"GREEN BUILDING MATERIALS AND TITEIR APPLICATIONS IN GREEN ARCHITECTURE TOWARDS SUSTAINABLE FUTURE" WITH SPECIAL REFERENCE TO SRI TANKAN CONTEXT

The dissertation was submitted to the department of architecture of the University of Moratuwa in a partial fulfillment of the requirements for the degree of Master of Science in Architecture

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2007

Abstract

At the earth's population continues to explode and developing nations began to use their share of the world's resources, it is necessary to ascertain how we as a planet, use our earth's precious resources. In the world lover one-third of this energy is consumed by buildings. This does not consider the amount of embodied energy use in the manufacture of the building materials or the finite resources used in the product composition. During construction or at the end of useful building life, construction materials and components are discarded with construction debris. Inappropriate use of building materials that emit chemicals can pollute the indoor environment contributing to poor indoor air quality. Green or environmentally friendly materials can help to create more sustainable health full and ecologically sensitive buildings. This is achieving through environmental material assessments and green building specifications. Most of the developed countries are using environmental material assessment systems and used Green materials for their architectural practice. In present situation it becomes one of the most concern issues for the developing countries. The contemporary architects should be more concerned and responded about that issue. The study goes through an analytical reception of the issue with respect to the Sri Lankan practice.

DECLARATION

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

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I hereby declare that the particulars given above are true and correct.

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Contents

ACKNOWLEDGEMENTS

This study owes much to the assistance and guidance given by all the following; to whom I wish to extend my heartfelt gratitude.

Prof: Samitha Manavadu – Head of the Department, Faculty of Architecture for the advices and guidance given for this study.

Dr: Harsha Munasingha Group Coordinator for M.Sc. Dissertations, Senior Lecturer, Faculty of Architecture for the valuable guidance and advice given in making the scope of the study as well as in 'Academic Writing' from the initial stages of this dissertation.

My Supervisor –Arosh Gamage , Senior Lecturer, Faculty of Architecture who has been the 'Main Force' of making this task a success for the critical and important guidance in setting the scope of the study, managing the topics and relevant data, organizing the research and analysis and for teaching the correct way of writing focus to the topic.

Vijitha Basnayake - Senior Lecturer, Faculty of Architecture for his valuable advices on the main subject area and for the coordination in selecting case studies and conducting research.

The Staff of the Main Library, University of Moratuwa who has been helpful in collecting latest information both in printed and electronic media.

My colleagues who helped me in finding data, computer works and typing the manuscript and encouraged me in difficult situations.

My Parents and my brother and my husband who always encouraged me throughout my study.

INTRODUCTION

Observation

Since late 1990s there was 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 and building materials consumed large amount of energy in their life cycle. 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 related applications (transportation, urban planning, landscape considerations and infrastructure applications) is responsible for a larger part of environmental degradation which progressing rapidly.

Criticality

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 in to the natural environment creates problems to the ecological balance. Unlike in the past, developed countries have begun to put up new buildings on the face of the earth at an alarming rate. Day by day, the number of constructions is increasing and in future, most of the building materials contribute to the environmental pollution and energy crisis. This impact will create an environmental devastation on earth and its living beings.

Intentions of the study

Identifying of green concepts, green building materials, 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 objectives of the study. Hence redefining and modifying of approaches that can be used in contemporary practice become the deliberate focus for the entire thesis.

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 building materials their applicability of Green design approaches in Sri Lankan context and the shortcomings in terms of futuristic approach of Green designing for Sri Lanka.

To do this, the study evolves in three major chapters. The first chapter will contain definitions, principles relevant to the topic and the framework will be 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 and definitions of Green building materials. Environmental assessment systems. Green building materials evaluating criteria will be discussed at the final part of the chapter.

The second chapter will discuss Green building material evaluating criteria with contemporary Green material applications. First part of the final chapter identifies applicability of Green materials in Sri Lankan traditional architecture as an eco-sensitive architectural practice. At the second part of the chapter, the case study will be done as a comparative research to elaborate Green materials and their contribution in contemporary Green architectural practices in Sri Lanka. Green material assessment matrix use to evaluate the Green materials. Final part of the chapter will discussed important and impact of introducing new green materials to Sri Lanka.The final chapter and conclusion 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.

Chapter 01

1.0. Green materials and their response in Green Architecture

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

"The patterns of life were founded in a sensitive symbiosis between man and nature. The subtle accommodation of mans needs with nature ensured the survival of both" Phillip drew, 1972, p.53

As it is described '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.

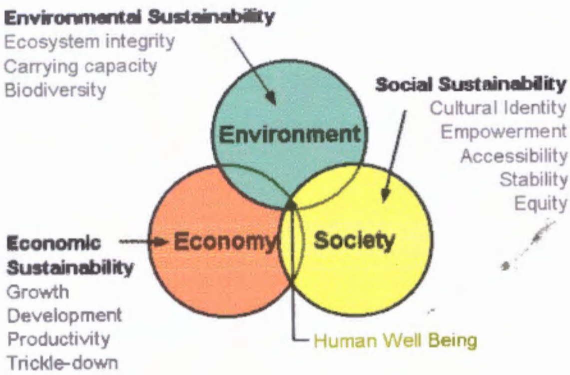


Fig 01. Sustainability, a diagrammatic illustration

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.

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 al over the world. As designers, there is a responsibility on architects towards the preservation of the ecological systems that supports life on earth.

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." Brenda ,vale R.1991

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

Brenda ,vale R.1991

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

1.5. 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.

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.

1.5.1 Green building material: Definition

Green building materials are composed of renewable, rather than nonrenewable resources. Green materials are environmentally responsible because impacts are considered over the life of the product. (Spiegel and Meadows, 1999)

1.5.2 The role of Green building materials towards green Architecture

The concept of Green building incorporates and integrates a variety of strategies during the design, construction and operation of building projects. The use of green building materials and products represents one important strategy in the design of the building. Green building materials offer specific benefits to the building owner and building occupants.

- Reduced maintenance / replacement cost over the life of the building
- Energy conservation
- Improved occupant health and productivity
- Lower costs associated with changing space configurations.
- Greater design flexibility.

Building and construction activities world wide consume 3 billion tons of row material each year or 40% of total global use (Roodman and Lenssen, 1995) using green building materials and products promotes conservation of dwindling non renewable resources internationally. In addition, integrating green building materials into building projects can help reduce the environmental impacts associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials.

1.5.3 Environmental material assessment

The assessments of environmental materials begin with establishing criteria for evaluating building materials. The criteria should complement overall environmental project goals. Often extensive research is necessary to evaluate prospective products, based on the environmental material criteria established for a green building project, selection of appropriate building products and system can be accomplished.

The green building material assessment system,methoeds very from country to country.The environmental criteria may very per project. Criteria may also vary depending on whether a project is new construction, a renovation of an existing building, or whether site work is associated with the building project.

The environmental assessment of green building materials can be broken into three phases: research, evaluation, and selection. The most time-consuming aspect of the three-part process is research. Evaluation can be equally difficult and dependent on product information provided by manufactures that is often incomplete as it relates to environmental issues. Since there us currently no standard format for providing environmental product information, interpreting and comparing product information can also be difficult. When selecting green building materials ,environmental criteria and proper application of the materials should be considered. There are many green material system and methoeds in the world.

The following are recommended environmental material criteria for use in green building product or system assessment and evaluation.

Environmental Assessment methods

- Candle to grave approach –material assessment tool
- Life cycle assessment–material assessment tool
- BREEAM-UK –building assessment tool
- BEPAC-Canada-- building assessment tool
- LEED (USA)- building assessment tool
- Leadership in Energy & Environmental Design
- Athena (Canada) –material assessment tool
- BEES (USA) –material assessment tool

Environmental Assessment methods in Asian countries

- HK-BEAM- building assessment tool
- Taiwan Green building Label - building assessment tool
- Japan Green- building assessment tool

1.5.3.1 The cradle to grave approach

Assessing the full environmental impact of a product or construction can be done only if consideration is given to its effect throughout all the stages of its life. Focusing simply on its impact during use, or on one of its characteristics, such as recyclability or energy efficiency, gives only a partial and possibly misleading picture of its overall performance. The cradle-to-grave idea underlies the assessment systems developed for most official eco-labeling systems and its use as a framework for product development and design can thus be Expected to spread rapidly. The cradle-to-grave approach acknowledges that sustainability issues may emerge at any stage, including raw material extraction; ingredients processing; manufacture or construction; distribution use and disposal.

The cradle-to-grave form of assessment provides a useful framework and checklist for ensuring that every aspect of the product is considered. For practical purposes though, it may prove necessary to focus attention on a limited number of areas which cause the greatest potential environment impact, while ensuring that performance in all other areas meets certain standards.

1.5.3.1 Life cycle assessment

As set out by the ISO 14040 standards, life cycle assessment (LCA) is a method of evaluating the environmental impact of a material or product over its whole life. In the Netherlands, government and the building industry have worked together to produce and environmental performance standard, the Dubo-eisen (requirements for sustainable construction), to apply to all new housing. The method is based on LCA and considered the whole life cycle of the different components, but sets and environmental performance standard for the building as a whole, allowing significance flexibility in choice of materials and processes. The resulting material base environmental profile for buildings, or MEPB, IS applied alongside other environmental requirements such as the energy performance coefficient defined in the Netherlands building code.

1.5.3.3 Environment assessment in Britain

BREEAM

Building **R**esearch **E**stablishment **E**nvironmental **A**ssessment **M**ethod

In the UK, it is estimated that building (energy consumption and the building materials industry) accounts for almost half of co2 emissions. Since the 1980s, expert in high-tech architecture have worked with the BRE on environmental alternatives this British equivalent of the French CSTB has carried out extensive research in this area, and in 1990 produced its own environmental assessment methods, or BREEAM. This is a tabular system using a no of criteria, and was originally intended for use in office projects. Specific version is also now available for housing, the service sector, commercial and industrial buildings

1.6. Evaluation of Green building material

There is no specific Green building assessment method for south Asian countries. But Conference on Sustainable Building South East Asia was held on 11-13-April,2006 Kuala Lumpur,Malasia. At the conference proposed to introduce Evaluation and assessment techniques for sustainable building. How ever it did not established yet.

Following are the proposal of school of Architecture and Urban Design at the University of Kansas, America which was comprehensive analytical criteria for evaluating green building materials. They successfully completed five year research to find out best Green material evaluating criteria from world wide assessment methods.

Most of above assessment methods also proposed very similar criteria's for evaluate green building materials. Yet Kansas university assessment method is much descriptive, common assessment tool and it described social aspects as well.

The following are the ten evaluating criteria for use to assess the green building material.

1. **low embodied energy**
2. **recyclable**
3. **use renewable resources**
4. **locally or regionally product**
5. **energy efficient**
6. **low environmental impact**
7. **durable**
8. **minimize waste**
9. **positive social impact**
10. **affordable**

Chapter 2

2.0 Evaluation of Green building materials

Preamble:

This chapter analytically discuss about the ten criteria of the Green building materials. Building material should be achieved these ten criteria to ensure as the green material. Present situation Green materials never fulfill all this criteria and it becomes very difficult target to achieve for the contemporary Architectural practices.The expected outcome of this chapter is to further clarify the study area and its global establishment. Therefore the target is to find clear and comprehensive established principles to prepare a 'Green material evaluating matrix' to study their applicability in assessing Sri Lankan architecture in the final chapter.

2.1 Low Embodied energy

Low Embodied energy is the most important selection criteria for the Green building material. Most cases Green building materials have low embodied energy.

Embodied energy

Embodied energy is the energy consumed by all of the processes associated with the production of a building, from the sourcing, manufacturing, transportation and construction with a building material, eventual demolition of the building and disposal of the material.

Lawson, B 1996 Building materials, energy and the environment: Towards ecologically sustainable development RAIA, Canberra

As some of these variables differ significantly from project to project, a number of techniques have been developed to measure different elements of this process. These techniques include:

- **Life –cycle analysis**
- **Cradle to grave approach**
- **Gross energy requirement(GER)**
- **process energy requirement (PER)**
- **ecological sustainability (BES) index**

Every building is a complex combination of many processed materials, each of which contributes to the building's total embodied energy. Renovation and maintenance also add to the embodied energy over a building's life.

It was thought until recently that the embodied energy content of a building was small compared to the energy used in operating the building over its life. Most effort was therefore put into reducing operating energy by improving the energy efficiency of the building envelope. Embodied energy can be the equivalent of many years of operational energy.

2.1.1 Assessing embodied energy

Whereas the energy used in operating a building can be readily measured, the embodied energy contained in the structure is difficult to assess. This energy use is often hidden and can only be fully quantified through a complete LCA. As some of these variables differ significantly from project to project, a number of techniques have been developed to measure different elements of this process. These techniques include: the cradle to grave approach, gross energy requirement (GER), process energy requirement (PER), building material ecological sustainability (BES) index, and life-cycle analysis (LCA).

2.1.1.1 Life cycle assessment

The importance of embodied energy and other environmental impacts does not become apparent until we examine the materials from a life cycle approach, usually known as Life Cycle Assessment (LCA). LCA examines the total environmental impact of a material or product through every step of its life - from obtaining raw materials (for example, through mining or logging) all the way through manufacture, transport to a store, using it in the home and disposal or recycling. LCA can be applied to matters to consider when conducting a life-cycle analysis of a material include.

- What is the embodied energy of the building material over its entire life?
- Are renewable or sustainable energy sources used in the manufacture of the material?
- Are there less energy consuming, longer-lived alternatives for the same application?
- Are local sources of the material available?
- Can the material be recycled or reused at the end of its useful life in a structure?
- How easy or difficult is the material to recycle?
- Do different construction systems offer better opportunities for resource recovery at the end of building life?
- How much maintenance does the material require over its life in a structure?

