Energy conscious design in hot and humid climates

Design Guidelines on the use of natural lighting & natural ventilation in housing in Sri Lanka

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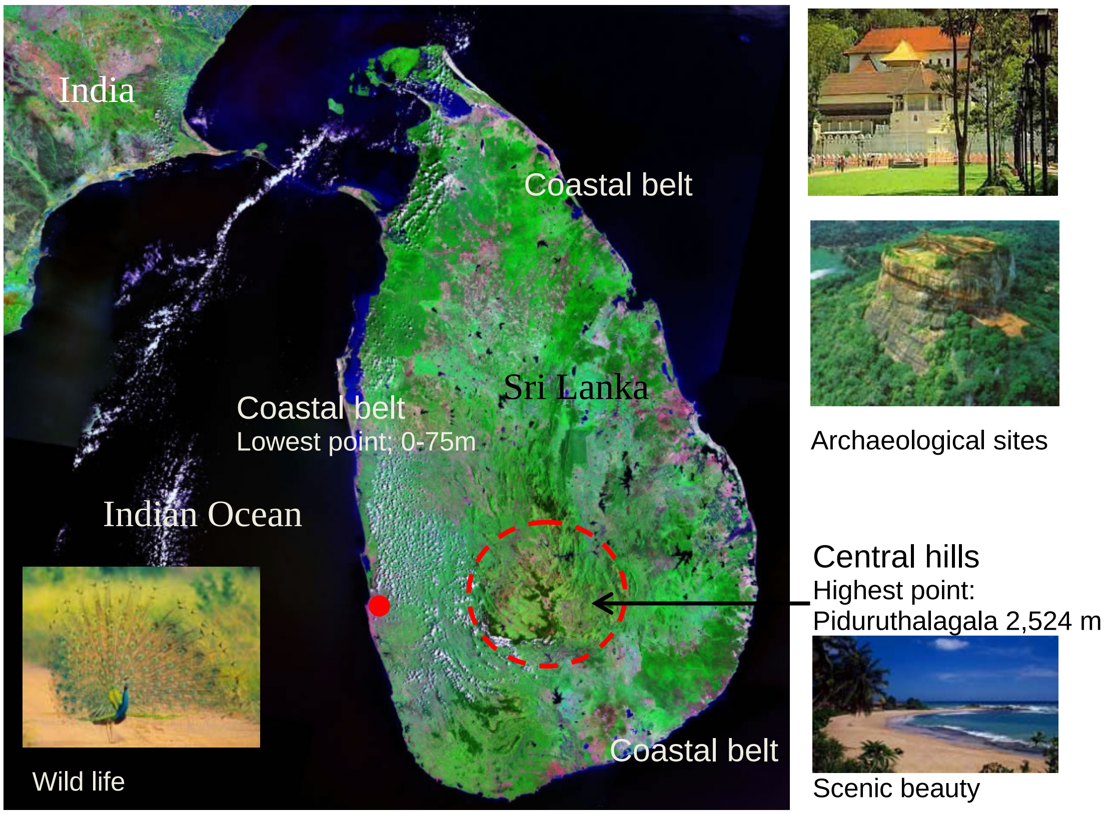
Rapid urbanization in the tropics has brought into many changes not only to humans and animals but also to the physical environment. However, the climatic effect of urbanization has not given priority in the past and now there is a world wide need for energy conscious design. Buildings are the major consumers of energy in the constrution, operation and maintenance. About 50% of global energy used is estimated to be due to buildings. Energy requirements in the buildings will be further increased in developing countries with rising economy.

The focus of this paper is to develop design guidelines combining economic, environmental and social considerations to create buildings that will conserve energy, conducive to human productivity and cost effective in order to mitigate the negative impacts of the above. These guidelines will not only be useful when designing new housing and city plans for low income families but also for slum upgrading in hot and humid countries like Sri Lanka.

1 Shelter Situation Analysis

1.1 Basic General Data

Geography



Geographical coordinates of Sri Lanka are 7 00 N, 81 00 E and is located in the Indian ocean. Length and width of the county is 432 km and 224 km respectively. The total area is 65,610 sq.km. from which 64,740 sq. km. comprises of land and rest by water. Being an island Sri Lanka inherits a 1,340 km long coastal line with many tourist attractive beaches. The terrain is mostly low, flat to rolling plain with mountains in south-central interior. Limestone, graphite, mineral sand, gems, phosphate, clay and hydropower are among the natural resources of the island.

Sri Lanka is considered to be one of the biodiversity hotspots in the world. At present, 13% of land is under biodiversity protection, compared to 8% in the 1950s.

Administration

A strong influence on Sri Lanka's history for at least 2000 years as a safe and important haven is the position in the Indian Ocean; as a small island midway between east and west. The low rain fall of the dry, sparsely forested area between the hill country and the sea, on the north and east sides facilitated irrigation based settlements. This was the cradle of the ancient Sinhalese people which dates back to the 3rd C.B.C.

Throughout the long period of history, invasions from north and also possible droughts and diseases, caused fragmentation of the first Sinhalese kingdom of Anuradhapura and creation of another capital further east in Polonnaruwa. Then from 1225 AD onwards Sinhalese capitals shifted steadily southwards to Kurunegala, Yapahuwa, Dambadeniya, Gampola and finally to Kotte. So the focus to dry zone was gradually bent towards the wet zone.

After the conquest of the coastal plains by the Portuguese in the early 16th century, Colombo was made their capital. A century and a half later Sinhalese attempts to drive the Portuguese from Sri Lanka resulted in invitations to the Dutch to intervene. At the end of the 18th century the British used the excuse of the Dutch siding with the French Revolution in Europe to occupy the coastal districts of Ceylon. Soon afterwards they took the important step of conquering the Kandyan kingdom. Thus the last independent Sinhalese state came to an end.

