Buildings in the Context of Global Warming

Designer's involvement

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1 ENERGY USE AND GLOBAL WARMING

As we enter a new age of heightened environmental consciousness, the terms "Energy" and "Resources" are subjects generating considerable interest. Energy use by human activities contributes to the increase in energy demand and energy production. This may not be a problem when energy comes from renewable energy resources such as hydro and wind but an environmental problem when energy comes from burning non-renewable resource such as gas, coal and other petroleum products. This process leads to the increase of carbon dioxide emission thus contributing to the increase of carbon particles and greenhouse gas effect in the upper atmosphere. This phenomenon ultimately contributes to global warming which is one of the main reasons for climate change. Therefore, our activities have an important role to play in both reducing and adapting to climate change, and built environment is such an area where our contribution come into play in reducing negative and unfavorable effects on natural environment.

Global warming is potentially the most important environmental problem today. The most recent Working Group Report of Intergovernmental Panel on Climate Change (IPCC) shows built environments as a major contributor to global warming. Research carried out in the global context shows that buildings offer the largest potential for energy saving and conservation. Some Sri Lankan building professionals argue that this is not a problem for us because we have a living and building traditions which respond to the natural environment and therefore, our building related activities do not pose any threat to the sustainability of the environment. This is totally a misconception in the context of present day building tradition in which most of the current buildings and other construction activities are moving without any respect to the environment.

2 LOW ENERGY BUILDINGS

Built environments are responsible for over a one third of all greenhouse gas emissions in the world and the buildings are responsible for nearly thirty to forty percent of the energy demand in the form of electricity. This is a common scenario for most of the developed countries in the world and a developing and tropical country like Sri Lanka is no exception in the context of present day building practice.

Low Energy Building concept seeks to find out built environment solutions with "minimum negative environmental impacts" from "construction" and "operation" whilst providing indoor thermal and visual comfort through passive or/and inclusive of efficient active means. Passive means employ low-energy technologies at "master planning" and "building design" level improving "demand side efficiency" of buildings for optimum energy use. In the perspective of promoting low energy building concept, the implementation of facilitating strategies into town planning and urban design should also be considered.

3 ENERGY DIMENSION OF BUILDINGS

Buildings use energy during two different stages i.e. "construction" and "operation" Energy use in "construction" involves manufacturing and transportation of building materials, ground preparation and structural system of the buildings etc. Energy use during "operation" involves with maintaining thermal and visual comfort inside buildings and running equipment. The need to minimize embodied energy in building materials and construction is of significant importance. The need to minimize operational energy of buildings and in the running of active systems/maintaining indoor comfort has focused attention on two sets of factors as follows.

- The demand side efficiency
- The supply side efficiency

Demand side efficiency comes from the elements/components of the building that drive the

need for power in the building whilst the supply side efficiency is related to elements that produce power. The first important way to save energy is to use less of it, so the first goal is to cut the demand, and second goal is to supply power in a manner that is benign, using renewable energy sources (solar power, hydro power, wind power and etc). In addition, the selection of plant and equipment can deliver needs for energy more efficiently (Hyde, 2000:68).

On the other efficiency side, one can consider improving the energy efficiency through direct approaches in terms of local government codes, standards, legislations, incentives, or indirect approaches in terms of educational programs and increasing public awareness.

4 DESIGN STRATEGIES FOR DEMAND SIDE EFFICIENCY

The use of passive strategies for maintaining a set of indoor environmental conditions for thermal comfort involves DESIGN STRATEGIES or design variables. The inclusion of appropriate design strategies in the building for this purpose may involve at several levels, particularly for a building functions as a climate filter. The work of Hyde (2000:55) suggests a level of hierarchy in a set of climate responsive design variables. Thus, it is argued that,

- There are a number of first- order decisions that have to be taken with regard to design strategies that are related to the modification of macroclimate environment to produce a favourable**microclimate** environment for the building,
- Then second order decisions concerning the manipulation of **building form (plan form and sectional form)** in modifying the microclimate to a favourable indoor climate as well as supporting the first order decisions, and
- Finally the selection of different types materials in the building envelope in promoting a favourable indoor environment

5 BUILDING MICROCLIMATE

Environmental condition of the building microclimate is one of the principal factors that affects the temperature and intensity of airflow. The effects of microclimatic conditions on the effects of airflow at microclimatic level can be summarized as follows;

Table 01Effects of microclimatic conditions on the airflow

Microclimatic condition	**Effects on the airflow**
IN SUMMER	
• Higher wind permeability	• Removes heat built up in the area
• Shading and thermal mass	• Reduces solar incidence
IN WINTER	
• Smaller density of built forms and vegetation	• Passive solar
• Less wind permeability to winter breeze	• Prevents airflow