• How energy intensive is the maintenance regime?

• Are waste byproducts produced during maintenance?

• Does the material require special coatings or treatments that could present health or safety hazards?

• If the material off-gasses during and after installation, how is indoor air quality affected?

• Are hazardous solid, aqueous, or gaseous wastes produced during the manufacturing process?

• How do the amounts of waste resulting from manufacture, fabrication, and installation compare with those from alternative materials? Whole product (a house or unit) or to an individual element or process included in that product.

http://www.ecomail.com

2.1.1.2 Cradle to grave approach

The cradle-to-grave approach acknowledges that sustainability issues may emerge at any stage, including raw material extraction; ingredients processing; manufacture or construction; distribution, use and disposal. Focusing simply on its impact during use, or on one of its characteristics, such as recyclables or energy efficiency, gives only a partial and possibly misleading picture of its overall performance.

2.1.1.3 Gross Energy Requirement (GER)

Gross Energy Requirement (GER) measures the embodied energy according to the following parameters

• the energy consumed in extracting, processing and transporting the original raw materials for the building materials or components;

• the energy input to the manufacture of the building components;

• the energy input to the support services and transport to the building site;

• the energy input to the construction of the building, including transport of the workers, equipment and materials;

• the energy used to construct the plant used in the extraction and processing of the raw materials; and

• the energy cost of repairing damage caused by the component manufacturing process (Assessing the GER of a building material can be difficult as it is not always possible to accurately measure all of these inputs. In addition, some are site specific and will vary from project to project.

2.1.1.4 Process energy requirement (PER)

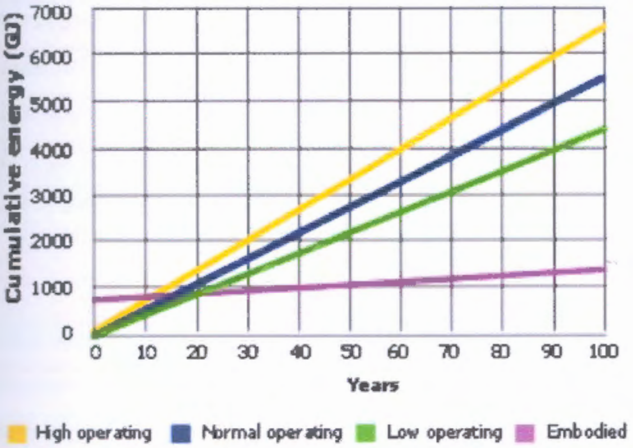
Process energy requirement (PER) is believed to provide a firmer basis for comparing materials (Lawson 1996). PER is an estimate of energy consumed in obtaining and processing of the raw materials, transportation between manufacturing processes and the actual manufacturing process. No allowance is made for transport to the building site or for the provision and maintenance of infrastructure, or for energy used in on-site construction.

2.1.1.5 Ecological sustainability (BES) index

The BES index was developed to provide design professionals with a tool to assist in the assessment of the relative environmental impacts of building materials (Partridge Partners1996). The BES system evaluates building materials and products according to sixteen environmental parameters from initial resource extraction through to end of life disposal or recycling. BES also measures embodied energy as PER

2.1.2 The importance of embodied energy

Embodied energy content varies enormously between products and materials.



Source: (www.green home guide.com)

True low energy building design will consider this important aspect and take a broader life cycle approach to energy assessment. Merely looking at the energy used to operate the building is not really acceptable. **Operational energy** consumption is dependent on the occupants.

Embodied energy is not occupant dependent - the energy is built into the materials. Embodied energy content is incurred once (apart from maintenance and renovation) whereas operational energy accumulates over time and can be influenced throughout the life of the building.

Embodied energy content varies greatly with different construction types. In many cases a higher embodied energy level can be justified if it contributes to lower operating energy. For example, large amounts of thermal mass, high in embodied energy, can significantly reduce heating and cooling needs in well designed and insulated passive solar houses. As the energy efficiency of houses and appliances increases, embodied energy will become increasingly important.

The embodied energy levels in materials will be reduced as the energy efficiency of the industries producing them is improved. However, there also needs to be a demonstrated demand for materials low in embodied energy.

2.1.3 Embodied energy of common materials

Typical figures for some materials are given in the table below. Generally, the more highly processed a material is the higher its embodied energy.

MATERIAL	PER EMBODIED ENERGY MJ/KG
Adobe, straw stabilized	0.5
Kiln dried sawn hardwood	2.0
Air dried sawn hardwood	0.5
Hardboard	24.2
Rammed –earth cement	0.8
MDF	11.3
Plywood	10.4
Glue-laminated timber	11.0
Laminated veneer lumber	11.0
Plastics - general	80
PVC	80.0
Synthetic rubber	110.0
Acrylic paint	61.5

Stabilised earth	0.7
Imported dimension granite	13.9
Local dimension granite	5.9
Gypsum plaster	2.9
Fibre cement	4.8*
Cement	5.6
Insitu Concrete	1.9
Precast steam-cured concrete	2.0
Precast tilt-up concrete	1.9
Clay bricks	2.5
Concrete blocks	1.5
AC	3.6
Glass	12.7
Aluminium	170
Copper	100
Galvanised steel	38

Lawson, B 1996 Building materials, energy and the environment: Towards ecologically sustainable development RAIA, Canberra

Materials with the lowest embodied energy intensities, such as concrete, bricks and timber, are usually consumed in large quantities. Materials with high energy content such as stainless steel are often used in much smaller amounts. As a result, the greatest amount of embodied energy in a building can be either from low embodied energy materials such as concrete, or high embodied energy materials such as steel. most people it is more useful to think in terms of building components and assemblies rather than individual materials. For example, a brick veneer wall will contain bricks, mortar, ties, timber, plasterboard and insulation.

Comparing the energy content per square metre of construction is easier for designers than looking at the energy content of all the individual materials used. The table above shows some typical figures that have been derived for a range of construction systems.

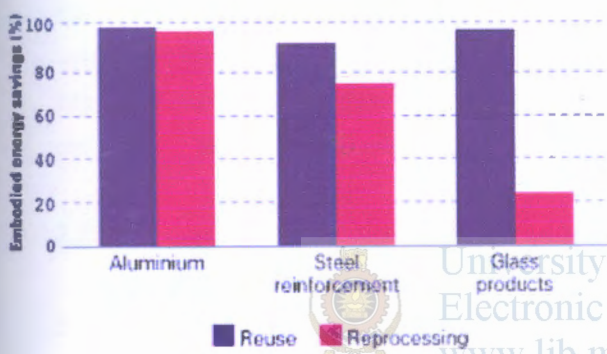
2.1.4 Guide lines for reducing embodied energy

- Lightweight building construction such as timber frame is usually lower in embodied energy than heavyweight construction. This is not necessarily the case if large amounts of light but high energy materials such as steel or aluminium are used.
- There are many situations where a lightweight building is the most appropriate and may result in the lowest lifecycle energy use (eg. hot, humid climates, sloping or shaded sites or sensitive landscapes).
- In climates with greater heating and cooling requirements and significant day/night temperature variations, embodied energy in a high level of well insulated thermal mass can significantly offset the energy used for heating and cooling.
- There is little benefit in building a house with high embodied energy in the thermal mass or other elements of the envelope in areas where heating and cooling requirements are minimal or where other passive design principles are not applied.
- Each design should select the best combination for its application based on climate, transport distances, availability of materials and budget, balanced against known embodied energy content.
- **Design** for long life and adaptability, using durable low maintenance materials.
- **Ensure** materials can be easily separated.
- **Avoid** building a bigger house than you need. This will save materials.
- **Modify or refurbish** instead of demolishing or adding.
- ***Ensure*** *materials from demolition of existing buildings, and construction wastes are re-used or recycled.*
- ***Use*** *locally sourced materials (including materials salvaged on site) to reduce transport.*
- ***Select*** *low embodied energy materials (which may include materials with a high recycled content) preferably based on supplier-specific data.*
- ***Avoid*** *wasteful material use.*
- ***Specify*** *standard sizes; don't use energy-intensive materials as fillers.*
- ***Ensure*** *off-cuts are recycled and avoid redundant structure, etc. Some very energy intensive finishes, such as paints, often have high wastage levels.*
- ***Select*** *materials that can be re-used or recycled easily at the end of their lives using existing recycling systems.*
- ***Give preference*** *to materials manufactured using renewable energy sources.*
- ***Use*** *efficient building envelope design and fittings to minimise materials (eg. an energy efficient building envelope can downsize or eliminate the need for heaters and coolers, water-efficient taps allow downsizing of water pipes, etc).*(www.green home guide.com)

Reuse and recycling of materials to reduce embodied energy

Reuse of building materials commonly saves about 95% of embodied energy that would otherwise be wasted.

Some materials such as bricks and roof tiles suffer damage losses up to 30% in reuse.Savings from recycling of materials for reprocessing varies considerably with savings up to 95% for aluminium but only 20% for glass. Some reprocessing may use more energy, particularly if long transport distances are involved.



Lawson, B 1996 Building materials, energy and the environment: Towards ecologically sustainable development RAIA, Canberra

2.2 Recyclable materials

Using recycle materials reduces waste and saves scarce landfill space. Recycled materials also preserve the embodied energy of their original form, which would otherwise be wasted. This also reduces the consumption of materials made from virgin natural resources. Many building materials, particularly steel, are easily recycled, eliminating the need for more mining and milling operations. Products are manufactured all or in part with recycled materials, and can also be recycled themselves after use. Using recycled products, or products with recycled content help the environment and the economy in several ways. A significant effect is that of lessening the need for manufacture with virgin, non-renewable resources, which saves precious resources and also saves manufacturers money. Material that would have ended in landfills after its useful live instead can be reprocessed for use in other products. Newspapers can be reprocessed into cellulose insulation, for instance. Plastic milk cartons can be shredded, melted and reprocessed into toilet partitions. Rubber from automobile tires can be processed into roofing and flooring materials. Some products can be salvaged and reused again as they are.

2.2.1 Incorporate Reclaimed or Recycled Materials

Buildings that have to be demolished should become the resources for new buildings. Many building materials, such as wood, steel, and glass, are easily recycled into new materials. Some, like brick or windows, can be used whole in the new structure. Furnishing, particularly office partition systems, are also easily moved from one location to another.

During the process of designing the building and selecting the building materials, look for ways to use materials that can themselves be recycled. This preserves the energy embodied in their manufacture.

Most materials can be recyced .the following materials demonstrates some re-use options. There are many more and the list is growing rapidly.

Steel: Electric arc furnaces (EAF) produce reinforcing bar, mesh and sections from 100 percent steel scrap. Conventional blast furnaces can incorporate up to 30 percent steel scrap. Recycling steel reduces embodied energy by 72 percent.

Aluminium is 100 percent recyclable. Recycling aluminium reduces embodied energy by 95 percent.

Gypsum Plasterboard: CSR recycles plasterboard and other companies are considering doing so. Plasterboard disposed of in landfill produces poisonous hydrogen sulphide and has a foul odour.

Timber can be re-processed into horticultural mulch. A particle board manufacturer in Australia is developing a recycling facility that requires little or no pre-treatment of the waste.

Concrete: Un-set concrete can be "washed" out at the plant to remove cement. Sand and stone can be re-used. Set concrete can be crushed and recycled as aggregate for new concrete or road base and fill.

Most glass can be recycled. Construction glass must be separated from other glass such as drink bottles. Glass may be cut and re-used or recycled as aggregate for concrete. Some patterned glass incorporates all types of recycled building glass. Recycling glass reduces embodied energy by 20 percent.

Carpet in good condition can be sold and re-used. It can also be recycled into secondary carpets. Some carpet can be recycled as weed barrier or a covering and food for worm farms.

Bricks and Tiles can be re-used where appropriate or crushed on site for backfill, aggregate and gravel with portable crushing plants.

Plastics: Many plastics can be granulated and re-used to make new plastic products and include:

- High Density Poly Ethylene (HDP): rubbish bins, buckets and traffic cones.
- Low Density Poly Ethylene (LDP): shrink wrap and bubble wrap
- Polystyrene: containers, insulation, UPVC pipes, fittings and flooring.

Reuse Non-Conventional Products (Discarded materials) as Building Materials

Discarded materials can be defined as substances which are used for some thing and thrown, or have no use in one instance hence thrown away by human beings or the nature.

Building materials from unconventional sources, such as recycled tires, pop bottles, and agricultural waste, are readily available. These products reduce the need for new landfills and have a lower embodied energy that the conventional materials they are designed to replace.

2.2.2 The importance of using discarded materials for architecture.

Our mass consumption society is more throwing away society and this throw away of huge disposal is creating great environmental problems, waste is a big problem not only in building construction or maintenance but every activity of life. It causes an aggressive environmental problem. Using discarded materials for architecture is more advantage able than using of building materials due to various reasons. They are freely available in the environment. Therefore it is not difficult to find them, and the same time it is not spending any amount money to buy them. It is not wasting energy to produce them also. Therefore it is helping to clean the environment and save the energy also.

2.2.3 Preserving environmental problems.

Stagnation of the garbage and the discarded things in the environment is a big problem today. These things become garbage, as they not used for any thing and hence thrown way. If the man is using these discarded things for something it will be more helpful for protection of the environment. It will reduce the stagnation of the garbage and will make more environment also.

" *Just as gardeners who are in sympathy with nature have defined a weed as no more than a plant in the wrong place , so pollution could be redefined as a waste-product in the wrong place."* Reyner Banham theory and design first mashine age ,1960 p.313

Therefore when the discarded or waste things are used for architecture they are not discarded things further. When they are in the right place people can see them as new kind of materials but not as waste that makes the environment ugly.

