**Title:** Undergraduate thesis: Green Building Awareness Centre.

**Anup Kumar Prasad**

*B. Arch. from Dept. of Architecture, Jadavpur University*  
*Kolkata, West Bengal 700032, India.*  
*Sr. Architect in CEFD, Larsen & Toubro*  
*Chennai, Tamil Nadu 600089, India*

Anup Kumar Prasad Email: prasad.anup1@gmail.com  
anupju@lncecc.com

**Abstract**

Nature is rich of resources which are costless, but still one has to expend energy to get those resources in a desired manner. E.g., in hot/warm environment one wants sunlight without sun heat, for ventilation one needs external wind flow unaccompanied by dust or noise, and these filtering devour large quantity of energy. If one learn to design a building which itself can act as a filtering machine, one can save plenty of energy. As a part of UG-thesis author started research on various ‘building forms’ to develop a module of building which can adequately deals and blends with the environment. Author also visited various Green buildings around India for case study. Later on author get involved in developing a software for ‘Climate Optimized Synthesis of Architectural Forms’. Through this paper author wants to share his Study, Research, Synopsis and Conclusions for developing a building module to save energy.

**Keywords:** GBAC – Green Building Awareness Centre, Fig. – Figure, OAT – Open Air Theatre

**1. Introduction**

The construction process and building use not only consumes the most of energy and creates a lot of carbon dioxide emissions, they also creates large amount of wastes, use of maximum non-energy related resources and also responsible for the heavy pollution.

![Fig. 1 – Pollution by building industry](Image)
At the one end fact is that mankind are serious about climatic changes and need to stop such happenings which goes against the environment, on the other hand buildings fulfil their basic needs by providing shelter for living and working. From above inferences, it is necessary to achieve sustainability in buildings. Sustainability can be achieved by adopts the creates structures with minimum intervention to the environment due to this construction requires less energy and time along with using processes which are environmentally responsible and resource-efficient throughout a building's life-cycle. One of the highly effective steps towards sustainability of any building usually occurs during design process by incorporating zero-energy and green building concepts. There are many organisations like Indian Green Building Council (IGBC), The Energy and Research Institute (TERI), Energy Star, Green Building Certification Institute (GBCI), Built Green (BG), etc. are coming out with various techniques, practices, methods and materials towards making any design sustainable, green and zero energy by several rating system like Green Rating for Integrated Habitat Assessment (GRIHA), Leadership in Energy and Environment Design (LEED) etc.

However, with a concerning about these, author in this paper titled “Undergraduate thesis: Green Building Awareness Centre”, willing to give a general idea for proposing a building for Indian climatic conditions along with the structure using process that is environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. This building in topic provides model for the application of alternative energy systems at a larger urban scale. It has to be design as a demonstration of a modern building in which the building’s materiality and its spatial qualities are based on energy conserving considerations. Along with that author also considered necessary to give brief information of some potential green buildings around India as a case study.

2. Historical Background

Security and protection from climatic elements have been the prime considerations in human beings effort to create shelter for themselves. Man has relied on various resources to build shelters for protection from the heat, cold and rain. As materials and techniques of construction developed, vernacular built forms evolved, through trial and error, to provide a harmonious balance between buildings, climate and people’s life style.

Man’s endeavor in finding a shelter for himself probably began with a cave. In caves he found protection from the fury of nature as well as wild animals. The insulating and absorption properties of the earth mass provided warmth in winter and coolness, shade in hot summer.

In different parts of world, man has found various solutions for protection against climatically unkind conditions through locally available materials. For example, in the hot and humid regions of Asia, Australia, Polynesia and Amazon, the roof was more important than walls for modifying the indoor conditions. In fact the walls could be omitted altogether. Hence, lightweight

Fig. 2 - Lohani Caves, Mandu [2]
structures of timber skeleton, wooden frames, thatched roofs and woven, lathe and venture walling were used in such regions. On the other hand, in the mountainous cold forest regions in the north-west U.S.A., Scandinavia and Himalayas, one found well-insulated timber houses. In case of early vernacular architecture, the roof played a determining role in the general form and appearance [3].