6 SHADING AND AIRFLOW EFFECT

The experimental studies of Givoni (1998) indicate the effectiveness of shading in minimizing solar gain. It shows a significant reduction of the solar gain due to shading and thus the indoor air temperature in ventilated buildings in warm climates. Further, research has shown that while making due allowances for natural light, the shading on the windward openings can achieve significant control of solar heat gain and thus energy reductions in building operation. Optimum shading of building microclimate for the modification of climate to microclimate involves a number of design variables. Apart from landscaping, the building form and orientation of the building determine the solar exposure of the building, which should be minimized in warm climates.

7 NON-UNIFORMITY OF AIR TEMPERATURE AROUND A SINGLE BUILDING

This is another important concept to be understood in the design of buildings for climate response.

Experimental work has indicated that different microclimatic effects with regard to the air temperature involved in heat gain for the fabric can occur all around a single building. This non-uniformity is considered to take place through the control potential of the fabric and orientation. An extension of this phenomenon is that there is a non-uniformity of shading and ventilation potential in different microclimates around the building through the manipulation of building form with orientation.

Consequently, the coincidence of optimum shading with ventilation can be promoted on the microclimate of the windward sides thus enabling the indoor airflow to generate from shaded microclimates. The positioning of openings and windows in the fabric would need to be addressed to the orientation with regard to microclimates, where optimum shading is found.

Shading can reduce heat and radiant temperature of incoming air. Studies illustrate that radiant temperature of air can be lowered by even 2-5 degrees C below the level of the outdoor air with proper shading and the effect of thermal mass.

8 THERMAL MASS EFFECT

Combining the use of thermal mass and shading can modify the air temperature in a building microclimate. Permanent shading on the building microclimate can promote the minimization of incident solar radiation. When the incident solar radiation (whether direct, diffused or reflected) is limited the surface absorption is low and the surface temperatures of the ground tend to become lower. Such external building microclimates with high mass surfaces (at the external surfaces of building envelope or immediate earth around the buildings), when exposed to wind, exchange heat by convection with the ambient air. The consequence is that the air temperature in the microclimate tends to be lower than the corresponding ambient level. This outdoor environmental condition helps to prevent outdoor-indoor heat flow with ventilation and thus avoids indoor overheating in naturally ventilated buildings in warm climates.

9 BUILDING FORM AND BUILDING ENVELOPE

Building form can be considered in respect to the following:

- Plan form of the building
- Sectional form of the building

Building envelope is the material content used in the external and internal fabric of the building design. Building form (the plan form and sectional form) can regulate different types of radiation coming in the building and thus heat transfer between building and external microclimate. The types of radiation are direct, reflected and diffused. Wind forced ventilation can create heat gain in buildings in warm climates. Therefore, a reduction of the radiant heat in the incoming airflow is of great importance in warming climates. Reducing radiant heat at the microclimatic level by good shading can reduce the radiant heat and temperature of incoming airflow. Under these conditions, ventilation can enhance comfort and space cooling. The plan form and sectional form of the building form can regulate wind forced pressure fields around a building and therefore indoor airflow behaviour. These variables can be used to create shading in windward microclimates as well as internal airflow patterns.

Options regarding the shading characteristics on the building form and fabric involve the climate type. For warm humid climates, shading is required not only against the direct and reflected solar radiation but also against the high intensities of diffused radiation from the sky. This requires the optimization of broader coverage of shading on the openings of the form and fabric. The characteristics of important design variables and their architectural response to meet climate modification are summarized and presented in the followingTable.

Table 02A summary of passive strategies and design variables for indoor thermal comfort in a non-domestic building in the tropics

.1.1 Passive strategies and design variables for cooling in tropics	.1.2 Purpose/Climate odification
.1.3 Airflow effect ● Manipulation of plan form and sectional form of the building to optimize shading on the windward building microclimates	**M**inimizes the elevation of indoor air temperature due to solar gain with ventilation
● Openings in the plan form and sectional form of the building facing shaded microclimates on the windward directions	Minimizes solar gain with ventilation and increases internal heat loss
● Manipulation of section and geometry to enhance stack effect	**E**nhance ventilation while increasing heat loss **B**etter cross ventilation
● Minimising plan depth with proper shading around the building	
9.1.2 Thermal mass effect ● Higher heat capacity of thermal mass and cavity walls to westerly walls	Reduces conductive heat gain and peaks of indoor temperature swings
● High thermal mass for the internal fabric and surfaces of easterly oriented, shaded windward microclimates to act as heat sinks	Thermal mass as heat sinks. Lowering of indoor air temperature below the ambient
● Location of openings to westerly orientation to optimise night ventilation but with appropriate shading to avoid daytime heat gain	Structural cooling and passive cooling. Lowering of indoor air temperature below the ambient
● Smooth surfaces and light colours to increase solar reflectance	Reduces conductive heat gain
● External/internal insulation to westerly oriented walls	Minimizes conductive heat gain