British ruled Sri Lanka for over hundred years until on Feb. 4, 1948 Sri Lanka became a self governing dominion.

Demography and Health

Population	-	20.328 million (2008)		
Population growth rate	-	0.904% (2009 EST.)		

The civil war on the northern part of Sri Lanka during almost last 30 years which caused many deaths had affected population growth rate in a considerable way.

Urban Population	-	Urban	-	17% (2008)
		Annual growth rate	-	0.8% (2008)
		Projected (2025)	-	22% (2008)
Sex- age structure	-	0-14 years: 23.9% (male 2,594,815/ Female 2,493,002) 15-64 years: 68% (male 7,089,307/		

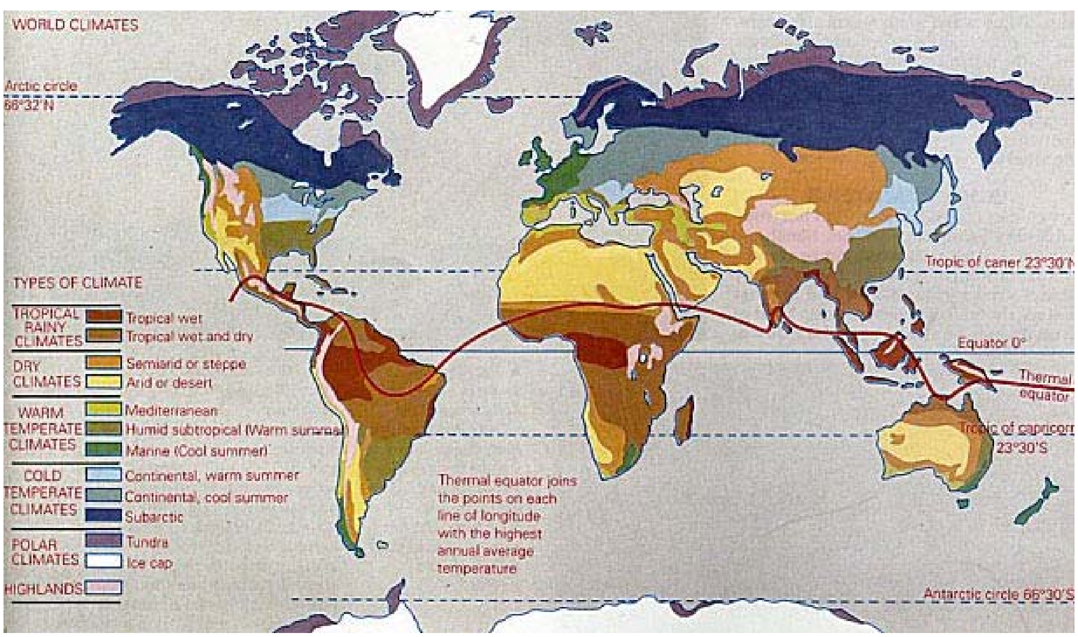
		female 7,418,123) 65 years and over: 8.1% (male 803,172/ female 926,372) (2009 est.)
Life expectancy at birth	-	Total population: 75.14 years
	-	Male: 69 years
	-	Female: 76 years (2009 est.)

Due to the free health facilities given by the government and the educational background on the preventive measures from the diseases, in Sri Lanka life expectancy rate is higher than most of the developing countries.

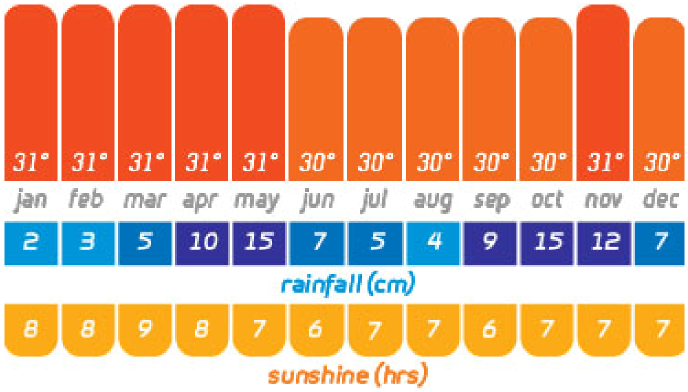
Total Fertility rate	-	1.99 children born/woman (2009 est.)
Net migration rate	-	1.47 migrant(s)/1000 population (2000 est.)

Climatic data

Being located to the north of the equator Sri Lanka experiences a Hot Humid climate with few rainy seasons. The common characteristics of Hot and Humid climate is the average maximum temperature of about 30 degrees Celsius but on clear days solar intensity can be much higher and temperature may reach about 38 degrees Celsius, coupled with very high humidity. However, most of the time the sky may be partially cloudy and diffused radiation from the sky comprises a significant component of the total solar heat gain.



Temperature and Rain fall



Area	Jan - April		May - Aug		Sept - Dec	
	Max	Min	Max	Min	Max	Min
Colombo	30 C	22C	30C	24C	29C	22C
Kandy	31 C	17C	29C	21C	28C	18C
Nuwara Eliya	21 C	14C	18C	16C	18C	15C
Trincomalee	32 C	24C	33C	25C	33C	23C

Sri Lanka is roughly the same size as Ireland yet contains a much wider range of climate types owing mainly to monsoonal influences and great differences in elevation between the coastal plains and the high interior, especially in the southern half of the island.