Flat roofs appeared in hot regions, vaulted roofs in hot and dry regions and inclined roofs in temperature dry climates. Higher pitched roofs were used in wet-temperature and cooler places. Both domes and vaults were popular in the hot-arid regions of the Middle East and northern Africa, where low humidity leads to intense radiation exchange, and the variations between day and night temperatures are high. The logic here is that a hemispherical vault has about 3 times the surface area as the base of a square roof, so the solar radiation is diluted to that extent.

Also, the cooling by radiation exchange to the night sky is faster [3].

![Fig. 3 – types of Roof][4]

Bio-climatic aspects such as orientation, house form, open spaces, etc. were well integrated in vernacular residential architecture. For example, the ancient Greeks gave their homes a southern orientation and used thermal mass for heating purposes. Thick earthen walls stored the heat and prevented undesirable air-infiltration. Later, the Romans improved on their techniques to incorporate clear window-coverings, greenhouses and radiant floor heating. Natural lighting through clerestories and skylights has been used in many historical buildings such as the temple of Amman at Karnak and the Pantheon at Rome. Palladio, the great renaissance architect, employed ‘thermal windows’ to transmit the sun’s rays into the building interior for heating, as key features of his designs.

A group of six villas near Vicenza, Italy, built in the 16th century AD, incorporated a remarkable system of underground air conduits that provided air-conditioning during the hot summer [3]. Building with natural and local materials, using process that is environmentally responsible and resource-efficient isn't anything new in India.

![Fig. 4 – Pantheon, Rome][5]
2.1 Traditional Indian Architecture

Indian experiences diverse climatic conditions which in turn have influenced the development of vernacular architecture in various regions. Control of microclimate around the building was always an important aspect of indigenous designs. The urban forms ensured that individual buildings were not exposed to the sun. While planning a town, care was taken to orient the streets keeping the effects of sun and wind in mind. For example, towns in Gujarat and Rajasthan which experience hot and dry climate had row-houses with common walls.

![Fig. 5 – Typical settlement for hot and dry regions [4]](image)

These were tightly packed along the streets and lanes to minimise the exposure to direct sun and hot winds. The front facades were further shades with well-articulated balconies called ‘Jharokhas’.

![Fig. 6 – Jharokhas at Rajasthan [5]](image)

Air inlets were usually located on the front facades where the air was relatively cooler since the streets and the lanes were well-shaded. Each house had an open courtyard which acted as an exhaust for warm air and provides enough natural light for the interior of the house [3].

In towns like Kolkata which is warm and humid are laid out to make maximum use of the prevailing breeze. Buildings are scattered vegetations are arranged to provide maximum shade without hindering natural ventilation.

![Fig. 7 – Typical settlement for warm-humid regions [4]](image)

2.2 Punchbhutas

Punchbhutas for centuries, man has manipulated the five elements to build comfortable houses even in the most hostile environments. For example, in the Desert, where the heat of the Sun (Fire) can make it impossible to live, man has built houses with internal courtyards (Space), thick walls (Earth), slit windows (Air) and water bodies and fountains (Water) to cool the house by ensuring good ventilation and flow of air [1].

![Fig. 8 – Punchbhutas](image)
2.3 Vastu shastra
House is static and sun is moving around the earth so, house should design in such a way that windows and all sources of ventilation absorb as many positive rays as possible. Vastu shastra prescribes an ideal plan called Vastu Purusha Mandala, in which each room (depending on its function) is located in specific Cardinal direction.

- East (Poorva): It is common knowledge that the sun rises in the East. (Surya/Sun)
- West (Paschima): Sun sets in the west (Varuna/Water)
- North (Uttara): (Kuber/Wealth)
- South (Dakhshina): (Yama)
- North-East (Eeshanya): (Supreme being/God)
- North-West (Vaayavya) (Vayu/Wind)

Sun – synthesis of vitamin D and has germicidal property. Aim of Vastu Shastra is to ensure that the inmates of a house are inadvertently exposed to the useful rays of sunlight even if they are inside the house whole day.

