GREEN ARCHITECTURE AS AN APPARATUS SUSTAINABLE DESIGN; WITH SPECIAL REFERENCE TO CONTEMPORARY SRI LANKAN ARCHITECTURAL PRACTICE

A Dissertation

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In

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DECLARATION

I declare that this dissertation represent my own work, except where due acknowledgement is made, and that it has not been previously included in a thesis, dissertation or report submitted to this University or to any other institution for a degree, diploma or other qualification.

Signed: ..... *UOM Verified Signature* .....

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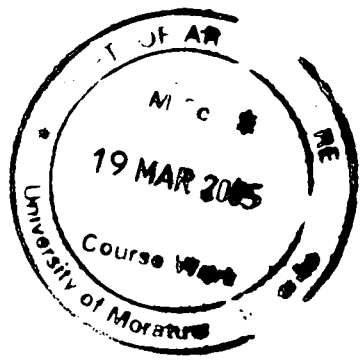

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ABSTRACT

The world today is fast moving into highly sophisticated, technological realities where quality and conditions of living meant to be easier more than ever. In this exercise man has forgotten that is compromising resources and opportunities meant for a future. Subsequently entire plant has dragged to a greater risk of environmental devastation, which will be affected for a future in consequence.

Damage done to the environment is such that life on earth is a 100% risk in terms of environmental consideration. At a wedge of this catastrophic event conception of 'sustainable development' has been introduced as a remedial action for an issue. As far as Architecture conserved in this context a great deal of exploration is usable within a practical reality.

Further an a Architectural starting point will be responsible for a sensual manipulation of environment as most of a development strategies are associated with some sort of construction and building industry.

In this context achieving of sustainable design solutions can be done using different channels and approaches. Green Architectural practice is highlighted as one of a most environmentally sensitive and productive means of realizing the foresaid aspect. This particular study focuses to seek a validity of practical realms of such a concept with contemporary application in Architectural practice in Sri Lanka.

INTRODUCTION

Observation

From the end of 1990s there is an increased awareness throughout the world of the problems associated with the environment such as global warming, ozone depletion, destruction of rain forests, air pollution, acid rains etc. it is widely accepted that the creations made by human beings destructively change the natural environment of the planet.

About 50% of the CFC (Chloro- Fluoro Carbon) produced throughout the world, which causes the widening of the hole of the ozone layer, is coming from buildings. About 50% of the fossil fuel consumption is related to servicing of the buildings. It is apparent that water pollution and building industry are interconnected and acid rains that occur due to air pollution in turn affect the building materials. In this context, it is very apparent that contemporary building industry and its related applications (transportation, urban planning, landscape considerations and infrastructure applications) is responsible for a larger part of environmental degradation which progressing rapidly.

Criticality

It has been identified that both global warming and ozone depletion are directly the result of decisions made by the architects. Man's activities on earth have created a remarkable imbalance in natural systems on earth, which became a problem in the present and doubtlessly for the future. Any incompatible thing added to in to the natural environment create problems to the ecological balance. Unlike the past, developed countries have begun to put new buildings on the face of the earth at an alarming rate. Day by day, the number of constructions is increasing and in the future, this impact will create an environmental devastation on earth and its living beings.

Causes

As the Rate of environmental impact goes up in a way that the natural orders and systems can never be able to in corporate, results an uneven pattern of consumption in every resource of the planet. For every movement of development, buildings become strategic. Thus the consumptions relating to then escalates in a rapid pattern. Burning of fossils becomes one of the threatening issues in this context as it creates larger environmental problems in terms of global warming, ozone depletion, acid rains and so on. (these will be discussed in coming chapters)

> Everywhere the disposition (powers) of nature perform all works, But deluded by Egoism, man thinks, 'I am the doer'
>
> *Bagawath Gita*

Remedies

All over the world the awareness on the environmental degradation is spreading and search for solutions becomes as universal need. As the problem severely is a consequence of built environment at large the world is in a position to reach out solutions within the frame work of construction related ethics. Architectural interference in this context signifies a greater impact as the total picture bears the color of decision making at the very inception stages of every development process. Thus, it is understood that the sustenance of each of the parties will be a reasonable and effective methodology to follow up. Architectural practices all over the world are focused in to a sustainable stream where different approaches have been identified in an applied reality. Namely, they are green principles, eco sensitive methodologies, energy efficiency etc. for this particular study architectural practices towards green principles is dicussed within a frame work of sustainable development.

Intentions of the study

Identifying of green principles, which were part and parcel of the indigenous planning, designing and construction methods and their applicability to the healing of contemporary environmental issues emerging from global warming and other related faculties will be the fundamental objective of the study. Hence redefining and modifying of approaches that can be used in contemporary practice become the deliberate focus for the entire thesis.

Scope and limitations

Literal scope expands up to the architectural discussions of sustainable development where green architectural practice is considered as the approaching mechanism.

Total picture is expected to be discussed considering environmental issue in a global perspective and the relative impact on the domestic context. As contemporary Sri Lankan Architectural practice was highly devoted to the foresaid strategies of development, it is important to study those principle aspects as to gain the knowledge to acquire theoretical and practical streams of them. Having studied the conceptual base modifications and alterations to the principles can be trace out considering its adaptability to the contemporary application. For this to be realized, contemporary architectural movements are also expected to study for the ability of fusion of the principles has to be understood in advance.

Methodology

The study is based on the extensive references made on relevant literature sources in order to derive the design steps. At the same time a literature survey and physical survey were done to identify the Green concept, the applicability of Green design approaches in Sri Lankan context and the shortcomings in terms of futuristic approach of Green designing for the Sri Lanka.

To do this, the study evolves in to three major chapters. The first chapter will contain definitions, principles relevant to the topic and the framework will be set focus on the main topic by sequentially narrowing down the study from contemporary practice of architecture and its' impact on environmental awareness, sustainability to green architectural practice. Green concept, definitions and principles of Green architecture will be discussed at the final part of the chapter.

The second chapter will be discussed the applicability of Green architectural principles in the Sri Lankan context. First part of the chapter has been identified unique Green architectural characteristics of Sri Lankan traditional architecture as an eco-sensitive architectural practice. At the final part of the chapter, the case study will be done as a comparative research to elaborate contemporary Green architectural practices in Sri Lanka.

Finally the third chapter will be illustrated the futuristic approaches of Green architecture and there applications to the Sri Lankan contemporary architecture. The final chapter and conclusions stress the need for a fundamental change in the attitudes and value system of people in order to restore this in its true sense. It also remarks finally that Green thinking has to dwell lives of each and every person if we are to keep on this earth for future generations.

1.0. CONCEPT OF GREEN ARCHITECTURE

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1.1. Architecture; environmental response in its manner of operation

"We enjoy the fruits of the plains and of the mountains, and the rivers, and the lakes are ours, we saw corn, we plant trees, we fertilize the soil by irrigation, we confine the rivers, and the straighten or divert their courses. In fines, by means of our hands we essay to create as it were a **second world within the world of nature."**

[Cicero, de Natura deorum (1st century BC.)]

As it is established, comparative to other arts and many of the human interpretations (other forms of art, inventions etc.) that help man to dwell on earth, architecture became the art of defining humanity within the natural environment.

"Architecture is a second nature that is laid on top of the real one. When people who practice our profession speak of the environment they ought to remember this"

Piano,248

As it was started with the simple living hut for human dwelling, the so-called built sense preceded its succession against time resulting a countless extent of meaningful spaces... to be put in a nut shell -the origin and proliferation of architecture.

Ever since man tried to hear the inner voice of his own, it made him prepared to respond to the natural environment that he belonged to thus sustained his dwelling a physical reality on earth and learned the art of building. With all the influences of the external world he gradually developed the way he lives (as Heidgger defines, dwelling is simply to live on earth...) for he had the responsibility to come up with more subtle way of intervening the natural and man made.

As described above what we are imposing on earth is rested up on the natural environment is named as built-environment. Simply it is second nature up on the original. Being stated the above it is understood that the built environment should bear the kinship to nature of which it originally came from.

"The character is determined by the material and formal construction of the place. We must therefore ask how is the ground on which we walk, how is the sky above our heads or in general: how the boundaries is depends upon its formal articulation, which is again related to the way it is built"

"Looking at a building in this point of view we have to consider how it rests on the ground and how it rises towards the sky"

(Norburg schulz, p..14)

1.2 Sustenance of the environment – the interrelationship between architecture and environment

As it is described earlier, 'built environment' even in its face value shows the indivisibility and the acquaintance of the fore ground (natural Environment) to the object (built environment) . Hence, the built reality always stands as to relent to the scheme of operation of the patterns of nature as it is born and bred because of the environment that allowed such an edifice to lie up on her.

Thus, the environment and the structures built should essentially maintain a closer relationship that ascertains the sustenance of each other.

1.2.1. Human involvement to the environment throughout the history

Considering the early construction techniques, materials that were being used and the nature of structures that our ancestors used to live this concept is very much appreciated and used as a practice of culturally and socially poised to their way of life.

Beginning from the simplest living hut; the first human impact of a house where man made his first step to an endless journey of built reality, he used to make a lesser impact on the environment as they build. The structures were very small and easy to convey the impact on nature. Materials used were found directly from nature and did not need any preparation or conversion, and further they were bio degradable and soundly absorbed when the purpose or the use is over. Used techniques were rather simple and straightforward and not complicated. So the

environmental impact was least. Most of all the number of structures and constructions was a minimum.

The idea of overcoming the natural environment became one of the most outstanding reigns of human development along with the time as the faculties of psychological and physical stared widening their scopes occupied.

1.2.2. Contemporary practice of architecture and its impact on global environment

Focusing in to the contemporary situation, human development with the cramped fusion of technology, rate of consumption and frequency of usage escalates in a magical speed where we hardly see remind the roots of our own history. Human activities on earth has created an imbalance in natural systems and ended up with a catastrophic stance for the livability of the planet.

Every step taken by the name of development has to be considered with building construction and energy. Increasing number of buildings is and indication of bumping up the usage of fossil fuels. Each of the building introduced causes adverse impact on the environment as the planet is in an excess of building fabrics. Clearing of rain forests and burning of fossil fuels which signifies as unavoidable occurrences of construction industry will lead the planet in to an environmental devastation in the coming future.

1.2.2.1. Global Warming

Increasing of the fabric (buildings) results a huge area for emission of radiation heat. Besides more buildings result a greater consumption of energy that brings a large amount of heat to the atmosphere. Burning of fossil fuel on the other hand release Carbon Dioxide and monoxides, which simply ease the mechanism of green house at large. Each of these constituents finally heat up the atmosphere. As it is evident within last two decades increasing of global temperature has resulted the lessening of thickness of the poles. Liquefied ice is continuously accumulating in to the

oceans and the sea level rises up. Implies the lands to share in this plant became lesser day by day.

1.2.2.2. Ozone Depletion

About 50% of the world production of CFC is used in buildings either as refrigerants, fire extinguisher systems or in foamed insulation. CFC pass very slowly up through the atmosphere in to the ozone layer where they break down to their basic constituents, one of which is chlorine which directly break down the ozone molecules resulting holes in the layer.

1.3. Sustainable development

Sustainable development is development which meets the needs of the present without compromising the ability of the future generation to meet their needs.

World commission of Environment and Development, our common future, pp5 Oxford University Press, New York, 1987.

1.3.1. Architecture towards sustainable development/ design

Sustainable design is the thoughtful integration of architecture with electrical, mechanical, and structural engineering. In addition to concern of the traditional aesthetics of massing, proportion, scale, shadow and light, the facility design team needs to be concerned with long term costs: environmental, economical and human.

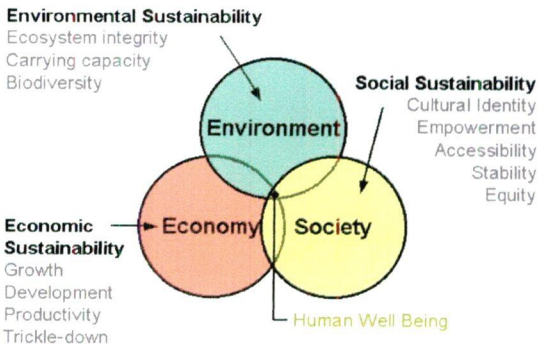


Fig 01. Sustainability, a diagrammatic illustration

As Sim Van der Ryn once revealed, what we imposed on the environment should essentially be harmonized and then the effortless sustenance of each other can be revealed. Reality of natural order and the way of human performance over the environment in a sound, corporative process is explained as below.

"We design places
Where nature is the foreground and
Cannot be over powered
by our temporary creations.

We use geometry not only
To recognize space and to mark
The social interactions within,
But also to resonate with landscape.

The building is not a fixed object
But part of the larger pattern
And flows with the change –
A preamble living membrane
Responding to changes in use and place.

We use natural materials
Native to a place – earth, stone,
Trees as well as advanced technology and scientific intelligence.

Architecture is part of the process
Of 'remembering' putting back
Together our collective dreams.
The design places for living,
Healing, reflection, coming together.

Design should tell a story
About place and people –
And be a pathway to understanding
Ourselves within nature."

-Sim Van der Ryn

The Rocky Mountain Institute out lines five elements for sustainable design:

- Planning and design should be thorough. Sustainable design is 'front-loaded' compared with traditional design. Early decisions have the greatest impact on energy efficiency, passive solar design, day lighting and natural cooling.
- Sustainable design is more of a philosophy of a building than a prescriptive building style. Sustainable buildings don't have any particular look or style.
- Sustainable buildings don't have to cost more, nor are the more complicated than traditional construction.
- Integrated design that is design where each component is considered part of a greater whole is critical to successful design.
- Minimizing energy consumption and promoting human health should be the organizing principles of a sustainable design. The other elements of design can be organized; energy saving architectural features, energy conserving building envelop, and energy efficient and health promoting mechanical, electrical and plumbing systems.

