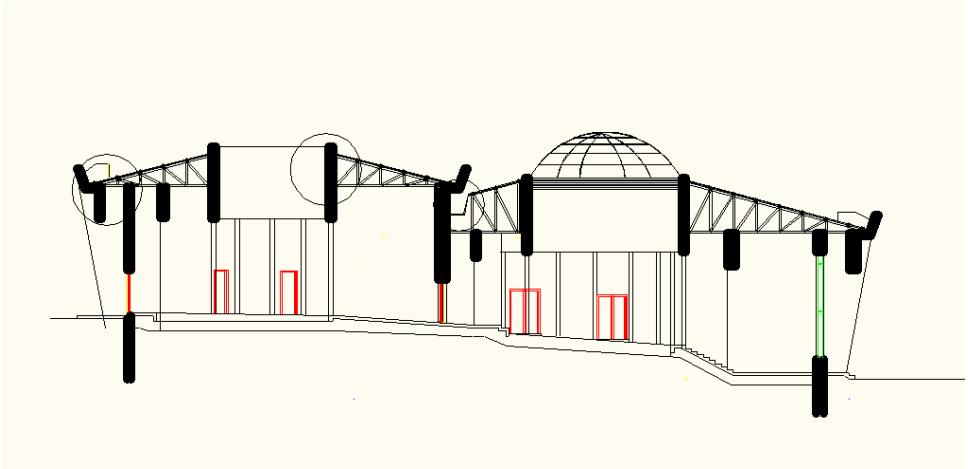
Appendix 15 ELEVATIONS RESTAURANT



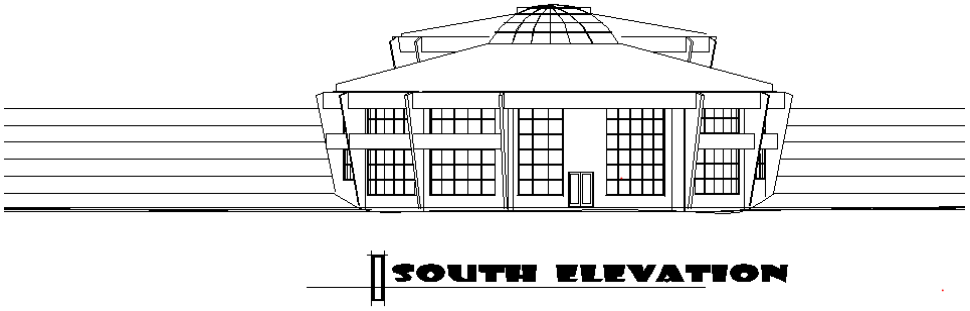
Appendix 16 FLOOR PLAN FITNESS CENTRE

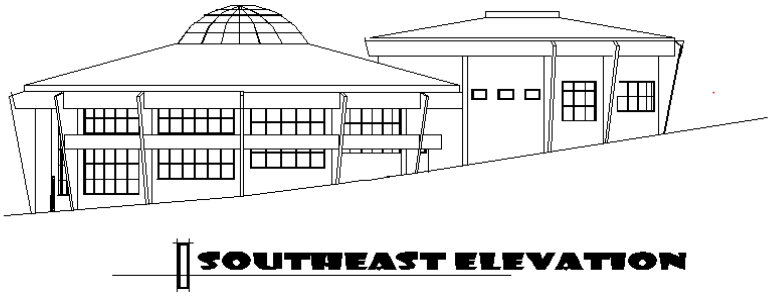


Appendix 17 ROOF PLAN FITNESS CENTRE



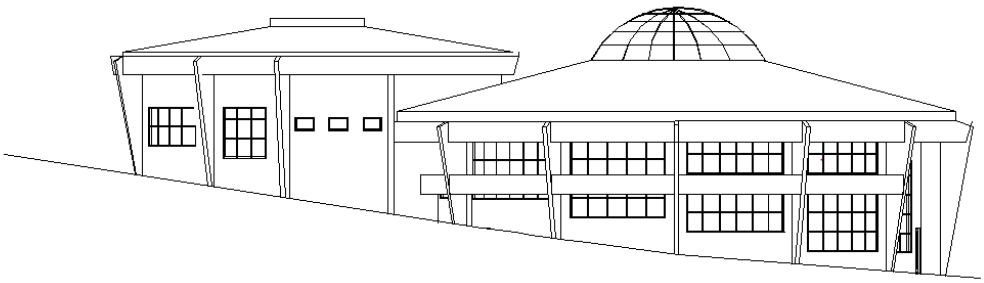
Appendix 18 SECTION FITNESS CENTRE





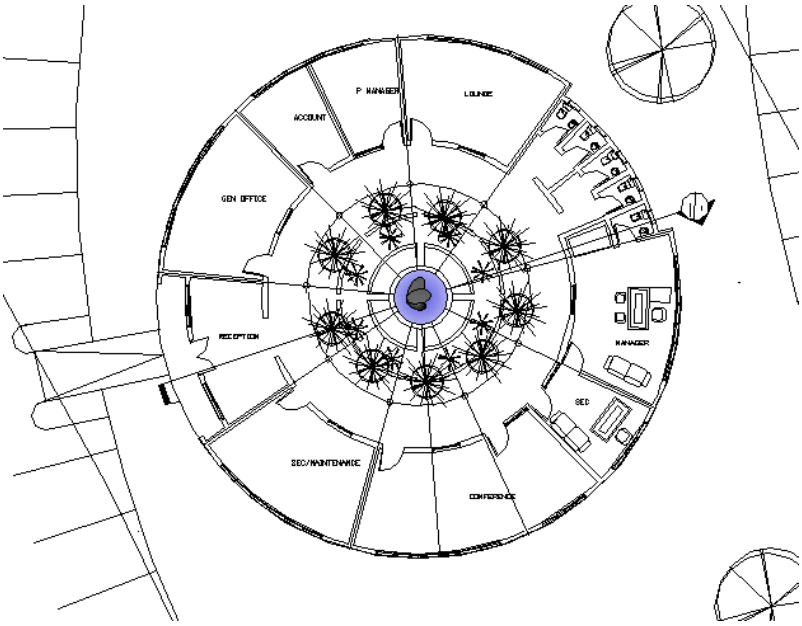


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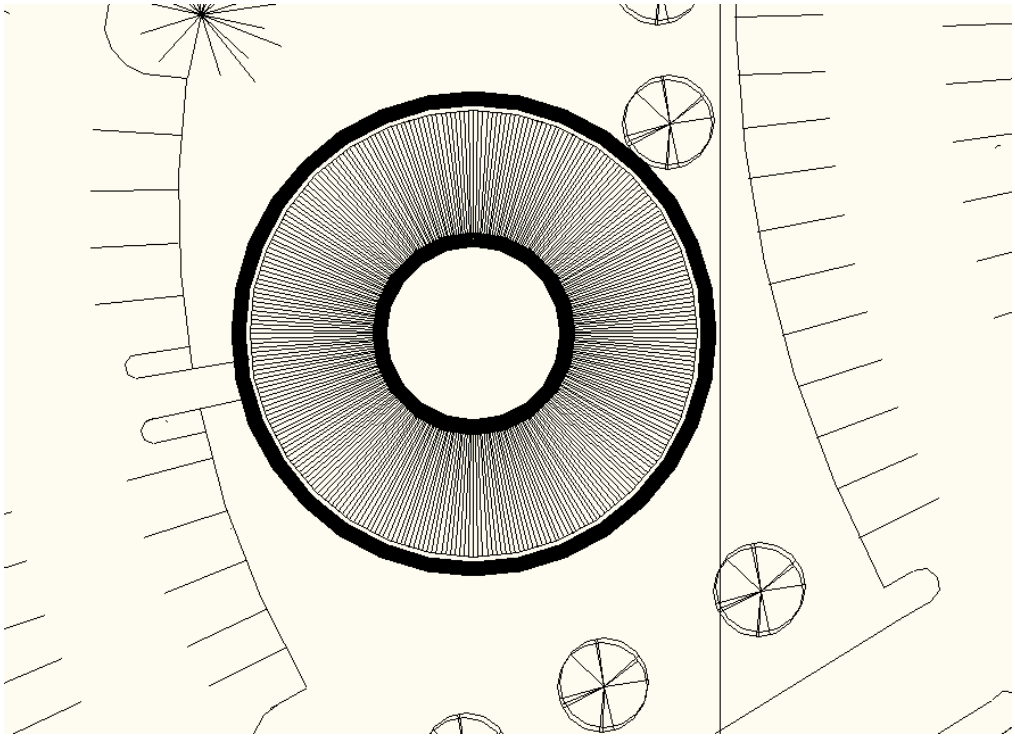