There are four main climatic zones:

- The western and southern coastal areas which are generally hot and humid.
- The mainly flat north and east, which is generally dry except during the north-east monsoon.
- The high hill country, where the weather tends to be much like an average northern European summer all year round – some warm sunny days, some rainy and misty ones.
- The mid-country which is warm and rarely either very hot or cold but which does tend to get more rain than the coast.

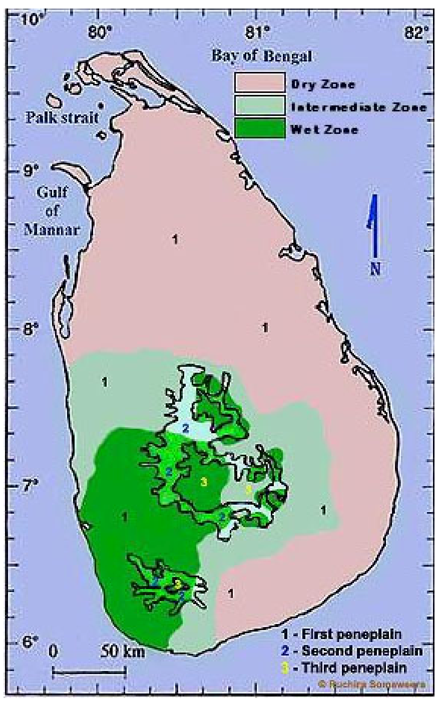
Sri Lanka gets two monsoons which used to be as regular as clockwork but, probably as a result of climate change, these days less predictable in timing, duration and intensity. The south west monsoon occurs at any time from May to

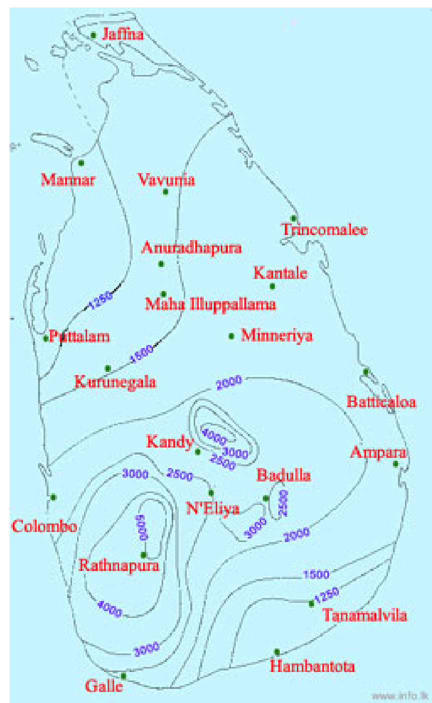
July and the north-east monsoon at any time from October to December. While monsoon rains are spectacular it rarely rains all day even at these times and half the day or more can be spent in warm sunshine. Some days are sunny from dawn to dusk.

The months of January, February and March are generally the sunniest. The climatic zones were determined basically by the two monsoons.

(Source: http://jungletide.com,06/05/2009)

Annual rain fall - 2540mm to over 5080mm in south west of the Island.
Less than 1250mm in the North West and south east of the inland.





Economy

In 1977, Colombo abandoned statistic economic policies and its import substitution trade policy for more market-oriented policies, export-oriented trade, and encouragement of foreign investment. Recent changes in government, however, have brought some policy reversals. Currently, the ruling Sri Lanka Freedom Party has a more statistic economic approach, which seeks to reduce poverty by steering investment to disadvantaged areas, developing small and medium enterprises, promoting agriculture, and expanding the already enormous civil service.

GDP (purchasing power parity)	-	$91.9 billion (2008 EST.) $86.7 billion (2007) $81.18 billion (2006)
GDP – per capita (PPP)	-	$4,300(2008 EST.)
Labour force	-	7.588 million
Household income or consumption by percentage share	-	lowest 10%: 1.1% highest 10%: 39.7%
Distribution of family income Gini index	-	49
National poverty rate	-	22%

1.2 Shelter Related Fact and Figures

Access to Shelter

Housing Stock

Among the population of Sri Lanka 22% are being the urban poor. According to the UN Habitat estimates 65000 slum dwellers are living in 1507 settlements in Colombo, the capital. Overcrowding is commonly seen in such areas and they have to satisfy with an average of less than 32 sq.m. of space. It is a well known fact that the slums occupy prime lots of commercial land in Colombo city.

(Source: http://sundaytimes.lk/090215/FinancialTimes/ft326.html,22/03/2009)

Colombo

National housing stock (permanent)	-	42%		
Temporary housing stock (slums /shanties)	-	51%		
Floor area per person				
Average no. of persons per room (1987)	-	Total	Urban	Rural
		2.2	2.3	2.1
Ownership (formal and informal)				
National ratio of home ownership	-	80%		
In urban areas	-	60%		

Access to tenure

Proportion of households with access to secure tenure	-	1994	2001
		93.8	95

Access to and cost of Basic Services/Infrastructure

Electricity

Production - 9.814 billion kWh (2007 est.)

Consumption - 8.276 billion kWh (2007 est.)

Electricity is generated mainly by the hydropower and coal power. During the dry seasons the hydro electricity production decreases and cause power cuts through out the country.