1.3.2. Different Approaches in sustainable architecture

The built environment and its pattern have a direct and clear relationship through a sustainable growth of any society. It is not possible to imagine a self sustainable system of built environment, but a built environment which will contribute to sustainable growth both in material a spiritual terms. The structures built by the animals identified as natural. Nevertheless, when it comes to the terms of man made it is not natural any more. The natural structures are part of a sustainable, livable system of the environment

It is found that buildings are responsible for a large part of the environmental degradation all over the world. As designers, there is a responsibility on architects towards the preservation of the ecological systems that supports life on earth.

1.3.3. Principles of Sustainable Design.

Sustainable designing strategy comprises of different considerations in its implementation framework. Following will be one of the established sets of principles that can be identified in the contemporary application.

Understanding place – sustainable design begins with an intimate understanding of place. If we are sensitive to the nuances of place, we inhabit without destroying it. Understanding place helps determine design practices such as solar orientation of the building on the site, preservation of the natural environment, and access to public transportation.

Connecting with nature – weather the design site is a building in the inner city or the more natural setting, connecting with nature brings the designed environment back to life. Effective design helps inform us of our place within nature.

Understanding natural processes - In nature there is no waste. The byproducts of one become the food for other. In other words, natural systems are made of closed loops. By working with living processes, we respect the needs of all species. Engineering processes that regenerate rather than deplete, we become live. Making natural cycles and processes visible bring the designed environment back to life.

Understanding environmental impact - Sustainable design attempts to have an understanding of the environmental impact of the design by evaluating the site, the embodied energy and toxicity of the materials, and the energy efficiency of design, materials and construction techniques. Negative environmental impact can be mitigate through use of sustainably harvested building materials and finishes, materials with low toxicity in manufacturing and installation, and recycling building materials while on the job site.

Embracing co-creative design processes – sustainable designers are finding it is important to listen to every voice. Collaboration with systems consultants, engineers and other experts happens early in the design process, instead of an afterthought. Designers are also listening to the voices of local communities. Design charettes for the end user

(neighborhood, residents or office employers) are becoming a standard practice.

Understanding people – sustainable design must take in to consideration the wide range of cultures, races, religions and habits of the people who are going to be using and inhabiting the built environment. This requires sensitivity and empathy on the needs of the people and the community.

1.4. The role of Green architectural practice – way towards sustainable design

The term green generally gives a feeling of greenery that is natural fauna and flora. But here the term green stands for not only the same aspect and it goes beyond to the meaning of environmental friendliness in a broader sense.

When it relates to architecture the term green qualifies yet an other aspect in architecture such as classical expressionist, modern or post modern. At a broader level of acceptance the concept of green architecture act as an ethic in an applied reality.

1.4.1. Green Architecture; Definition

A green approach to the built environment involves a holistic approach to the design of buildings. All the resources that go in to a building be they materials, fuels or the contribution of the users needs to be considered if a sustainable architecture is to be produced. Producing a green building involves resolving many conflicting issue and requirements. Each design decision has environmental implications. Measures for green buildings can be divided in to four areas.

- Reducing energy in use.
- Minimizing external pollution and environmental damage
- Reducing embodied energy and resource depletion
- Minimizing internal pollution and damage to health

What makes a building green?

A green building places a high priority on health, environmental and resource conservation performance over its life cycle.

These new priorities expand and compliment the classical concerns; economy, utility, durability and delight. Green design emphasizes a number of new environmental, resource and occupant health concerns;

- Reduce human exposure to noxious materials
- Conserve non renewable energy and scares materials
- Minimize life cycle ecological impact of energy and material used.
- Use renewable energy and materials that are sustainably harvested.
- Protect and restore local air, water, soils, flora and fauna.
- Support pedestrians, bicycles, mass transit and other alternatives to fossil fueled vehicles.

Most green buildings are high quality buildings; they last longer, cost less to operate and maintain, and provide greater occupant satisfaction than standard developments. Sophisticated buyers and lesser prefers them, and are often willing to pay a premium for their advantages. What surprises many people unfamiliar with this design movement is that good green buildings often cost a little or no more to build than conventional designs. Commitment to better performance, close team work throughout the whole design process , openness to new approaches, and information on how these are best applied are more important than a large construction budget.

1.4.2. Principles of Green Architecture

According to Brenda Vale and Robert Vale the seven green design principles such as,

1. Energy conservation
2. Working with climate / climatic responsive design
3. Minimization of new resources
4. User respect
5. Respect to site
6. Waste management
7. Holism

Principle 1

Conservation of Energy

This Principle is having the idea to minimize and conserve the energy used for a building during its' construction and after occupation.

Any building activity is huge amount of energy consuming exercise. This can be in various stages of a building. Especially during the construction and after occupation of the building, amount of energy consumed in the building is very high. This can be minimized or energy can be conserved taking precautions to minimize the energy and ways of conserving energy during it' design stage.

Design stage is the most important and critical stage of any built structure because all decisions which are taken for the sustainability of any built structure is taken in this stage. They will determine the future of any building / structure. There are several areas which have to be considered in this stage in any design activity in minimization of energy such as,

1. Site planning
2. Materials selection
3. Used of natural light and ventilation
4. Use of low energy systems
5. Reuse of old buildings
6. Design for flexibility

All these areas have to be considered during the design stage of a building.

1. Site planning

At first, the building has to be integrated with the surrounding landscape as much as possible when it is constructed. This is also the first stage of a construction of the building, preparing the site for construction by clearing it and sometimes excavation also have to be done. The methods of taking materials to site, materials which can be obtained from the site, availability

of water have to be looked at. Excavation, cleaning water supply consumes energy. If these activities do not involved heavy machinery and very sophisticated equipment and large amount of energy can be saved. This can be done even by reducing the excavation or cleaning areas at the design stage itself. The way of orientating the building on site will also conserve energy. It can be orientated to get maximum light and ventilation naturally, while getting the advantage of the natural landscape of site.

2. Materials selection

Most appropriate materials for the construction of the building must be decided in this stage. Traditionally designers choose the materials to be used based on factors such as, cost, aesthetics, and availability, installation, durability and maintenance requirements. But sustainable design calls for the impacts on environmental and human health to be paramount consideration as well.

There are several ways that materials are connected to energy such as

1. Production of materials
   This includes, quarrying and processing and producing from other material.
2. Transportation of materials
3. Installation of materials
4. Degradation of materials- recycling

Production of building materials is an energy consuming activity. If the energy consumption can reduced to a certain level, then it will be a considerable contribution to a sustainable future. There are few considerations, in this regard.

1. Use of building materials which are possible to convert back to its Original form with less amount of energy

or

2. Use of building materials which are able to regenerate within natural ecosystems in a short period of time or able to be produce by less amount of energy consuming and pollution free manufacturing process.

It is clear that, manufacture of conventional building materials such as cement, bricks also energy consuming. But the amount of energy consumed during the cement production is lower when compared with the production of steel. Similarly, when comparing burnt brick wall and un burnt clay wall, clay wall needs less energy for production than burnt brick wall, and clay wall can be converted to its original position. Timber is more appropriate material because its ecology friendliness and the consumption of less energy than alternatives such as metals or concrete.

Energy consumption during transportation also to be consider when selecting appropriate materials. Comparatively if more energy is consumed for transportation of materials, it is not a sustainable building material. Therefore the use of local building materials for construction is a more energy saving consideration.

Production of new building materials that are not in the conventional market and using less energy for manufacturing is now developing. This idea has come into action with use of local waste materials as resources for manufacturing of new building materials. There are resources going on all around the world and some of them have produced materials manufactured in mass scale. Materials taken from the earth by querying also energy consuming. However usage of heavy machinery can be controlled and the processing can be developed, energy can be saved.

Some of the materials are energy consuming not only in the production but in its installation. For example: Aluminum productions of metals are more energy consuming. If they consumer more energy in its installation they are not sustainable materials.

Therefore the selection of most sustainable building materials is not an easy exercise. And it is a responsible task of any designer.

3. Use of natural light and ventilation

Use of natural light and ventilation can make a good contribution to energy savings in buildings. At the design stage of building, primary decisions must be taken to control artificial lighting and air conditioning. Here, the designers' decision is very important, as the client's requirement is often override the designers' decision. Energy consumption for air conditioning a building is very high and in some of the occasions it is not affordable form and economic point of view. In the design stage, decisions taken for reduce of energy consumption make great advantages on the construction stage.

In the day time, natural ventilation can be effectively used for internal activities of a building, when providing natural lighting for interior, positioning of openings plays a major role, in order to cut glare and heat coming into the building, Therefore openings have to be positioned in various levels and it various sizes. Then it will control the amount of light coming into the building. For example In the office spaces, day light from one side will always suffer from glare problem because of the contrast between the windows and window wall.

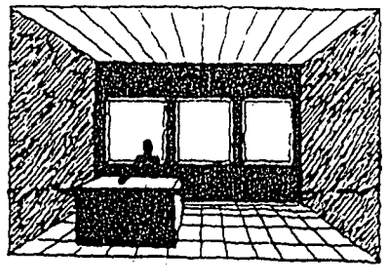


Fig 02. Windows from one side causes glare

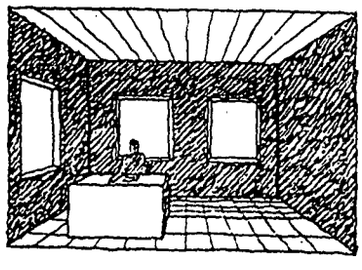


Fig 03. Windows from two adjacent walls reduces glare

In the absence of supplementary lighting (artificial) such spaces will bare a gloomy character. This problem can be rectified by lighting a work place from two opposite of adjacent walls.

Most efficient way to take the natural lightening into the building is having windows of two sides to achieve better distribution of lighting and deeper penetration. On one side the window to be put a higher level and on the other side at a lower level for view.

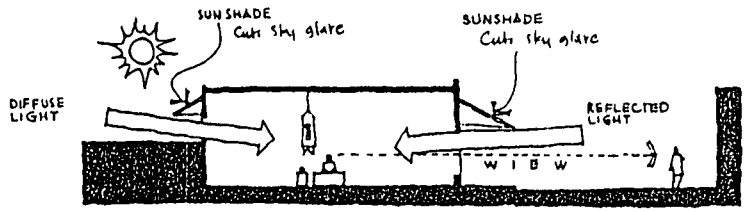


Fig 4. Window positioning for good ventilation

Ventilation can be provided by also using openings of buildings. They can be louvers or full openings. Here most important thing is the orientation of the building. Because the cross ventilation can be effectively used for buildings by orienting the building with identifying the wind patterns of a particular area. Natural stack effect also can be used for effective natural ventilation. Building orientation can reduce overheating of internal spaces. This will provide more comfortable working areas without air conditioning.

For example, when designing multi storey (the facades which take light and ventilation) should not be orientated in east and west direction. It should be orientated north south direction. Because facades which open out to direct solar radiation will result excessive heating of internal spaces. More solid and heavier facades of the building can be oriented towards east and west.

This will become very effective when air conditioning the buildings also. it will reduce the energy for air conditioning by cutting the excessive heat internally. Areas where air conditioning is essential can be provided with low energy consuming solar air conditioning units instead of normal air conditioners. It requires flat plate solar collectors to trap solar energy and a vapor absorption refrigeration unit to produce cooling. Electricity is required for blowers and pumps only.

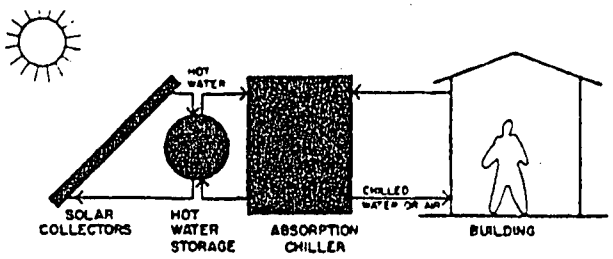


Fig 05. Low energy consuming solar air conditioning system

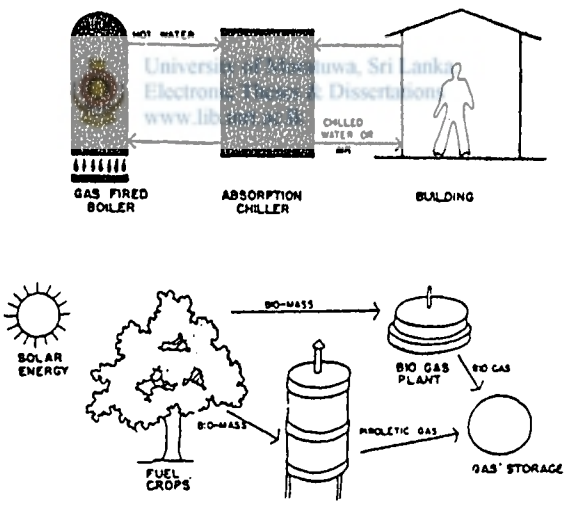


Fig 06. Bio gas also a good alternative for fuel gas

4. Use of low energy systems

When a building needs artificial lighting for its interior, energy saving precautions must be taken at the designer stage to save energy. Such automatic systems, which are switching off when people went off the

building or sensor switches which cut off extra lighting as adjust to daylight intensity.