2.2.4Saving energy

Making of new products from raw materials for any kind of purpose requires a lot of energy. As they make something for some activity or usage and throws it a way after using it is not only an environmental hazard but also it is a waste of energy. This wasting of energy can be reduced if those materials are reused for some other activity. Saving energy will protect the environment by rising the temperature in the air and being the green house effect.

2.2.5 Economically profitable.

It is possible to find any amount of discarded materials in the environmental for free of charge. Therefore using discarded materials for architecture may be more economical than using other materials specially made for building constructions. Any way this will spend some initial cost for collecting and cleaning them before use for architectural purposes. But that amount will be very low comparing to the cost of standard materials.

2.2.6 Modern approaches

Used automobile tires are a real problem in our world. They become terrible garbage in the environment and result for environmental problems. There are almost indestructible. They create plums of noxious black smoke. so they quickly fill our dumps. By the same token , the property that makes tires terrible trash make them a great building materials. Tires are durable in most situations. They are relatively unaffected by water and sun and unpalatable to insects.

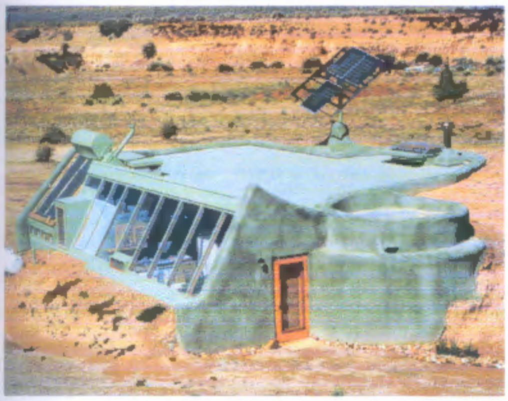


Fig 01: Earthship: the buildings' exterior walls are made mostly of used tires stacked and tamped full of dirt.
Source : The good house book

Michael Reynolds, a Taos, new Mexico and visionary, has pioneered the use of waste tires in housing . in his system ,tires are tamped full of dirt and used like bricks in earth –sheltered homes that that he calls earth ships.

Earthship .this building 's exterior walls are made by mostly of used tires stacked and tamped of dirt.

Fig 02: Concretebond beam served as a surface on which to connect the tire walls and wood roof framing.
Source: The good house book

Straw has been used for thousand of years in buildings, but straw bales are relatively new development. The first baler was invented in late 1800s, allowing straw to be packaged in nice tidy blocks. Today, straw is most often a byproduct of industrial agriculture. After cereal grasses are harvested and processed to extract the grain, the skeletal stalks are left over. This straw is generally viewed as waste and is to extract the grain; the skeletal stalks are left over. This straw generally viewed as waste and is burned as much. Baled straw can be a superior building material .its, excellent insulation, fire resistant, exceptionally durable. in addition, its' easily renewable,

Fig 03: House made out from the straw bales.
Source: www. Strawbalecentral.com

Many industries create huge amounts of wood based waste that can be recycled into useful building materials, for a example, recycled paper and newsprint are used to create cellulose insulation. This material has many of the advantages of straw and is superior to fiberglass insulation in many ways. Composite blocks made of cellulose and concrete, such as Fasswall and Durisol,are another use for industrial wood waste. These blocks are made of recycled wood fibers, nontoxic ally treated for protection against rot and insect damage and bound together with Portland cement.

Fig 04: Plastic lumber: these materials ,made of recycled plastic milk jugs, designed to replace wood in many of its common use in building
Source: www. Green house.com

Timbron

Timbron is recycled plastic product and it is International produces a green product as building material. A green product is designed to reduce both the direct and indirect environmental consequence associated with its design, development, manufacturing, distributing, and installation. Timbron premium interior moldings are comprised of 90% recycled plastics; 75% post-consumer and 15% pre-consumer. Purchasing products with the highest content of recycled material supports the recycling system, reduces waste and conserves resources.

- Post-consumer recycled material is derived from a product that has been used by the consumer for the duration of its useful life and is then recycled. It has a greater environmental value than pre-consumer recycled material.
- Timbron can be recycled at the end of its useful life, thus creating a closed loop manufacturing system. A closed loop manufacturing system continuously converts discarded materials into new raw materials, reducing waste and conserving energy.
- Timbron is durable and long-lasting, reducing the need for frequent replacement and use of additional materials.

Fig 05: recycled plastic moldings.
Source: www. Green house.com

2.3 Use Renewable Resources

"Green building materials define as the Green building materials are composed of renewable, rather than nonrenewable resources. Green materials are environmentally responsible because impacts are considered over the life of the product "(Spiegel and Meadows, 1999) *The Construction Specifier*, a publication for members of the Construction Specifications Institute (CSI))

Products are manufactured with resources that are renewable (i.e. wood or solar power) rather than non-renewable (i.e. fossil fuels). Depletion of the earth's resources is occurring at an alarming rate. As we continue to extract raw materials from the earth, entire ecosystems are affected, causing species to become extinct. Fossil fuels are not unlimited; we will run out of them eventually.

Building and construction activities worldwide consume 3 billion tons of raw materials each year or 40 percent of total global use. Using green building materials and products promotes conservation of dwindling nonrenewable resources internationally. In addition, integrating green building materials into building projects can help reduce the environmental impacts associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials. U.S. Green building Council mentioned in their sustainable building measures:" *Reduce the use and depletion of finite raw and long-cycle renewable materials by replacing them with rapidly renewable materials"*

By utilizing renewable energies, such as wind, solar, tidal, as well as renewable products, such as wood, grasses or soil, we can lessen the impact on biodiversity and ecosystems. (Examples of renewable resources are wood and paper products; solar-, wind-, tidal-energy power; organic cotton, wool, sisal, straw, earth/soil, other grasses. Some non-renewable resources are petroleum, natural gas, coal and aluminum.)

2.3.1Use Materials Made From Renewable Resources

Renewable resources are those that can be grown or harvested at a rate that exceeds the rate of human consumption. Using these materials is, by definition, sustainable. Materials made from nonrenewable materials (petroleum, metals, etc.) are, ultimately, not sustainable, even if current supplies are adequate. Using renewable materials wherever possible reduces the need for nonrenewable materials.

2.3.2 Use Materials Harvested or Extracted Without Causing Ecological damage

Of the renewable materials available, not all can be obtained without significant environmental effects. Therefore, the architect must be aware of how various raw materials are harvested and understand the local and global ramifications. Most of our traditional building materials such as adobe, straw bales, earthen plasters, timber derived from natural environment and they become most appropriate example for renewable materials.

2.3.4 Modern approaches for renewable material

Recycled Wall Systems-

In constructing the new visitor center at Gran Quivera, Salinas Pueblo Missions used a wall material constructed from recycled Styrofoam/concrete. The visitor center is 1550 square feet and the restroom building is 300 square feet. Both buildings were constructed with an Ener-grid - wall system. Ener-grid is a pre-formed wall system made from recycled Styrofoam and concrete, that when completed provides an R-30 insulate value.

Fig06: the visitor center made out from recycled Styrofoam and concrete
Source: Good house book

Recycled Lumber- Plastic/Alternative Woods

Salvaged, re-milled or recovered lumber products are available material use as timber. For many applications such as boardwalks, decking, docks d fencing, wood substitute material made from recycled plastics are

Fig07:recycled plastic used for this house as substitute material for the woods.
Source: www. green products.com

nany applications such as boardwalks, decking, docks and fencing, wood substitute material e from recycled plastics are available. Yellowstone, Redwoods, Everglades, Indiana Dunes, Scott and Apostle Islands have experience utilizing recycled plastic woods.

ısider Building Integrated Photovoltaic

, designs in photovoltaic applications allow for the substitution of photovoltaic energy erating building members. Roofing products include slate shingles with embedded PV cells, ıposition shingles incorporating amorphous PV, skylights with integrated PV and vertical ade material with AC voltage PV.

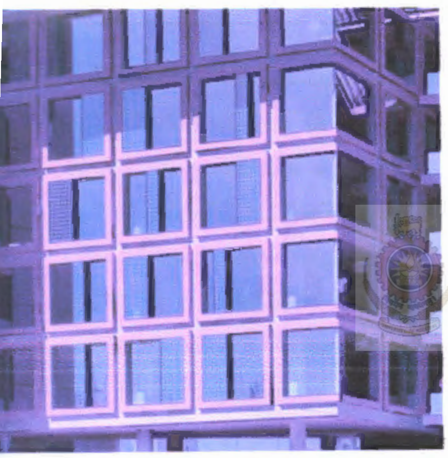


Fig08: a photovoltaic solar energy panels placed on the façade of the building.
Source : cowiprojects.com

2.4 Locally or Regionally Produced:

Traditional materials were adjustable to local environmental requirements. Plaster, concrete, and mud mixes were developed through experimentation to withstand the particular environment in which they were utilized. Traditional building materials were almost always local. Today, many materials are traditional in origin but no longer local. Cement, bricks, and even wood are shipped long distances from where they're produced to where there're used.

Products are manufactured closer to their use, causing less pollution in transportation, and also helping to support regional economies. Using building products that are manufactured within a 500-mile radius of use can help lessen air pollution from transport vehicles. Just as significant, it robs builders of materials with site –specific flexibility. Availability of materials is varied to region to region and country to country. Scared material of the one region can be unlimited material to another region. Ex: earth becomes limited resource in some agricultural regions in China.

Alternative builders are leaning toward local materials in an attempt to regain flexibility, move toward self-sufficiency, and reduce pollution of both the indoor and outdoor environments.

2.4.1 Earth as a locally available material

Though many modern building materials originate with natural substances extract from the earth, they seldom utilize the dirt available on the building site itself. This traditional practice integrated with the modern technology. Soil mix "recipes" and guidelines for traditional practices such as adobe and cob have been developed to help people utilize their local dirt. Modern rammed earth building is a relatively technical undertaking requiring substantial formwork and close soil monitoring, but nonetheless also utilizes site extracted dirt. The basic cob is made by mixing local clay soil with sand, straw, and water. The mixing is usually done with our feet, then the material is placed by hand to create thick beautiful wall.

Fig09: Interior of a cob house near Austin Texas.
Source: Alternative construction

Cob is an example of a simple, natural building material, used successfully for centuries by people all over the world. Because of the nature of the material and the building process cob building generally have human scale are as unique as the people who built them.

Fig10:Earthen plasters complement and contribute to the sensuous, organic, alive feel of a well-built natural home.
Source: Good house book

2.4.2 Wood and Plant based material.

Modern day builders and our traditional builders seldom use wood or other plant based materials from the building site, or even immediate area. Wood can be a sensible building material, especially if it's harvested from the site. Wood is the hard, fibrous tissue that conducts water and gives structural strength to the roots and stems of trees and shrubs. The first wooden structures were the woven frame works of twigs used in wattle and daub buildings, the wooden poles of tents, and the wooden framework of yurts. There's evidence of construction using heavy timber dating from thousand of years.

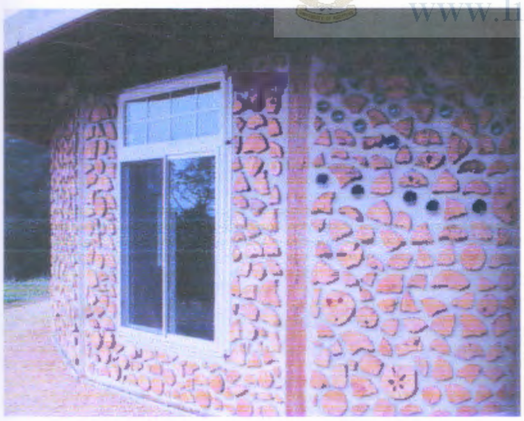
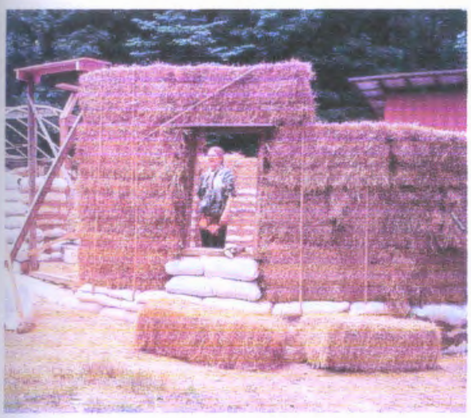


Fig11: Cord wood construction: this wall building technique makes use of small diameter trees, which are routinely bulldozed and burned on conventional construction sites
Source: Good house book

Fig12Grass house: large overhangs for the shade, permeable walls and free ventilation beneath the floor all the contribution to keeping this building cool in hot season.
Source: Alternative construction



Straw is the by product of the agricultural regions. These materials are most popular locally available material around the world. Straw can be harvested every year, unlike trees, which makes it a more likely candidate a renewable ,locally available building materials.