Access to water and sanitation

Indicator	1994	2001	2015 (targeted)
Proportion of population with sustainable access to an important water source, urban and rural	72	82	86
Proportion of urban and rural population with access to improved sanitation	73	80	93

1.3 Housing Policy

Successive governments of Sri Lanka had various approaches in order to increase the availability of housing for the urban poor but have not come up with a long lasting solution. However, there are certain partially succeeded programmes conducted by Sri Lankan government. For example, in 1999 “Sustainable Township Programme” was founded by Ministry of Housing and Plantation Infrastructure, with an innovative strategy “Homes for people and Land for Development”. Main aim of this programme was to provide the urban poor with a housing unit including free hold of the property and the liberalized land occupied by them to be used for economic development. The cost of construction of the dwelling to be rewarded by that land.

Through these types of programmes by giving proper legal ownership to their dwelling units it was aimed to make slum dwellers to feel more socially accepted citizens.

First ministry of Housing (1952)

National Housing Department established (1952)

Ceiling on Housing Property law (1973)

National Housing Development Department (1977)

Urban Development Authority (1977)

Hundred Thousand Houses Programme (self-help and direct construction of houses throughout the country (1972-1982)

> Due to following facts this programme was considered as unsuccessful. The poor sites and services had escaped the scope of the programme; the improvement of the slums had not received the attention it deserved; the falling price of direct construction costs was neglected; there was little dialogue with the people concerned with housing.

Million Houses Programme (Devolved ‘enabling’ strategy for housing and infrastructure (1984-1989)

> This was the result of a critical consideration of the earlier programmes, in particular the Hundred Thousand Houses Programme. The State proposed to assist families in the building of their new houses instead of direct building. It developed links with the local government who should intervene directly and actively in the formulation and application of programmes.

1.5 million Houses Programme (withdrawal of subsidised credit for housing (1990)

> This programme aimed at reaching of families of all income groups in the country that aspire to secure basic shelter for themselves. Further it led to an increase in brick-built houses with permanent roofs. In terms of strategy, practically all the strategies used in the Million Houses Programme were being reinforced.

From these facts it is understood that developing a proper programme for Sri Lanka is not simply copy and adopt programmes coming from abroad. It should allow for the links between housing and cultural standards.

1.4 Actors in Shelter Delivery and their Roles

Actor	Role
State Engineering Corporation of Sri Lanka Central Engineering Consultancy Bureau	Community based housing Resettlement Sites and services Core housing Medium rise housing
National Housing Development Authority	Community based housing Resettlement Core housing Medium rise housing
Buildings Department	Community based housing
NGOs	Community based housing Core housing
Private Developers	Medium rise housing
Housing Development and Financing Corporation, State Mortgage bank	Housing financing

1.5 Shelter Design

Physical Planning

Land Use

Arable land	-	13.96%
Permanent crops	-	15.24%
Other	-	70.8% (2005)
Irrigated land	-	7,430 sq km (2003)

Population Density

For the 18 districts	-	319 persons/sq km

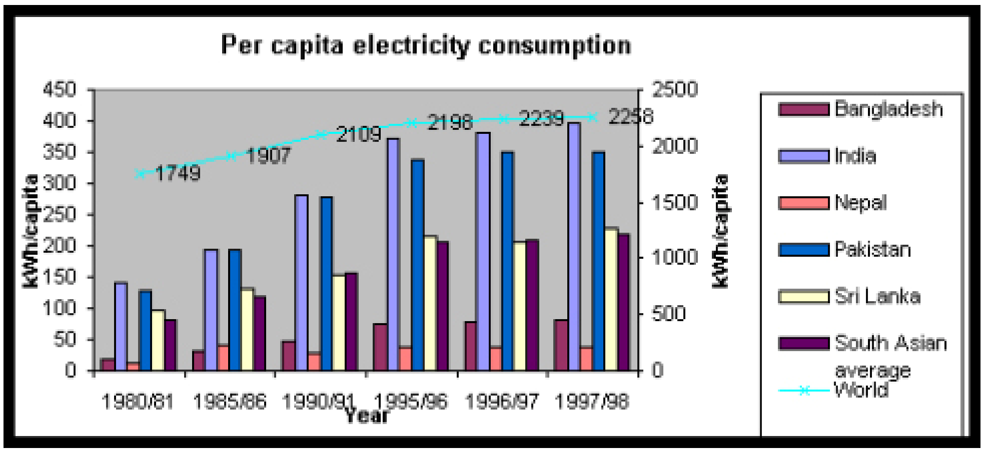
Number and Percentage of Occupied Housing Units

District	Total Occupied Housing Units	Type of Housing Unit					
		Permanent		Semi permanent		Improvised	
		No.	%	No.	%	No.	%
Total (18 districts)	3,969,027	2,771,860	69.8	1,123,003	28.3	33,799	0.9

Number of Slums and Shanties by District

District	Total occupied housing units	Sector		
		Urban	Rural	Estate
Total (18 districts)	3,969,027	488,365	3,262,505	218,157

(Source: 2001 C*olombo Metropoliton Structure Plan*)



2 Organisation

State Engineering Corporation (SEC) of Sri Lanka established in 1962 is the oldest contracting and consulting organization in Sri Lanka. The strength of SEC lies in the fact that it has a wealth of accumulated experience and a large number of qualified and experienced Engineers, Architects, Quantity Surveyors and Technical staff. This comprehensive service is provided for building projects in vast areas such as Commercial, Residential, Educational, Medical, Recreational, Community and Industrial.

2.1 Organization Structure

Divisions in SEC

Consultancy | Construction | Construction components (pre cast) | Mechanical & Electrical

Consultancy: Architectural | Structural | Quantity Surveying

2.2 Projects related to shelter

SEC has proudly taken part in the designing of shelter for all income groups in the society. Following are some examples from the recent past.

- Apartment complex at Gaswatte, Colombo (upper income)

(49 apartments. 120 sq.m floor area per unit.)