Another alternative is used solar energy for artificial lighting. During the day time solar energy can be stored as electric energy in batteries and they can be used in the night and day time also to fulfill the requirement of additional lighting.

Energy usage for other building activities such as operating pumps lifts, cooking etc also to be taken into consideration. Normally high rises operating lifts, which around 3 to 5 storied can be served by stairs. Reduce the number of lifts for a building to a minimum is another alternative. But it must be done considering the requirement also. The water pumps of buildings can be used wind power also. Windmills are practical solution to be used for water pumps as energy source to take water to higher levels. Cooking purposes of a building can use bio gas and it is very economical when using waste produced in the building as a materials. It will eliminate environmental problems arising due to waste produced by man.

5. Reusing existing buildings

Instead of constructing a new building for particular purpose, considering the possibility of using an existing building is one way of saving energy. Any building requires large amount of energy for its various stages as construction, operational or even its demolishing, if we built new one it causes additional amount of energy for its various stages. If an existing abandoned building is used after renovating and altering, it will save considerable additional amount of energy. It is possible to convert many of the old buildings according to today's requirements. The most of the systems within the building can be used doing little renovations and the designs decisions must take care of avoid high energy consuming system installations. The existing buildings materials, furniture also can be reused in most of the cases.

6. Design for flexibility

Design a building with a possibility of converting it into several functions make a large amount of energy saving than designing it for a one particular function. Any building if it is used by altering to various functions through out a period of time it will avoid the construction of several buildings. Then it will be a great contribution made for energy saving. The flexibility of converting a building to several different functions is to be incorporated in the design stage of a building.

During the construction of the building, a considerable amount of energy is consumed use for machinery, pumping, water, and lighting transportation and so on. This energy consumption can be minimized if the following aspects can be considered.

1. Use of low energy methods of construction –construction methods must use less amount of energy and must be efficient.
2. Efficient use of machinery.
3. Use of appropriate construction method-This is to use most suitable construction method in a particular occasion.

4 Proper management of above areas.

At the stage of construction most important thing is management of the construction work. Decisions are taken at the design stage to minimize the waste of energy and save it. Therefore a good management is essential.

Maintenance period of a building after occupation is comparatively a large time period than design and construction stages. This will span throughout the lifetime of the building. Here the participation of user is very important.

Most important thing here is to maintain the building and its system in the way it was designed to be used. There are two areas to be considered for this:

1. Take maximum advantage of systems within the building including low energy systems
2 Good supervision of the maintenance of the systems.

Therefore, user and designer have responsibility about energy conservation in a building complex. A well designed project may consume less energy than a similar conventional project, is supposed to consume.

Principle 2

Working with climate\Climatic responsive design

The idea behind this principle of green architecture is buildings must be worked with the local climatic conditions and available natural energy sources.

The primary purposes of a building are to be providing a sheltered and scheme space for one or another of man's activities. Traditional buildings in many of the places provide shelter from extremes of climates in a variety of ways without consuming very much energy. The climatic parameters that influence the building fabric are solar radiation, temperature, relative humidity, speed and direction of wind and precipitation.

Architects and engineers must develop building envelopes which will interact with and moderate the adverse effects of the climate, while simultaneously capitalizing on free energy sources such as the sun and wind. Our future buildings respond to local climate change much like chameleons change their skin

Any building structure will make changes in it microclimate and built up elements will determine the factors affecting comfort.

"The built environment produces changes in the micro climate. The configuration of building, their orientation and their arrangement in space create specific micro climate for each site. To this must be added building materials, surface texture, colours of exposed surface of the building and the design of open spaces such as streets, courtyards, gardens and squares. These man made elements interact with the natural micro climate built environment: light, heat, wind and humidity"

(Fathy, 1986)

The exercising the climatic variations will vary with the place of the occupants. A man in a taller building will experience the climate changes in specific way to him than a man in a building which is not tall. If a tall

building is to be designed, a climatically responsive design should provide the building's users with the opportunity to experience the external environment. A building either tall or not tall to be oriented in the same way to make internally comfortable by cutting down the excessive solar gain. It will reduce the energy usage of the building for making it internally comfortable. Ex-air conditioning needs more energy to run the machine. Natural ventilation can effectively use for comfortable conditions by cutting down the excessive heat of the internal space.

New designs of building are leading towards energy efficiency, environmental awareness while making the occupants to experience the various change in climatic conditions. This is an idea which is developing day by day from single storey home to sky scraper, around the world. It is successfully achieved that, the designing buildings which make comfortable condition inside in the presence of various adverse climatic parameters which getting the maximum benefit from sun and wind.

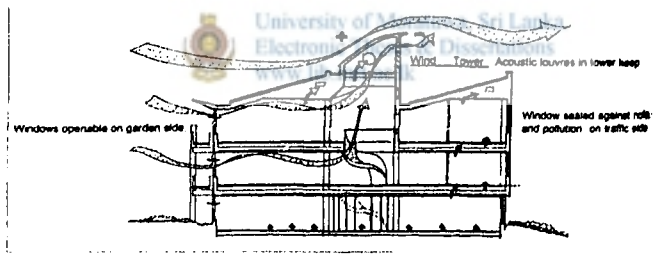


Fig 07. Maximum contribution from sun and wind to make comfortable inside environment

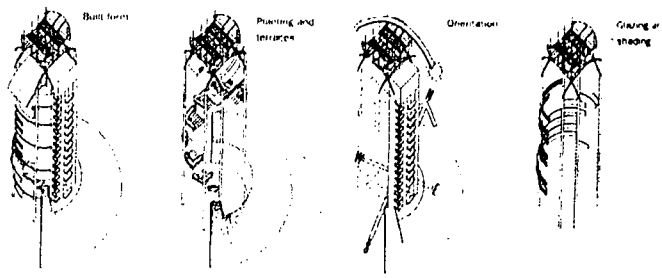


Fig 08. Design high rises for obtain maximum benefits from its local climate –Monera tower, Malyasia

Very basics of designing building such as orientation of buildings, overall form, external skin and approaches such as energy efficiency are clearly important consideration in designing climatic responsive buildings. Each climatic area has characteristics which can be determined suitable responses creating an architecture that is appropriate and unique to place. Building form, elements that are responsible to protect the occupant from adverse climatic conditions should be designed at the design stage of the building. During the construction it is important to get a clear idea about the climatic variations about the place/ site which differs with seasons. This may affect the construction work during that period. After occupation, any addition or alteration must follow the climatic responses determined by side climate.

Principle 3

Minimization of new resources

This strategy is leading the idea of minimizing the use of non renewable resources used in building designs. This is particularly important in the face of climatic change. Since the devastation caused by deforestation, the extraction and processing of materials for building industry is largely responsible.

There are several factors to be considered in minimizing the use of new resources in the building design such as:

1. Minimizations of materials used in building construction that are processed non renewable resources.
2. Reused of old buildings instead of new ones.
3. Use of waste as a material/ resources
4. Avoid the use of materials containing toxic substances and CEC.S and so on.

1. **Minimization of materials for construction that are processed from non renewable resources**

Any of the materials used for construction of the buildings has a connection with the earth in direct or an indirect way. Therefore for such materials can face a shortage when it is take constantly for a long period if it is formed by non renewable resources. Then there is a responsibility to save those resources for the necessities for future generations. Constant extraction of such materials from earth crust will lead to environmentally unbalance situations. Such environmental problems may result adverse reactions such as earth slips and so on.

2. Reuse of old buildings

Existing built environment is already consists with a large part of non renewable resources. Therefore constructing a new building is utilization of new amount of resources on earth. Therefore it will directly affect the resources that are existing. Reuse of old buildings after renovation is saving new resources in our habitant, actually it is a wise use of resources.

3. Use of waste as a material /resource

Waste is a big problem not only in building construction or maintenance but every activity of the life. It causes aggressive environmental problems also. Since few years, building industry is an industry which makes the largest amount of waste around the world and there are may be organic as well as non organic waste. Waste can be taken as a material for construction by recycling or adding another substance to the waste.

For example

Waste paper can be turned into insulating materials for ceiling and so on, by adding suitable substances

Waste material such as bottles, cans, wrapping parts can be used to construct

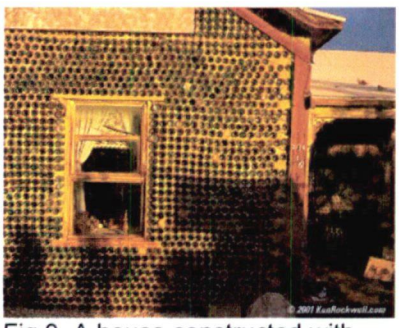


Fig 9. A house constructed with bear bottles as wall material

walls, fences and so on.

4. Avoid the use of materials containing toxic substances

Use of materials contains environmentally destructive substances such as C.F.C and toxic substances for human beings must be avoided. They may cause environmental problems as well as health problems on human beings.

Most important consideration and decision have to be taken to minimize the use of new resources at the design stage. Identified actions which can be taken for the achievement of such goals are,

1. Take necessary action in designing a building to minimize the use of materials taken from non reusable resources, and check the durability of such materials.
2. Make decision to convert, renovate or alter old building as sustainable solution by using most efficient way.
3. Try to incorporate materials made by using water to design.
4. When specifying materials, action can be taken not to specify materials which consist of toxic substances or environmentally hazardous things.

Construction stage also has a responsibility to check whether the above mentioned factors are present in the stage 2, and another several areas to be checked.

1. When using quarrying materials the purposes of quarrying must be done as to minimize the damage to the earth and other resources.
2. Waist water used for construction must be released back after purifying.
3. In the process of renovating of old buildings for reuse, appropriate methods and machinery must be used.

During the lifetime of the building good maintenance must be certified. Then the life time of the building can be increased and, it will lead to the minimization of resource utilization. The water used for building must be managed well to avoid wastage.

Principle 4

Respect for Users

There are number of resources need to construct a new building. A construction of building may relate to issue of pollution, global warming and so on with all the resources which goes into it, including human beings. Most of the people are involved to building construction by giving their man power. Therefore, there is responsibility to protect and respect the human beings who are involved in the construction, and its ultimate users. This principle is forwarding such an idea.

During the construction or in the maintenance stage participation of user is important during the construction or in maintenance usage of materials and machinery may affect the health of the human beings, therefore protecting them is necessity of the situation.

Each individual's involvement in a building project will be very according to the role of the person. An each stage different people will have a specific part to perform generally, design stage is responsible for all the future work and the designer has a major responsibility on all decisions on the project. The extent of human involvement to be decided at the design stage. Then the construction stage and the maintaining stage both have more involvement of human beings. Construction, team work, labor management and so on have important considerations.
The respect of physical, psychological and emotional aspects are also to be considered when designing buildings.

Principle 5

Respect for Site

The idea of the principle is that a building must lightly touch the earth. This would mean a building could be removed from its site and leave it in almost the same condition before the building was placed.

Architecture should remain in tune with the site to ensure that the inhabitant is part of the events around him experiencing the quality of light, winds, sounds even scenes. The use of local materials and construction techniques that do not disturb the site are preferable. By using local site characteristics as a generator, a varied architecture that breaks with the monotony of the so-called "international styles" can be created leading to global regional characteristics influenced by place and culture.

As we replaced natural world with an artificial one, precious wild life and plant habitants may be lost. These on particular site must be preserved as much as possible with leading a maximum vegetation cover. Inevitably environments have to change to some degree, the aim must be to put back a little of what the building has taken away of from the site. There are several ways that this achieved such as building lightly touching the earth, going underground to preserve the existing landscape of the site, creating roof gardens, planting on facades and so on.

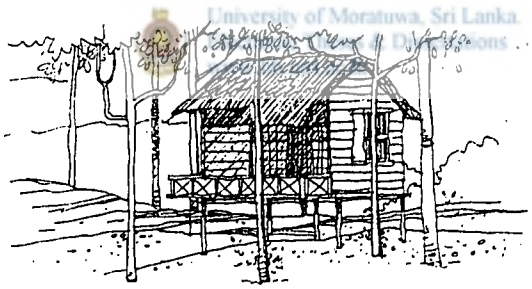


Fig 10. Lightly touch on earth

A design must be site specific from its design stage itself. At the Design stage of building how the building join to touch the earth, how it is going to response to surroundings, and what part of the land is acquired by the building etc. must be considered.

To what extent the building is going to use environmentally benign materials and local materials, techniques for construction and so forth a re also things to be considered at the design stage.

During the construction of a building, actions must be taken to minimize the environmental impacts. Appropriate construction techniques that are not environmentally destructive can be carefully selected. Excavation works, heavy vibrations can be reduced on site. Environmental pollution due to waste, effluents from machinery chemical from materials can be controlled by proper management. All construction work must protect the existing and remaining vegetation.

A large amount of waste is produce by a building throughout it's lifetime, causing various environmental problems. Most of the organic waste produced during maintenance stage of a building can be used on a source for getting energy such as making energy by manufacturing bio gas. Any of the alternation or addition to the existing building must follow the same rule the existing building has been followed.

Principle 6

Waste Management

This principle is dedicated to minimize the waste in both during construction and post completion stage. How ever the decision must be taken to minimize the waste at the design stage of a building, by focusing ways to minimize the impact to the environment from waste during the construction, because water, air and the site environment is being polluted during the process of construction. Waste can be recycled into usable product or bio degradable waste to avoid environmental impacts.

