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Inclusion of Green Buildings Concepts in Au-Hub Building, Andhra University, Visakhapatnam

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Abstract: ***Infrastructure Industry is experiencing a rapid growth in India. India is a country where infrastructure is main hurdle for the growth of Indian businesses. In today's scenario, Buildingswhich are present already are contributing 45% of worldwide energy use. The Green House gas emissions from these buildings are contributing mainly for Global Warming, Acid Rain and Etc. Our demand on natural and finite resources such as energy, water and building materials can be reduced and our contribution to environmental quality can also be enhanced by incorporating green building principle into the design, construction and renovation. Green buildings are designed and constructed to maximize the whole lifecycle performance, conserve resources and enhance the comfort of occupants. This is achieved by the use of technology such as fuel cells and solar heated water tanks and by attention to natural elementssuch as maximizing natural lighting, wind and building orientation. The Indian Green Building Council (IGBC), which was formed by the Confederation of IndianIndustry (CII) in 2001, has developed a green building rating system that conforms with the LEED certification of the US Green Building Council, which is a globally recognized greenbuilding rating system. The IGBC rating system has a scoring system of 100 points for new buildings. These points are divided into various categories, where it is essential for the buildingto meet the specific requirements to secure points as per the IGBC guidelines. The certification level is as follows: the building must secure minimum 50 points for a certifiedrating, 60 points for a silver rating, 70 points for a gold rating, 80 points for a platinum rating and 90 points for a super platinum rating. The IGBC rating system is based on modules including sustainable architecture and design, site selection and planning, water conservation, energy efficiency, building materials and resources, indoor environment quality, innovation and development. The primary goal of this research project is to develop a set of parameters to modify the existingAU-HUB building located in Andhra University, Visakhapatnam, India into a green building. This is achieved systematically by merging different techniques and procedures available and attainable in the prescribed area and using the available technology. It entails an in-depth study on the available literature of green buildings from different scholarly articles around the world and incorporating them considering the location of interest i.e. Visakhapatnam city, Andhra Pradesh, India, as well as the climatic factors and centring the analysis on the IGBC guidelineson green building design to achieve a set of parameters which are then suggested for modification of the building in consideration i.e. AU-HUB Building in Andhra University, Visakhapatnam, India. The results of this research project work are then presented in a systematic manner to provide a reliable comprehensive, useable, adaptable, and user-friendly data feasible for application in any future similar construction endeavours in Visakhapatnam city, India or other locations around the world with similar climatic factors and geographical features.***

Keywords: Green Infrastructure Green Building, The Indian Green Building Council Passive Designs, HVAC Systems, Nearly Zero-Emission Buildings (NZEBS) Building Orientation, Building Massing Internal Gains Building Envelope Thermal Insulation Locked Air Thermal Conductivity, Solar Heat Gain Coefficient (SHGC) U Factor, Visible Light Transmission Air Leakage, Day Lighting, Sensor Based Lighting Pervious Concrete, Space Geometry Natural Ventilation Glazing, Daylight Analysis Ventilation Analysis Thermal Analysis Sun Shading, Thermal Transmittance Albedo (Solar Reflectance) Emittance, Thermal Conductivity Building Colours Visakhapatnam Climate Solar Path, Indoor Air Quality Solar Radiation Double Glazing Green Roof, Green Pathway Green Facades

General

Infrastructure sector is a key driver for the Indian economy. The sector is highly responsible for propelling India's overall development and enjoys intense focus from Government for initiating policies that would ensure time-bound creation of world class infrastructure in the country. The infrastructure sector includes power, bridges, dams, roads, and urban infrastructure development. In other words, the infrastructure sector acts as a catalyst for India's economic growth as it drives thegrowth of the allied sectors like townships, housing, built-up infrastructure and construction development projects.

There is a compelling need for enhanced and improved delivery across the whole infrastructure spectrum, from housing provision to water and sanitation services to digital and transportation demands, which will assure economic growth, increase quality of life, and boost sectorial competitiveness.

Conventional buildings compared to green buildings are not as efficient in reducing thequantities of natural resources and energy required for its service as technology allowsthem to be today. Contemporary green buildings are superior in both carbonsavings and cost savings. Green buildings use a mean 21% lower energy than conventional buildings, and with improvements and modifications conventional buildings could rival that statistic. Compared to conventional buildings, green buildings save money and reduce carbon footprint by utilizing energy efficiency; converting existing buildings to green buildings can be accomplished at a low price and solve these problems.