SOUTHWEST ELEVATION

Appendix 19 ELEVATIONS CENTRE



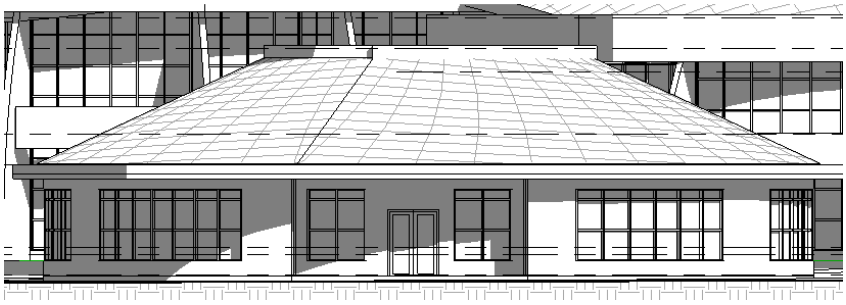
Appendix 20 FLOOR PLAN ADMINISTRATION

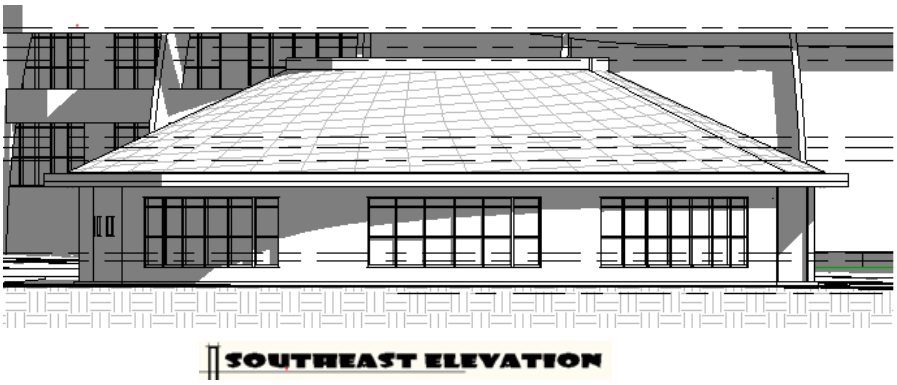


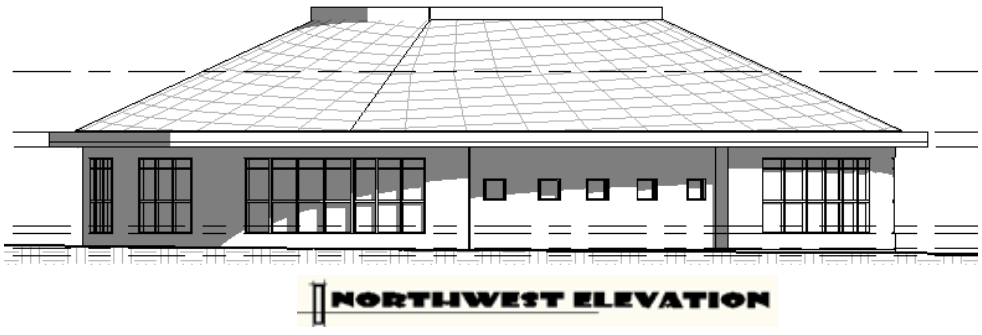
Appendix 21 ROOF PLAN ADMINISTRATION



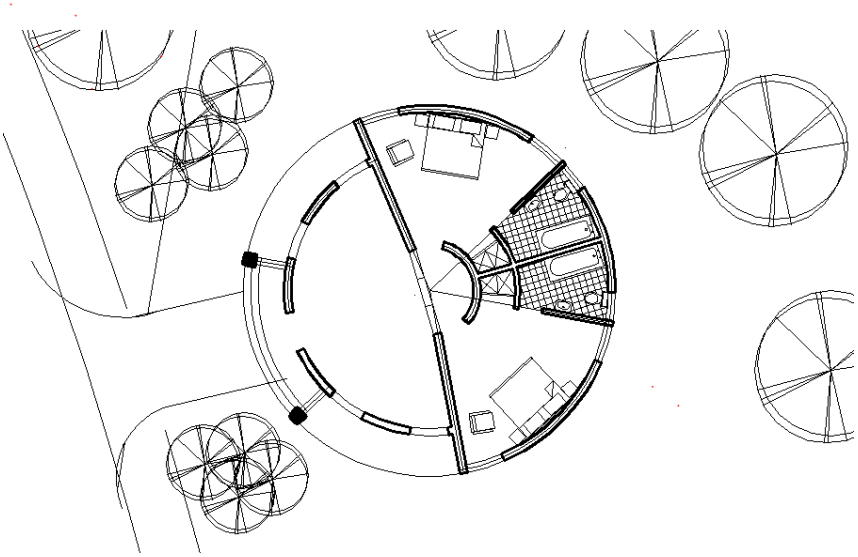
Appendix 22 SECTION ADMINISTRATION



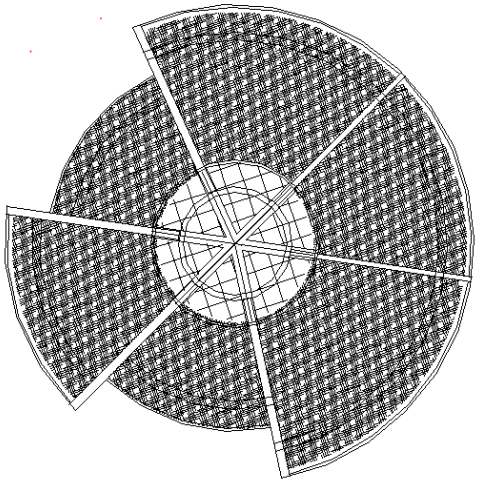




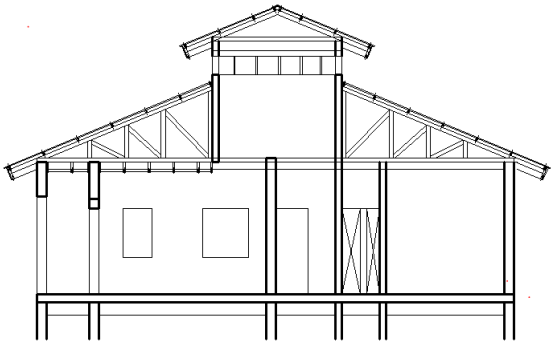
Appendix 23 ELEVATIONS ADMINISTRATION



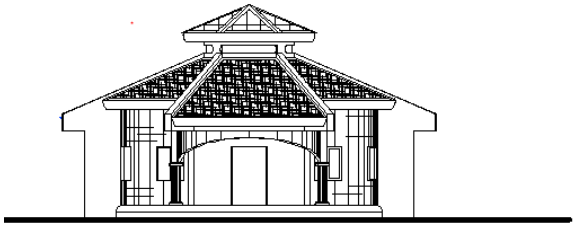
Appendix 24 FLOOR PLANS 2 BEDROOM CHALET