At the first stage of the design, designer can decide which materials as to be used, to avoid waste, basic dimensions of materials and their way of use in most efficient ways, qualities and standards of the materials and so on. For an example, when using timber, material sizes must be decided by avoiding the waste or cut pieces glass, material sheets, roofing materials and so fourth have to be properly sized before being transported to the site. Selecting accessories for final completion must be planned by

avoiding the wastage. Most of the packing materials also make problems. On the construction sites waste is produced by bad transportation of materials due to improper sizing, wrapping waste of materials and by the waste produced by construction workers. There can be controlled by good planning of the above the areas. Waste produced by shuttering –concrete moulds etc can be avoided using plastic moulds, which can be reused of several times. The possibility of recycling waste in to useful materials or non-hazardous parts is very important at sites. Most of the organic waste can be used for getting energy for construction works such as heat or light. Water and air is polluted at this stage considerably. Water polluted must be purified and reused.

There are several techniques called OGT-(on site green techniques) can be used to reduce waste, such as,

1. Use of concrete construction methods that does not need moulds
2. Use of reusable plastic moulds
3. Use of pallets to carry illuminates or any other accessories to construction fields
4. Reduction of waste in co-operation with materials supplier.

After occupation of a building it is important to manage the waste of the building, because it will be a problem which extends throughout the life time of the building. Waste production will vary in this stage such as waste produced by occupants, naturally occurring waste with time due to weakening of some materials and so on. Waste recycling is very important in this stage.

Example - making bio-gas for the use of building by using the waste

Principle 7

Holism

Actually it is not easy to find buildings that embody all the principle of green architecture. But there is a possibility to incorporate majority of principles.

Energy efficiency, environmental awareness are not barriers on our architectural creativity. However an architectural language will naturally develop for this approach giving meaning and purpose to form and systems used, akin to renaissance architectural philosophy, where nothing could be taken away without compromising the whole.
Holism also implies user participation in the design process, where by user has a meaningful involvement to get an experience about new work place.

Large organization such as the NMB BANK in Holland, have shown, there is no threat to unity from the process of consultation, the pride of this particular client suggest that an ecologically sound approach can equally well produced architecture that is "prestigious" with the design team working democratically, each specialist connecting on the other input.

2.0. APPLICABILITY OF GREEN ARCHITECTURAL PRINCIPLES IN SRI LANKAN CONTEXT

2.0. APPLICABILITY OF GREEN ARCHITECTURAL PRINCIPLES IN SRI LANKAN CONTEXT

This chapter is dedicated to evaluate an analytical study to assess the applicability of Green architectural principles in Sri Lankan context. Since we study the applicability in local context, it is important to have a basic understanding on traditional Sri Lankan architecture and the Sri Lankan perception on natural environment and its' built component. Therefore first part of this chapter deal with the traditional Sri Lankan architectural practice and applicability of Green principles in traditional architecture as an echo-sensitive architectural practice. Research and Analysis of the case studies will be done using the Green principles and discuss their applicability in contemporary architectural practice in Sri Lanka.

2.1. Traditional Architecture in Sri Lanka

Sri Lankan traditional architectural practices were presented ecologically sound, sustainable architectural solution for the varying needs of the people. It is apparent, that we had a great architectural practice in the ancient time. Thousand of evidences can be found from our ancient ruined cities and temple complexes. Sri Lankan traditional house is the significant example, which is survived as a part of environmental friendly architecture by its way of harmonizing with the environment and use of materials.

As **De Silva** (1990.02) perfectly explained that, *"the traditional house that has existed in Sri Lanka for more than two thousand years was an out come of a strong philosophy of Buddhist life. The simplicity and the impermanent nature of life.. The house was part and parcel of nature, the materials were borrowed from the nature and returned to the nature".*

2.1.1. Traditional Architecture before arrival of foreign cultures

Architecture of every country is peculiar to that country as language dress or folklore. As a result all over the world, distinctive local forms and details in architecture exist.

Sri Lanka has a long standing architectural tradition which has grown from the time of the ancient kings through the Portuguese, Dutch, and the British era. Sometimes it is an amalgamation of a wide range of influences. Buddhist influence from India, building from the Mediterranean brought by Muslims and Arab traders and colonist, Dutch and British modification of European styles, all of which were incorporated and indigenous simple way of buildings in the topics with mud, brick and woven coconut fronds and so on.

The architectural tradition in ancient Sri Lanka had been primarily motivated and determined by internal condition of the country. There were few major elements in architectural tradition of the country. Roof was a "great umbrella", which was emerged against the sun and rain with an elongated rectangular 'pasada' or hall or a number of variations on this basic forms. The simplest building consisted only of a roof or wooden post relatively light and supported by a timber frame work and pillars, and the roof was always rectilinear wide eave and sloping against heavy rain fall and sun. The earliest simple built forms were related to the scale of the man.

Buildings were responded to the proportions of human being in terms of length, width and height. The basal platform which formed the basic foundation, which was built by mud and it was given protection to the building from damp, reptiles and vermin. It clearly defined the building by raising it above the surrounding ground and also provided a solid counter balance to the sloping roof of the building. It is clear that there has been a continuous indigenous architectural traditional of this country right up to the arrival of first alien cultures.

2.1.2. Traditional Architecture during colonial occupation

The Dutch in comparison to Portuguese left a more substantial ligancy in architecture, the roofs built by Dutch were more steeply pitch to heighten the elevation to make a distinction from the rest of the popular and thus built larger, taller and more prominent building to carry larger roof loads, thicker walls were constructed and the original timber columns were replaced with masonry shafts.

However Dutch in Sri Lanka had more successful adaptation of European models to the requirement of a warm climate and modified by local materials, further more a close look at the architectural tradition in Sri Lanka demonstrates, that old these primitive and pre industrial vernacular buildings have been primarily motivated and determined by internal conditions or constraints, which can be described as fundamentals. These included the existed social and religious needs, economic and technological resources, available materials and the climate.

2.1.3. Early building in Sri Lanka

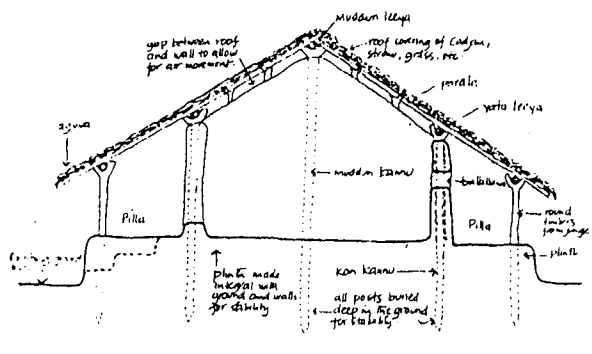
Most of our early traditional buildings were constructed using available local materials like clay, stone, timber poles and Cajuns. Actually houses of rural villagers were constructed by using these materials and the chieftain of the village had a house, which was constructed by white washed clay walls and tiled roof. Following statement prove this idea perfectly.

"These houses are small, low thatched cottages built with sticks, daubed with clay, the walls made very smooth. For there are not permitted to built there houses above one story high neither may cover with tiles nor whiter their walls with lime, but there is a clay which is as white, and they use sometimes"

*(**Knox**,1681,p249)*

The forms of the buildings of the ordinary Sinhalese were constructed of temporary materials. The primitive structures were a result of direct and self conscious translation of their needs in to physical form. The Sri Lankan folk buildings even with limited technology, materials and several restrictions of the rules, could be attributed to the life style of the people.

The simplest and earliest house form was a one roomed hut with verandah in front. A section of which was raised into a sitting flat form, 'THE PILA' it afford protection against damp, vermin and reptiles. The basic traditional Sri Lankan dwelling has a verandah as a significant feature and has evolution over varies eras of Sri Lankan architecture. Master of the house welcomed to his guests in to the verandah and more public activities were given in this place. It also provided privacy for the interior spaces and certain amount of privacy and protection is achieved by bringing down the roof eave just below the human height. Construction materials used in walls have insulation capacity. The verandahs with eaves around the house and small windows kept the hot sun away and provided cool and comfortable conditions within the house.



TYPICAL SECTION THROUGH TRADITIONAL RURAL DWELLING UNIT

Fig11. Typical section – Traditional house

2.2. Traditional Sri Lanken Architectural practice as an Eco sensitive Architectural practice

The first part of this chapter deals with traditional Sri Lankan architectural practice, its special elements and its evolution during history from the time of ancient kings through colonial era up to recent history. It is clear that Sri Lankan architectural practice was congruence with its surrounding environment in the way of using materials, responding environment and the man. Therefore it is important to analyze the traditional architecture within the basis of green architectural concept.

2.2.1. Energy conservation in traditional Architecture in Sri Lanka

1. Site planning

From the site cleaning to completion stage of building all the works were done by human labor and they used small man made tools for this purposes.Therefore heavy machinery was not needed for large excavations. Wattle and daub, cabook or unburned bricks used for the different construction methods and there were not needed any type of foundation trenches. It was started by planting timber poles, which were collected from the jungle for the supports for roof and walls. Therefore it was a one way of touching the earth lightly. The method used to construction for wall was not very much energy consuming. All the heavy works were done by human energy and sometimes they used cattle' driven vehicles.

2. Material selection

There are several ways, materials can be related with the energy, such as processing materials, transportation, installation and recycling process. Throughout the practice of traditional architecture most widely used building materials were stone, sand, clay/mud, timber,straw, cadjan and their various combinations. Among these most widely used building materials, two categories can be identified as organic materials and inorganic materials. Organic materials are palm,grass,bmboo wood,straw,cadjan. Sand,clay/mud lime and bricks are inorganic materials, which were specially used to the construct walls. Cadjans were most popular roofing material in that time.

Cadjans were prepared from dry coconut fronds by weaving in wet condition and after they let in drying. Timber and bamboo used for structural strength for the walls. Clay was used by processing in wet condition and mixing well. Preparation of all above mentioned materials were not consumed too much energy. But preparations of burnt bricks, lime need more energy than above mentioned materials. But their usage was not very common and lime was used very rarely. Therefore the energy consumption to preparation of these materials was very much less than the present situation. Prepared materials were transported by using mainly human energy and carts driven by cattles. Most of the materials collected from immediate surrounding and therefore transportation was a less energy consuming exercise. Material installation was based on the construction methods. Human energy mostly used for the construction methods, therefore well equipped machinery was never used. Early mentioned materials could be recycled back to their original form without using energy at considerable amount. Most of them are naturally degradable.

3. Use of natural light and ventilation

Sunlight was easily taken into the interior spaces of the houses by having windows and doors on external walls. Most of the internal walls were not very

high and therefore it could be easily lighted up from openings in external wall, especially for the temple shrine rooms.

The orientation of the building according to the sun path is the most important consideration. Most of the large openings were placed on north south facing walls to avoid excessive heat coming from sun light in to the buildings. Verandah was significant element in most of the traditional houses and helped to cut down direct sunlight and heat, while providing comfortable transition space. Verandah also provided comfortable lighting level to the internal spaces of the house.

Providing good ventilation in to the building also mainly depend on the orientation of the building. It would be resulted of effective ventilation by means of cross ventilation and through ventilation. Building elements like verandahs,colonated areas, half walled open areas were more effective areas for good natural ventilation.

4. Design for flexibility

Traditional buildings in Sri Lankan vernacular architecture had a great flexibility to change and renovations. It was especially needed in the houses when the family expands in number. The simple rectangular or square plan form provided great flexibility to change and gable or hipped forms provided facility for expanding.

2.2.2. Climatic responsive in traditional Architecture

Traditional buildings were responded to the available climatic condition within the surrounding environment. The orientation of the building was given primary consideration to make comfortable internal environments. Traditional houses consisted of high plinth, thick clay/mud walls and roof covering which was porous. The high plinth also helped to avoid heat coming from the earth.

Heavy clay /mud walls avoided external heat going in to the interior spaces. In the day time heat was absorbed and at night it was released in to interior spaces and they made the comfortable conditions. Excessive heat coming into the interior was controlled by having large openings on walls which was facing to north, south directions. Roof was consisted of organic materials, which was created on a timber structure. Thick porous roof cover worked as an insulation layer for heat transfer. The porous quality was given by cadjan, straw or palm leaves. Air holes as well as air gap between the roof and the wall were helped to good air circulation in inside the house. Cross ventilation and stack effect also helped to make good air circulation.

Courtyard was kept open to the sky and activated air flow through the house while providing lighting to the interier. Courtyards played a major role on creating good spaces in traditional houses and providing good responds to climatic conditions within buildings.

2.2.3. Resources utilization in traditional Architecture

Resources utilization in traditional architecture was played significant role in the history. This was achieved by used of materials which were recyclable, biodegradable and reusable materials and use of resources at a minimum amount for a particular need.

For an example: the use of stone for walls (sakka bema) can be again used for similar purpose. Clay can be recycled back in to its' original position. Timber also could be recycled because it is bio degradable. Clay was used as a material alone as well as in combination with sand, stone, cow dung and so on. Therefore usage of main materials was minimized. The timber was a most popular building material in that time and it was only used for essential purposes. People also planted trees for use for them. Most of the old buildings were used by adding new parts to them instead of new buildings. The flexibility to alter or add new parts was available to the designs. There for

new resources that go into the new buildings were minimized by certain extent. Environmentally hazardous materials were not used in traditional architecture. All the materials were in congruence with the natural environment.

2.2.4. Respect for Site in traditional Architecture

Traditional architecture was mostly in tune with the surrounding landscape of a particular location. It was slightly carried in individual plots of lands for cluster houses in villages. When the construction was carried in the site, existing vegetation was protected in all these cases to make the surrounding environment comfortable and harmonizing with the environment. Any of the traditional construction methods were not used the deep excavations or removing of soil strata. The theme of this principle 'touching the earth lightly' most effectively used in the traditional architecture. For an example "warichchi bitti " can be taken, Timber poles collected from the jungle and they fixed on the ground, then walls were filled by clay / mud with the help of small timber sub frame which constructed between the main timber poles. The total form of the building also related very gracefully to the covered with environmental friendly materials.