1. Introduction

Energy use in buildings can be drastically reduced in half through energy usage efficiency improvements within conventional buildings. While the green buildings movement originated in the 1970's the amount of existing conventional buildings still outnumber the amount of newer green buildings. Conventional buildings are not as energy efficient due to older technology and construction techniques, lowering potential energy savings. In modern green buildings, the potential energy-saving steps are implemented from the start, increasing carbon and cost savings.

Green Building

A "Green Building" is a building or structure that uses environmentally responsible practices from conception until the deconstruction of the building. Green building refers to both a structure and the application of environmentally responsible and resource-efficient processes throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition.

Green Building Concept

The `Green Building' concept is gaining importance in various countries, including India. These are buildings that ensure that waste is minimized at every stage during the construction and operation of the building, resulting in low costs, according to experts in the techniques associated with the `Green Building' include measures to prevent erosion of soil, rainwater harvesting, use of solar energy, preparation of landscapes to reduce heat, reduction in usage of water, recycling of waste-water and use of world-class energy-efficient practices.

Green Buildings in India

IGBC is a leading green building movement in the country. The Indian Bureau of Energy Efficiency (BEE) launched the Energy Conservation Building Code (ECBC). The code is set for energy efficiency standards for design and construction with any building of minimum conditioned area of 1,000 m^2 and a connected demand of power of 500 KW or 600 KVA. The energy performance index of the code is set from90 kW·h/ m^2/year to 200 kW h/m^2/year where any buildings that fall under the index can be termed as "IGBC Compliant Building"

1.1 Background

This research project analyses the concept of green building and the development direction of green building, studies the application of green building in housing construction, and discusses in detail some principles that green building design should follow. It also includes a detailed analysis of The Andhra University Innovation Centre, located in Andhra University College of Engineering in Visakhapatnam India, design and surrounding features as well as recommendation of possible modifications which will help advance it to a green building. The normal role of green building design concept can make the construction industry achieve sustainable development, and also make people's lives happier.

1.2 Objectives

- Define green building and analyze the concept of green infrastructure
- Identify and describe general aspects of green building
- Describe the design parameters of green building in Visakhapatnam city, India considering weather patterns and environment.
- Analyze the design aspects of the existing Andhra University Innovation Centre in Andhra University, Visakhapatnam India.
- Recommend various modifications to the Andhra University Innovation Centre to make it a green building.

1.3 Scope of the work

- This project will involve a thorough study through the existing literature of existing buildings to understand the concept of green buildings and salient features.
- Study various existing green buildings will be made to assess and compare the construction parameters and possibility of implementation in Visakhapatnam City, India.
- Study on the design drawings and visit to the actual site to assess the environmental features and actual building characteristics.
- An analysis of the building information obtained from the engineering designs and project site.
- Propose modification on the design aspects of the building.

General information on green building and specifically passive buildings with special consideration to Visakhapatnam City is provided.

General

Green building is a holistic concept that starts with the understanding that the built environment can have profound effects, both positive and negative, on the natural environment, as well as the people who inhabit buildings every day. Green building is an effort to amplify the positive and mitigate the negative of these effects throughout the entire life cycle of a building. While there are many different definitions of green building out there, it is generally accepted as the planning, design, construction, and operations of buildings with several central, foremost considerations: energy use, water use, indoor environmental quality, material section and the building's effects on its site. The details of each of the aspect of the green building planning and design are presented.

2. Theory of Green Building

2.1 Benefits of Green Building

The built environment has a vast impact on the natural environment, human health, and the economy. By adopting green building strategies, we can maximize both economic and environmental performance. Potential benefits of green building can include environmental, cost efficiency and economics, and health benefits, as a way of:

1) Environmental advantages of building green
2) Cost efficiency and economic benefits
3) Health benefits
4) Energy saving & energy efficiency
5) Improving air quality (inside and outside the house)

2.2 Green Buildings: Planning and Design

Green design, also known as sustainable design or green architecture, is a design approach that integrates environmental advocacy into building infrastructure. Common elements of green design includealternative energy sources, energy conservation, and reuse of materials. Some concepts directly pertain to architecture

1) Passive Designs

Passive design uses layout fabric and form to reduce or remove mechanical cooling, heating, ventilation and lighting demand. Examples of passive design include optimizing spatial planning and orientation to control solar gains and maximize day lighting, manipulating the building form and fabric to facilitate natural ventilation strategies and making effective use of thermal mass to help reduce peak internal temperatures.

2) Building Orientation

Orientation is how a building is positioned in relation to the sun's paths in different seasons, as well as to prevailing wind patterns. Managing the natural elements mainly the sun and wind features helps to evolve a building that has good orientationfeatures.

3) Metal Building Products

Metal building systems and metal building products can be used to aid building design strategies. The systems are very quick to assemble and disassemble. metals reflecting capacity can increase a products solar reflective index (SRI) value, aiding in the reducing the cooling Leeds through passive design.