- Apartment complex at Guwanpura, Colombo (upper income)
- Housing project for public servants at Homagama (middle income)

(504 number of units of different sizes 65sq.m., 85sq.m. and 120sq.m.)

- Housing project at Mayura place, Colombo (middle and lower income)
- Housing project at Ipalogama, Anuradhapura (low income)


3 Shelter Problem

3.1 Introduction

Reflecting its location and status as an entrepot of Indian ocean, trade from time immemorial the island of Sri Lanka has always open to the movements and patterns of world culture. Indigenous architectural and cultural traditions, colonial intrusions as the vagaries of living in a tropical environment have combined to produce a distinctive Sri Lankan architectural style: thick lime washed walls, tall windows and doors, terracotta or granite tile floors, open pavilions and verandhas and courtyard gardens. During the twentieth century more and more outside influences flooded in and the Sri Lankan style continued to absorb and evolve.

The overall emphasis of the state policy is to be on the social justice and equity, economic well-being and individual rights. But the policy of the state, with regards to Housing and Infrastructure, was not remained consistent and stable, with the changes of government and political structures. Furthermore, the economic policy of the government was increasingly oriented towards free market mechanisms which came with the rapid urbanization. Due to this, urban migration to the capital city was inevitable for seeking job opportunities and better infrastructure. As a result, unauthorised and unplanned settlements were increased during past years. On the other hand, implementation of the law has been slow and inadequate to tackle the problem.

3.2 Analysis of the Shelter Problem

In hot and humid climates, the adaptation of architectural solutions which are suitable for totally different climatic conditions has caused an important thermal discomfort inside the buildings and a strong increase in cooling energy consumption. A building design practice based exclusively in economic and aesthetic considerations, without an environmental analysis, leads almost always to a prejudice for the final user, resulting in buildings strange to the environment and with comfort parameters far above the tolerable limits. Furthermore, with the urbanization, buildings have grown in number and scale all over the country causing serious energy crisis, thus making energy a precious and more to the point, expensive commodity. It has been recognized that energy used in the making of buildings is as important as that expanded in use. Thus, method of construction and the design of component eco-sensitively need to be tailored towards most energy efficient and environmentally acceptable methods.

In 2000 the proportion of the world's population in the tropical climate zone was estimated at about 40%. Most tropical countries are developing countries and most are experiencing rapid urbanization. Urban areas act as climate modifiers. (E. Johansson 1980:352) Energy directly deals with the physical comfort of the human being. Physical comfort affects the efficiency, productivity and health condition of the people.

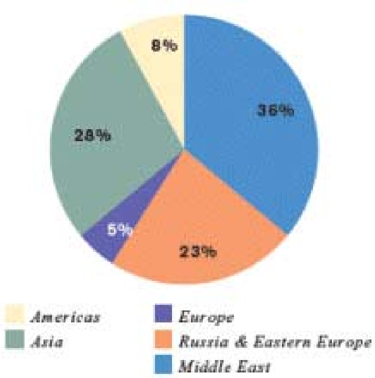
3.2.1 Human response to the thermal environment

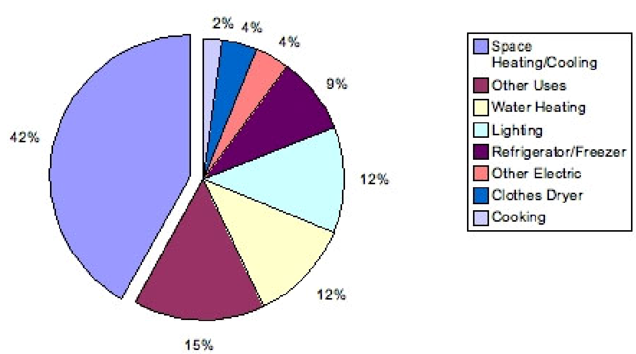
The body produces heat by food metabolism and this heat is transferred to the environment by convection and radiation. When the surrounding temperature is higher than the skin, heat exchange becomes positive. If the rate of heat loss is not enough to balance the metabolic rate, further cooling is provided by evaporation of sweat.

The ambient temperature and the air speed control the convection exchange whereas the radiant exchange in the indoor environment depends on the average temperature of surrounding surfaces. The humidity does not play a considerable role in the heat loss but higher humidity level controls sweat evaporation. Thus, thermal comfort can be defined operationally as the range of climate considerations considered comfortable and acceptable in designing of buildings.

Urban design has an influence on energy needs for building envelope. Energy consumption in the developing world has grown tremendously over the past two decades. As per the World Bank reports developing world used 20% of the energy consumption in year 1970, has increased to 33% in 1988. Although many facts are cited as causes for the increase in consumption, it is generally agreed that urbanization in the region is the prime cause.

3.2.2 Energy consumption in Asia





Source :(msnmoney.brand.edgar-online.com)

Above data shows that energy consumption in Asia is comparatively high and the main cause for that may be the location close to the equator. These pie-charts also describe the usage of energy in different activities and it is clear that most of the energy is using to keep indoor spaces in comfortable condition.

Patterns of Commercial Energy consumption

Activity Energy Consumption (% of total country needs)

	US	UK	Sri Lanka
Industries	41.2	32.0	9.9
Transportation	21.0	18.0	16.4
Building energy needs	28.0	48.0	67.0
Agriculture/others	7.7	2.0	6.7

Source (2005, Emmanuel, An urban approach to climate sensitive design, Taylor & Francis)

3.3.3 Climatic challenges in building design

The main force on the indoor climate which increases cooling costs and affects comfortable environment is the intense solar radiation. So methods to be taken to minimise the impact of it on buildings. Moisture in the form of high humidity and high rainfall is another significant problem. Most of the hot and humid climate zone receives more than 40 inches of annual precipitation. Some areas get more than 60 inches of annual precipitation.