2.2.5. Waste management in traditional Architecture

Waste produced by a building can be of two types, waste produced during construction of the building and after the construction. Timber poles were supplied by jungle and prepared only for their necessities. The adequate amounts of materials were also same as the timber. Most of the materials were collected from the immediate surrounding. Therefore waste of the materials was not produced during the construction stage. Stones or similar material were used for the construction and the remaining parts were used for landscaping purpose or land preparing purpose. All the materials were bio degradable and do not create serious problems regarding the environment. In most of the situations remaining materials after constructions such as lime,

sand or similar things were given to neighbors whenever necessary without any hesitation. Therefore waste produced by materials was minimized at that time. Other type of waste was produced by occupants. This waste was used as fertilizer after degrading by biological systems.

2.2.6. Holistic approach

The traditional vernacular Sri Lankan architecture was followed all the Green architectural principles in a very successful way. Therefore the traditional Sri Lankan architecture can be named as an echo- sensitive architecture.

2.3. Contemporary Architecture in Sri Lanka and the practice of Green Architectural principles

Sri Lankan indigenous architecture has existed since ancient time up to the colonial occupation of the country. Being environmentally responsible is a part and parcel of our culture. It began to change during the three colonial occupied eras and influenced by western architectural styles. During the Dutch period the architecture was not totally Dutch but it was a style suited to Sri Lankan styles. Even in today British architectural influences can be seen in most of the buildings which constructed in recent past. Modern influences, varies needs of people and there attitudes also change the Green architectural solutions in our traditional architecture. Creative abilities of people began to degrading and they were become a nation of imitative.

Green designing is one of the most accepted criteria as a solution for global affects due to environmental awareness. Sri Lanka is gradually reaching to an era in which design solutions derived from Green approach of architecture are to be expected. Practicing of Green architecture is fragmented in contemporary Sri Lankan architecture and it becomes difficult challengeable task to achieve for Sri Lankan contemporary architects. There are few

contemporary Sri Lankan architects, motivated to search design solutions from Green architecture by their architectural practice on echo-sensitive brief. Difficult task for them to approach whole essence of all the Green principles by their designs but majority of green principles were succeeded.

For the case studies three different examples are selected from contemporary Sri Lankan architecture and case study will be done as a comparative research deal with the analytical study on Green principles.

Case study one

Adventure park-Ella

There are many reasons to select this hotel as a case study. Adventure Park Ella is the very good example in Sri Lankan Architecture which is greatly achieved green architectural principles as an eco-friendly design. The design contains important features that facilitate with the green architecture, such as energy conservation, working with climate, minimization of new resources, respect for the site and the user, waste management, design for flexibility and holistic approach.

Location

The camp site - Adventure Park situated in the forested ridge in Ella area, which is in eastern part of the Uva province. The mountains in this area are noted for precipitous gradients, steep and narrow mountain rifts, gaps and passes with stunning panoramic views which hold an undisputed natural beauty. The site is accessed via a 2 km trek along jungle foot path, where surrounded by are of rich bio diversity.

Fig 12. A gallery to experience nature
-Ella Adventure Park

Back ground

The Adventure Park Ella was designed by the architect Sunil Gunawardana. The beauty of the surrounding topography and rich bio diversity of the area enhance the eco-friendly sensation. The architect successfully achieved his echo friendly ideas by creating serous of mud huts in a forested ridge. The serous of mud huts simulating a traditional village. Low scale single storied structures are resting lightly on the terrain. The design is mostly respected to the surrounding natural entity. Jungle streams, boulders, abandon bird life and an interesting selection of indigenous trees are mostly integrated with the

design ideas. Magnificent specimens of the "Riti" tree like living sculptures rising 25-30 m into the forest canopy. The jungle trail culminates in a 1m foot-bridge of timber planks, suspended on steel cables, which span diagonally across the Kirindi Oya river. It is the outstanding natural feature of the site and a major focus of public activity, combing large boulders with still natural pools and a thick growth of forest trees along its banks. The individual pavilion like building forms are linked together by the strong, sweeping curve of the service corridor. This 2m wide path links up with the kitchens and the service area. The corridor continues as an open foot path which leads to the two story cabana units which front of the river. Elevated platforms, pavilions and viewing decks provide facilities to the visitors for experience the nature. Ella Adventure park is the one of the prominent example in Sri Lanka which promote the idea "Eco Tourism. The design also gives perception of the interrelation between the vernacular architecture in Sri Lanka and green architectural concepts.

Analysis and Evaluation of Green principles for the Adventure park-Ella.

Conservation of energy

The design mostly respected to the surrounding landscape and integrated with the varied topography ranges. These series of small low scale single storied structures are resting lightly on the earth. The structural support system consists with treated trunks to support raised timber decks. At the construction stage of the design there was no need to involve heavy machinery and sophisticated equipment for large excavation at the site. Therefore large amount of energy could be saved. Eco-friendly organic and inorganic materials such as clay / mud, timber stone, sand, Illuk were used to construct the hut and all these materials were found by immediate surrounding. So there no need too much energy to material preparation and transportation. At the Adventure park most of the construction methods were used human energy and well equipped machinery were never used.

Most of the early mentioned materials can be recycled back to their original form without using energy at considerable amount. Most of them are naturally degradable. Use of timber is more appropriate because its ecology friendliness and the consumption of less energy to produce than alternatives. Some of trees themselves used as structural supports to the elevated platforms and every hut are low scale storied timber structures and their no need to use heavy machinery and heavy concrete works which consumes more energy. They are many clean natural water resources at the site and no need to consume energy to purifying the water. Existing flora and fauna at the site used to landscape very sensitively to cut down the direct sun light and glare, surrounding water bodies at the site also absorb large amount of heat at the air. The use of local building materials and mud wall also has high degree of that heat absorption, high insulation capacity and low heat gain through the wall. "Illuck" roof also obstruct the heat coming into the internal spaces by solar radiation. Most of the huts are fully opened or have large openings in both sides. So cross ventilation is activated in the design in very affective way. Large openings used to enhance the design and achieve of architectural cooling. So there is no need to more energy consuming to operate air conditioning plants or mechanical ventilation.

Fig 13. Traditional technology and Simple geometry -Ella

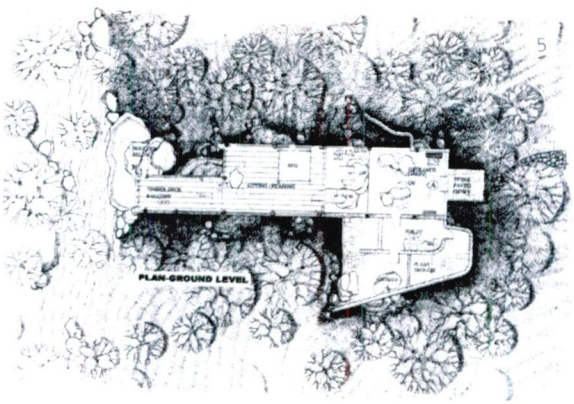


Fig 14. Plan of timber deck- Ella Adventure Park

Working with Climate

Adventure park specially designed according to the local climatic conditions in Sri Lanka. Adventure park Ella situated in the eastern side of the Uva province and more than 2000 mm rainfall brings to this area specially from December to March by northeast monsoon. Steeply sloped thatch of Illuck roof is the dominion feature of the design. Thatch of illuck roof and its long eaves provide protection to the wall and indoor spaces from heavy rain falls. They also prevent them from winds and breezes. Manually operated bamboo mats, PVC mesh, doors and windows provide adequate protection from different weather conditions. Thatch roof also provide protection to internal spaces from solar radiation. Natural ventilation has been considered to avoid discomfort from direct sun and glare. Water bodies reduce heat of the flowing air and cooled before entering the building. Surrounding endemic vegetation also provide additional protection from different climatic factors.

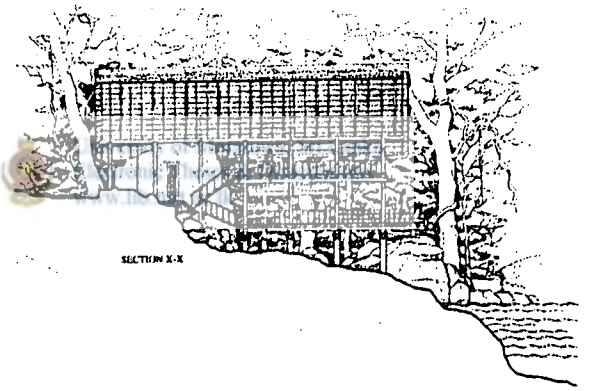


Fig 15. Section through main deck- Ella Adventure

Respect for Users

When we discuss about the principle we should be concern about the psychological comfort of the user and how he protect from the environmental hazards factors. During the construction stage there were not used heavy machinery and toxic materials that can be effect the survival of human beings. Adventure park is the camp-site with the echo-friendly simple structures. So there was no used machinery, which produces toxic things or environmentally

hazards things. At the maintaining stage also not used environmentally hazards things.

The architect Sunil Gunawardana created the camp site- Adventure park for the people who want to get environmental sensible experience to avoid from their uncomfortable boring lifestyle. Nature lovers are attracted by the site to investigate the nature. The trees, streams, river, boulders, wild life and all other admirable features of surrounding environment create high level of Eco-friendly sensation and number of magic views excites the visitors mind. There are elevated Pavilions, Viewing decks and elevated plat forms among trees. These are places for visitors to appreciate nature in order to relax and refresh their body and mind. The bird watching, jungle tracks, swimming and so many echo-tourist experiences are offered by the Adventure park to bring the physical and physiological comfort for the visitors / users.

Minimization of new resources

Inspirations of vernacular architectural characteristics can be seen in the Adventure park. Although most of environmental friendly (natural) materials used for the overall design such as mud / clay sand, stone, Illuck and timber poles / tree trucks. These are bio degradable materials and also they not produced environmentally destructive substances such as toxic substances. So these kinds of materials never occurs health problems of human beings and environmental effects. The minimum use of steel can be seen in the suspended bridge and the reinforced concrete stubs. Concrete also used in the concrete stubs which is acting as the supports for the timber decks. Reuse of timber poles in light posts can be seen in this timber structure.

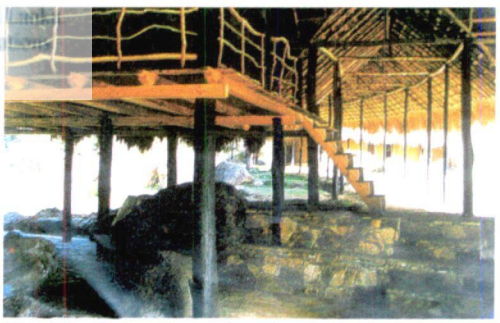


Fig 16. Selection of natural material and simple technique-Ella Adventure Park

Fig 17. The harmony with natural context
-Ella Adventure Park

Respect for the Site

The most popular idea of the principle is 'building must lightly touch the earth'. The idea is mostly proved by the low scale single storied structures which are lightly rest on the terrain on a structural support system of treated tree trunks. But there are so many considerations to achieve this idea "Respect for site". Rare and unique geological and geomorphologic features were preserved and they were part of the design, which enhance the Eco-friendly characteristics. Most of the indigenous trees and native wild life well preserved at the site. There were no used toxic substances, environmental hazards factors in the construction and maintenance stage of the design which can be effected to the site.

Waste management

The self contained and recycling methods have been use for waste treatment. The sewage treatment plant is in operation. Separation wastes are removed for recycling purposes. Polythene is not allowed taken into the site. Minimum use of plastic materials can be seen there and mostly used materials are bio-degradable materials.

Design for flexibility

As the name "Adventure park" suggests, the design of the camp-site attempts to link out door spaces with simple open pavilions, which act as informal leisure spaces, having a certain flexibility of usage.

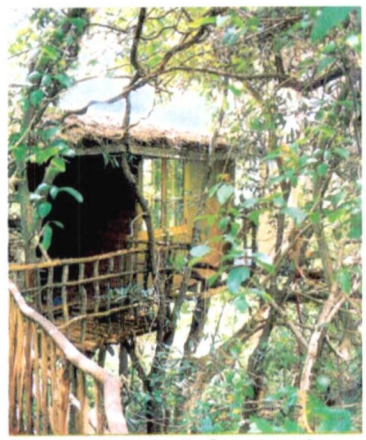


Fig 18. The built form and nature –Ella Adventure Park

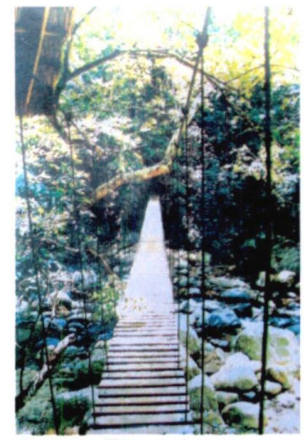


Fig 19. The bridge -Ella Adventure Park

Holism

The camp-site Adventure Park successfully achieved majority of green architectural principles and that embody of all these principles succeeds holistic approach.