4) Building Science Principles BehindPassive Building

The building science principles behind passive building are:1) Continuous insulation breaks thermal bridges between inside and outside,2) airtight constructions stops heat and moisture,3)optimized windows keep heat in and out, 4)balance ventilation ensures fresh air and controls moisture and minimal mechanical is all a super building needs.

5) Climate Characteristics

Climate characterizes the average weather conditions for a particular location over a long period of time. Study of the climate, its variations, extremes and change over the past, present and the future and its impacts on a variety of social and environmental sectors supports an evidence-based decision-making on how to best to manage the risks of climate variability, adapt to a changing climate, to ensure human safety and well-being and proper indoor environment. Several climatic factors that affect the overall building environment have been considered and analysed in the context of Visakhapatnam city. They include temperature, humidity, solar radiation, wind and rain.

2.3 Building Massing

Massing is the overall shape and size of a building. A building that is successfully massed will use the general shape and size of the building to maximize its free energy from the sun and the wind by minimizing energy loads. Passive heating, cooling, and day lighting are all important factors that are considered in massing a building during the design process.

Sun Exposure in DifferentDirections

As with massing for visual comfort, buildings should usually be oriented east- west rather than north-south. This orientation lets you consistently harness daylight and control glare along the long faces of the building. It also lets you minimize glare from the rising or setting sun. To maximize the sun use, place the longest side of your house facing south. Design this south facing wall with little to no jogs and offsets, which would increase shade on the south side and thus reduce light. Also consider what rooms will be sharing this south-facing wall.

Remove/ Reduce InternalGains

External shading should be designed to let in the winter sun but shade the summer sun.The use of sun control and shading devices is an important aspect of many energy- efficient building design strategies. In particular, buildings that employ passive solar heating or day lighting often depend on well-designed sun control and shading devices.

Building Envelope

The building envelope is the boundary between the conditioned interior of a building and the outdoor. Green envelopesimprove air quality and reduce pollution byfiltering fine particles out of the air. They also minimise heat island effects and contribute to reduce noise levels. Plants and flowers can be grown from seed in-situ on a temporary mat that is easily fixed.

Heat Transfer through Roof and Walls

Conduction is heat traveling through a solid material. On hot days, heat is conducted into your home through the roof, walls, and windows. Heat-reflecting roofs, insulation, and energy efficient windows will help to reduce that heat conduction.

Heat Flow in Buildings

The amount of heat that is escaping throughthe exterior walls is based on the amount of insulation in them and building material. Heat moves through building assemblies primarily in three ways: by conduction, by convection, and by radiation.

Thermal Insulation

Thermal insulation refers to the many ways we attempt to inhibit the transfer of heat from one object to another. If a building is designed properly, the extra money invested in better insulation, better windows and better roof will result in reduction of cost of the mechanical and electrical systems and passive design structure. Insulation is particularly important for buildings in colder climates. Insulation helps the building envelop toresist the conductive flow of heat and it is typically most effective when installed in continuous insulation (which significantly reduces thermal bridging as compared to gravity insulation). Continuous insulation means the building is essentially wrapped with a blanket of insulation outside the structure to thermally separate the inside from the outside with no thermal bridges.

Different insulation materials

An insulation material is one that provides thermal insulation, or the reduction of heat transfer between objects. Heat transfer can be an issue in a range of industries, where two objects are in contact but they have varying temperatures. The heat flow between these two objects is unavoidable, but an insulationmaterial can be used to reduce the transfer. These materials work by reducing thermal conduction or reflecting the thermal radiation instead of absorbing it.

Insulation using materials

A material insulates by reducing the intensity of matter to reduce conduction by locking or suppressing any fluid to avoid conversion by using opaque or even reflecting materials to reduce radiation and by keeping the product dry to avoid evaporation, condensation. Most insulationis used to prevent the conduction of heat. In some cases radiation is a factor. A good insulator is obviously a poor conductor.

Locked air - Main thermal insulation material in buildings

Air is poor thermal conductor. It is locked in foam bubbles in between fibres, preventing convection. Baffles, walls and fibres are themselves opaque to thermal radiation. Trapped air is a natural insulator and because it is trapped, convection currents cannot be set up easily. So, trapped air reduces heat loss by conduction and convection. Many insulating materials incorporate trapped air.

Insulation Application

Insulation materials are reliant upon their inherent molecular make-up, to minimize the three forms of heat transfer, that is radiation, conduction and convection. The greatest building heat losses are from air movement.