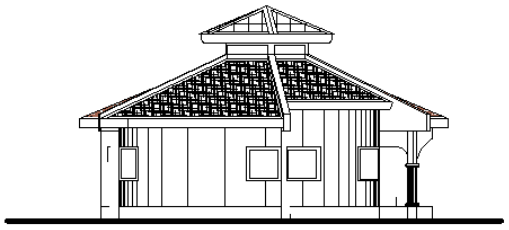
Appendix 25 ROOF PLAN 2 BEDROOM CHALET



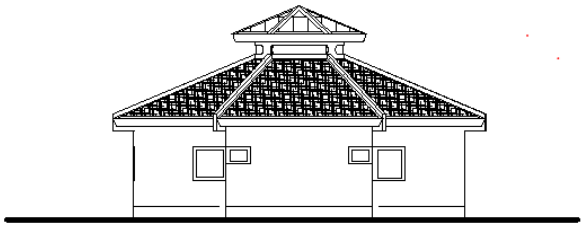
Appendix 26 SECTION 2 BEDROOM CHALET



TYPICAL APPROACH ELEVATION

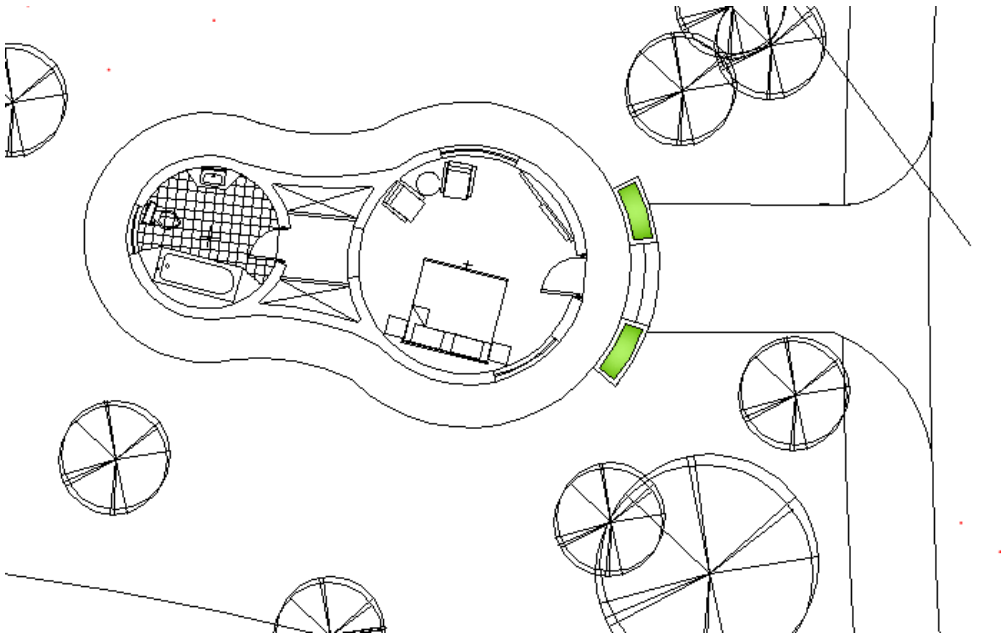


TYPICAL SIDE ELEVATION

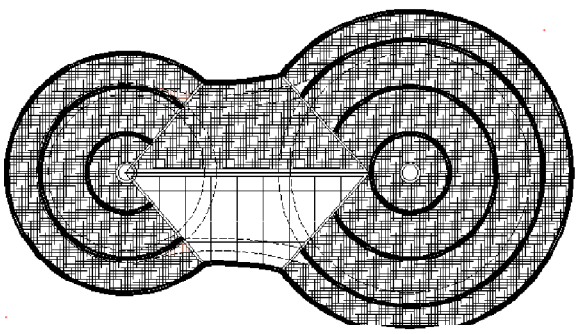


REAR ELEVATION

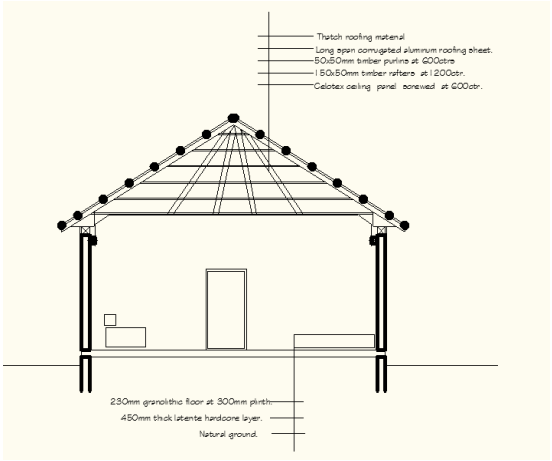
Appendix 27 ELEVATIONS 2 BEDROOM CHALETS



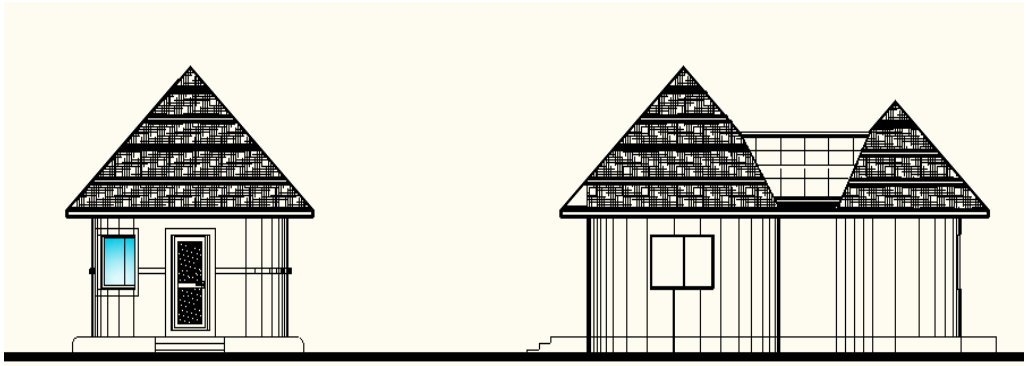
Appendix 28 FLOOR PLANS 1 BEDROOM CHALET