Concluding remarks

- The architect sensitively used simple natural materials like timber, stone, mud walls and traditional thatch put together, with an attention to detail, creating and appealingly, rustic ambiance which stimulate the characteristics of eco-friendly design.
- Series of mud huts mutually merged with the surrounding environment and enhance the eco-friendly significant characteristics of Sri Lankan vernacular architecture.
- Highly concerned about the site, which has rich biodiversity. Indigenous trees, wild life and topographical features were well preserved.
- Different facilities provide to visitors for the experience nature. Environment sensible spaces, minimum use of hazards materials are respectively considered for physical and psychological comfort of the user.
-

Case study two

Kandalama hotel

The Kandalama hotel is one of the significant example in Sri Lankan architecture which is successfully followed most of the green architectural concepts. The site also close to the foothill in the cultural triangle and the construction of these hotel environmental issues were brought to the fore in the construction of any building in this country for the first time. It is very difficult task to architect Geoffrey Bava to design five-star luxury hotel as a eco-friendly design. Majority of the green principles were practically applicable for the design and it is important to study this hotel as a case study.

Location

The hotel is located on the border of the vast primeval forest overlooking the scenic Kandalama lake in Dabulla. Kandalama hotel is setting on such beautiful and unpolished Eco-system of the surrounding and it is immerged with the natural lush landscape in hot dry climate. The historical Dabulla and Sigiriya rocks dominate the back ground.

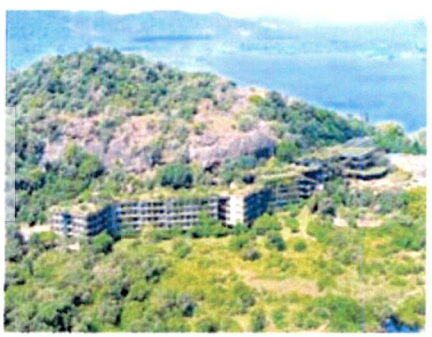


Fig 20. An Arial view of Kandalama hotel

Back ground

The Kandalama hotel is Geoffrey Bava's great contribution to modern Sri Lanken tourist architecture. The design is simple horizontally spreading and existing rock boulders and trees are taken to the design. Views are directed towards wewa and the surrounding landscape. Though it is a three storied structure and it is almost hiding in the landscape. Its flat roof and simple clear

black columns are strengthened the spirit of the place. Bava's architecture has engaged directly with the immediate environment of the site. Huge rock stands in lobby suggesting the potency of the environment. The dining room becomes a rock formation is seemed held back on a delicately folded concrete retaining wall.

The building has been constructed on the least possible ground area without compromising its' essential function for capturing the landscape around it. The snaking form of the design makes it possible for the two residential wings to echo the shape of the ridge and 162 luxury rooms are located there. The sharp focusing of kandalama lake and the pools which are located in two different levels and stimulate the creativity of the design.

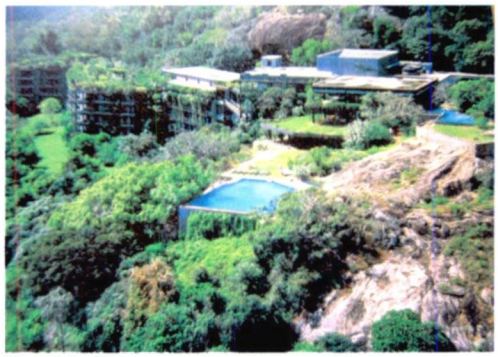


Fig 21. The true harmony with nature –Kandalama hotel

Analysis and Evaluation of Green principles for Kandalama hotel

Conservation of energy

The hotel is situated in between unique jungle setting and the Kandalama lake. Free fresh air properly flows through the building and create cool and comfortable indoor spaces during the day. Main lobby, public rooms, lounge areas have more opening to provide plenty of cross ventilation. The hotel has been oriented to minimize the use of energy for artificial lighting during the sunny day. Roof lights, court yards, huge glass panels can be seen every where in the hotel. Glass panels and roof lights provide natural sunlight into the buildings and court yards play insignificant role for natural lighting and ventilation. The hotel has flat roof with natural endemic vegetation. Natural endemic vegetation has considerable insulation capacity and not changes the thermal balance of the area.

Considering the surrounding topography natural rock formation is used as a rock wall. So the usage of natural materials in natural form conserves the labor energy and material consumption. The hotel consists of natural ventilated areas and air conditioned areas. Designer should have responded to five star hotel requirements. There are 162 luxury rooms which are provided with individually controlled air condition system with CFC free gases.

Working with climate

Kandalama Hotel is located in a dry zone of Sri Lanka. Temperature is about 30 C" So the climate is higher than the hot dry condition.

Sun protection/orientation

The hotel is oriented mainly in north east and North West directions. Sun protection devices are provided to cut off the direct sun rays and rain and winds in the Sigiriya and Dambulla area. Most of the terraces and gathering spaces are in north direction. Pools are located in a two different levels. Thus hot air may flows through those water bodies and reduces the heat of air before entering the buildings. The orientation to the wind direction will reduce the heat of the air.

The excellent articulate spaces according to the sun path variation and day light have been considered to avoid discomfort from direct sun glare and rain etc.

Shading is the most prominent feature to protect building from different climatic conditions. Hotel Kandalama effectively used different shading devices for attempt this goal. Three

Fig 22. The sun protection pergolas blended with nature –Kandalama hotel

Fig 23. pergolas – Kandalama hotel

feet wide pergolas run around the bedroom wings in each floor. These are created to protect the large glass walls from sun and rain. Projected balconies with creepers of dry zone plants and conservation of existing canopies of the ancient trees help to shade of the building. Façade of bedroom wings are located in North-West and North- East to cutting down the direct sun rays. Architect Geoffrey Bawa very sensitively used existing flora and fauna in dry zone for the landscape. Landscape provides protection from direct sun and glare. Glazed windows which can be open, provide natural ventilation into the building. An internal courtyard is located towards Dambulla wing to provide natural skylight and ventilation. The flat roof is covered with grass and it receives solar radiation continuously throughout the day. Dry zone plants and soil layer may reduce the reflection of the direct sun rays. The soil layer act as an insulation layer and cooling the air above the roof and moisture helps to keep the temperature down. Gray and black colours of external walls may reduce the absorption of heat.

Minimizing the new resources

The building has been built only on 12 acres in order to use the minimum space for the building. The existing natural features such as ancient trees, rocks have been preserved and use to design purpose. The architect highly concerned to avoid use of materials containing toxic substances and CFC.S. Ex: Air condition system with CFC free gases.

"Building with appropriate material" is one way to achieve criteria of the green concept. They used aluminium, glass and steel for the construction as alternative materials. As a result it could be reduce the timber construction

and also conserve the rain forest to create sustainable industry. The conservation of local natural materials and appropriate use of alternative materials are rudimentary to echo sensitivity in architecture.

Respect for User

Kandalama hotel very closed to the Dambulla, Sigiriya and other historical places. Therefore so many local and foreign visitors come to the Kandalama hotel. The architect Geffery Bava used totally new language to design articulate spaces to achieve idea "Respect for user". The country road encourages the psychological impression of nature for the visitor. The low scale/volume, texture of the rock wall and cave like reception verandah makes the eco-friendly sensation, which automatically transfers to the mood and mode of behavior of the visitor. Large volumes with maximum views provide visual experience the unique surroundings. So uplifts the visitors mind and make high level of sensation. The charming colours in interior and black, gray colours do not disturb visitors mind. The hotel offers excellent imperative programs to educate the visitor about local environment and culture in order to relax and refresh the body and mind. The hotel provides facilities for user, such as providing local foods, Ayurvedic medical facilities and echo-tourist experience. The bird tours, jungle tracks, elephant safari, boating is the success of climate and eco-tourist experience to the guest that have been provided.

Fig 24. Natural rock wall and cave -Kandalama hotel

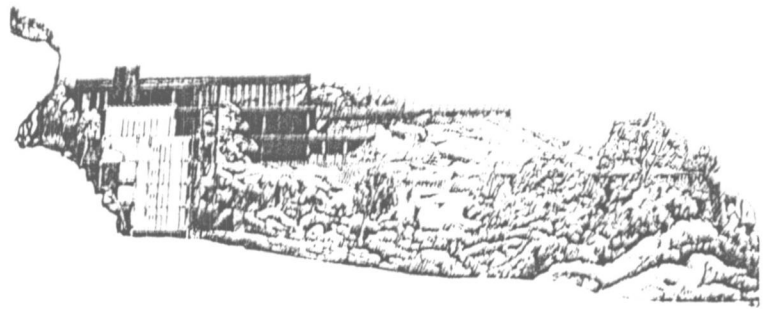


Fig 25. Section of Kandalama hotel

Respect for the Site

The hotel has achieved the idea of "touch this earth lightly" so the builders ensured that no structure would be on the rock. Behind the hotel is a massive rock with a dense jungle area from which rain water cascade down to the tank, during the monsoon. The builders have made provision for this rain water to flow unobstructed into the tank by the skillful designed of a raised ground floor. The rare and unique plants, plant communities and habitants for animals and other wildlife are conserved. Rare and unique geological and features are preserved and they are incorporated wherever possible into the planned development of a site to add to its' special sense of place. Biodegradable waste are composted and recycled to improve the soil at the site. Any foul water produced on a site properly clean before returning it to the natural environment.

Waste management

The waste water from the kitchen, toilets, swimming pool and sewage will flow to the treatment plants where it will be purified. This will ensure according to the standards set by national environmental act. However this water before it flows into the tank will be first used for watering the roof garden and plants in the hotel. The sewage treatment plant has been in operation and the plants have achieved a slightly better effluent quality of water. The hotel staff also has been well trained in the waste separation and disposal. After separation

of papers, shopping bags, bottles, plastic, glass lids etc. and they removed for re-cycling and reuse purposes.

Holism

The hotel has achieved of majority of green principles mentioned in chapter one. The architect Geoffrey Bava tried to follow majorities of the above principles and design strategies in a successful way. Finaly hotel can consider as a great product of holistic approach of green principles in contemporary Sri Lankan architecture.

Concluding remarks

- The design itself response to the tropical climate especially for dry zone eco-system. Similarly, they work with it and design to experience the environment. Design strategies respond to prevent tropical sun, rain and sky glare.
- Consciously the use of alternative materials, design itself and other principles that achieved are to be appreciated.
- Articulated spaces, non decorative architecture make psychologically comfortable built environment or eco-friendly sensible spaces.
- The designer has successfully achieved majority of Green principles, although the energy consumption is fairly high therefore the maintenance cost has comparatively increased.

Case study three

The Media center at Pelawatta

Sri Lanka is the country that is blessed by the sunshine in through out of the year. Therefore use of solar energy as an alternative to the ever-increasing demand for hydro power could become key to the bright ecological future. The media center at Pelawatta is the great example for energy efficient building in Sri Lanka by using solar power as an alternative energy and most of the green principles are facilitated with the design. There for it is important to study as a case study.

Location

The Media center is located in the Pelawatta in Battaramulla.

Fig 26. The media center at pelawatta

Back ground

This is the first time in Sri Lanka and the east where solar power is being fed to the national grid and it is a landmark for the CEB. The Media center is the most prominent design of architect Harold N. Rostvik, which reflects the green concept to the sustainable future is Sri Lanka. Traditional and modern technology play significant role to achieve the green concepts by providing methods of natural ventilation, cooling, day lighting, waste recycling and using solar power as an alternative energy resource. The Media center is the three story building, which situated in beautifully landscape area. The vegetation is placed to ensure natural cleaning of the air. Solar panels are placed on the second floor and the space underneath the panels will be used as meeting places for the various

departments. Different gathering spaces are created to informal discussions for the user and act as a place for relaxing after a long, hard day.

Analysis and Evaluation of Green principles for Media center at Palawatta.

Energy conservation

The Ceylon Electrical board (CEB) has accepted a solar PV grid inter-live system of 25 kwp expandable up to 75 kwp in a building. The expensive and bulky energy storage systems like batteries, which require constant maintenance, have been avoided as the grid it self becomes the storage. Large air conditioned areas are equipped with cooled air recovery units, and they saved energy by reducing the AC load of this area and extra costs will be recovered within a period of two years. The usage of energy efficient light bulbs not only reduces the electricity consumption by 25% but also eases the cooling load by emitting the less heat into the surrounding environment. The computerized spaces uprights have been used to avoid screen reflections. These combined with individual task lights provide the adequate lighting levels for the type of usage of the buildings. Areas which do not possess equipment requiring air conditioned cooling are naturally ventilated. Fans on top or architecturally visible extract ducts assist in naturally cooling air conditioned spaces. Most of which have been located against the existing hillock used as a brim and areas filed in order to provide insulation, minimum heat again and thereby reducing the AC load.

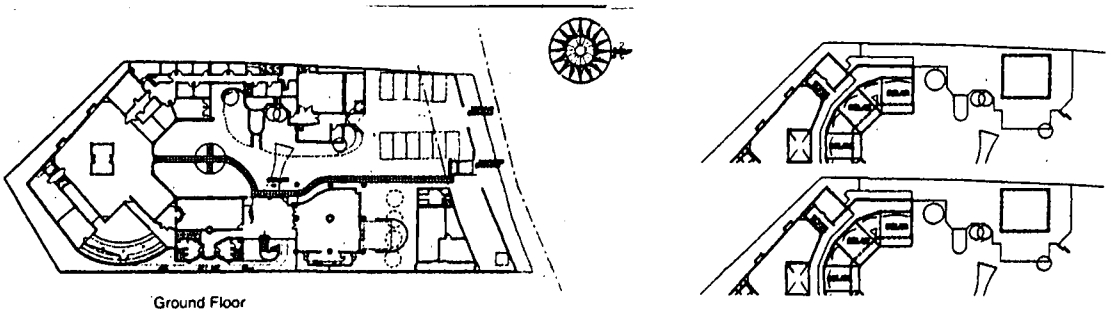


Fig 27. Floor Plans –Media center Pelawatta

The building is designed to allow maximum indirect daylight penetration into room via court yards, yellow painted light wells and patios cutting right through the building mass. Therefore energy consumption for lighting is considerably reduced in the building.