Fig13: straw bales are serve as both the insulation for and the structure of the wall. The earth bag stem wall liffing the bales off the ground.
Source : The good house book

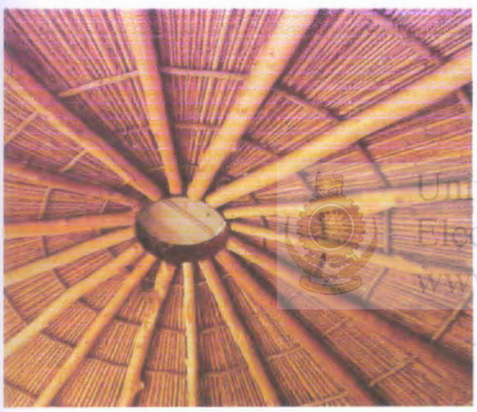


Fig14: roof constructed with bamboo site harvested plant materials such as bamboo are useful wherever they're abundant
Source: Alternative construction

Fig15: Animal products: the camel dung drying near this house in Rajastan,India will be used as a fuel, dung is also used as an additive in earth-based building materials.
Source: Good house book

2.4.3 Evolution of a modern materials : using locally available materials.

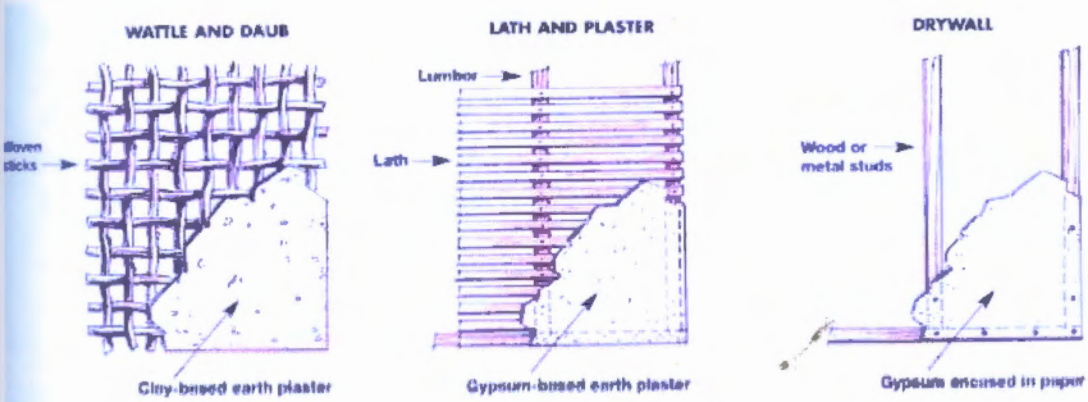


Fig16: Evolution of a modern materials: the modern material we know as drywall is essentially a mass – produced version of traditional wattle and daub. Source : Good house book

Modern approach to rammed earth is to use small permanent forms for the packed dirt. I already discussed one example oft his technique, the rammed earth tire walls of Earthships. Another exsample is *superadobe,* pioneered by Iranian born Architect Nader Khalili. In this technique, polypropylene or burlap bags are filled with soil and laid in courses like bricks. Each layer must be compacted by hand tamping. Reinforcement is provided by barbed wire laid between courses, the resulting wall or dome is then covered with thick layer of plaster. superadobe building also can be constructed using long fabric tubes instead of bags.

Fig17: Superadobe construction
This dome at Khalali's Cal –Earth Institute is being constructed of long fabric tubes pumped full of damp dirt, then coiled like a huge coiled clay pot.
Source: www. Calearth.com

2.5. Energy Efficiency

Products use as little energy as possible. Construction and operation of buildings produces almost half of the world's energy use. With a few key strategies, designers and builders can reduce energy loads on structures, reducing energy requirements and the strain on natural resources. Thermal mass of the building material and high R-value are very important criteria for the energy efficient of the building.

2.5.1Energy efficiency of the building

The following strategies contribute to this goal.

- Passive design strategies can dramatically affect building energy performance. These measures include building shape and orientation, passive solar design, and the use of natural lighting.
- Develop strategies to provide natural lighting. Studies have shown that it has a positive impact on productivity and well being.
- Install high-efficiency lighting systems with advanced lighting controls. Include motion sensors tied to dimmable lighting controls. Task lighting reduces general overhead light levels.
- **Use a properly sized and energy-efficient heat/cooling system in conjunction with a thermally efficient building shell. Maximize light colors for roofing and wall finish materials; install high R-value wall and ceiling insulation; and use minimal glass on east and west exposures.**
- Minimize the electric loads from lighting, equipment, and appliances.
- Consider alternative energy sources such as wind, solar and tidal power, photovoltaic and fuel cells that are now available in new products and applications. Renewable energy sources provide a great symbol of emerging technologies for the future.
- Computer modeling is an extremely useful tool in optimizing design of electrical and mechanical systems and the building shell.

Typically passive solar building designs incorporate materials with high thermal mass that retain heat effectively and strong insulation that works to prevent heat escape. In addition, Low energy buildings typically have a very low surface area to volume ratio to minimize heat loss. Windows are placed to maximize the input of heat-creating light while minimizing the loss of heat through glass (a terrible insulator).

2.5.2 Thermal mass of the building material

All materials have ability to store heat, through some are able to hold more heat per unit of weight or, more technically correct, mass than others. A thermal mass is any mass used to collect and hold heat. Specific heat is the measure of a material's capacity to hold the heat. Among the building materials, adobe, brick, concrete, and stone share similar specific heat and are often used as a thermal mass. A thermal mass such as adobe or brick walls or a concrete floor absorbs the heat, collecting it slowly through out its exposure. Later when the sun goes down or the stove burns out and the indoor air begin to cool, the thermal mass can help maintain stable temperature as it slowly radiates stored heat into the building.

2.5.3Material as an Insulator

Insulation retards the movement of heat. Heat moves through three possible mechanisms: radiation, convection, and conduction.

High-performance windows and wall insulation prevent both heat gain and loss. Reducing such heat transfer reduces the building's heating and cooling loads and thus its energy consumption. Aside from these tangible benefits, high-performance windows and wall insulation create more comfortable thermal environments. Conductive heat is transfer is slowed by materials that resist the movement of heat through their volume. A material ability to do this ,its thermal resistivity ,is expressed as its R-values. Materials made up of little units,cells or short strands ,tend to have higher r- values because heat can't take direct route through them.

2.5.4Energy efficient approaches.

Dealing with the sun has long been a major motive in human building. People in hot, arid desert climates have, for an example, built thick walls and roofs of adobe for thousand of years.thick adobe walls will slow the movement of the suns' heat sufficiently thick. Adobe walls will slow the movement of the suns heat sufficiently to allow building interiors to remain cooler. Cooler desert night allow walls to dissipate this heat to the outside by morning.

Fig18Traditional adobe;
thick thermal mass walls absorb solar heat, slowing its movement toward the interior. This building is in sanosa, Mali
Source : www, kleiwerks.com

Fig:19 Anasi solar
south facing windows and heavy timber and adobe roofs and thick adobe walls protect the interiors from hot summer sun.
Source: Adobe construction

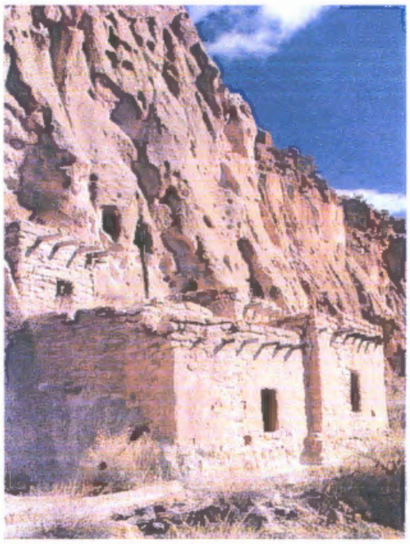


Fig:20 Thermal mass floors are made of a wide variety of materials including concrete, brick, tile and earth.
Thermal mass tile floor: in summer the south facing room is shaded from the sun.
Source: Good house book

Fig:21 In winter on a sunny day the deep red tiles are bathed in sun and collect heat, preventing overheating during the day and slowly radiating heat into the room after sunset.
Source: Good house book

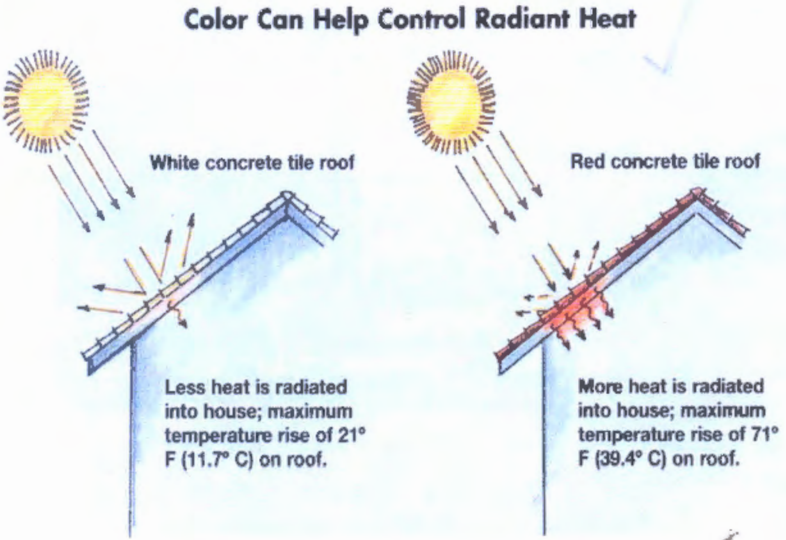


Fig:22
Reflective or light-colored materials absorb less heat and therefore help prevent too much heat from radiating building.
U.S *department of energy study.*

2.5.5Combining thermal mass and insulation

In alternative buildings, earth materials are often chosen because they are available locally, have a low embodied energy, and make an excellent thermal mass. Mass walls are excellent in preventing convective heat loses. But the very reason such materials provide good thermal mass – they absorb, or conduct, heat easily – makes them poor insulators against conductive heat loss. Heat move easily through them. On the other hand, mass walls tend to be very thick, so a poor R – value per inch can add up to decent insulation in a two-foot thick wall.

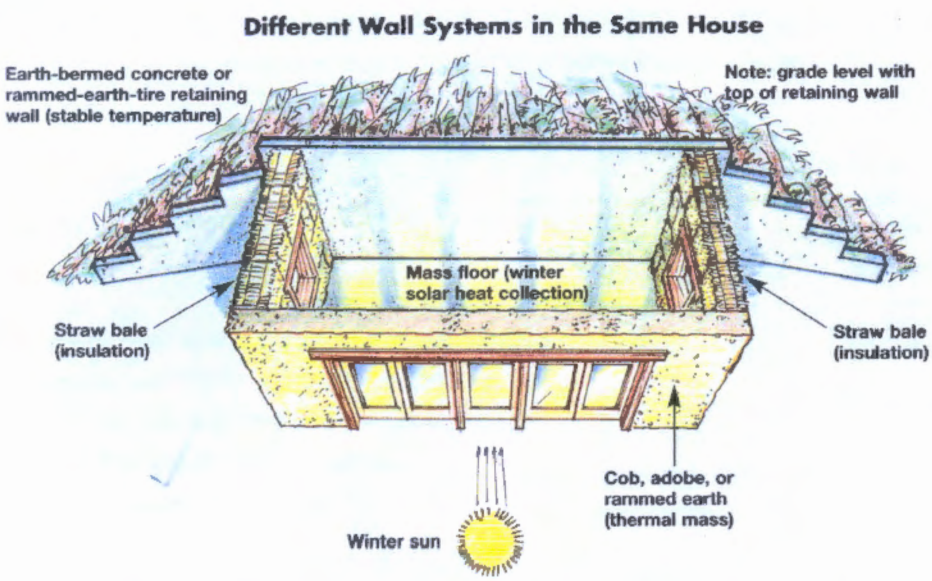


Fig:23 : Using a variety of materials to build walls can help to make the most of each materials strength in thermal performance
Source: Good house book

Fig: 24Earthship hybrid: this building uses tires, srawbales, and many other ecologically sensible materials
Source: www.calearth.org

2.5.6Energy efficient glass.

Glass as a green material for energy efficient building
Compared to other building materials a single pane of clear glass is poor insulator for this reason, several improvements for window and door glass, also called glazing, have been developed. "Insulated "glass, in which to or sometimes three panes of glass are sandwiched together , with a sealed air space between panes, offers greatly increase R-values. Other measures that make glazing some insulative include low-emitance coating and gas fills. Low–e coatings are microscopically thin reflective layers applied to or between glass panes.

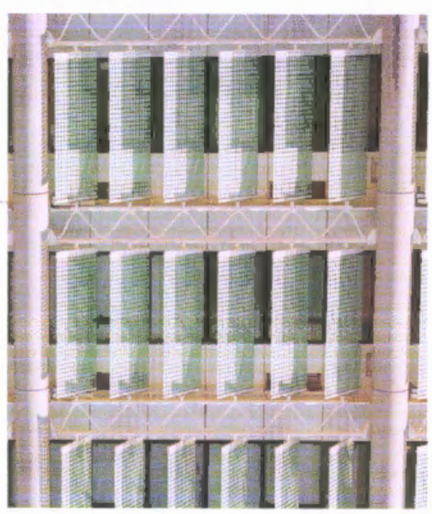


Fig: 25Avax Head quarters building in Athens, Greece. The façade with fritted glass panels filters sunlight according to internal temperatures thus regulating solar gain and light effects automatically
Source: Sustainable Architecture

"Sage" glass as a green product

Fig: 26Art center – Sagi glass building Minnesota

Source: www.green top ten.com

Sage glass awarded in this year 2006 as one of the best Green product. according to the Leed rating system it awarded for

EA Credit 1 - Optimize Energy Performance

IEQ Credit 6 - Controllability of Systems
IEQ Credit 7 - Thermal Comfort

IEQ Credit 8 - Daylight and View

Fig: 27 ; interior of Sagi glass building

An abundance of day light and a connection to the outdoors for everyone in the building.

Source: www.green top ten.com

2.6 Low Environmental Impact:

Green materials do not harm the environment, pollute air or water, or cause damage to the earth, its inhabitants and its ecosystems in their manufacture, use or disposal. They are non-toxic and contribute to good indoor air quality. Worldwide industrial production uses billions of tons of raw materials every year, some irreplaceable or finite. Pollution caused in excavation, manufacture, use or disposal of a product can have untold consequences on the Earth's ecosystem. Poor indoor air quality caused by product off gassing or VOC emission costs billions in medical bills and lost productivity to companies every year. Manufacture and use of green building products should strive to lessen the impact on the Earth.