Table 2.1: Heat transfer characteristics

Envelope component	Climate zone	Max U- Value W/CM2 K	Min R- Value of Insulation M2k/w	Max U- Value w/m2K	Min R-Value of Insulation M2k/w
Roofs	Warm and humid	0.261	3.5	0.409	2.1
Opaque walls	Warm and humid	0.440	2.10	0.440	2.10

Thermal Conductivity

It is the property denoting materials inherent ability to conduct heat. Thermal conduction is the diffusion of internal heat within a static (rather than fluid) body as a result of a temperature difference across it. Everysubstance has its own capacity to conduct heat. The thermal conductivity of a materialis described by the following formula:

$$K = (QL)/ (A\Delta T \qquad (2.1)$$

Where,

K is the thermal conductivity in W/m. K

Q is the amount of heat transferred through the material in Joules/second orWatts

L is the distance between the twoisothermal planes

A is the area of the surface in squaremeters

ΔT is the difference in temperature in Kelvin

Thermal resistance-R value

Thermal resistance is a measurement of a material's or a component's resistance to heat flow. It is the reciprocal of thermal conductance, which is the ability to conduct heat. Resistance of a layer of material withthicker diameter to heat transfer is denoted as R=d/k. The higher the R value, the better the insulation. More material thickness means high R value. Lower thermal conductivity means higher R value.

Heat transfer through windows- single glazing

The solar energy passing through a clear glass glazing warms up the internal surfacesby absorption, and these surfaces then become heat radiators of low frequency and start re-emitting trapped heat, causing the temperatures to rise. Some types of glass can help make your windows more energy efficient.

Heat transfer through windows - double glazing

In a double-glazed window, heat will be directly radiated from the inner pane across the gap to the outer one. The amount of radiation also depends on the surface's emissivity. Though glass itself isn't much of a thermal insulator, it can seal and maintain a buffer from the outside. Double-paned windows offer a significant advantage when it comes to the energy efficiency of a home,providing a better barrier against outside temperatures than single-paned windows. The gap between glasses in a double-paned window is commonly filled with an inert (safe and non-reactive) gas, such as argon, krypton, or xenon, all of which increase the window's resistance to energy transfer.

Design decisions for windows

Design decisions define the direction and outcome of design projects. Designers use research and data to validate assumptions and eliminate biases during the decision-making process. Making decisions is one part of this process. They are influenced by placing and area (window wall Ratio), Solar protection Glazing and frame properties.

Solar Heat Gain Coefficient

SHGC is the ratio of solar (radiant) heat gain that passes through the fenestration to the total incident solar radiation that falls on it. SHGC is a dimension number between 0 and 1.The SHGC rating represents the fraction of solar radiation that can be transmitted through or is absorbed by the window. This gives you an idea of the window’s performance in terms of how much solar heat and sunlight will be released inside your home.

Factors Influencing SHGC

The factors influencing solar heat gain coefficient include solar protection or shading type of glass and number of panes tints and coating on the glazing and gas fill between glazing layer. Glass absorbs and redirects heat inward in three different ways: conduction, convection, and radiation.

U Factor

As with opaque envelop components U factor measure thermal conductivity through the windows components. A window’s U-factor measures how much heat a window transfers, and therefore how well it insulates. A low U-factor means there is low heat flow through the windows.

Heat transfer coefficient, U value

Heat transfer coefficient is a quantitative characteristic of convective heat transferbetween a fluid medium (a fluid) and thesurface (wall) flowed over by the fluid

Factors influencing U factor

The factors influencing the u factor include;the size of the air gap between glass panes, coatings on the glazing, coat fill between glass panes and frame construction. The better-insulated a structure is, the lower the U-value will be. Workmanship and installation standards can strongly affect the thermal transmittance. If insulation is fitted poorly, with gaps and cold bridges, then the thermal transmittance can be considerably higher than desired. Thermal transmittance takes heat loss due to conduction, convection and radiation into account.

Visible light transmission

VLT is the ratio of visible light that passes through a glazing unit to the total visible light incident on it. It is the amount of visible light that can pass through an optical or sun lens. It can also be called visible lighttransmittance or VLT%. This is measured as a percentage which indicates the darkness of a lens within a sunglasses frame. The lower the VLT, the darker the sun lens will be.

Factors Influencing VLT

The factors influencing VLT include; colour of glass, tints and contingents and the glazing number of glass panes. It's important to point out that the less light that passes through the film, the darker it is. With a darker colour, more light is blocked and is unable to pass through.

Different glazing types

Windows are an integral element of a house or any building, providing ventilation and lighting during the daytime, while ensuring privacy indoors. Over the years, window designs have evolved due to technological advancements. The Table 2.2 provides the details of various glazing types and their transmittance characteristics.