Appendix 29 ROOF PLAN 1 BEDROOM CHALET

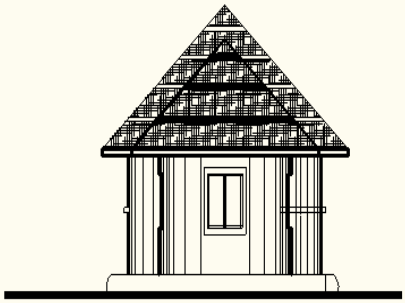


Appendix 30 SECTION 1 BEDROOM CHALET



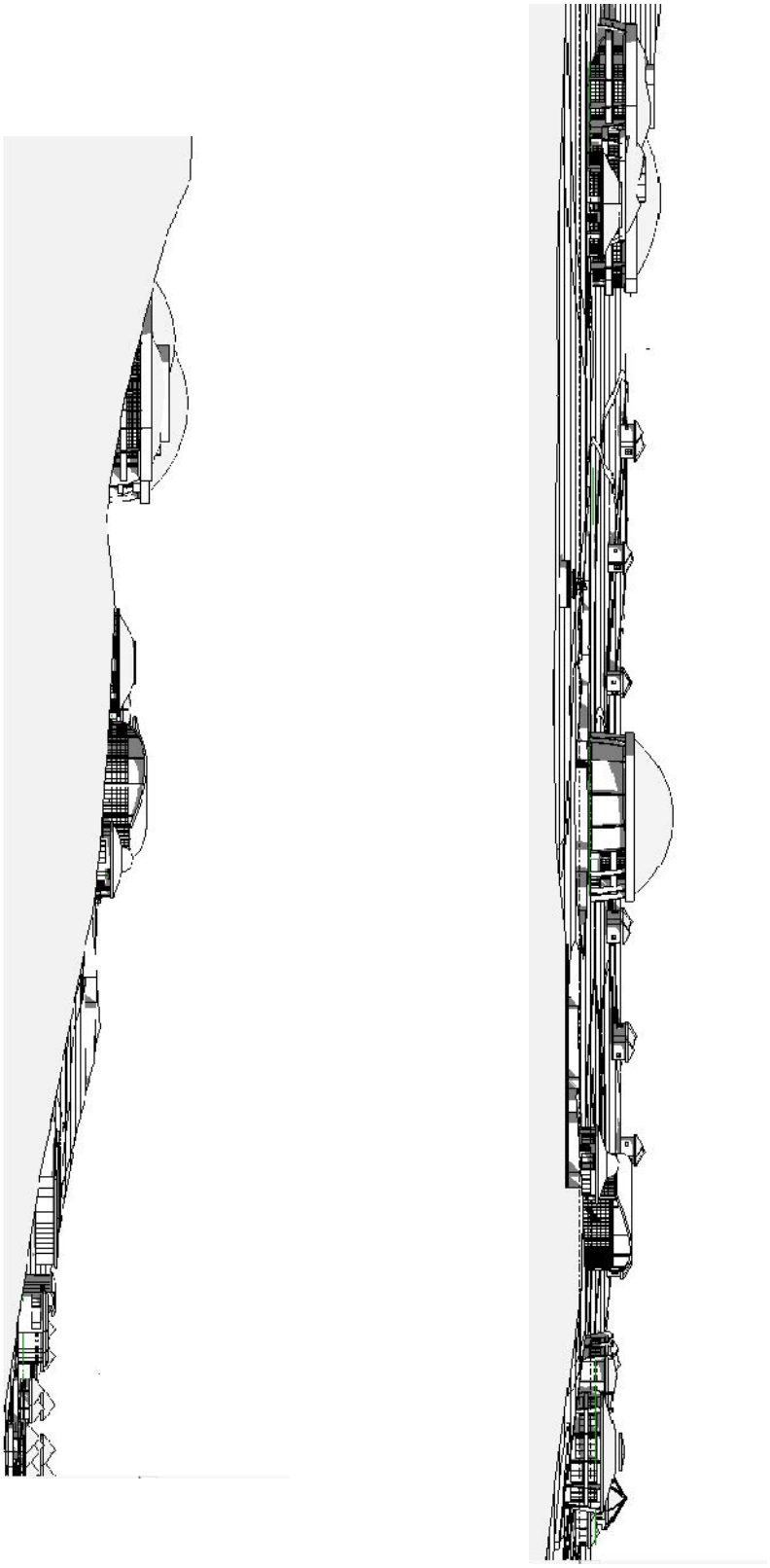
TYPICAL APPROACH ELEVATION

TYPICAL SIDE ELEVATION

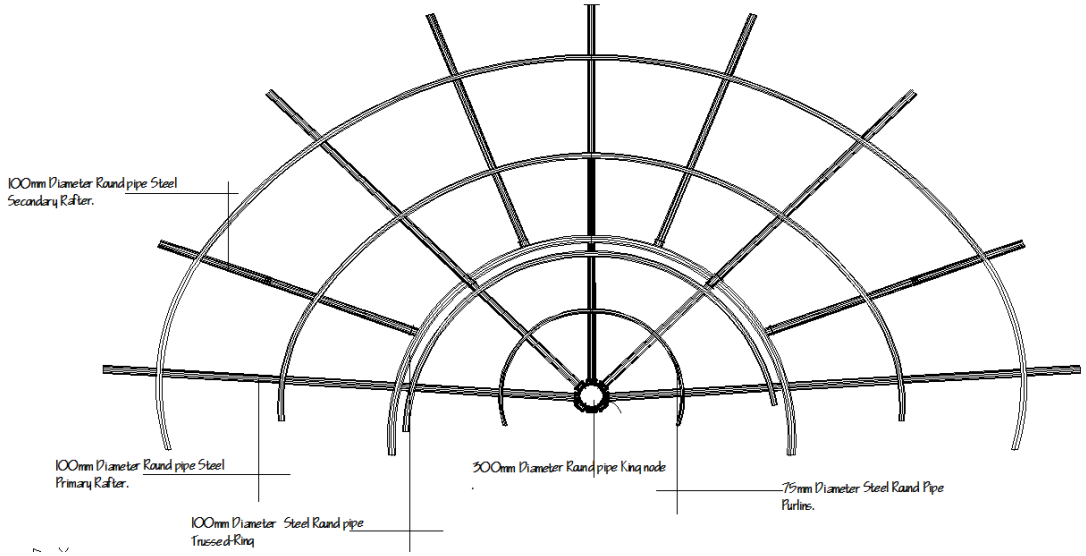


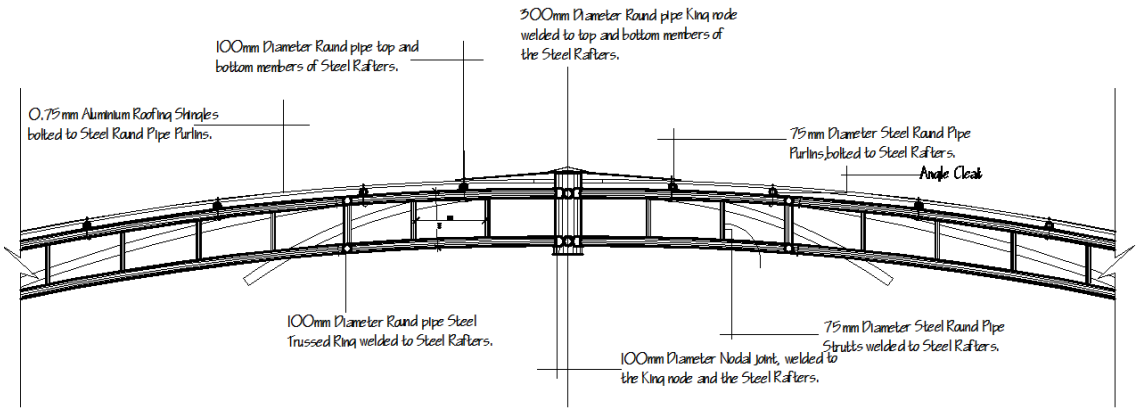