2.6.1 Indoor air quality

Indoor air quality, which is defined as: "Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people do not express dissatisfaction." *(ASHRAE* 62-1999) March 2002 Environmental Stewardship Committee 25

Contributors to indoor air pollution include:

The use of synthetic building materials, finishes and furnishings which release outgas pollutants. Pollutants including Volatile Organic Compounds (VOCs), e.g. formaldehyde, are found in many building materials and assembled products.The use of personal care products, pesticides and household cleaners, biological sources such as insects, pests, moulds and other fungi.

2.6.2Strategies to achieve good indoor air quality to provide a clean and healthy environment

- Monitor and avoid indoor air quality problems during renovation, demolition, and construction activities.
- Provide occupants with operational control of lighting and HVAC systems whenever possible.
- Provide Effective Lighting

Human Factors

- Produce environments that enhance human comfort, well- being, performance, and productivity by reducing sick time.
- Provide Views, View space, and Connection to Natural Environment.

- Exterior and Interior Views: Use design strategies to provide windows, skylights, and/or clerestories for outside view access from all work areas or regularly occupied spaces or to provide contact with patterns and textures of the natural world through interior
- Provide Appropriate Thermal Conditions
- Address environmental and seasonal considerations for dry bulb temperature and radiant temperature profile, relative humidity

2.6.3 Factors to consider for health effects of materials

There are four factors to consider when addressing the health effects of materials. They are: **Emissions,Toxicity. Quantity Proximity**

Emissions

Some materials will emit more contaminants than others. Emissions are generally highest when materials are new, and in conditions of high humidity and temperature. Some sources, such as building materials and furnishings, release pollutants more or less continuously, although the quantity decreases over time. High pollutant concentrations can remain in the air for long periods after some of these activities and can settle on exposed surfaces to be re-emitted over time.

Toxicity

Toxicity describes the potential harm a compound can inflict. Toxic effects can be acute and immediate or chronic over a long term. Pollutants such as lead or asbestos manifest their effects over long term exposure. Airborne pollutants show their effects over short term exposure.

Quantity

The materials used in floors, ceilings and walls are present in greater amounts than others. Low emissions from large quantities of materials can result in high total amounts of chemicals in the air.

Proximity

Materials found inside the home are more likely to affect people than materials found outside. However people who are very chemically sensitive may also be affected by outside materials.

Green material not only contained recycled content, but also included low-or-no Volatile Organic compounds (VOCs) and rapidly renewable materials. It should be contribute good indoor air quality.

2.6.4 Guidelines to achieve good indoor air quality by using building materials (source TOM and Wooley Green building hand book)

1. Select materials which have been pre-dried, are quick drying, use water as the solvent or are classed as zero or low VOC. Ask to see the products material safety data sheet(Including paints, coatings, adhesives, carpet, ceiling tiles, and furniture systems) to help ensure good indoor air quality

2. Selection and management of new construction materials and renovation activities in order to minimize indoor air quality issues.
3. Ensure that all construction materials, interior finishes and major furnishings installed at Stanford comply with most recent industry standards or regulatory agency Volatile Organic Compound (VOC) emission standards, including specific requirements for carpet systems and paint products.
4. Follow material conditioning procedures.
5. Follow project sequencing procedures (e.g., allow wet products to dry before installing porous products).
6. Reduce dust emissions in occupied buildings through the use of wet methods, etc.
7. Control Moisture to Prevent Microbial Contamination Where moisture precautions are needed, materials should be specified to discourage microbial growth.

However not all traditional materials are safe. Old paint contains high levels of lead and creosote wood preservative is highly toxic. Many 'traditional' materials such as lime wash for walls, beeswax polish and linseed oil for wood finishing, vinegar and lemon juice for cleaning, and herbs for pest control have no or very low levels of toxicity.

Timber is generally non-toxic. Provided it is not sealed with material that is impervious to air it maintains its breath ability. Very low VOC treatments are readily available nowadays and most are water rather than solvent based

Leadership in Energy and Environmental Design (LEED Assessment method) awarded materials for as the Green materials in 2006) these are selected two exsamples.

Fig: 28

Restro plate : concrete polishing material

Free of voc emissions

Leed credit relevance 1

(Leadership in Energy and Environmental Design)

Source ; www.restroplatesystem.com

Fig: 29

100%/recycle content panal product material

Leed credit relevance

IEQ credit 4;low VOC emitting material

Source ; www.restroplatesystem.com

2.7 Durability

Green materials are long-lasting and need little maintenance. Product replacement puts a strain on the earth, its resources and inhabitants. In making products more durable and easy to maintain, manufacturers can help eliminate a costly, damaging and time-consuming process of replacement. The following selected examples illustrate the durability of the materials and these materials are fulfilled the other many important criteria of the Green materials.

2.7.1 Durability and moisture resistance of Aerated Concrete

The compressive strength of AAC is very good and load-bearing structures up to 3 storey high can be safely erected. Entire building structures can be made in AAC from walls to floors and roofing with reinforced lintels. Aerated concrete is very important to construction industry as a Green material.

The purposely lightweight nature of AAC makes it prone to impact damage. With the surface protected to resist moisture penetration it is not affected by harsh climatic conditions and will not degrade under normal atmospheric conditions. The level of maintenance required by the material varies with type of finish applied.

The porous nature of the material means that it can soak up moisture. Appropriate design can avoid this. AAC will not easily degrade structurally when exposed to moisture but its thermal performance may suffer.

2.7.2 Durability and moisture resistance of mud brick (Adobe)

With thick enough walls, mud brick can create load bearing structures up to several stories high. Vaults and domes enable adobe to be used for many situations other than vertical walls. The mud brick may be used as infill in a timber frame building or for load-bearing walls; although it's compressive strength is relatively low. In the Yemen there are buildings 8 stories high and more that have stood for centuries.

Fig 30: mud brick house
Source: www.ecobrick.com

Adobe walls are capable of providing structural support for centuries but they need protection from extreme weather (eg. with deep eaves) or continuous maintenance (the ancient structures of the Yemen have been repaired continuously for the centuries they have been standing). As a general rule, adobe needs protection from driving rain (although some adobe soils are very resistant to weathering) and should not be exposed to continuous high moisture.

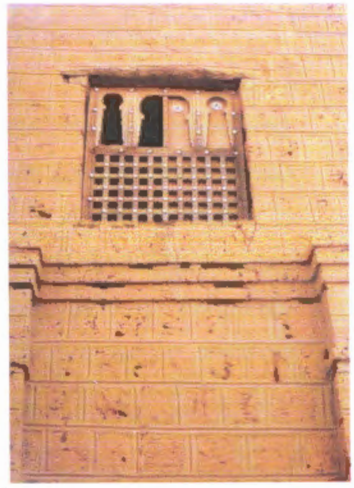


Fig 31: the residence in Timbuktu,Mali is made out of adobe blocks
Source: adobe construction

2.7.3 Durability and moisture resistance of Lightweight timber

Wooden structures have been used in all kinds of building types for many years. Lightweight timber construction has a long history and it is the most common house construction type. In a world living with the effects of global warming, timber provides a renewable building material that stores carbon in its production.

Timber is an organic material and deteriorates due to weathering. Moisture plays a role in the deterioration of all building materials with the possible exception of some synthetic polymers. The main way of preventing weathering is protection of the timber surface. This may be achieved by appropriate design detailing, so that the timber remains dry or sheds water quickly. It may be achieved by treatment with an appropriate surface coating of oil, varnish or paint. Such coatings on external timber components of buildings generally need replacing every 5–7 years. Weathering can be reduced by the selection of durable timber species in the first instance. Over a forty year life a fully maintained timber clad building will require less embodied energy than common alternatives.

A lightweight timber construction can have a very long life, making the dwelling more valuable both from an economic and environmental perspective. This is easy to achieve using appropriate design, building practices and detailing.

2.7.4 Durability and moisture resistance of Rammed earth

Rammed earth is very strong in compression and can be used for multi-storey load-bearing construction. Research in New Zealand indicates that monolithic earth walls perform better under earthquake conditions than walls made of separate bricks or blocks. There is a five storey hotel in Queensland built of stabilized rammed earth. Rammed earth can be engineered to achieve reasonably high strengths and be reinforced in a similar manner to concrete, although horizontal reinforcement is not recommended and excessive vertical reinforcement can cause cracking problems.

The basic technology has been around for thousands of years and there are many rammed earth buildings still standing that are centuries old. Rammed earth possesses a generally high durability but all types of rammed earth walls are porous by nature and need protection from driving rain and long term exposure to moisture. It is essential to maintain water protection to the tops and bottoms of walls. Continued exposure to moisture may degrade the internal structure of the earth by reversing the cement stabilization and allowing the clays to expand, however, in general, rammed earth has moderate to good moisture resistance and most modern rammed earth walls do not require additional waterproofing. New water repellant additives that waterproof the walls right through may make rammed earth suitable for very exposed conditions, including retaining walls, but may inhibit the 'breath ability' of the material.

2.7.5 Durability and moisture resistance of Straw bale

The structural capacity of straw bale construction is surprisingly good. In the load-bearing ('Nebraska' style) straw bale method, walls of up to 3 stories have been constructed, but straw bale construction commonly uses a frame for the building structure. Most buildings require a frame of timber or steel to comply with current building codes. There are now several examples of multi-storey buildings in framed straw bale construction, including 3 houses with 2 storeys of straw bale wall in the City of Adelaide,Australia.

Provided the straw is reasonably well protected and is not allowed to become waterlogged it can last many years with moderate maintenance. Indeed, it is reasonable to expect that straw bale buildings can have a lifetime of 100 years or more.

The most detrimental factor affecting straw bale wall durability is long term or repeated exposure to water. Given enough moisture and two to three weeks, the fungi in bales produce enzymes that break down straw cellulose. But for this to occur the straw moisture content must be high (above 20% by weight). Straw bale walls should not exceed moisture content of 15%. Reasonable and sensible precautions against water penetration during construction, such as covering otherwise unprotected walls with tarpaulins, make it unlikely that water damage will be a problem in most building programs. The best way to prevent rot in a finished structure is to create a breathable straw bale wall and the success and survival of historic structures in Nebraska and Alabama demonstrate the durability of straw bale structures in climates with variable moisture and temperature.

Fig: 32 interior of the straw bale house.
Source: www. strawbalecons.com

2.8 Waste minimization

The treatment and disposal of waste is an issue of increasing environmental concern. Materials produce as little waste as possible in their manufacture, use and disposal. Buildings are tremendous generators of waste. Landfills are overflowing, especially with construction waste, which accounts for large amount of the usage at landfills. By utilizing methods of reuse and recycling of scrap and trimmings, employing strategies that minimize waste through the life cycle of a product, manufacturers can radically reduce the amount of products that are put into the waste stream. Minimizing and recycling this waste can have significant social, economic and environmental benefits.

2.8.1The three types of waste minimization

- Reduce consumption of resources by building smaller houses that are better designed for your needs. This is the most effective way to conserve precious resources for use by future generations and reduce waste. It also lowers costs.
- Re-use existing buildings and materials and reduce demand for resources, lower waste volumes and save money. We should never demolish old buildings. Deconstruct, give old buildings new lives.
- Recycle resources that are left over or have reached the end of their useful life. This will reduce demand for new materials and lower the volume of waste going to landfill.
- Use renewable resources like sustainable managed forests. This creates a sustainable economy and helps conserve non-renewable resources.
- Use materials with high recycled content to create a market for recycled resources. It will raise the price paid by recyclers for recovered resources and increase the viability of recycling.

2.8.2 Life cycle thinking and building waste

Life Cycle Assessment (LCA) of C&D waste streams indicates that significant energy savings can be achieved at little or no cost by considered C&D waste management and planned recycling. Materials with high embodied energy (eg. metals, especially aluminium) or with high environmental cost in extraction can have their lifecycle impact reduced by end use recycling. The environmental impact of most materials can be substantially reduced by their re-use qualities.

2.8.3 Waste minimization strategies in architectural practice

Cost effective, waste minimization strategies must be agreed to and implemented by all parties involved in design, construction and operation stages. A team approach by the owner, builder and architect (designer) is the most effective way to implement waste reduction.

Waste minimization of building materials in design and construction stages

The design stage

Designers are responsible for introducing and planning waste minimization strategies from the earliest stages of design through to completion. This includes deciding what to build, whether to demolish, what materials to use and how they might be recycled. A commitment to reducing waste at the initial consultation is more likely to endure throughout the project. In that stage designers should be concerned about the building systems with law waste rates.

Designing in waste minimization :Building Designers Association of Victoria 1998 given guidelines for the waste minimization

Guidelines

Concept design

Choose construction to minimize cut and fill.
Plan for end use and deconstruction.
Select building systems, materials with low waste rates.
Identify recycled materials that can be used.

Design development

Dimension to suit standard modular construction sizes and minimize waste.
Select materials with known minimum waste rates; manufacturer waste recycling schemes and recycled content or other LCA benefits.
Engage like minded design professionals (eg. engineer, interior designer).

Working drawings and detailing

Design operational waste handling facilities.
Select efficient appliances.

Plan for waste separation and sorting on-site during construction.

Design final dimensions to suit available sheet and materials sizes.

Specification

Specify:

Materials with known minimum wastage rates (e.g. plywood, finger-jointed timber).

Materials with known recycled content (e.g. paper and polyester insulation.

Durable materials and finishes.