3. Case Study:
1. The Energy and Resource Institute University, New Delhi
2. CII – Sohrabji Godrej Green Business Centre, Hyderabad
3. Centre for Environment Education (CEE), Ahmadabad

3.1 The Energy and Resource Institute University, New Delhi

3.1.1 Automatic adjustable louver system
Energy efficient features in TERI University
- Automatic adjustable louver system
- Passive Solar Design through orientation
- Wind Control
- Thermal Insulation
- The campus is equipped with energy efficient cooling systems
3.1.2 Passive Solar Design through Orientation

3.1.3 Wind control
The predominant wind direction is taken into account in designing the open space. The hot air from outside moves into the central court, where it passes over the water body to make the central atrium area always cooler than the surrounding exterior.

Fig. 11 - Roof Plan - Adjustable louvers and solar panels

Fig. 12 - Passive Solar Design through Orientation

Fig. 13 – wind chart, New Delhi

Fig. 14 - Section - showing wind flow
3.1.4 Thermal Insulation of Walls
Use of efficient double glazing window units helps significantly reduce the heat gained through window glazing in the summers and the heat lost in the winters without compromising on the day lighting integration and the levels of visual comfort. The walls that are exposed to the harsh solar rays have a stone cladding which is fixed to the wall by channels. The air gap between the wall and the stone cladding by itself acts as an insulation layer. On the facades rock wool insulation is also provided in the wall. Energy efficiency is further proposed to be enhanced by insulation in the roof slab.

3.2 CII – Sohrabji Godrej Green Business Centre, Hyderabad
The centre is housed in a green building which received the prestigious LEED (Leadership in Energy and Environmental Design) Platinum rating in 2003.

3.2.1 North Light For indoor Daylighting
The most prominent feature of the building is that almost 90% of the interiors are daylight. This is achieved by providing north lighting and windows looking into courtyards. The regularly occupied areas of the main office and information centre are daylight.
3.2.2 Solar energy
Photovoltaic panels
In-site renewable energy is generated. Photovoltaic panels have been installed on the roof of the Technology Centre. The Roof orientation and inclination have been designed considering the efficiency of PV panels.

About 17% of the total energy costs are supplied by on-site photo-voltaic system.

Fig. 20 P.V. Panels on inclined roof

3.2.3 Wind Towers integrated with HVAC
The wind tower is one of the traditional passive-cooling techniques of the sub-continent. Here, it has been combined with the HVAC system to reduce energy consumption. The fresh air that goes in the AHU is pre-cooled in the wind tower, reducing the intake air temperature by 3 to 5 deg. C. The wind tower itself is made of hollow masonry, and acts as a ‘thermal mass’. It is cooled periodically by tricking water from the top of the tower.

Fig. 21 – Wind tower integrated with HVAC

3.2.4 Materials Recycled, Re-used, Regional
Recycled content: 80% or the building materials have a large proportion of post-consumer or post-industrial recycled content.

- The masonry construction has a considerable content of fly ash, which is an industrial waste.
- The walls are constructed using fly ash blocks and fly ash cement.
- The ceramic tiles used for flooring have cullets, broken tiles, paper etc.
- The roof lawn trays are made entirely of recycled plastic.
- Instead of conventional ply or wood, this project uses a co-posite agro-board manufactured from biogases.

95% of the materials used in the project are harvested, extracted or manufactured within a radius of 500 miles from the project site.

Fig. 22 – Different areas in building with recycled materials
### 3.2.5 Roof Garden Insulation & vegetation

Roof gardens provide an aesthetic delight in the campus. They prevent formation of heat-islands on the roof and act as insulation to ingress of solar heat.

![Roof Garden providing aesthetic delight](image)

**Fig. 23 – Roof garden**

### 3.2.6 Traditional elements Courtyard and ‘jaali’ work

The building is cantered around a circular courtyard. The screen wall or ‘jaali’ is effectively used to cut down the harsh sun, yet allow the flow of wind.