10 PASSIVE COOLING AND PREVENTION OF OVERHEATING

During summer or in warm climates, buildings are exposed to heat gains from "environmental loads" due to high intensities of solar radiation and high temperatures. This can result in indoor overheating conditions, which exceed the threshold of thermal comfort, increase the demand for energy use and thus contribute to emissions. To extend the comfort zone for higher humidity and higher temperatures ventilation is required. In addition, prevention of overheating and cooling of building interiors are of prime importance. This includes measures that provide,

- Prevention of heat gain through the building envelope
- Transferring of heat gain from the interior spaces to various natural heat sinks

The prevention of overheating through passive means is aimed at minimizing heat gain due to **direct, diffused or reflected solar radiation**from reaching the building interior and removing any heat generated within the building as well.This is a fundamental requirement for buildings in tropical and moderate climates with more warm periods where the potential for indoor overheating is stronger from higher levels of solar irradiance.

Passive cooling, on the other hand, aims at lowering the indoor air temperature below the ambient temperature through the design variables using passive strategies of heat transfer from the building interior to various heat sinks such as the upper atmosphere, the ambient air, the earth and water using heat flow paths (conduction, convection, radiation, evaporation) or enhanced mechanically with the use of fans. The prevention of overheating is a useful pre-condition for passive cooling of buildings.

11 NON-DOMESTIC BUILDINGS

Non-domestic buildings have higher heat gains from internal loads as compared to domestic buildings where primary heat gain is from environmental loads. Figure 01summarizes the potential heat gain sources for domestic and non-domestic buildings.Process loads, electrical appliances and higher occupancy rates in non-domestic buildings can contribute for higher levels of internal heat loads. Therefore, the challenge is to employ passive strategies to find additional cooling for these internal loads without the contribution of active systems.

12 ACTIVE SYSTEMS

Buildings consume electricity in the process of controlling climate in mediating between the external climate and the internal environment in order to provide indoor thermal comfort. This method of climate control is known as an active system and such buildings are called conditioned buildings which guarantee a level of thermal comfort through the use of mechanical plant and equipment. However, improvements to the efficiency of active systems such as HVAC, lighting and equipment can optimize the energy use.

13 CONCLUSION

Building design the context of global warming should essentially deal with strategies to minimize energy use in construction and operation. Research carried out in this area shows that buildings offer the largest potential for energy saving. An appropriately designed building consumes less energy up to 60 percent saving than a conventional building. Although this is a promising subject in the world, it is far from concrete realization unless we at least act now in Sri Lanka. Widespread integration of low energy strategies in town planning, urban design and architecture of everyday building practices needs to be among national priorities. Development of environmental conscience in designers of the built environment professions, general public and developers could contribute to expand built environment solutions towards the right direction for sustainable design futures. The objective of this article was to create a preliminary awareness among all stakeholders about possible interventions that can integrate in the design of buildings to optimize passive climate control with the aim of minimizing energy use for indoor climate control.

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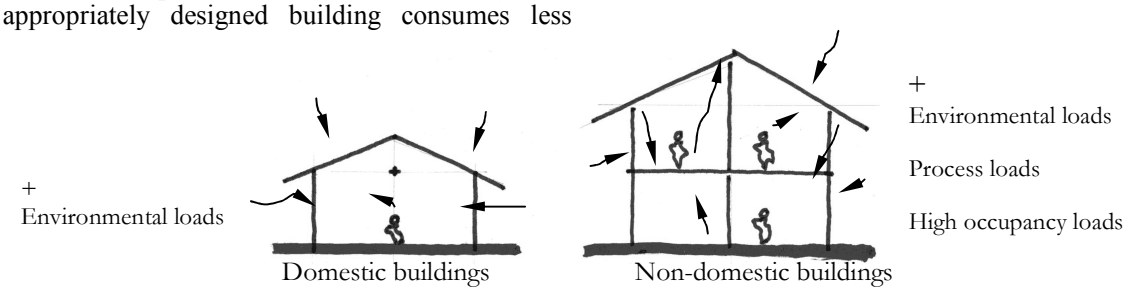

Fig 01Indoor heat gain in domestic and non-domestic buildings