TYPICAL REAR ELEVATION

Appendix 31 ELEVATIONS 1 BEDROOM CHALETS

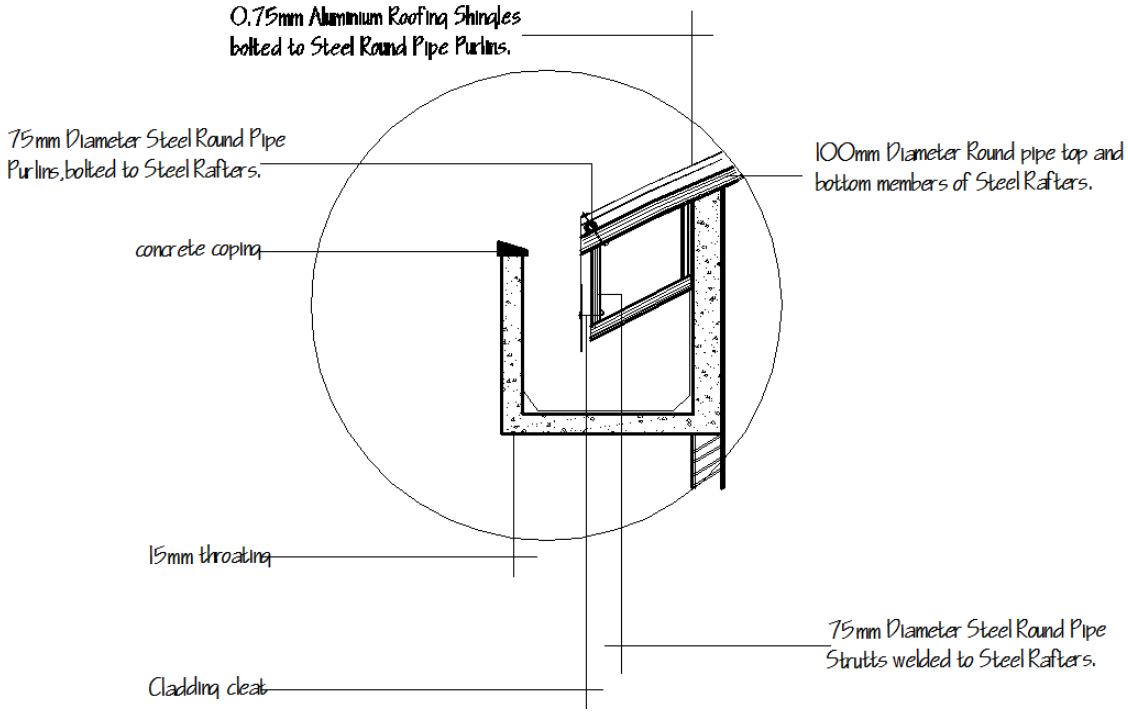


Appendix 32 GENERAL SITE ELEVATIONS

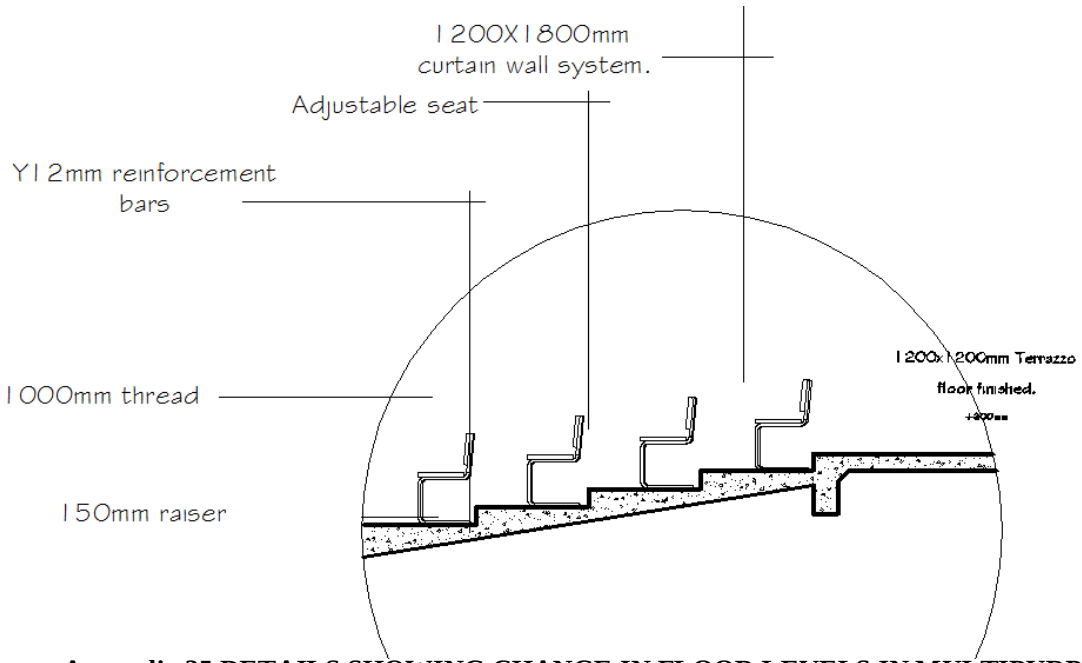




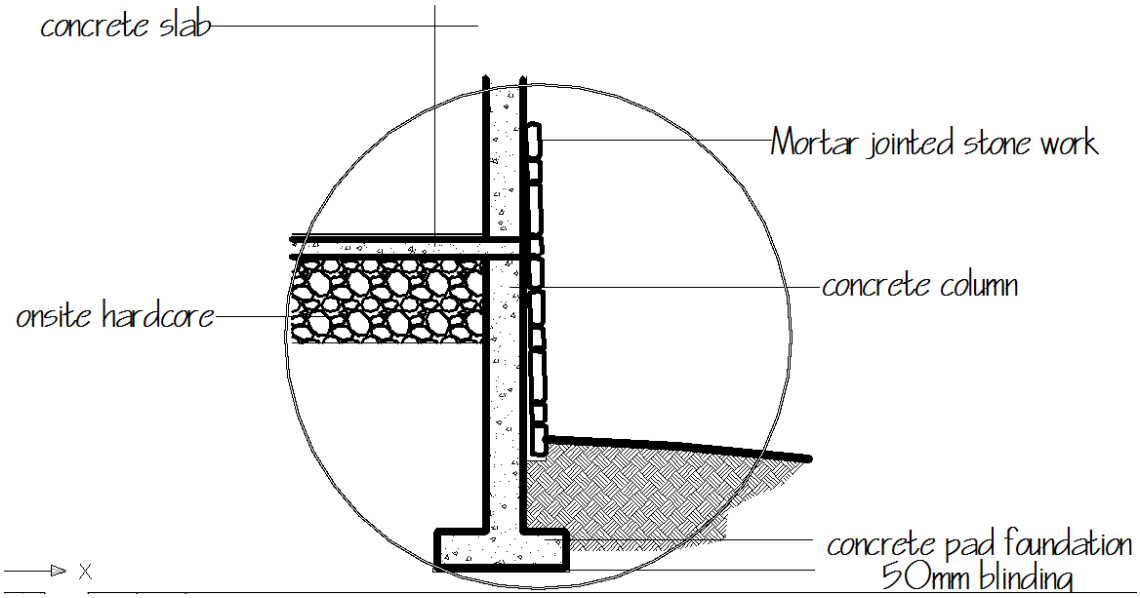
Appendix 33 DETAILS SHOWING LATICCE STEEL TRUSSES IN MULTIPURPOSE HALL