![Central Courtyard & ‘jaali’ work around toilet](image)

**Fig. 24 Central courtyard and “jaali” work around toilet**

### 3.3 Centre for Environment Education (CEE), Ahmadabad

Important aspect in organization of built and unbuilt spaces the unbuilt spaces are continuous linear spaces establishing axis for circulation within the built environment. It is also binds the build mat around it which does not follow strong geometry or orderliness principle.

![Main level Plan, CEE](image)

**Fig. 25 - Main level Plan, CEE**
3.3.1 Typology of built and unbuilt spaces:
The built mass is broken horizontally and vertically at various stages which gives a smooth integration of built and unbuilt volumes in the CEE complex. The undulating site also adds to it. As the ground rises to built mass or the steps from built spaces meet the base plane at various spaces. The interface even varies at different open spaces and adds surprises in the spatial experiences.

Fig. 26 – Typology of unbuilt spaces

Each unbuilt space, used for circulation in the institute establishes a human scale. They do not become a narrow open lane for movement but with variations in, levels and enclosing mass, they provide an interesting circulation area.

Fig. 27 – exposed brick surface, R.C.C. beams and lintels in built form

The brick surfaces with exposed R.C.C. beams and lintels in the built form create attractive visuals.
4. Climate Responsive Design Features
The main objective of climatic design is to provide comfortable living conditions with a minimum and meaningful input of artificial energy. This also reduces investment and running costs as well as ecological damage.

Climatic Conditions: In general, in tropical and subtropical regions the daytime temperature is uncomfortably high, particularly during the warmer seasons and in low altitude locations. However, the differences between regions are immense, depending mainly on the distance from the equator and on altitude.

Air humidity is also of great importance. This factor influences the precipitation pattern and the amount of solar radiation that reaches the earth’s surface. The influence of a cloud cover is most obvious, but invisible humidity in the atmosphere also alters the amount of radiation. Whereas with dry air conditions the radiation is strong and direct, humid air results in a less intense but diffuse radiation and also reduces the amount of re-radiation to the night sky.

The above mentioned points are the framework for design in tropical and subtropical climate conditions. They have to be adapted to each climatic zone because the dominant climatic factors differ highly between these zones. This leads to different solutions for various types.

4.1 Vegetation in landscape
Design using vegetation in the urban environment is of functional, aesthetic as well as climatic importance for its radiation absorbent surface and its evaporative and shade-giving properties. The vegetation in and around cities also has definite effects on air movement.

Vegetation is desirable both for shade, thus reducing the temperature in such shaded areas, and for reducing the effects of strong solar radiation on the walls of buildings and structures. Also, by forming a thick barrier of foliage, the velocity of strong wind reduced. The foliage of different types of wooded land acts as filter and purifies the atmosphere by keeping down dust.

Advantages of vegetation:
- It improves the microclimate both outdoors and indoors
- It checks hot and dusty winds in arid regions
- Its shade lowers daytime temperatures and heat emission at night is also reduced, thus resulting in more balanced temperatures.
- It balances the humidity, during precipitation much of the free water is absorbed and during dry periods water is evaporated.

Fig. 28 – foliage act as shading device
Fig. 29 – Green Street place [4]
Fig. 30 – Advantages of slow drainage systems: intercepts the rainwater in the greenery, in the ground and ponds, natural way of prevent flooding [4]
4.2 Building Design

4.2.1 Orientation of building
Orientation of building is important for the optimum response to sun and wind. To define the optimal orientation of a building, three factors have to be considered:

4.2.1.1 Solar Radiation
To get optimum orientation with regard to heat gain by solar radiation, it is necessary to do analysis of radiation intensity on different oriented surfaces and its diurnal change and its change with season.