Nominate:

Waste handling and recycling contractors.

Waste streams to be recycled.

Contract documentation

Prepare a waste management plan.

Agree which party or parties receive financial benefits of recycling.

Provide economic incentives for recycling.

Include waste minimizations and recycling performance clauses in the contract.

Tendering period

Promote economic benefits of waste minimization and recycling to tenderers.

Familiarize tenderers with recycling, waste management and minimization strategies.

Answer questions and allay concerns (costs).

Engender a spirit of cooperation to achieve waste minimization objectives (team building).

Supervision

Monitor recycling rates and on-site sorting and storage of various waste streams.

Verify contractor performance or certification.

The construction stage

Site operation

Plan locations for depositing and stacking of materials prior to delivery.

Provide recycling skips and ensure waste stream sorting compliance by all trades.

Form a compound to contain plastic film, cardboard, glue and paint tins.

Use reputable waste service providers.

Negotiate recycling paybacks with local resource recovery firms.

Use waste aware sub-contractors.

Use written contracts with all trades including clauses requiring waste minimization practice.

Require trades to dispose of their own waste.

Back charge for sorting of waste streams not sorted by each sub-contractor.

Colour code or label waste skips and protect them from contamination, rain and wind.

Provide regular waste bins for food scraps and household waste during construction.

Lock special skips at night and weekends to prevent rubbish dumping in recycling bins.

Materials storage and handling

Minimise time between delivery and installation and the risk of damage or theft. Suppliers should encourage collect/recycle packaging.

Have fragile materials and fixtures delivered and installed close to completion date.

Use prefabricated framing and trusses to reduce time on site before installation.

Check quantity, condition and quality on delivery. Report discrepancies immediately.

Reject inferior goods or materials if their quality will result in additional waste.

Refuse oversupply as compensation for inferior quality or condition.

Report careless delivery staff to the supplier.

Concreting

Use concrete with recycled aggregate in all viable applications.

Use reinforcement made from recycled steel.

Form up accurately and fine tune estimating to minimise waste. Up to 10 percent is often wasted.

Return surplus to the plant for recycling.

Buy from plants that wash out cement to allow recycling of sand and aggregate.

Carpentry and joinery

Use engineered timber products that make efficient use of materials where possible.

Use sustainably sourced timber.

Encourage your supplier to find sustainable sources.

Prepare accurate cutting lists before ordering.

Give joiners a copy of the cutting list.

Ensure that carpenters have a complete cutting list to allow efficient timber e.

Bricklaying

Have bricks dropped around perimeter to save damage in transporting to place of use.

Use appropriate mortar strength. Softer mortar saves cement and helps in recycling.

Plastering

Buy plasterboard from suppliers who recycle.

Sort off-cuts and store on site for return to recycler.

Keep off-cuts clean and dry.

Carry useful sized off-cuts to the next job.

Glazing

Separate construction glass from other glass such as drink bottles.

Most glass can be melted down and recycled but requires sorting.

Glass can also be recycled as aggregate.

2.8.4 Waste management plans

Many types of Council require waste management plans prior to granting of development consent. They usually require the builder or designer to estimate the total waste stream volumes from both demolition and construction and nominate means of disposal including recycling contractor, recycling waste station or landfill site. The site plan is often required to show waste storage facilities on site during construction and a schedule for delivery or pickup. Time and cost of waste plan preparation is usually recouped through reductions in waste disposal costs or dividends from sale of salvaged resources.

2.9 Positive Social Impact:

Green building materials should contribute to a higher, healthier quality of life for users and better replacement become most important character. A green material doesn't exist without a major impact on the social strata. People that mine the earth, manufacture, distribute, consume, recycle or demolish products all have a stake in that product. Consideration of their treatment, health and well-being is an integral part of the product's integrity. Humane treatment and a fair wage for workers should be a part of the green equation. Also in consideration should be the users' well-being and overall health in regard to the product. Increasing day lighting in a building not only helps reduce energy loads, but often makes workers more productive.

2.9.1 Green material for Humane Design

Humane design is concerned with the livability of all constituents of the global ecosystem, including plants and wildlife. Humane design arises from the humanitarian and altruistic goal of respecting the life and dignity of fellow living organisms. Green building materials are given birth to buildings with good overall environmental quality. It can reduce the rate of respiratory disease, allergy, asthma, sick building symptoms, and enhance worker performance. Many building materials and cleaning/maintenance products emit toxic gases, such as volatile organic compounds (VOC) and formaldehyde. These gases can have a detrimental impact on occupants' health and productivity. But green materials with zero or low emissions improve indoor air quality and enhance the human health and good worker performance.

In modern society, more than 70% of a person's lifespan is spent indoors. An essential role of architecture is to provide built environments that sustain occupants' safety, health, physiological comfort, psychological well-being, and productivity. Because environmental quality is intangible, its importance has often been overlooked in the quest for energy and environmental conservation, which sometimes seemed to mean "shivering in the dark." Compounding the problem, many building designers have been preoccupied with style and form-making, not seriously considering environmental quality in and around their built environments.

2.9.2 Social aspects for Green material

Our traditional building materials have unique green characteristics .unfortunately nowadays that traditional and simple construction methods are abundant in the most of areas in the world. Less-developed regions are trying to make their houses look more modern at one time; traditional materials are ensured many considerable criteria in the Green materials. Despite these advantages, it is difficult to find people willing to build their houses with traditional materials. Which is perceived as "the old way" or as "the poor persons' house" in as much as it appears that all wealthy people live houses made by modern materials. The low income person most likely will have just one chance in like to buy or build a home and does not have the experiments. It will always broaden acceptance for those or affluence to use natural, environmentally friendly materials for construction in Travendrun, India, Laurie Baker has been putting this principle to work getting the rich to build with fired brick , using no plaster inside or out. He does this specifically to show those with low incomes, who can not afford plaster, that it is find to have expose brick.

Some Habitat for Humanity International houses are been built of earth blocks, a techniques previously believed affordable only by the wealthy. Habitat for Humanity is employing this method to build affordable houses with low income families by using natural materials, donated labor and keeping the house modest in size. It is also building homes with ecological, natural systems that require less heating and cooling, there by reducing utility bills and making the homes sustainable affordable. Good looking, Durable Habitat For humanity housing has been building other countries using natural materials such as locally fired bricks and compressed earth blocks. In Malawi Uganda, an other countries, HFHI has combined local resources with a bit of industrialized technology. Many houses are built with locally fired clay bricks. Some times bricks are fired with agricultural waste such as rice husks, the ash of which can also be use as an additive to cement. Foundations can be made with local stone. Mud motor is used, and on the out side it is some times pointed with a cement motor to make it more durable and weather resistance. Combinations of method and materials, with only a little of the industrialized materials such as cement, can reduce the need for maintenance. Our traditional green material and other green materials should be developed with the modern technology for the socially accepted level.

2.10 Affordable:

Affordability can be considered when building product life-cycle costs are comparable to conventional materials or as a whole, are within a project-defined percentage of the overall budget. Products are not significantly more costly than their counterpart conventional building materials. Payback period (initial costs recouped through lower long-term operating and maintenance costs) is reasonable. Green building materials will not become mainstream until they are ubiquitous in the marketplace, which will happen largely due to costs comparable to traditional counterparts. It should be noted that many transnational competitors are mass-producing, distributing and marketing their products manufactured overseas with cheap labor and lower environmental standards. Wise consumers are attracted to the best price for the most value, and with the added caveat of environmental awareness, products should move more readily among a segment of the population. Consideration of life-cycle costs against first-costs is very important. While the product might be more expensive at first, it should pay for itself with five years with reduced energy costs, replacement and maintenance cost, and worker productivity.

2.10.1Economic Benefits of Green Buildings

A green building may cost more up front, but saves through lower operating costs over the life of the building. The green building approach applies a project life cycle cost analysis for determining the appropriate up-front expenditure. This analytical method calculates costs over the useful life of the asset.

These and other cost savings can only be fully realized when they are incorporated at the project's conceptual design phase with the assistance of an integrated team of professionals. The integrated systems approach ensures that the building is designed as one system rather than a collection of stand-alone systems.

Some benefits, such as improving occupant health, comfort, productivity, reducing pollution and landfill waste are not easily quantified. Consequently, they are not adequately considered in cost analysis. For this reason, consider setting aside a small portion of the building budget to cover differential costs associated with less tangible green building benefits or to cover the cost of researching and analyzing green building options.

2.10.2Affordable as a main considerable character in assessment methods

Life cycle assessment

Life cycle assessment recognizes that all stages from raw material extraction to waste management have environmental and **economic impacts**. It is a tool which assesses the **economical,** environmental aspects and potential impacts associated with a product or service.

Energy and Environmental Design (LEED)

The green building rating system of The Leadership in Energy and Environmental Design (LEED) recognizes the U.S. Green Building Council (USGBC) as the national leader in promoting healthy, environmentally responsible and **profitable building.**

2.10.3 Life –cycle cost and affordability

Affordability of the green building material can be achieved by reducing the life-cycle cost of the material

"Life-cycle cost" of the material

Life-cycle cost" means the amortized annual cost of a product, including capital costs, installation costs, operating costs, maintenance costs, and disposal costs discounted over the lifetime of the product.

Guidelines to reduce the cost of the building material

- Use Locally Manufactured materials. Thereby minimizing energy use, cost and pollution associated with transporting materials from great distances.
- Use homogeneous material rather than composite material (such as reinforced plastics and carpets fibers and backing), as they are generally easier to separate and recycle
- Reuse and recycle construction and demolition materials. For example, using inert demolition materials as a base course for a parking lot keeps materials out of landfills and costs less.
- Use dimensional planning and other material efficiency strategies. These strategies reduce the amount of building materials needed and cut construction costs. For example, design rooms on 4-foot multiples to conform to standard-sized wallboard and plywood sheets
- Require plans for managing materials through deconstruction, demolition, and construction.
- Design with adequate space to facilitate recycling collection and to incorporate a solid waste management program that prevents waste generation

- Use materials. Systems, and components that can be assembled or fastened in a manner that facilitates reassembly into new construction or remodeling.
- Design cladding systems that are fixed by snap release connectors, friction, or other joints that do not require sealants
- Employ design strategies to use fewer materials, including reducing the size of the building and spaces; eliminating
- Use products or materials (including masonry, steel, glass, and some timber products such as beams, columns, floorboards, etc.) that are durable (with a life cycle of at least 50 years), weather well, and last more than one building lifetime
- Design for Less Material Use
- Employ design strategies to use fewer materials, including reducing the size of the building and spaces; eliminating

Chapter 3

Green building materials and their applications in Sri Lankan context.

Preamble

This chapter is dedicated to evaluate an analytical study to assess the applicability of Green building materials in Sri Lankan context. Since we study the applicability in local context, it is important to have a basic understanding on traditional green materials and their perception on Sri Lankan vernacular architecture. Our traditional shelter is prominent example to discussed applicability of green materials in Sri Lankan architecture. The first part of this chapter discussed traditional shelter and applicability of green materials. Research and Analysis of the case studies will be done using the Green material evaluation matrix and discuss their applicability in contemporary architectural practice in Sri Lanka. Formulation of an 'Evaluating matrix on Green materials is the one of the important part of this chapter. This will be done by preparing the 'Scorecard' using the ten evaluation criteria which was introduced by the school of Architecture and Urban Design at the University of Kansas, America. This 'scorecard' will facilitate evaluation as 'Excellent', 'Good' and 'Poor', also with as a provision for a 'General Comment' in addition to that.

Newly introduced Green materials and their influences to the Sri Lankan context will be discussed at the final part of this chapter. Tsunami generated large quantity of demand for the materials and alternative methods in construction industry. Therefore alternative construction methods and their influence for the green materials also discussed as the major concern current issue.

3.1 Sri Lankan traditional shelter.

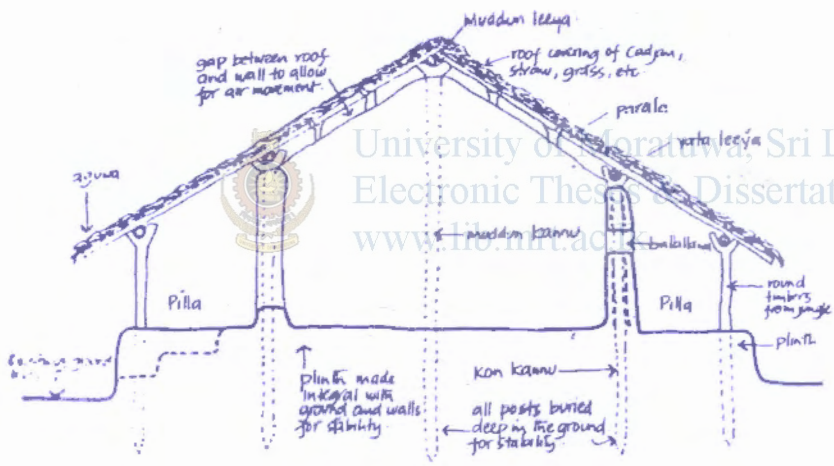
Architecture of every country is peculiar to that country as language dress or folklore. As a result all over the world, distinctive local forms and details in architecture exist. Ancestors were more sensitive their living natural environment. In Sri Lankan tradition they were strove express a harmony between people land and cosmos to make forms that linked earth to spirit. In Sri Lankan tradition there has always been a deep-seated relationship of architecture and environment. Green concept and Green idea is not a new concept to Sri Lankan tradition it derived along the long period of time with response to social, cultural environmental changes.

As De Silva (1990;02) explains, "The traditional house that has existed in Sri Lanka for more than two thousand years was an outcome of a strong philosophy of Buddhist life – i.e. 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".