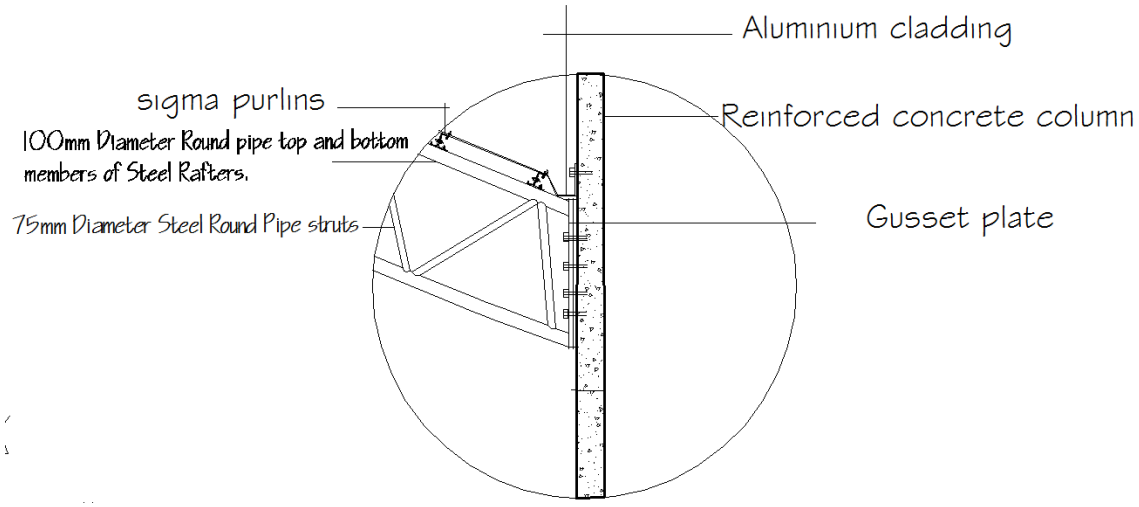
Appendix 34 DETAIL SHOWING PARAPET CONNECTIONS IN MULTIPURPOSE HALL



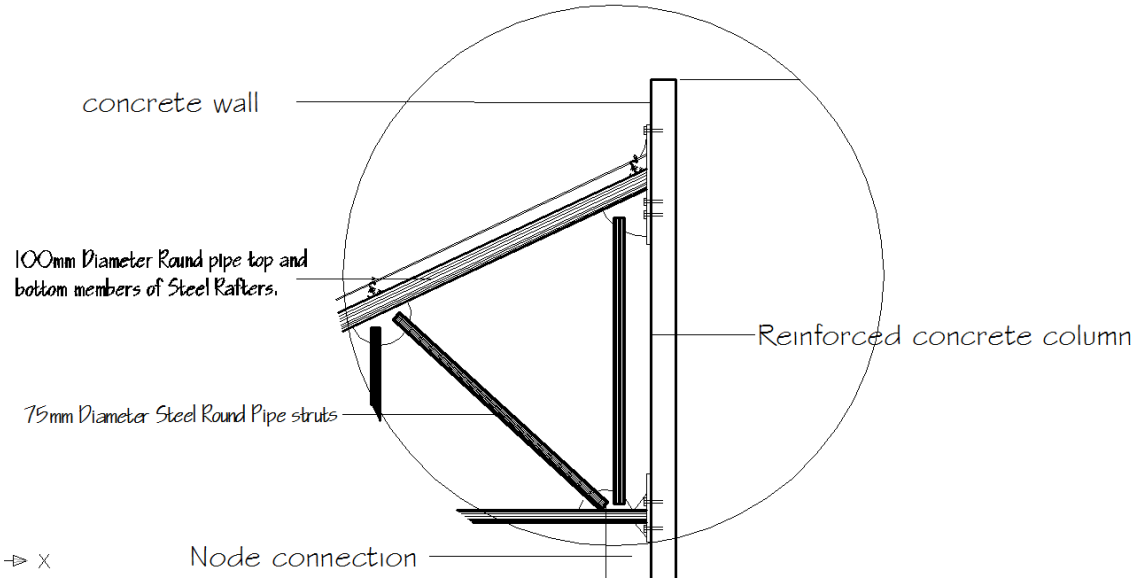
Appendix 35 DETAILS SHOWING CHANGE IN FLOOR LEVELS IN MULTIPURPOSE HALL