Fig. 31 – Sun Path

Optimum sun orientation reduces radiation to a minimum in the hot periods, while allowing adequate radiation during the cool months. East and West facing walls receive intensities of radiation, especially during the hot periods. These walls should thus normally be kept as small as possible and contain as few and small openings as possible.

Fig. 32 – North and South facing preferred orientation for GBAC

4.2.1.2 Wind Orientation
Usually cooling by ventilation is desired. Building should be oriented across the prevailing breeze. This direction often does not coincide with the best orientation to the sun. One should pay more attention to the effects of solar radiation, because the direction of the wind can be influenced to a certain extent by structural elements.

Fig. 33 – predominant wind direction within site for GBAC

4.2.1.3 Topographical Orientation
The surface of the surroundings may store and reflect solar radiant heat towards the building, depending on the surface’s angle relative to the solar radiation and on the type of surface. Where this heat is not desired, the orientation of the building should be changed of the surface of the surroundings should be covered with greenery that improves the microclimate.

Fig. 34 – Topography reflecting solar radiation
4.2.2 Shape and Volume
The function as well as socio-cultural requirements and particularly the climatic conditions define the form of the buildings.
The heat exchange between the building and the environment depends greatly on exposed surfaces. A compact building gains less heat during the daytime and loses less heat at night. Therefore, the ratio of surface to volume is important factor.
A simple model demonstration on differently arranged units illustrates:

![Diagram of differently arranged building units]

Fig. 35 – Volume to Surface ratio by differently arranged building units

Volume to Surface ratio is least for case ‘a’ and maximum for case ‘c’.

4.2.3 Types and form of buildings
The suitable form of building differs very much between the main climatic zones. Traditional regional dwellings types illustrate this clearly.

4.2.3.1 The compact, inward oriented house of the hot-arid zone
Massive wall and roof structures even hot arid outside of hot days and cold night condition, the indoor climate is maintained. The surface is kept at a minimum compared to the volume so that the heat exchange of heat and cold is minimized. Ventilation should be controlled: minimized during the heat and increased during periods when the outdoor temperature is at comfort level.
Such type is generally appropriate in areas with large temperature differences between day and night.

![Diagram of a typical house of the hot-arid zone]

Fig. 37 - Typical house of the hot-arid zone

4.2.3.2 The open outward oriented, detached, built on stilts house of the warm-humid zone
The surface is large compared to the volume and therefore the exchange of heat energy high. As consequence the indoor temperature approaches the outdoor temperature. The walls are light and maximum ventilation can easily be achieved. Large overhanging roofs are the main important element.
This type is appropriate in zones with even day and nighttimes temperatures.
4.2.3.3 A compromise between the two extremes is the house of the temperate zone.

It composed of shading roofs as well as protective walls which are less massive than in 4.2.3.1 above. The windows are of medium size, providing good ventilation and moderate solar heat gain.

5.0 Design Guidelines

The main objectives of building design in warm humid zone should be:

1. Resist heat gain by:
   a. Increasing thermal resistance
   b. Increasing buffer spaces
   c. Increasing shading
   d. Increasing reflectivity

2. To promote heat loss by:
   a. Ventilation of appliances
   b. Increasing air exchange rate through day
   c. Decreasing humidity levels

Design considerations involve site conditions, building orientation, plan form and building envelope.

5.1 Site condition

Warm Humid climatic (Rajarhat-Kolkata, India) A site consideration involves macroclimate and microclimate.

5.1.1 Macroclimate

The macroclimatic conditions predominantly define the climatic zone and requirements of comfort for a particular place. They include solar radiation, air temperature, humidity, precipitation, wind, etc.

5.1.2 Microclimate

Under the heading of ‘microclimate’, are the conditions of the wind, sun, radiation, temperature and humidity experienced at particular locations around a building. The building itself, causing a bluff obstruction to the wind flow, and casting shadows on the ground and other buildings.