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.

"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)*



TYPICAL SECTION THROUGH TRADITIONAL RURAL DWELLING UNIT

Figure 33

Source: De Vos (1998), SLA Journal, Vol. 100, No.4, p 11

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 high plinth' THE PILA' and impermeable nature of the clay used for construction prevented the rising dampness during rainy days. "The materials required for construction was selected from the locality and the simple technology utilized to put it together was the basic reason for a low cost shelter"(De Silva, 1990:02)

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. 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. The use of stone for walls (sakka bema) can be again used for similar purpose.

Roof was a "great umbrella", which was emerged against the sun and rain. 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. The verandahs with eaves around the house and small windows kept the hot sun away and provided cool and comfortable conditions within the house.

Our traditional house made out from natural materials and they were renewable and biodegradable materials. After their life time they were part of the nature. All the materials were taken from surrounding environment. because of the bio degradable quality building material waste also minimized. All the materials are environmental friendly materials and they were not produced environmentally harmful chemicals as present use new materials. Energy efficiency of these building materials was very high as early described. In early Sri Lankan tradition these building materials and house were socially acceptable. Most of the materials were borrowed from surrounding and their houses were made out from themselves. According to the traditional culture these materials are more affordable to any other person.

Most of the important qualities of the Green materials successfully visible in our traditional materials and important thing is contemporary Sri Lankan architects should be used these Green materials for contemporary practice by using new technology with response to environmentally and socially acceptable level.

3.2 Case study one

Adventure park-Ella

Adventure Park Ella is the very good example in Sri Lankan Architecture which is greatly achieved green objectives as an eco-friendly design. Green materials play remarkable role to enhance eco-friendly design goals.

3.2.1 Location and climate

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 consist with rich bio diversity.

Climatic data

Adventure Park Ella situated in the eastern side of the Uva province and more than 2500 mm rainfall brings to this area especially from December to March by northeast monsoon. Average temperature of the area is 15 c

Fig 34 A cottage to experience nature
-Ella Adventure Park

3.2.2 Sprit of the place

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.

Fig 35: traditional 'pala' retain on the timber pillers

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 stories cabana units which in 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 promotes the idea "Eco Tourism. The design also gives perception of the interrelation between the vernacular architecture in Sri Lanka and Green architectural concepts.

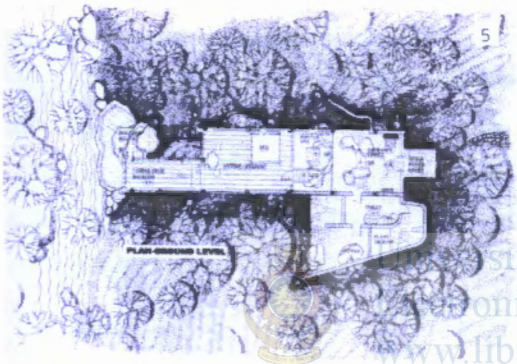


Fig 36. Plan of timber deck- Ella Adventure

Fig 37. Section through main deck- Ella Adventure Park

3.2.3 Analysis applicability of Green materials

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 tree trunks to support raised timber decks. Some of trees themselves used as structural supports to the elevated platforms and every hut are low scale storied timber structures. Timber is mostly available material in that area and it consumes less energy due to transportation, preparation and installation. Therefore it consider as the material with low embodied energy.

Fig 38. Traditional technology and Simple geometry -Ella -Ella Adventure Park

Timber also recyclable, biodegradable, non toxic material which is not harm to the existing biodiversity. This produces little waste and waste can be easily recyclable and biodegradable. Use of timber is more appropriate because its ecology friendliness and the consumption of less energy to produce than alternatives. Bamboo is common material to the Adventure Park Ella. Bamboo is renewable building material which has same qualities as the above material. Manually operated bamboo mats, provide adequate protection from different weather conditions. Most of the furniture made out from timber products and reuse recyclable concept is emphasized. More than sixty percent of furniture made out from bamboo. Architect carefully uses timber without damaging existing biodiversity. Most of the timber taken from the out side (specially planted area for economical purposes), some existing trees use as the structural support without removing them from the site.

Fig:39 high pitch roof retain on the reused light post columns.
Wide corroder focus on to viewing decks.

The roof is a steep sloped thatch of illuck, and the dominant feature of this 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.' Illuck' thatch roof act as an insulation layer and reduce the heat transmission. high pitch of the roof angle promote the upward hot air flow. 'illuck' also renewable available materials in Ella meadows.

Fig40: 'illuck' thatch roof is the dominant feature of the Ella Adventure park

Green materials and simple geometry of the mud huts stimulate the inherent traditional technology. Sand, mud and straw put together create mud walls. High quality of heat absorption and low heat gain promote thermal comfort to the indoor environment. Mud plaster avoids using toxic paints and aesthetically bond with surrounding natural environment.

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.

Fig41: protecting tree and creepers become part of the design.natural materials give eco-frendly sentation

There are 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.

Fig42: timber viewing decks create numerous leisure spaces for visitors.

Fig43: solid mud construction under floating 'illuck' thatch roof.

3.2.4 Green material assessment matrix (introduced by Architecture and urban design at the University of Kansas America.)

Assessment criteria	General comments	Rating
Low embodied energy	Used materials with low embodied energy. (mud,'illuck',timber,bamboo) Most of the material used from surrounding context,no need too much energy for transportation, installation, extraction and excavation.steel cable(high embodied energy) only used at the suspended bridge. Minimum use of concrete.	O
Recyclable and reuse quality	Reuse option can be identified using light post for the columns and tree trunks, branches for the structural support and create furniture.	O
Use renewable resources	Most of the places used natural materials like bamboo, illuck, timber and they are recyclable,biodegradable materials. Mud,illuck,timber,bamboo are renewable resources.	☺
Locally or regionally produced	Most of the parts designed by using naturally available materials such as illuck,bamboo.mud,timber and they are locally available materials at the site	☺
Low environmental impact	Many places architect use natural materials. These materials are nontoxic and no VOC emissions. All the natural materials are biodegradable and after their life time they become part of the natural earth. Mud plaster avoid using toxic paints	O

☺ **Excellent** O **Good** O **Poor**

Green material assessment matrix

Assessment criteria	General comments	Rating
Energy efficient	Mud wall high thermal mass and high R value provide High quality of heat absorption and low heat gain promote thermal comfort to indoor environment.' Illuck' thatch roof act as an insulation layer and reduce the heat transmission.	Good
Minimize waste	Never used plastic related products, nonbiodegradable products. Used alternative methods (reuse) :e.g. light post. Timber used without damaging existing quality. Therefore minimize waste due to preparation and installation. Construction waste also minimize.	Good
Durable	Mud hut created as the temporary structures. Timber,illuck, mud bamboo not so durable materials. therefore they need good maintenance and well treated for different weather conditions.	Poor
Affordable	Architect used low cost natural materials and he never used lxuryfinishes.but most places timber used as the main material . According to present market price ranges constructing timber structure canbe more costly than the concrete structure. Maintenance cost of the natural materials is very high.	Poor
Positive social impact	Never used toxic and VOC emission materials which affected to the human beings. natural materials and their better replacement promote eco friendly sensation to users.	Excellent

☺ **Excellent** O **Good** O Poor

Concluding remarks

- The architect sensitively used Green materials like timber, 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.
- Architect successfully achieve main characteristics of the Green materials. that embody of all these principles succeeds holistic approach
- 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 2:

3.3 Basnayake House, Ganemulla

This is a very good example for traditional architecture of Sri Lanka in its origin, which contain green materials and important elements that facilitate green architecture objectives.

3.3.1 Location and climate.

The house located in a remote area in Gampaha District of the Western province. Situated facing Kandana – Gampaha main road facilitates public transport while two railway stations Batuwatte and Bulugahagoda in walking distance. Situated in the Wet Zone of the country, the area receives 2500-3000 mm of average annual rainfall and average temperature around 28^0C with a maximum of 32^0C and minimum of 22^0C (Department of Meteorology Golden Jubilee Publication, 1998; p75) . Meanwhile, this house has a specific micro climate within its premises. This has purposely created by the conscious use of the landscape which includes preservation of natural trees as a significant component of the landscape.

3.3.2 Background

The house is the family house of the owner Archt. Vijitha Basnayake who is a person with a great concern of the environment. Most of the places in his design he shows traditional way of architectural practice using green materials. The house was renovated in three generations of the known history stands in harmony with its surrounding as the Architect makes significant changes to its spaces as well as its built elements as the third generation renovation.

As the Architect explains "*the culture of ours which influenced with the eastern way of thinking and Buddhist philosophy of impermanent nature of the life makes it impossible to make a complete architecture....For us there is no specific beginning or specific destination but a process continuously growing*"

Fig 44
:varandah overlooking to forest garden

old front garden (which is now a side space) to be grown naturally as a small forest.The contribution of this forest in preservation of the 'biodiversity' of the site and for the indoor and outdoor comfort can be simply experienced for one who has been there. It is easier to explain the project from the main changes of the use of spaces or rather reuse of functional spaces. As the plan (fig) shows a typical Sri Lankan courtyard house oriented its front to the East, the new entrance have come up to the North directing to the tree on central courtyard while the old front garden has leaved for the animal who had their natural paths at that time. Verandah has been a important space and it is well ventilated open space overlooking the forest garden. Central courtyard pond is given passive natural cooling to the indoor spaces. As architect Basnayake says this was purely inspired from nature with an experience on a rainy day when only the courtyard was existed.

Fig: 45
Courtyard converted into the pond

This important feature further facilitates the day lighting with its reflection to the ceiling as well as enhancing the cross ventilation of all the spaces around.

While being a physical barrier for human to crossover it serves the fishes and other water animals as their living space inside a nature lover's residence. Many reused items can be seen used for different purposes which irrespective to their original use.

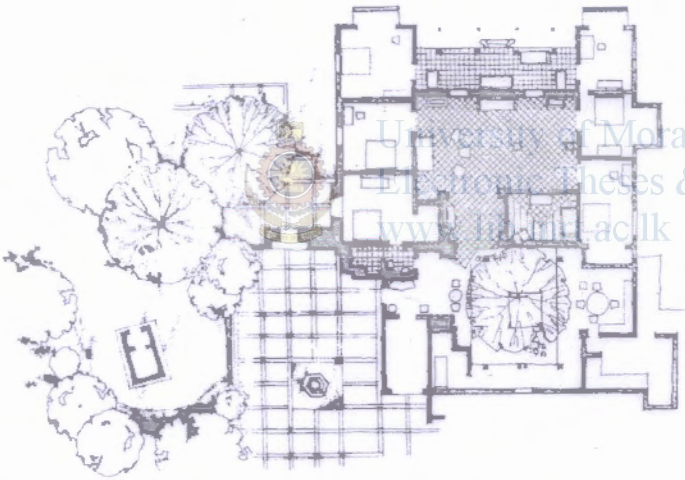


Figure 46: Plan of Vijitha Basnayake House, Ganemulla
Source: *'Vasthu'* (2000), p 08.

Figure 47: Section showing the new Entrance and Extended Verandah.Source: *'Vasthu'* (2000), p 09.

3.3.3 Analysis applicability of Green building materials

The architect used traditional green materials to achieve his design goals which are originated from our vernacular architecture. Successfully used and better replaced Green materials enhance the Green concept and architectural value. The entrance was highlighted with an arch made out of bamboo strips and clay obtained from the site. The arch at the entrance made out of locally available materials with mud and bamboo frame. Bamboo and mud are renewable and recyclable building materials which are easily found from surrounding environment and they mutually engaged with the surrounding vegetation.

Figure 48: The entrance door
The entrance arch made out from mud and bamboo strips

The grillwork above the entrance door was prepared by reused steel rods taken from old window welded to a semicircular frame. Steel consider as the material with high embodied energy. Large amount of embodied energy deal with material production and reuse of material for the new purpose reduce large amount of reproduction energy of same material. Therefore it is good approach of green material.

Figure49: the entrance door steel grill work prepared by reuse steel

Additional set of reused columns were used to extend the verandah in order to prepare a large space, probably a well ventilated open space overlooking the forest garden. In this case the early front verandah has been a secondary space but comparatively a main space of the house. In this design hard wood branches used as the structural support.

Figure 50: The verandah
This was the old entrance has now converted into a new space overlooking the forest garden.
Additional row of columns makes the long eaves; prepares shady comfortable living space.
The additional columns were reused.

Most of the walls in this house made out of 'kabok block' and it also easily found material from the site and it also naturally biodegradable material as above. Thermal mass and high R value of the 'kabok' walls absorb heat in the hot day time and slowly radiate heat in to the building at night. ' kabok' wall become good Green material to maintain stable temperature in the house.

Fig51: Reuse window frame as a structural support

The details of construction materials and finishes can be seen in interior spaces, while some structural parts of the old house can be seen as elements in the living space. The colour selection expresses the age of the house while lime-washed walls stays calm with less impact to the environment than expensive and artificial paints.

kabok' blocks and mud the demolition waste of the renovation was less pollutant. However even these waste were also used to make a barrier to the main road in front. They were put next to the old boundary wall to form a small hillock. The clay was taken from the site and their pits were leaved as dry ponds which fill in the rainy seasons and evaporate in the dry seasons.

Fig 52: Lime wash 'kabok' Wall

Fig53: Red clay tiles
Daytime deep red tiles absorbed heat and slowly radiating heat at the evening.

The Architect's studio is the old rubber processing 'smokehouse'. Now it is an interesting 'design studio' which can very simply explained as a Green design. Hardwood branches found from the site were used as supports for its long eaves and even as the main support of the monitor roof, which is the chimney of the smokehouse now being the main source of day-lighting.