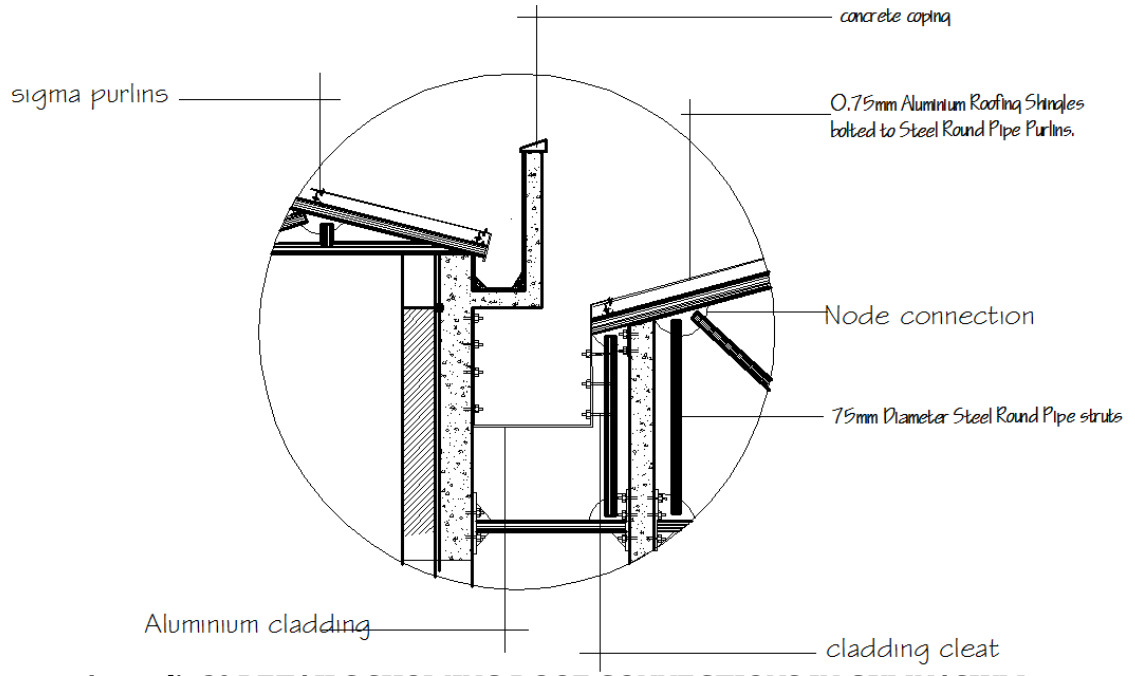


Appendix 36 DETAILS SHOWING FOUNDATIONS IN RESTAURANT

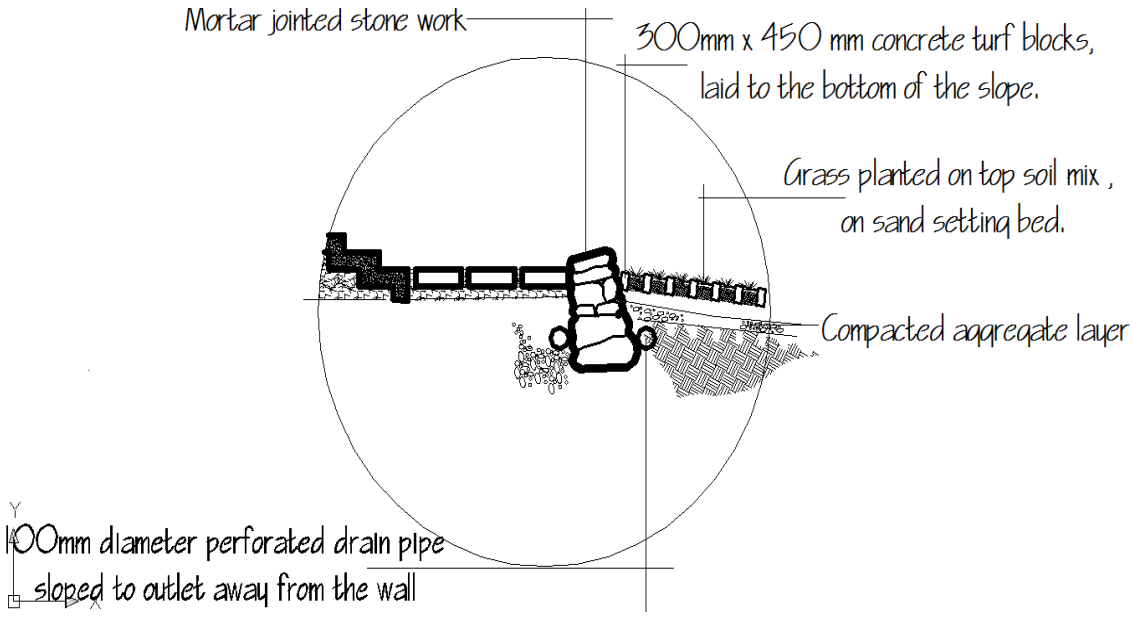


Appendix 37 DETAILS SHOWING LATICCE STEEL TRUSSES IN RESTAURANT