Table 2.2: Glazing Types and Their Corresponding Characteristics

Glazing type	Glass pane thickness	U factor	SHGC	VLT
Single clear glazing	6	6	0.81	0.89
Double glazing (clear)	6	2.7	0.7	0.79
Double glazing (low -e)	3	1.8	0.71	0.75
Triple glazing (clear)	3	2	0.07	0.74
Double glazing arg on filled (low – e)	6	1.4	0.57	0.73

Air Leakage

Normal air movement in and out of a building infiltration and exfiltration is known as air leakage and it is usually measured using changes per hour (ACH). As it is uncontrolled and admits or expels conditioned air it leads to more energy consumption in conditioned building. It is estimated that up to 1/3 of a building HVAC energy is wanted due to air leakage.

Envelope Airtightness to ReduceAir Leakage

Reducing air leakage by making the building envelope airtight is estimated to save 5% to 40% of heating and coding energy. An airtight envelope is needed in all buildings in all climates, except those without any mechanical ventilation for fresh air, i.e. naturally ventilated buildings. Thus air leakage rates are often specified with consideration of mechanicalventilation for fresh air.

Prescribed minimum air leakage rates<3.0 ACH – cold climate and <5.0 ACH – hot climate

Day Lighting

Day lighting is the controlled admission of natural light, direct sunlight, and diffused - skylight into a building to reduce electric lighting and saving energy. It is composed of a mix – direct sunlight, diffuse skylight and light reflected from the ground and surrounding elements. Light from the sun isintense and directional. Light from the sky is soft and diffuse.

Design Decisions for Daylight

Design decisions for daylight are influenced by;1)space geometry, 2)Light reflecting features, and 3)Light shelves etc. and internal surfaces. day lighting design needs to consider orientation and building site characteristics, size and placement of window openings, glazing and shading systems, and geometry and reflectance of interior surfaces. Good day lighting design ensures adequate light during daytime.

Space Geometry

Light penetrates into a room roughly 2.5 times the height of the top of the window from the ground. The windows can be responsible for unnecessary energy consumption in a building, if incorrectly designed, shadowed or oriented. Considering an annual thermal comfort assessment of a space, if windows are over- dimensioned, they can contribute to the increase of the heating needs due to heat losses, and also to the increase of cooling needs. The higher the window, deeper is the daylight penetration into the room.

Light Reflecting Factor

Reflection factor is a ratio of luminous fluxreflected by a body (with or without diffusion) to the flux it receives i.e. The ratio of the total amount of radiation, as of light, reflected by a surface to the total amount of radiation incident on the surface. Lighter colours on interior surfaces reflect light better. They help in daylight distribution and reducing glare.

Natural Ventilation

It is defined as using passive strategies to supply outdoor air to a building's interior for ventilation and cooling without using mechanical systems. Natural ventilation has become a key component of green building today and is required in order to be certified by The Indian Green Building Council (IGBC).

Concluding Remarks

Green buildings preserve and maintain precious natural resources. They also improve the quality of life. In their design, construction or operation, these buildings reduce or eliminate negative impacts and can create positive impacts on our climate and natural environment. There are fivebasic elements of green and efficient buildings and these are: waterconservation, indoor air quality, resource conservation, energy efficiency and liveable communities.

General

The project considered the following planning and design considerations for the applications of green technologies to upgrade the present conventional buildings. The factors considered for the present project study will help in logical, systematic planning and design to enhance the quality of building towards environmental protection. It encompasses what data they're going to collect and where from, as well as how it's being collected and analysed. The aspects considered are described in details in the following sections.

3. Planning and Design Considerations

Daylight and Ventilation Analysis

Daylight analysis is done using the prescribed approach whereas ventilation analysis is done using the analysis for natural ventilated spaces. IGBC norms manifest the separate procedures for individual and multi dwelling residential units for both the analysis. Building unit or "Unit of a Building" means, in any building subdivided into separate units or spaces, any interior space occupying any portion of the ground floor of any building, and having its own exterior entrance, and separated from other such spaces by a party wall or walls. Units are made according to area of flats. The calculations are done according to the following formulas;

$$Glazing\ factor = Window\ area\ sq.m / floor\ area\ sq.m * AVTG * constant * 10 \quad (3.1)$$

Where, AVTG is actual visible transmittance or glazing and constant values are taken 0.2 and 1 for window wall and windows on roof respectively.