For office buildings, social housing, private homes as well as apartment buildings climatic design principles can be accommodated. Especially in the delivery of low cost housing, energy efficient design principles would have numerous benefits to the poor families living in these houses as it will greatly affect to the running cost of houses.

Natural ventilation systems rely on pressure differences to move fresh air through buildings. Pressure differences can be caused by wind or differences in humidity. In either case, the amount of ventilation will depend critically on the size and placement of openings in the building. It is useful to think of a natural ventilation system as a circuit, with equal consideration given to supply and exhaust. Openings between rooms such as transom windows, louvers, grills, or open plans are techniques to complete the airflow circuit through a building. For example, historic buildings used the stairway as the exhaust stack.

Natural ventilation, unlike fan-forced ventilation, uses the natural forces of wind to deliver fresh air into buildings. Fresh air is required in buildings to alleviate odours, to provide oxygen for respiration, and to increase thermal comfort. At interior air velocities of 160 feet per minute (fpm), the perceived interior temperature can be reduced by as much as 5°F. However, unlike true air-conditioning, natural ventilation is ineffective at reducing the humidity of incoming air. This places a limit on the application of natural ventilation in humid climates.

Being a hot humid tropical country Sri Lanka immensely experiences natural light and natural ventilation. But because of the unplanned shelter situation these free blessings have being converted to monitory value.

4 Proposal for Change and Improvement

4.1 Introduction

More than one-third of energy is consumed in buildings worldwide, accounting for about 15 percent of global greenhouse gas emissions. In cities, buildings can account for up to 80 percent of CO_2 emissions. The built environment is therefore a critical part of the climate change problem – and solution. Most existing buildings were not designed for energy efficiency, but by retrofitting with up-to-date products, technologies and systems, a typical building can realize significant energy savings. Improving the energy efficiency of buildings is a priority for reducing both greenhouse gas emissions and energy costs.

(Source: http://www.clintonfoundation.org/14/09/2009)

4.2 Basic considerations in energy conscious designs in hot and humid climate

The main aim of a house is to act as an envelope which shelters the indoor space from the whether outside, making comfortable indoor environment. There are two ways to achieve this comfortable indoor environment. One is to have mechanically controlled systems such as fans, air conditioners etc. But the most economical and acceptable method is the second option in which the benefits of the nature are taken into the consideration from the design stage so that the need to active space cooling is minimised or totally eliminated.

The principles applied in climate-sensitive design are based on the idea of using natural conditions to the best advantage. Orientation, detailing, colours, sometimes combined with building materials can be considered as principles of climate sensitive design. In other words this energy conscious design can be defined as principles encompasses all the available techniques of creating a 'healthy' interaction between indoor and outdoor climate conditions in buildings.

As stated above, positioning of the spaces to be done in such a way enhancing the cross ventilation thus reducing temperature inside. Such use of natural lighting and ventilation will minimize the utilization of energy resources. The exploitation of the relationship between inside and outside, the consideration on the shifting patterns of sun and shadow should be included in all good designs in the tropics which will inevitably be a cost effective way to create a comfortable, healthy and energy efficient indoor environment.

1. Solar effect

Solar gain to a building is identified in 3 main ways.

1. Direct gain
2. Indirect gain
3. Isolated gain

Indoor heating/ cooling, lighting and ventilation to be considered when handling this solar gain in effective way. The main aim of managing of solar energy is to gain natural lighting and natural ventilation into a building according to our needs. But in a tropical country like Sri Lanka, it is the diffused and reflected radiation which should be considered in designing than the direct radiation.

2. Wind effect

Wind can blow air through openings in the wall on the windward side of the building, and suck air out of openings on the leeward side and the roof. In other words wind causes a positive pressure on the windward side and a negative pressure on the leeward side of buildings. To equalize pressure, fresh air will enter any windward opening and be exhausted from any leeward opening. Temperature differences between warm air inside and cool air outside can cause the air in the room to rise and exit at the ceiling or ridge, and enter via lower openings in the wall.

In the context of a hot humid climate, energy efficient urban layout needs to address the following issues.

1. Site and building orientation for avoidance of sun.
2. Site and building orientation encouraging air movement.
3. Shading device requirement for open spaces.
4. Landscaping requirement for heat gain reduction.

4.3 Architect’s role in House design process

It is a well known fact that climate considerations of indoor climates are different from the surrounding outdoor climate. On the other hand the building itself and especially groups of buildings modifies the climate conditions surrounding it. The fact that most of the countries in the hot-humid areas are developing countries has direct impact on the practicality of some ‘modern’ concepts of urban and building design from climatic viewpoint. The vast majority of people cannot afford air conditioning. Therefore, thermal stress and its impacts on health and productivity should be minimized primarily by appropriate urban and building design details which do not involve high cost.

Being an Architect in a leading state organization in Sri Lanka, which acts as shelter provider for the nation, there’s a huge responsibility to the society in providing energy conscious designs. It is clear that there should be a guideline to follow to fulfil that target in an effective way. Hence, the aim of this paper is to prepare a “Design Guidelines” in order to achieve energy conscious design in terms of using natural lighting and natural ventilation. This is intending to be done for both city and individual house plan levels.

These guidelines could be adopted by the architects, engineers, planners and politicians as well to tailor towards the energy conscious design.