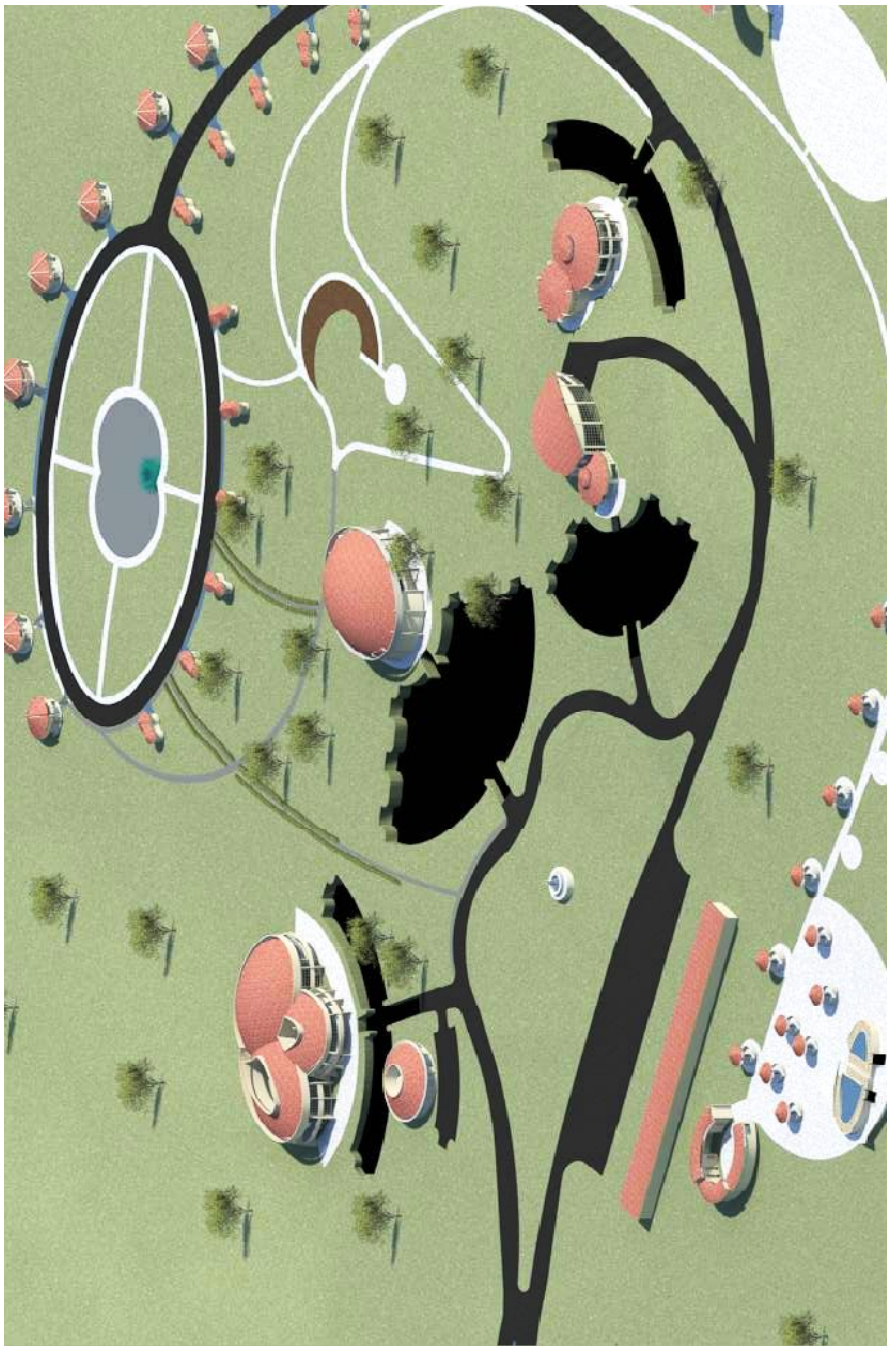




Appendix 38 DETAILS SHOWING ROOF CONNECTIONS IN GYMNASIUM



Appendix 39 DETAILS SHOWING FLOOR SLAB IN GYMNASIUM



Appendix 32 PERSPECTIVE VIEW