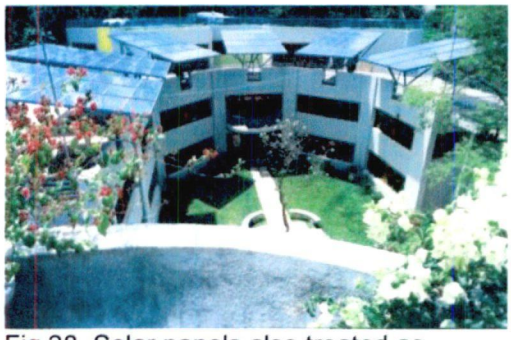


Fig 28. Solar panels also treated as building element - Media center

Optimum use of area and material is the one of the important consideration to reduce energy consumption. The users who are a group of companies dealing with Media television production, software engineering and information technology are presently scattered throughout Colombo in six different locations by gathering these different units together an efficient use of time and energy in terms of communication, transport, etc. as well as a more rational use of space has been introduced by sharing common areas. This process has resulted in an area and material reduction of up to 30%.

Fig 29. Solar panels placed as sun protector also –Media center, Pelawatta

Working with climate

The site is situated in wet zone which receives 2000-2500 mm of average annual rainfall and average temperature around 28 C with maximum of 32 C minimum of 22 C.

The building is designed for worked with the local climatic conditions and specially response to the available natural energy resources such as solar power. The surrounded green and vegetation to be reduced reflection of solar

radiation. Most of the areas which not required air –conditioned cooling are naturally ventilated. The Solar PV has a double function as a shading device over office areas, windows, staircase and walkways. The flat concrete terracotta roof top is not a very efficient shelter for topics.

Minimization of new resources.

The more rational use of space has been introduced by sharing common areas, this process has resulted in an area and material reduction up to 30%. Toxic and harmful building materials have been avoided. Timber, which is a bio-degradable, renewable material has been used but in possible sections for doors and windows. Concrete work and locally manufactured brick work are used for the design. Wherever Building regulations do allow, concrete is substituted by less harmful, while the use of Steel/ Aluminium is limited.

Respect for User

The lush tropical garden spaces landscaped within the architectural setting serves as a backdrop for a pleasant work environment and also provides inspirations to those engaged in creative work. Benches have been placed in shady nooks and corners, creating little gathering spaces in which to hold informal discussions or act as a refuge for seeking respite after a long, hard day. The building is carefully designed and planning for accessible to the handicapped. Wide threshold-free doors, handicapped toilets and low-level electric switches provide easy access by wheelchair to all the major areas of the building. Imported lead-free paints based on natural non-toxic materials, which cause minimum health hazards, are used in air-conditioned, confined spaces.

Fig 30. View of greener garden space
-Media center, Pelawatta

Fig 31. Green cover with optimum footpaths
-Media center, Pelawatta

Flexible for living

All electric, telecommunication and data cables are located in, trunking ducts embedded in the concrete floor. At intervals, these cables enter a connection box, into which sockets have been connected. Work tables are clustered around such boxes providing them all with electricity, telecom and data facilities. Therefore this system allows maximum flexibility in locating work stations.

Waste water handling

A public sewage system doses not exit on site, all sewage from up to 450 people is treated on site in an Extended Aeration underground type sewage disposal unit. The wastewater treatment plant on site will recirculate "clean" water for the purpose of watering the garden and to flush the toilets.

Holism

Some of the Green principles in holistic approach were fulfilled in the design. Therefore Media Center at Palawatte can be considered as a green design but at the construction, it can be taken as ordinary building.

Concluding remarks

- the Media Center at Palawatte is presented as a pioneering project engaging traditional and modern technology to address aspects of ventilation, cooling, lighting, waste recycling and utilizing Solar power.
- Using solar power as an alternative power resource is to be appreciated.

3. GREEN ARCHITECTURE AS A MAJOR ISSUE IN FUTURE SRI LANKAN ARCHITECTURAL DESIGNS AND PRACTICES

3.0. GREEN ARCHITECTURE AS A MAJOR ISSUE IN FUTURE SRI LANKAN ARCHITECTURAL DESIGNS AND PRACTICES

The applicability of green architectural principles for Sri Lankan traditional and contemporary architecture have discussed in the second chapter. The third chapter will discuss the need of green architectural design practice for the present situation in Sri Lanka and how it will be achieve architectural practices for future design process to construction. Environmental awareness in global architectural practices has become an important issue from recent past. Buildings are obviously major impacts on environmental degradation. Sustainable development which oriented towards to the future and makes the idea for future oriented architectural practices. Sri Lankan traditional architectural practices were presented ecologically sound and sustainable architectural solution for the varying needs of the people. With the time, most of the green solutions in traditional practice were abandoned and resulted solutions which are creating environmental problems. The complex needs, attitudes of people may cause to evolve such solution.

Modern architectural trends in contemporary architectural practice in Sri Lanka demand the use of modern materials such as glass, aluminum, various cladding materials, vinyl finishing materials, etc. They demands not only materials but, air conditioning facilities also, instead of natural ventilation. Uses of glass in modern buildings offer many advantageous in taking natural daylight into the building with some beautification to the building. They also allow maximum advantage for showroom functions and add respectability on certain building facades. Glass is relatively transparent to the short solar wave radiation. Therefore it allows trapping the heat brought by solar radiation in to the building. But glass is less transparent for longer wave solar radiation which goes out from the building. This can be avoided by using glass for places which receives less direct solar radiation. Most of the

contemporary buildings are not to be taken the expected function of using glass. Most of the situations, glass have been used just for the beauty of façades or need of outstanding appearance in the neighborhood. Therefore glass curtain wall can be seen in most of the city spaces. Glass and aluminum are now available in anywhere in Sri Lanka even in a building materials shop. Except, early mentioned facts, glass is available in various qualities consisting various colours and type such as tinted reflecting / mirror or plain and etc. Aluminium and the glass facades / curtain walls are interrelated. Most of the buildings use Aluminium for their different applications and they are less durable than timber in similar situations. Most of glass curtain walls in buildings are open to direct sunlight and it will require large capacity of air conditioning to make the interior comfortable during hot daytime. It will not be a good solution in saving energy within a building.

Traditionally used materials do not require cleaning very much. However materials, which have glittering finishes and colours. These materials are suitable for sophisticated environments which require minimum cleaning and maintenance quiet thus consuming more energy. But the use of them is decided by the socio-cultural needs other than functional needs.

Metal is the most commonly used material for roofing and also has become a part of such trend. Metal is not suitable roof material for the Sri Lanka as a tropical country and it is required heavy insulation to make the space comfortable. Most of the people used metal roof, because of their neat finishes and get advantages of by using different forms. They never concern about their functional needs.

However these meaningless architectural trends have effected the built environment of the country and continuously increasing its affect with the time. As such, the prospects of Sri Lankan architecture are not Very bright in

Very bright in terms of environmental protection and the need for a green architectural revolving is clearly visible.

3.1. A Green Architectural design practice for Sri Lanka

There are two major considerations to achieve green architectural concept for the contemporary architectural practice and future architectural designs in Sri Lanka.

1. Following of green principles.
2. Include green thinking into building regulations.

3.1.1. Practice of Green principles in future Architectural designs

Green principles in architecture are based on the green concepts. These several principles cover the whole area in building design to construction stage. Each principle can be followed by several ways. Each step mentioned / consisted under each principle must not be followed for the achievement of the goal. Some of the aspects may not be possible to achieve in a given situation.

If taking an example within the Sri Lankan context.

Many buildings are located in opposite of the sea side along Galle road. Each building has two boundary walls in either sides and most of them are faced to the Galle road. Then its problem of avoiding direct sun during the half of a day time. This cannot be avoided by orientating the building on north south direction. Openings have to be placed on road side and the rear side, and front façade will be faced to the direct sun. therefore special device for shading have to be used to cut down the direct solar radiation.

From here each principle will be discussed with some of the Sri Lankan examples where possible and, mentioning required steps to be followed up every principle.

3.1.1.1. Conservation of Energy

This principle can be achieved by several considerations. Some of them are proper site planning and materials selection, use of natural light and ventilation, use of low energy systems, reuse of old building and designing for flexibility.

Site Planning

The contemporary context building requirements are increased and buildings become more complex, but urban plot of lands become smaller. The site planning is a very critical issue for that kind of plot, for example small strip of urban plot does not have an option to building orientation. The most of large projects, such as storied buildings are used heavy machinery which are conventional. For an example pile driving by hammering is waste energy and created high vibrations with sound pollution.

How ever ecological designers should have to take important decisions to avoid or minimize ground excavation works as much as possible. Another alternative is future buildings must have a minimum foot print with elevated parking spaces etc.

Materials Selection

The most commonly used materials are concrete, steel, aluminum, timber, glass, asbestos and mineral filter products etc. The important issue is designer should be aware from too much energy consumed materials in this flowing stages, such as of material manufacturing, transportation, installation, maintenance and possibility of reuse or recycling.

The flowing diagram shows embodied energy of some commonly used materials. But in the architectural practice energy is not an only fact that to be concern in material selection.

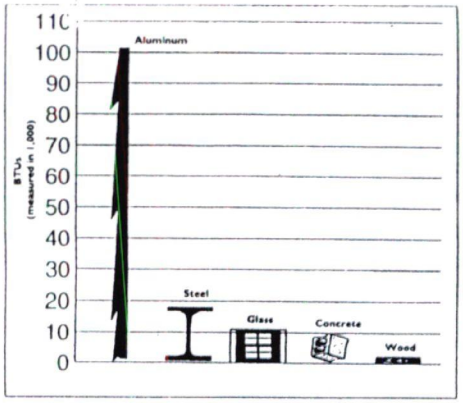


Fig 32. The embodied energy of some common materials

Aluminum contains high embodied energy than some other materials. But it has verity of design possibilities and no air quality effect in the usage. But as an energy issue Aluminum is not a very appropriate material.

Steel contain such embodied energy, but steel also has variety of design options. It is useful material to practice light weight architectural designs and steel can be recyclable. Therefore steel is a less harmful than most of other materials.

Concrete is stable substances, it has minimum indoor air impacts. Some how it contain amount of embodied energy.

Glass also has much embodied energy than concrete. But comparing its significant characteristics it can not be avoid for designs.

Timber is very low in embodied energy it is good source of renewable material and variety of design possibilities. Therefore timber is a good green material.

Fig 33. Mouli house By Arch.t V. Basnayake is good example for environmentally harvest material composing.

Use of Natural Light & Ventilation

Sri Lanka as tropical country, there is great potential to use renewable fuels as sun or wind to fulfill the power requirements of the buildings. Unfortunately some urban high rises or commercial complexes were air conditioned and artificially light up a result of following western influences. This is a very serous impact for the power consumption in Sri Lanka as a developing country.

Case studies are explained, some luxury hotels of Kandalama & Ella Adventure park are good example for natural lighting and ventilation with achieving luxury environments. The Mahawali building is a good example for use natural energy as urban high rise.

Natural lighting and ventilation are careful consideration to investigate at the design stage. Defused natural light utilize with pale reflecting materials and supporting systems. It will result in an optimal lighting design in interior spaces. colours are very important fact and careful colour selection will help to efficient lighting design.

Low Energy System

Energy consumption is very high in the maintenance stage of the building when compare with the energy consumption in building construction..

Energy is used for lighting. Air circulation (fans), air conditioning, cleaning purposes, pumps (water, sewer, storm water) and office equipment of the buildings. Therefore wastage of energy is very high during the maintenance of buildings. Buildings which have basements use additional energy for lighting, ventilation and for disposal of storm water. There are some sort of low energy appliances are motivated by Ceylon electricity board (CEB) to control electrical consumption of the country. As a result compact fluorescent (CFL) bulbs most commonly used in our buildings which comparison to incandescent bulbs save much energy as well as reduce heat production from

light source. Solar panels are much better low energy system for our country, but it is not widely use because initial cost is high.

Water heaters and cookers are the most high energy appliances in the home environment. The solar water heaters or gas fried water heaters are some sort of alternative appliances.

Numerous technical features will enhance energy savings in lighting. Separate circuiting and switching should be provided for different tasks and zones. Light controls should be easily accessible so that occupants can readily make lighting adjustments. Occupancy sensors, dimming stepped switching, programmable controls and energy efficient lamps are some possibilities.

Use of old buildings instead of constructing new ones is save large amount of energy.Tea factory hotel Kandapola and Jaffna library are very good examples in Sri Lanka, which is achieved idea perfectly. Jaffna library also explain under resource utilization.

Flexibility of Designs

Certain building designs have flexibility to convert several functions as well. There are two considerations deal with the flexibility.

1. Use single space for multiple functions.

Ex: there are several local examples are found. National youth centre arena is one of the good example. It can be use as indoor sport are for several sports, theater or conference hall.

2. The service systems of the particular space can be flexible for several functions.

Ex: Electrical system or communication net work has flexibility to adjust as new functions. The raised timber service floors are some sort of useful method for that.