4.4 Design guidelines for effective use of natural lighting and ventilation in City plan level – Proposal for change

There are number of design details influence on the climatic considerations affecting pedestrians walking outdoors with regard to protection from rain, sun and glare in the streets. Among them following are the major facts to be focused when designing.

1. Orientation

Orientation of buildings to be done with the glass façades to the north south direction with 30 degrees angle to the south.

2. Wind Shelter

Excessive amount of wind in buildings causes unwanted cooling within the building. It reduces the inside temperature as well.

Apart from these there are other measures to be concerned when sitting of buildings.

3. Building density

25 to 35 number of housing units to be placed in one hectare to facilitate gaining of daylight.

4. Spacing

When spacing between buildings reduces it causes shadow and dark places within the buildings. In a new subdivisions, the spacing of buildings should be carefully considered to avoid obstruction of the wind.

5. Access and layout

Road network to be designed to east west direction to facilitate buildings to face their front to north south orientation.

6. Use of vegetation

Shade producing trees filter the sunlight, reduce air temperature and reduce glare from bright overcast skies.

7. Use of shading devices

In city planning, care to be taken to protect pedestrian walkways from sun and rain to create more pleasant climatic condition for the urban pedestrian. The easiest way is to provide buildings with overhanging roofs, or colonnades in which the ground floor is set back from the edge of the road, with the upper stories jutting out supported by pillars. Such details inevitably important to reduce the thermal load on pedestrians.

8. Use of colour

Exterior light colours especially white, cool indoor atmosphere by reflecting the solar radiation. Thus, from the indoor climate aspect in hot climates white buildings are preferable but it also increase the glare in the streets. This shows a conflict between the energy conscious requirements for the indoor and outdoor.

However, careful detailing, for example use of external overhangs could be used to appropriate design details can resolve the conflict between these demands.

4.5 Design guidelines for effective use of natural light and ventilation in House plan level

1. Orientation

- Orientation of spaces considering sun path and wind direction.

Orienting the long axis of the house to east-west but considering the wind direction. The north south walls open to sun can be shaded by eaves.

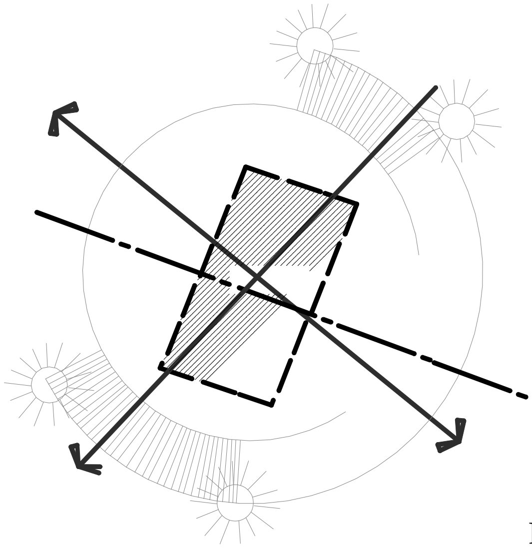


Fig 1. House orientation and placing of windows to catch wind

2. Plan/ 3D form

- Non deep plans to be designed to gain equal lighting and ventilation to every part of the house

It is difficult to distribute fresh air to all portions of a very wide building using natural ventilation. The maximum width that one could expect to ventilate naturally is estimated as 33 ft. Consequently, buildings that rely on natural ventilation often have an articulated floor plan.

- Open-plan designs with minimum walls and high ceilings, to maximise air movement and encourage heat evacuation.
- Placing of Spaces towards to the periphery of the house for easy gain of natural lighting.
- Bed rooms of long, narrow plans maximise ventilation through the spaces.
- By placing windows opposite each other cross-ventilation could be facilitated.

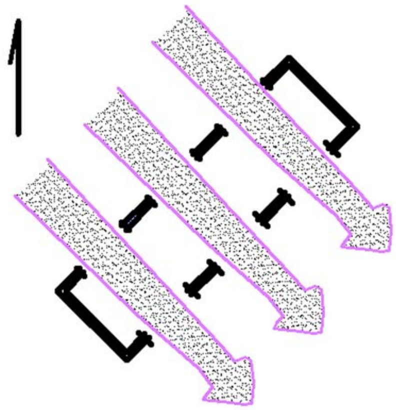


Fig. 2 House orientation and placing of windows to catch wind

- Each room should have two separate supply and exhaust openings. Locate exhaust high above inlet to maximize stack effect. Orient windows across the room and offset from each other to maximize mixing within the room while minimizing the obstructions to airflow within the room.

- Keeping windows on east and west walls to a minimum.
- Provide ridge vents.
- High roof angle with double height spaces will facilitate evacuation of hot air inside

A ridge vent is an opening at the highest point in the roof that offers a good outlet for hot air and wind-induced ventilation. The ridge opening should be free of obstructions to allow air to freely flow out of the building

- Ventilation of the roof space, to reduce heat build-up there.
- Use of vernacular courtyard concept to gain natural lighting and ventilation inside. The use of overhangs like verandhas, canopies and eaves will shade the walls and windows

2. Detailing

- Use of low Partition wall heights.
- Use of shading devices, monitor roofs wherever necessary.
- Properly designed openings to effective gain of sunlight and ventilation inside. This will reduce glare, while improving lighting and ventilation.
- Use of appropriate window types to facilitate airflow, for example louver panels offer maximum ventilation. Casement windows can be used to

catch breeze blowing parallel to the window while double sash offer a choice between high and low level ventilation.