Ventilation in an air conditioned spaces should be of 5cpm/second for each unit. Naturally ventilated spaces are preferred for their better utilization and reduction of artificial lighting. Actual open area calculation is done using equation below considering two third window are open, and assuming that door is opened for only half of the time, the factor $\frac{2}{3}$ and $\frac{1}{2}$ are used;

$$Openable\ area = area\ of\ door + area\ of\ window \quad (3.2)$$

$$Actual\ openable\ area\ (for\ living\ room\ and\ kitchen$$

$$openable\ area\ * \frac{2}{3} \quad (3.3)$$

$$Actual\ openable\ area\ (for\ bathroom) = openable\ area * \frac{1}{2} \quad (3.4)$$

IGBC norms manifest separate procedures for individual residential and multi dwelling residential units for both the analysis. Units are made according to the area of the flat.

The light transmission coefficient 'TL' indicates the percentage of sunlight passing through the glass. The higher the number, the more daylight passes through the glass. It is usually expressed as a percentage for standard insulating glass. Table 3.1 give details of various substrate lengths against corresponding light transmission percentage;

Table 3.1: Substrate Breadth against Concurrent Light Transmission Percentage

Substrate	Light transmission%
2mm clear	91
3 mm clear	90
4 mm clear	90
5 mm clear	90
6 mm clear	89
8 mm clear	88
10 mm clear	87
12 mm clear	87
15 mm clear	85
19 mm clear	84

Designed criteria openable windows anddoors

The design and specification of these important building components requires careful attention to such factors as material selection, fenestration performance, energy efficiency, sustainability, acoustical performance, security, and code compliance. The Table 3.2 highlights different IGBC guidelines on the minimum openable area percentage in different greenbuilding space types.

Table 3.2: Space Type against PreferredMinimum Openable Area.

Space type	Openable area %
Living space	10
Kitchens	8
Bathrooms	4

Thermal Analysis

The determination of the thermal properties of a building envelope is fundamental for the correct design of efficient energy condition. The main ways of heat transfer, conduction, radiation, and convection can be reduced through techniques and material selection. The insulating capacity of a wall depends on its global layout and on the characteristics of its single layers.

The thermal transmittance ofopaque walls

Built opaque wall means a vertical structure at least 6 feet in height constructed of cedar, masonry, redwood, or pressure treated lumber resistant to rot , that is opaque when viewed from a 90 degree angle directly in front of and behind the wall.

Sun shading

The necessity of sun shading is decided by relatively analysis the summer radiation intensity with the minimum radiation intensity required for sun shading 280wh/m. Well-designed sun control and shading devices can dramatically reducebuilding peak heat gain and cooling requirements and improve the natural lighting quality of building interiors.

Values for Thermal Transmittance

Thermal properties of buildings and insulating materials are hereby analysed. The properties of insulating materials include density, porosity, moisture resistance, and coefficient of thermal expansion, low odour level, in-flammability, compactness and surface tension. The most desired physical properties for an insulating material are, Low density (to decrease its weight

Table 3.3: Values of Thermal Transmittance

Type of material	Density	Thermal conductivity	Specific heat capacity
Building materials			
1 burnt brick	1.82	0.81	0.88
2 concrete	2.41	1.74	0.88
3 cellular concrete	0.70	0.18	1.05
4 timber	0.48	0.07	1.68
Insulating materials			
1 expended polystyrene	16	0.038	1.34
2 foam concrete	320	0.07	0.92
3 rock wool	92	0.047	0.84
4 glass wool	69	0.043	0.92
5 Soft board	320	0.066	1.30

Various building and insulating materialsand their thickness are shown in Table 3.4.

Table 3.4: Insulation materialcharacteristics

Type ofmaterial	Standards of thickness of exterior wall materials		
Building materials	*Minimum exterior*	*Maximum exterior wall thickness*	
1 burnt brick	114.3mm	228.6mm	
2 concrete	101.6mm	203.2mm	
3 cellularconcrete	100.0mm	200.0mm	
Insulating materials	Minimum thickness	Around 100mm thickness	Maximum thickness
1 expended polystyrene	41.0mm	100.00mm	100.0mm
2 foam concrete	101.6mm	101.6mm	-
3 rock wool	50.0mm	110.0mm	170.0mm
4 glass wool	90.0mm	115.0mm	140.0mm
5 Soft board	25.0mm	100.0mm	100.0mm

Estimation of thermal transmittance

Source: *arch daily (https://www.archdaily.com/tag/building-envelope)*

The general procedure for the estimation of the U-Value is presented below. The procedure for calculating the thermal transmittance values are as follows;

Step 1: Calculate the thermal resistance R of each uniform building material which constitutes the building units is

$$R = L/K \qquad (3.5)$$

$Where\ L\ is$ thickness of material in meters and
$K\ is\ thermal\ conductivity\ in\ w.k$

Step 2: Find the total thermal resistance as follows.