3.1.1.2. Working with Climate

Sri Lanka is a tropical Island and it experiences varied climatic conditions from cold to hot. This variation should be reflected by the building in each climatic zone within the country. Climatic response in traditional and contemporary architectural practice plays a significant role in architecture by providing comfortable living spaces. Unfortunately some contemporary urban practice does not respect to climatic issues. The same thing is very common to most of Asian countries. The architect Hassan Pathy illustrates in his national energy and vernacular architecture.

"In the eagerness to become modern, many people in the topics have abandoned their traditional age-old solutions to the problems presented by the local climate and instead have adopted what is commonly labeled as 'International architecture' based on the use of high technology materials such as the reinforced concrete and the glass wall. But a 3mx3m glass wall in a building exposed to solar radiation on a worm, clear, tropical day will let approximately 200 kilo calories per hour. To maintain the micro climate of building thus exposed within the human comfort zone, two tones or refrigeration capacity is required".

-Hassan Pathy

The tall buildings in urban areas are needed more attention to its climatic response, but in the contemporary practice, most of tall buildings are air conditioned. Either natural ventilated or air conditioned, building orientation is very important. The basic thing in the orientation is providing openings on north south directions and more solid areas have to be used on east west facades.

Natural ventilation is very difficult to provide into the internal spaces when the building is getting taller. The Monara tower of Malaysia is a significant example, which shows how tall buildings respond to its local climatic conditions in a sustainable manner.

Fig 34. The Mahaweli building

The Mahaweli building also a good local example of naturally ventilated building envelope with concrete sunshades etc.....

The following steps are important possibilities of climatic responsive design.

- Building must be oriented so as to get maximum effective ventilation into the building while avoiding excessive heating coming into the building.
- Sun shading devices, pergolas, or shelf shading must be used when the direct solar radiation cannot be avoid by orientation of buildings.
- Natural ventilation systems, such as cross ventilation / stack effect or through ventilation must be used to achieve thermal comfort in internal spaces whatever possible.
- Tall buildings must be naturally ventilated while providing the opportunities to occupants to experience the nature and its variations.
- Material should be selected by considering their durability and the ability to withstand in climatic conditions.
- The rain water can be a resource for secondary water needs such as flushing toilets, cleaning or landscape plants.
- The solar and wind power also converted to necessary power requirements of building such as solar electricity, wind power water pumps etc.

3.1.1.3. Resources utilization

Contemporary used materials are not very conscious on its resources. Any of the material production needs some resources. Aluminum, steel glass, concrete and timber are most usable materials in today. Although there are no perfect products, environmentally preferable one do exit. The architect must be knowledgeable enough to select correct material for correct purpose with respecting its manufacturing process, installation, and maintenance processes and although ability for reuse or recycling.

Building restoration, historic preservation, renovation and adaptive reuse is the most environmentally conscious way of resource utilization.

In the Sri Lankan practice there are certain examples were found in contemporary Sri Lankan architecture. Tea factory hotel at Kandapola is most creative example that shows an old factory converted into luxury hotel. Some factory equipments also used interior decorations and some other hotel applications.

The Jaffna library which was burned due to civil fights in Jaffna and it has renovated recently as Jaffna library again. If a decision is made to either remove entire building or part of it. Deconstructed materials can be recycled and reused rather than simply demolishing an unusable building.

Fig 35. The Jaffna library

In Sri Lankan material industry is much concerned about use of several substitute materials to minimize use to main materials, for example coconut husks pressurized with clay to make bricks instead of cement blocks. There are several waste materials such as paddy husks, ash of paddy husks,which are in experimental level to use construction purpose.

Anyway we have to use some sort of new materials for building purpose. The flowing steps to be important to select building material in an ecological manner.

- The material do not pollute inside air of the building (at least less pollution than others)

- It must conserve natural resources, if material it self is non renewable resource tries to be minimized use of it and or if it has some bad ecological impacts also minimized it use.
- The material should be water-conserving and energy efficient.
- Material manufacturing process does not result in excessive air and water pollution.
- The material can be recyclable or biodegradable.
- The uses of local materials are good enough because they need less transportation energy and it express the culture of the community.

3.1.1.4. Respect for User

There are different categories of users, who are involved in the building process. Persons who occupied the building is the most important user and others are maintenance staff who provided services & maintenance and construction staff who involved in the construction process. The idea is to be provided healthy, danger less, mentally comfortable environment. for the every human being in the building process.

In Sri Lankan building industry does not give much attention to construction and maintenance phases as user. Except large construction companies, other construction companies don't concern about the human safety. They don't provide safety hamlets, mouth guards, sanitary facilities etc for people who involve in the building construction process. Safety and health needs to be much concerned than others in the underground and high rise constructions. In Sri Lankan construction projects do not respect about the bad impacts of materials, the common examples are Asbestos, lead based paints causes to human health.

The following are some basic facts to make respective user environment.

- Indoor air quality is an important aspect to maintain comfortable and health full environment.
- High number of air changes per hour should be implemented (Tropical Green designs not enthuse for mechanically ventilation)

- Indoor plants, court yards to be introduced.
- Avoid use of harmful materials such as Asbestos , Lead , Cadmium , mercury based paints , pipe appliances, Formaldehyde adhesive based ply wood , carpeting , particle boards etc.
- Avoid directly exposure to electromagnetic fields, the design should careful enough to maintain optimum.
- Distance from high voltage lines, transformers, high voltage equipments, etc.
- noise pollution should be maintain by doing such design technologies , for example Acoustic boards cavity walls textured interior surfaces etc. the traffic noise can be reduce Landscaping such as earth beams and vegetation.
- Avoid use of Radon, Uranium or Phosphate mine training to explode stone granite or rocks especially in living environments.
- Particularly in Hospitals installation of equipment of X-ray machines, should be used safety precautions as Lead snitched doors, concrete walls etc.
- maintain comfortable psychological environments with addressing social and cultural issues of user.

3.1.1.5. Respect for Site

This is an important issue in green architecture. But important thing is, most of the architects respect it as an ecologically sound manner. Most of them respond to physical buildings characters and forget about vegetation, biodiversity, climatic concerns etc. In such urban situations there is no vegetation or biodiversity to be respond.

Fig 36. Boulder Garden respect to its natural rockery terrene

The low scale buildings do not much harm to its site. Large skyscrapers, Hotels, office complexes have huge impact on ecological issues of the site. For an example, in the under ground construction, large excavation are done by huge machineries as a result waste energy, destroy bio diversity, vegetation, natural site settings and also leads to environment pollution of construction phase.

But there are significant local and foreign examples, which shows how can be done large or luxury buildings with minimizing the damage to the site. The Ella Adventure park and Kandalama hotel are most important examples in Sri Lankan contempory architecture which is achieved that idea perfectly.

The 100% harmless situations are not realistic. But following facts are important considerations.

- The site design seeks to enhance and protect natural resources, vegetation and biodiversity of the land.
- Specific climatic characteristics should be considered in order to locate facilities to maximum human comfort, protection from sun wind and rain and use it as recourses for building facilities (eg. Solar panels)
- Topographical features are important fact. If handled properly, sloped topography can provide visual and sound separation than flat land. By reducing size of the building foot print, eliminating automobiles and parking spaces can be keep soil disturbance at minimum.
- Find out carrying capacity for development and human activity for the site is important to do a correct building with correct scale.
- Culture context, sustainable design should fit to enhance the potential success of site development which has to address local archeology, history and social issues.

3.1.1.6. Waste management

The waste can be produced in construction phases as well as building operational stages. The construction waste management is very rare to find

positive examples in our building industry. The huge amount of construction waste such as row material packages, material wastages, concrete foam works, waste or Garbage of workers are become problem of many sites, the following Facts will use to construction waste management process.

- minimize use of foam work or foam work can be made by materials like fiber for use several times.
- Selection and buying of materials can manage as minimum wastage
- prevent waste water directly contact with natural water bodies, some sort of water treatment may introduce.
- Waste materials can be direct to recycling or re use processes.
- provide well sanitary facilities for workers.

The waste on the Building operational stage such as sewerage, waste water, waste produced by cleaning & maintenance, kitchen waste ect. Basically those can be connected to two types of waste managing systems as recycling or Biodegradation (composting)

- Organic waste such as sewerage, some kitchen waste, wooden waste can be used for Biodegradation system (composting) this is and very efficient use of waste and it produces Bio gas and compost fertilizer. In our Local practice also found some sort of small scale examples but need to be introduces into large projects as well.
- sorting and recycling is very important to use public places like offices House apartments etc. and Building occupants need to encouraged For waste sorting process as plastic waste, paper waste, Glass were in creative manner.

3.1.1.7. Holism

Consideration of all green principles in an architectural solution is essential to make the architecture green. Even though contemporary practice hard to find

particular projects with holistic green approach in building construction, operational and post operational phase. The case studies illustrate holistic approach particularly in the operational phase. The Sri Lankan constructions (construction phase) does not experience holistic green application yet. Even though following all the principles in a construction site may not be practical, more number of principles have to be followed to achieve satisfactory results.

3. 2. Including Green thinking into building regulations

Incorporating green architectural concept in future architectural design can be enhanced by including green thinking into building regulations. Building regulations are meant to control haphazard developments of buildings and to ensure constructions, which follows certain disciplines with the use of lighting and ventilation requirements etc. including of green thinking into regulations will strengthen some of the building regulations also. Existing building regulations include regulations of the provision of natural light and ventilation. The need of planting trees, preservation of existing trees, waste control and climatic responses with some energy saving suggestions also can be included in it.

When the constructing buildings in urban situation, preservation of existing trees is very important than planting new trees. Planted new trees takes time to grow up and to provide necessary benefits such as shading, beauty and supply of fresh air with surroundings. Waste management can be activated if it is included in the building regulations. Waste is a great problem of people in multi storey apartments. Generally waste of apartments is taken to the ground by using refuse chutes. Waste is mixed by this method when using single refuse chutes. Today plastic waste has become a problem, because it is not a bio degradable, but it can be recycling and used for another purpose. When

waste is mixed and sorting out by serious process. It can be solved by having separate refuse chutes in future designs for organic waste, and others,

Energy conservation, resources minimization, climatic responsive designs and so forth also can activate incorporating it to future designs by including them into building regulations. Energy conservation can be done by incorporating regulations related to orientation, material use, use of low energy systems, design flexibility and so on. Materials used is also very important to be incorporated in to regulations in energy saving and resource minimization. Climatic responsiveness can be incorporated by weather resistant materials and devices for climate control.

3.3. A Green building process for Sri Lankan Architectural practice

The active involvement of architect as the designer in the building process is very crucial to make the project completely successful. This means the identification between the client and the architect to get the real requirements of the client. Generally architect act as the leader of the design team of a building. It is true that in the green building process, the role of the architect must be an outstanding one in decision making and taking action. In the beginning of a particular project the architect can advise the client on most of the necessary steps to be taken at initial stages in the green design approach. The preliminary discussions between the client and the architect may be helpful to convince the client on a new approach such as green approach to architecture. It is very important to advise the client at initial stages on green design approach within persuasive trends in contemporary architecture.

However following attempt of preparing a work plan is aimed at making an awareness of the practical applications of green ideas into the sequential

order in building process. This work plan is based on major steps in the building process such as Briefing, sketch plans, working drawings, and site operations.

According to these diagrams some of the green principles in the building process start from the inception stage. Some are starting from outline proposals stage. But for example principles of minimization of resources have to be started considering from inception, but it will active from outlines proposals. Therefore the following of green principles with the building process can be understood by this diagram of green building process.

CONCLUSION

In the context of increasing environmental awareness throughout the world, this study was orientated to find out the capability exploring solutions for environmental problems by the Green approach to architecture and the way of its connection with Sri Lankan traditional architectural practice and contemporary architectural practice. This study was done by assessing a Green architectural concept.

This study was started by searching a definition to Green architecture and it was clear that the Green architectural ethic was based on discovery of architectural responses which are in harmony with nature, corresponding, reassessing and challenging the conventional wisdom. It is apparent that always it was based on sustainability, eco-sensitivity and ecological architectural conceptions. However the Green approach to architecture was not a new one and has existed since the stone age of the history.

The concept was summarized and arranged in to a conceptual framework for the easing to evaluate and applicability to architectural practices in Sri Lanka. This conceptual framework was mainly based on Green architectural principles stated in literature. According to analysis of traditional Sri Lankan architectural practice and contemporary practice, it was clear that all of the Green principles have existed in Sri Lankan traditional architecture up to recent past and still some of them are existing in contemporary practice also. Traditional architectural practice in Sri Lanka can be called an eco-sensitive architectural practice which transferred its valuable architectural solutions from generation to generation.

Contemporary architectural practice has abandoned most of the great solutions in traditional practice and faces uncertain future. The need for re correction of abandoned solutions has been highlighted in the study by showing the importance of the Green approach for future architectural practice in Sri Lanka and formulation of a work plan with the help of Green ideas and building process. Prepare of list of requirements to be fulfilled in design stage to construction stage by following Green principles in architecture. The formulated building process will help to designer to get an idea tasks to be done in each stage in the building process. This is important to pay attention to each step separately because every Green ides cannot be incorporated at the beginning of the process. Some ideas have to be incorporated at a middle stage of the building process. But careful attention on each stage is required for the successful achievement of Green ideas. Some of the Green ideas have to be incorporated in stages depending on development stage of the design.

The study of the subject of Green architecture is vast subject area and the complete research will require more time and effort than the present exercise. This study has confined the need to make awareness about the Green approach to architecture and exploring solution on environmental problems arises due to buildings today. Therefore this study has not analyzed the situations in depth and do not provide detailed and practical solutions that can be directly applied as solution to specific problems. The study can be extended further by orientating it towards the human and psychological needs of people with the architectural solutions.

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