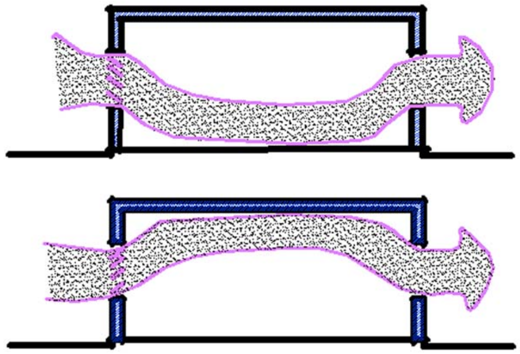


Fig. 3 Louvers can direct wind upwards or downwards

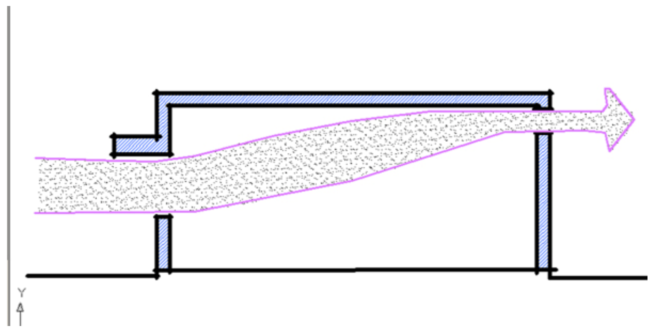


Fig. 4 A canopy over the window tends to direct wind upwards

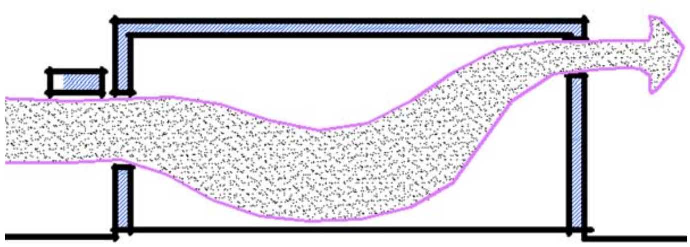


Fig. 5 A gap between canopy and wall ensures a downward pressure

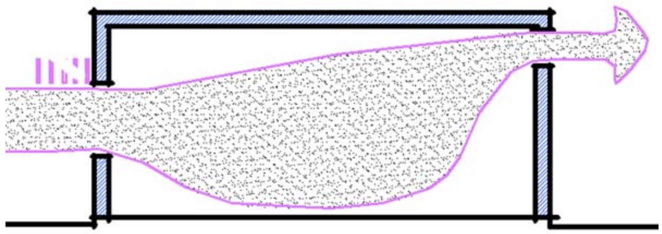


Fig. 6 Downward wind is improved further by a louvered sunshade

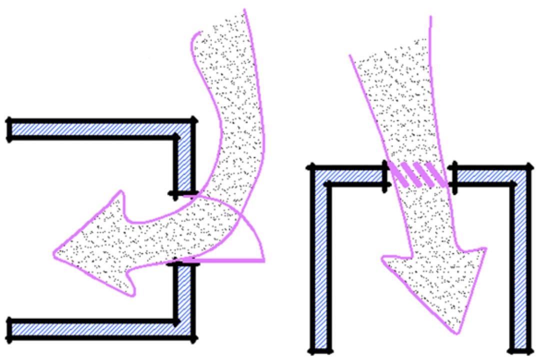


Fig. 7 Use of casement window and louvered window to divert wind direction

- The use of chain link fence instead of boundary wall is preferable for airflow within premises.
- Allow for adequate internal airflow.

In addition to the primary consideration of airflow in and out of the building, airflow between the rooms of the building is important. When possible, interior doors should be designed to be open to encourage whole-building ventilation. If privacy is required, ventilation can be provided through high louvers or transoms.

3. Use of lighter internal colours to reflect sunlight wherever necessary.

In case of gloomy or dark interiors where natural lighting is limited use of pale colours for walls and roof, will reflect the sunlight making it pleasant.

Conclusion

At a more general level, the energy conscious perspective identifies the predominant constituents of building construction, since sedentary settlements were founded around 7000 years ago. An energy conscious approach could also be illustrated how the layout, construction and use of building materials of individual units and settlements were related to the local climatic conditions conserving the social organization of the household and the community.
With the advent, growth, colonialism and industrialization, consequently, vast needs and new technology have gradually supplanted the basic constituents of traditional building construction. Because of this reason, the effective use of natural climatic solutions was started to lessen gradually, at the end resulting an energy crisis in the world.

With this framework, the study aimed at examining the methods of using natural lighting and natural ventilation effectively for designing of ciy plans and housing schemes of hot and humid climates like in Sri Lanka, from the view point of the energy conscious architecture. These findings will indeed act as guidelines not only to the home organization but also to the parallel organizations, in altering their practices, in an cost effective way.

Some of these methods are low to no cost (house orientation, positioning and size of windows, use of plants and colour); some are medium cost (roof overhang, shading devices) and some are high cost (roof and ceiling insulation; additional glazing). Because of that, appropriate selection of methods to be done considering the income groups for which the housing is designed for.

It is up to us, to ensure that, architecture which combines climatic responsiveness with the pleasing indoor environment, to become widely accepted. The process of awakening the clients and decision makers is yet to be improved. This has to be improved by the state patronage, in discovering environmental friendly policies, to make it an acceptable thing to follow.

But as a whole, it is an effort of all the people living in the world, to understand the role that they should play, on behalf of protecting the environment and it is a job of an architect, to convince the client on the value of building eco-sensitively.

We still need conscious effort and in the future we might even need more architecture as it did in the past, in exploring man and his relationship with nature, while providing a sense of protection for all, man and the environment.

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