$$R = \frac{1}{f0} + \frac{1}{F1} + R1 + R2 + \cdots (3.6)$$

Where
fo = outside surface film coefficient
$f1$= inside surface film coefficient
$R1, R2$ = Thermal resistance of differentmaterials

Following values are taken for the presentstudy (Source: Researchgate.com).
Outside film coefficient at an air velocity of8km/h $(f0)$ = $19.6w/mk$
Inside film coefficient at still air $(f1)$ =9.36

Step 3: Thermal transmittance (U)

$$I = L/R \qquad (3.7)$$

Concrete parameter, ThermalPerformance

The thermal performance of a pavement is defined as the change in its temperature (most often Surface temperature) over time or influenced by properties of paving materials (albedo, thermal emittance, thermal conductivity, specific heat and Surface Convection) and by the ambient environmental Conditions (sunlight, wind, air, temperature). It can also be influenced by evaporative Cooling, which is related to ambient Conditions, permeability and the availability of near Surface water (most often factor if fully pervious pavement Systems is used).

Albedo (solar reflectance)

Albedo is a measure of the ability of Surface to reflect solar radiation. Solar reflectance values range from 0(no sunlight reflected) the 1 (all sunlight reflected). Light coloured materials generally have higher solar reflectance values than dark- coloured materials, although colour alone isnot the only indicator of solar reflectance. Raising the albedo (solar reflectance) of a building's walls reduces unwanted solar heat gain in the cooling season. This saves electricity and lowers peak power demand by decreasing the need for air conditioning. It can also cool the outside air, which can mitigate the urban heat island effect and also improve air quality by slowing thereactions that produce smog.

Emittance

It is the efficiency with which a Surface emits radiant energy and is defined as the ratio of energy radiated by the surface to the energy radiated by a black body (a perfect absorber and emitter) at the same temperature. Emittance ranges from 0 (no emission) to 1 (perfect emission). Thermal emittance is the emittance of a surface near 300K (81°F or 27°c). Most non-metallic surface has thermal emittances in the range of 0.85 to 0.95.The thermal emittances of dense graded concrete and asphalt are similar, being in the range of 0.90 to 0.95.

Thermal Conductivity

It is a measure of the ability of a material to transmit or conduct heat. it is the ratio of heat flow (power per unit area) to temperature gradient and is expressed in units of $W/m.k$. A material with a high thermal conductivity will transfer heat at higher rate than a material having a low thermal conductivity. The thermal of pavement materials Varies widely in the reported literature from $0.8W/m.\ k$ to $0.2W/m.k$ or greater with similar Values reported for dense graded asphalt and concrete. Specific heat is the energy needed to raise a unit mass of a substance by one unit of temperature, typically expressed in units of $J/kg.\ k$. The specific heat of dense-graded asphalt and Concrete are Very similar being about $900J/kg.k$.

Sun Shading

Ideally, the sun shading device should be onthe outside of the window. Shading devices inside a closed glass window will still allow heat to get in. These include curtains, blinds and interior plantation shutters. Also, sun shading devices that still allow ample natural ventilation is ideal for tropical climates. On summer, the daily average temperature raises up to 33 degrees. Minimum temperature on winter is 18 degrees Celsius. The necessity of sun shading depends on whether the solar radiation exceeds 280kWh/m^2 or not as shown below;

Table 3.5 indicates the judgement criteria of sun shading requirement for different intensities of summer radiation.

Table 3.5: Sun Shading Requirements in Different Elevation Orientation

Elevation Orientation	Summer radiation intensity (kWh/m^2)	Judgment (sun shading necessity)
East elevation	Max < or >280	-
West elevation	Min < or >280	-
North Elevation	Max < or >280	-
South Elevation	Min < or >280	-

Building Colours

Different colours reflect and absorb the sun's energy differently. Study of colours and their relationship to thermal transmittance and heat gain is done using typical values since labour and technology required was unavailable. Colour only affects the amount of solar radiation absorbed, whereas all biological tissues absorb thermal radiation from the air, ground and other objects, irrespective of colour. Dark surfaces become warmer because they absorb more of the incident radiation. Light-coloured surfaces reflect more of the incident radiation, henceabsorbing less radiation.

Concluding Remarks

The Indian Green Building Council is working to implement solutions in sustainable buildings. They are striving to take an intelligent approach to energy. Their focus is to safeguard water resources, minimize waste and maximize reuse, and promote health and wellbeing. They are leading the way in keeping our environment green, while creating resilient and flexible structures. They understand that sustainability is also about connecting communities and people, and should consider all stages of a building's life cycle. The IGBC guidelines on green building construction when used correctly can enhance attainment of passive construction goals.