The microclimate of the site is affected by the following factors landforms, water bodies, open spaces and built form, vegetation.
5.1.2.1 Landforms
Landform represents the topography of the site. It may be flat, undulating or sloping. Major landforms affecting the site are mountains, valleys and plains. Consideration of the landform is immaterial for a flat site.
The site for Green Building Awareness Centre is almost flat. Natural slope here is from east to west (towards link canal) of site. *Planting Rain water reservoir towards west (near Link canal) will be site specific design.*

![Site plan showing flat topography and Link canal at west of the site (GBAC)](image)

5.1.2.2 Water bodies
Water has relatively high latent heat of vaporisation it uses up a large amount of heat in evaporation and causes significant cooling effect. Evaporation of water also raises the humidity level. Water absorbs or releases a large amount of heat per unit rise or fall of temperature because of its high specific heat. Since the humidity is high in these regions water bodies are not normally proposed.

Link canal (source of humidity) here is running parallel to North-South direction of site. Predominant Monsoon wind from south-west flows over the canal to the site. *Design should be done in such a way so that wind from west should not enter the building* (fig. 40).

5.1.2.3 Open spaces and built forms
Open spaces and built form are responsible for the different patterns of air flow in and around a building, affecting heat gain and heat loss. Both together can modify the micro-climate of the site. Courtyards can also be designed to act as heat sinks. If it is covered by grass and other vegetation, it would provide a cooler environment. *Buildings should be spread out with large open spaces for unrestricted air movement* (fig. 41).
5.1.2.4 Vegetation type and pattern

Vegetation in any form plays an important role in changing the microclimate of the place. Plants, shrubs and trees can cool the environment as they absorb radiation for photosynthesis. They are useful in shading a particular part of the structure and ground to reduce the heat gain and reflected radiation. By releasing moisture, they help raise the humidity level. Vegetation also creates different air flow patterns and can be used to direct or divert the prevailing wind advantageously by causing minor pressure differences.

Based on the requirement of a climate, an appropriate type of tree can be selected. Planting deciduous trees such as mulberry and champa on east and west side would prove beneficial. Besides providing shade from intense and glaring morning and evening sun, they also cut off hot breezes. Deciduous trees shed their leaves in winter to allow solar radiation to heat the building.
5.2 Building orientation
Orientation refers to the location of a building with respect to cardinal directions, i.e. North-South and East-West. Building orientation is an important parameter of design. In hot climates, the building needs to be oriented such that solar radiation is admitted to the minimum possible. East and West facing walls receive higher intensities of radiation, especially during the hot periods.

An unobstructed air path through the interiors is important. Since the temperatures in shade are not very high, semi-open spaces such as balconies, verandahs and porches can be used advantageously for daytime activities. Such spaces also give protection from rainfall.

The buildings are preferably oriented along an east-west direction to minimize solar radiation on external surface and thus reduce the heat gain. East west walls should thus normally be kept as small as possible and contain as few and small openings as possible. They could be long and narrow to allow cross-ventilation. Heat and moisture producing areas must be ventilated and separated from the rest of the structures.

To decide on an optimum orientation, it is essential to have an idea of the sun’s position and its movement pattern on a diurnal as well as seasonal basis.
Figure 45 – Sun path diagram, Rajarhat

Usually cooling by ventilation is desired. Building should be oriented across the prevailing breeze. This direction often does not coincide with the best orientation to the sun. One should pay more attention to the effects of solar radiation, because the direction of the wind can be influenced to a certain extent by structural elements.

Figure 46 predominant wind direction within site for GBAC

5.3 Plan form
The surface to volume ratio (S/V ratio) determines the magnitude of the heat transfer in buildings. Larger the S/V ratio, greater will be the heat gain or loss for a given volume of space. Conversely, a smaller S/V ratio will result in the reduction of heat gain or loss. In cold climates, it is preferable to have compact house form with minimum S/V ratio.
5.4 Building envelope

In addition to providing shelter from rain and heat, the form of the roof should be made such as to promote air-flow. Due to low diurnal temperatures, insulation does not provide any additional benefit for a normal reinforced cement concrete (R.C.C.) roof in a non-conditioned building.