Figure 54: the Architect's Studio

An old rubber processing 'smoke house' is re-used as the studio.
The chimney has become the main source for daylight.
Reused columns and elements were used
Branches of trees were used as the columns.

Figure 55: Detail of the roof of the Studio

The roof supported with hardwood found in the garden.
The monitor roof used as the main source of natural lighting.

Figure 56: Exit to the rear garden.

R e-used door and frame used entrance door
For Architect office

3.3.4 Green material assessment matrix (introduced by Architecture and urban design at the University of Kansas America.)

Assessment criteria	General comments	Rating
Low embodied energy	Used materials with low embodied energy. (mud,kabok,,timber,bamboo,reuse elements e:g reuse doors and windows) Most of the material use from surrounding context,no need too much energy for transportation, installation, extraction and excavation.steel (high embodied energy) used at the windows and other decorative works,used concrete granite tiles,lime for walls which has high embodied energy.	O
Recyclable and reuse quality	Reuse concept is major achievement for this house.most of the places used reused elements Ex: doors, windows ,their frames, furniture and. timber columns. Materials in the old house reused for the new additions. Newly introduced materials are minimum. Demolition waste was also used to make a barrier to the main road in front.	☺
Use renewable resources	Most of the places used natural materials like e.g :bamboo,clay ,kabok,timber, These are renewable resources.	O
Locally or regionally produced	Most of the parts designed by using naturally available materials such as ,kabok, clay, timber, bamboo and mud. Most of them available materials at old house.	O
Low environmental impact	Many places architect use natural materials. These materials are nontoxic and no VOC emissions. Lime plaster avoids using toxic paints. House was built according to without destroying surrounding environment.	☺

☺ **Excellent** O **Good** O **Poor**

Green material assessment matrix

Assessment criteria	General comments	Rating
Energy efficient	'Kabok' wall clay floor tile high thermal mass and high R value provide High quality of heat absorption and low heat gain promote thermal comfort at the indoor environment.' natural tile roof reduce the heat transmission into the house. This house is naturally ventilated house.	☺
Minimize waste	Never used, nonbiodegradable products. Used alternative methods and reuse materials at the old house. Demolition waste also use for new additions. Perfectly reused materials at the old house for renovations.Therefore minimize waste due to preparation and installation. Construction waste also minimize.	O
Durable	'kabok' ,lime ,natural stones, hard wood used for this house and They are durable materials.	O
Affordable	Architect used low cost natural materials and he never used luxury finishes. Most of the materials are reused materials. Therefore material cost is reduced.	O
Positive social impact	Never used toxic and VOC emission materials which promotes good indoor air quality. Sri lankan traditional materials emphasise traditional Sri Lankan court yard house and successfully merged with surrounding environment and village context. Create physically and comfortably living environment for users.	☺

☺ **Excellent** O **Good** O Poor

Concluding remarks

- Architect Basnayakas' house well planed traditionally personalized house.
- It emphasise the main characteristics of our traditional court yard house.
- Re-use concept of Green materials very successfully achieved in this design and other characteristics of Green materials and their better replacement of materials fulfil his design goals.
- Most important thing is he very successfully designs his house as a comfortable living space with the help of Green concept and most important thing is this house is socially bond with surrounding rural context.
- Architect well responded to surrounding natural environment and its' natural habitants (birds and frogs etc....)

3.4 Introducing new approaches of green materials for local context

Developed countries consumed large amount of energy from world energy consumption. Construction and building material production industry is responsible for a significant share of energy consumption and Carbon Dioxide emission to the atmosphere. Scientists and technocrats are increasingly focused on introducing 'Green technologies 'among world communities as a solution for the anticipated energy crisis our future generations will have to face. Third world countries will be faced that huge problem within next years. So this is the time to introduce green technologies to the third world countries. In that scenario green materials should be most concern issue.

3.4.1 Straw bale construction for Sri Lanka

Nearly 200 scientists, technocrats, academics and builders from 12 countries, both from East and West, gathered recently in Camp Kawartha at Lakefield Canada to deliberate on the above theme. More specifically, they examined potential of straw to be used to replace high energy consuming construction materials such as cement, concrete, steel or even bricks. The event was a week long affair from 23rd September to 1st October, and was named 'International Straw Bale Building Conference-2006' (ISBBC 2006).ISBBC is a by-annual event attended by international community working on straw and similar nature friendly technologies. Asian region was represented by China, Pakistan and Sri Lanka.

The presentation by Sri Lanka, on 'The First Straw Bale House in Sri Lanka' was a highlight of the seminar and was commented by many world experts for the pioneering effort of the Sri Lanka's research team. The team from Sri Lanka comprised Mr. Inagami Shozo, a Japanese researcher working for dissemination of Straw Bale Technology in Sri Lanka, his Sri Lankan co-researcher Mr. Piyal Ganepola, an Engineer in the housing sector and Mr. Mervin Perera, who was in-charge of construction of the first SB house.

Fig56 SB house at **Kalagedihena,**

This research team has constructed the first SB house at **Kalagedihena, Gampaha** and is researching on the adaptability of the technology in Sri Lanka.

Mr. Ganepola made the presentation on the Sri Lankan straw bale project, stated that the project aims to test the technical applicability of the SB technology to the Sri Lankan tropical atmosphere. (Straw bales are masses of straw compressed and bound into rectangular blocks). He further stated that many countries in the American and European continents and Australia has recognized SB technology within their building codes. International engineering testing authorities have tested and proved that plastered SB walls have much better fire resistant qualities and insulation qualities than many conventional building materials and that they last very long if protected from moisture. On the question of possibility of termite attacks, he stated that the experience in the western world is that straw is less attractive to termites than timber due to the presence of lesser amount of nutrients in straw.

According to Mr. Ganepola, justification to use straw in construction in Sri Lanka is different from that of countries with distinct seasons; winter and summer, where thermal insulation is the main advantage. Here in Sri Lanka we utilize very little of our rice straw as fodder and fertilizer and burn the rest adding toxic gases to the environment. On the other hand we destroy our environment by building with technologies introduced to us by Westerners in the colonial period. As examples he quoted the sand extraction in river beds and destroying trees to burn bricks. Another concern is the draining of foreign exchange for importing building materials and products. Straw Bale technology offers opportunities to masses of our unskilled labor force to gainfully contribute to build houses as the technology is very simple. SB technology has a range of applications from ultra comfort tourist accommodations to affordable low cost housing which creates a good condition space for SB technology to become sustainable in Sri Lanka. Straw has unbelievably excellent qualities as a construction material which the Sri Lankan construction industry has yet to realize. Several ways of using straw to build walls of buildings too, other than straw bales, were presented in the conference.

3.4. 2 Green materials for Tsunami housing projects

Sri Lankan construction industry shows rapidly growth due to tsunami construction. The. Most of tsunami construction projects carried in coastal areas by foreign nongovernmental organizations. Green approach, sustainable construction projects successfully carried in European and developed Asian countries. There for these nongovernmental bodies turn their attention to implement sustainable Tsunami housing schemes in Sri Lanka.

Fig57 . Purification of sea sand

In addition construction industry face huge problem to supply raw materials Tsunami constructions. Sand extraction in river beds occur huge problems like flood and destroying endemic bio diversity. There for government prohibited sand extraction in some places ('kalani" river) and sand become limited resources to construction industry. As result experimented advance technology used to purified sea sand and they used for the most construction as a result of sustainable solution.

3.4.3 Compressed earth blocks for Tsunami housing

Tsunami construction become reason to popular compressed earth blocks among the Sri Lankan people. Some Sri Lankan companies and organizations introduced compressed earth blocks to the Sri Lankan people but not much popular. Bosco apartments is successfully completed Tsunami housing project by using compressed earth bloks. The Permanent Housing Scheme is the long term project for them consisting of 13 blocks of 16 housing units in each totaling 208 housing units. This housing project is sponsored by Salesioan of Don Bosco, International Organisations and good hearted benefactors. This is being monitored by Urban Development Authority with technical expertise of National Engineering Research and Development Centre is under construction

Fig58. participation of the people for make compressed earth blocks

3.4.4 Technology used for compressed earth blocks

Compressed earth blocks and modern rammed earth wall technique consists of mechanical methods for compacting earth to increase the density o f its mass. It has to main results in terms of improving the quality of earth for building purposes. One is that it increases the strength of the earth, and the second is that compaction reduces the gaps in the earth mass, their by restricting the presentation

Fig59. construction of Don Bosco apartments Nigambo

of water.Compress earth blocks are similar to adobes .the main differences being they are not fully saturated with water, are denser than adobes, and are usually significantly more uniform. These blocks are created using a variety of machines. Some, like the Cinva-Ram invented in South America, use human labor and are relatively inexpensive .expensive fuel-powered machines, on the other hand, can produced thousands of bricks in a day. Soil, sand, stabilizer, water need for the compressed earth blocks as main raw materials. Because of their uniformity, compress earth blocks need little mortar, and can even be dry-stacked. This uniformity also speed up the laying process and results in straighter walls. Soil for compressed earth block production should have quite a high sand content, with just enough clay to act as a binder. Any material coarser than 5 - 10mm should be sieved out. The soil needs to be mix dry, especially if stabilizers are being added. Compressed earth blocks have low embodied energy, thermal mass and high R value and use regionally available resources like soil,sand,water. It is renewable, recyclable and ecologically sensitive building material without any nontoxic substances. Compressed earth block is a Green material and low cost affordable material to Sri Lankan people.

Most important thing is newly introducing green materials should be affordable and suitable to social and cultural context in Sri Lanka and it become good reason to popular among the Sri Lankan people. Early introduced Green materials proved, it becomes easy target for the third world countries as Sri Lanka to achieve green concept and sustainable future.

Conclusion

The world is limited entity. All its resources are static. They with over exploration it is fast never recover at the same place of his consumption. Becoming an unsuitable place for his habitation. Architecture and environment cannot be separated in the creation of a conductive habitat for mankind. On the one hand the basic physiological and economic needs of man must be full fill and architecturally express on the other hand there is a need to balance, harmonize and integrate the built environment with ecological, social, financial etc. Architecture with above factor is now being brought to shaper focus arising from recent movement towards sustainable development.

Architecture is a physical emotional as well as an intellectual experience having the potentially of making the ready temperament going even further bound intellect. Beyond thought where there is realization. Sustainable architecture is surpassing the many limitations direct man towards achieving this end little by little step by step. It is ultimate purpose that the contemporary architecture must serve more then any other day.

The ideology of sustainable development has a direct link with the green architecture. As said out of the many faces of the green architecture the present day accumulation is mainly on the environmental factor the study was started with the intension making awareness towards the issues. As far as concern the environmental aspect cannot be considered individually and it is important to reveal its roots and connections with the other segments primarily.

The attention of architect's world over is increasingly focused on Green architecture as a solution for the degrading of the environmental resources and anticipated energy crisis our future generation have to face. Buildings are large entities and, as such, they impact upon the environment in various ways. Present-day designs clearly consume large quantities of building materials, responsible for a significant share of energy consumption and Carbon Dioxide emission to the atmosphere and toxic materials contribute to poor indoor air quality. But they also can result in effects such as loss of amenity and biodiversity which are much more difficult to assess. These current trends will deprive the rights of our future generations to live comfortably in this planet unless we take corrective measures now. To empower the architect to use Green materials (eco friendly building materials) along with the practicing Green architecture and promote an alternative approach to building that has a positive impact on our planet today and for generations to come.

The study was started with such idea because when it collaborates with the architecture the scenario becomes complex and comprehensive exercise. The issue is being and concept this has to do with analyze of the available literature. The early part of this study got through this by discussing the concepts of sustainability, Green architecture and Green materials. Green material assessment system becomes most concern issue to develop Green material evaluating criteria. These criteria are analyzed and the factors noted out of them have used as the parameters to analyze material weather they are environmentally sustainable or not. The value of those is not only asses the material, they can use as a tool to improve the environmental consciousness of the buildings.

Therefore if we are going to search the issue of Green architecture today the old practices or the traditions have to be revisited. Our Sri Lankan traditional architecture was part and parcel of the nature. They borrowed materials from nature without damaging their natural entity. They were responding to the environment in constructions and have added their cultural identity as a wrapping. The most important thing to grab out of them is the unchanging attitudes they have kept with the nature. Therefore Green architecture and Green materials is not existed by instance and its' result of a long term process.

The change of architectural trends and the forces behind them such as economic development invention of modern materials and the updated technology has made a remarkable effect to change the human approach towards the preserving of nature. Sri Lankan architects have large responsible to achieve green concept for their design and green materials play remarkable role to fulfill their goals. There are few architects practicing green architecture in Sri Lanka. As a developing country attitudes of the people are changing from with response to cultural, social, environmental and economical consciousness. Therefore new generation are not expected our traditional way of green practice as same level of modern approaches. Therefore architects should have responsibility rebuilt our traditional green architecture by introducing new technology without causing our cultural, social and environmental aspects. Our traditional Green materials can be introducing to modern architecture and redeveloped them by using modern technology. Newly invented Green materials can be applied for the modern architecture and cultural and social issue becomes very concern. Other reason is affordable and socially acceptable Green building materials are important to third world country as Sri Lanka. Straw bale construction and compressed earth blokes are very good practical examples in Sri Lanka to achieve this goals. Therefore it is not difficult for the Sri Lankan architects to achieve 'Green idea ' towards the sustainable future..

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- *Sustainable Building Technical Manual*, http://www.sustainable.doe.gov/freshstart/articles/ptipub.htm
- *A Guide to Irrigation Water Needs of Landscape Plants in California*: www.dpla.water.ca.gov/urban/conservation/landscape/wucols/
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