The nature of the building envelope determines the amount of radiation and wind that will enter inside. It consists of roof, walls, fenestrations, external colour and texture and shading.

5.4.1 Roof

Since the roof receives a significant amount of solar radiation, the type of roof plays an important role in modifying heat gain or loss, day lighting and ventilation.

A massive roof as of reinforced cement concrete (RCC) tends to delay the transmission of the heat into the interior when compared to lighter roofs such as asbestos cement sheet roofing. The Terrace Garden (fig. 78) on roof provides good insulation for resisting heat gain.

The roof can also be used advantageously for effective ventilation and day lighting by incorporating vents and skylights (fig. 77 & 79) respectively.
5.4.2 Walls
Walls constitute a major part of the building envelope and receive a large amount of direct radiation. Depending on whether the need is for heating or cooling, variations in the thickness and material of the wall can be decided on. More than 25% of the heat gain occurs due to conduction by walls in the warmer regions of India. Control of the heat gain through walls must be an important consideration for reducing the cooling loads.
5.4.2.1 Cavity Wall
The cavity wall (fig. 80) helps in insulating the building by using as a thermal break between the two skins of the wall with environmental conditions becoming more of an issue to reducing energy wastage & cavity wall insulation is a cost effective way to reduce the amount of heat (as much as 35%) lost from convection of walls.

![Cavity Wall Diagram]

**Fig. 51 – Cavity Wall**

**Science of cavity insulation**
The reason cavity insulation keeps heat in is that the polymer and air in the cavity are good insulators. This is because the distance between the particles in the air is greater than in a solid. Other benefits of cavity walls are their resistance to moisture from the outer side to the inner side wall and the increase of sound proofing.

5.4.2.2 External facade (environmentally friendly and energy efficient structure)
The alignment of the building and the different facade treatments are all direct responses to the site, the shape of the building itself, the innovative cladding/ glazing system that incorporates shading and natural ventilation.

Global position of Rajarhat is 22.61°N 88.52°E.

![Sun Path Diagram]

**Fig. 52 – Sun path and inclination in Rajarhat**

The south facade of the building was required to be shaded from the direct sunlight of the summer sun. This can be accomplished by having the floor plates on the south side that stepped out from bottom to the top causing the overhang of the floor above to serve as a passive solar shading device for the floor below.
This shape effectively lowers the amount of direct sunlight that can enter the building while still admitting an adequate amount of daylight.

5.4.3 Fenestration (openings)

The pattern and configuration of openings such as windows forms an important aspect of climatic design. Appropriate design of openings and shading devices will help to keep out sun and wind or allow them in the building. Ventilation lets in the fresh air and exhaust hot room air, resulting in cooling. An indoor air speed of 1.5 – 2.0 m/s can cause comfort in warm and humid regions where the outdoor maximum air temperature does not exceed 28 – 32 °C.

Cross ventilation is important in these regions. All the doors and windows are preferably kept open for maximum ventilation for most of the year.

Natural light is introduced into the building through glazed openings, skylight, light shelves, clerestories, etc.
Fig. 55 – Directing south sun by vertical louvers in office (Admin. Block) GBAC

Fig. 56 – Skylight from cut-out of OAT to Display area

Fig. 57 – Diffused daylight for interior of workshop, GBAC

External wall above lintel is extended in such a way (1000mm) that direct sun from south should not enter the building. Lower end of upper wall makes an angle of 45° with the upper end of lower wall.

Fig. 58 – Inclined wall for East / West façade

Sun from East / West is harsh and having high solar radiation which causes heat gain. To minimize heat gain sun from East / West is blocked. Walls at certain interval (3000mm) are inclined at the angle of 15° so that harsh sun from can be blocked simultaneously, diffused daylight and ventilation can be done for indoor environment.
6. Conclusions
A survey with respect to energy consumption, orientation, shape, form, water use, waste production etc. and Green building methodologies, if followed, will render the building as “Sustainable”.

7. References
[1] architectureideas.info
[5] farm4.staticflickr.com