4. Application of the Green Building Concepts to Au-Hub

Analysis of the au-hub building has been done in this section including glazing details such as type and area. Description of original building details, analysis with calculations and modification recommendations has been recommended.

Andhra UniversityInnovation Centre

The existing conventional building was taken as part of the study for its modification through the inclusion of green building concepts. This building is located at the campus of the Andhra University College of Engineering, Andhra University, Visakhapatnam, and Andhra Pradesh, India. It is a four storey building as shown in Fig 4.1

Figure 4.1: The AU-HUB Building in the Campus of the Andhra University College of Engineering, Andhra University, Visakhapatnam

This chapter intends to explore the constituents and characteristics of the Andhra university innovation Centre. The aspects under consideration are: Floor plan, Elevation, Internal and, external facades, internal flooring, material of construction, glass, surrounding vegetation, outside pavement, perspective images, sizes and quantity of glasswork is also calculated. Details of different building components are given.

Figure 4.2: Floor Plan, Fourth Floor, AU-HUB building

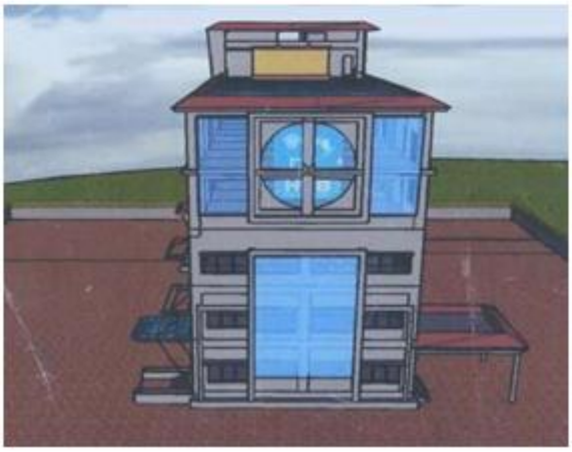

Figure 4.3: West Elevation, AU-HUB Building

Figure 4.4: South Elevation, AU-HUBBuilding

Figure 4.5: North West Image, AU-HUB

Figure 4.6: North East Image (AU-HUBBuilding)

Figure 4.7: Corridor, Ground Floor (AU-HUBbuilding)

The internal facades are painted white. The flooring is done with concrete tiles. Top slab is also painted white. Window size is 8ft by 5ft.Corridor width 1.5m. Tiles are most used material for flooring in this building.

Figure 4.8: Internal Space (AU-HUB Building)

Figure 4.9: Outside Pavement (North) Surrounding AU-HUB Building

Figure 4.10: South Image AU-HUB Building

The image shows the air conditioning, outside facades and glass work on the building. The outside pavement is also visible. Window size is 8ft by 5ft.

Glass Cladding Work

These are the details of the glass cladding in the South façade work and calculations as obtained from the Engineer's Office (Units are in feet). South facade has ~~two~~ windows with dimensions

For the windows in South facade, the aggregate glazing is calculated as follows. There are two glass panels to this window. Each panel has a height of 1.72ft and a length of 1.83 ft.

Surface Area of the glass panels of the window= 2 glass panels*1.72*(1.83+1.83)=12.39 ft^2.

Bottom sheet width = 0.49cm (as obtained from material specifications list)

There are three windows of this type hence total glazed area is given as:
11.91*3 = 35.73sqft

Other windows are of size 8ft by 5ft

Surface area of each rectangular window is 40sqft

There are total 24 rectangular windows hence total glazing is given by:
24*40 = 960sqft
Aggregate glazed area = 995.73sqft

Figure 4.11: Concrete Pavement (West) Surrounding the AU-HUB Building

The pavement is made of plain cement concrete. Small space is left for planting of vegetation. The pavement extends from the gate to the building entrance.

Pervious concrete pavement is a unique and effective means to address important environmental issues and support green, sustainable growth. By capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm water runoff.

Figure 4.12: East Side Image AU-HUB Building

Figure 4.13: West Image (AU-HUB Building)

Glass Work Cladding

The following calculations illustrate the glass cladding in the west façade asobtained from the Engineer’s office:

For the west façade, the aggregate glazingis calculated as follows

Rectangular windows glazed area is given by

L x B = 5.85* 10.37 (length x width) = 60.66sqft

There are two semicircles of radius 3.47 in the third floor. Their area is calculated as follows
2 * 3.14 * 3.47 = 21.79sqft

There are two rectangular glass sections in the 3rd floor . Their area is calculated as follows
2*2.97 * 3.45 =20.49 (two glass sectionseach of width 2.97ft and height 3.45ft)

There are two semicircles of radius 3.47 inthe 4th floor. Their area is calculated asfollows
2*3.14*3.47 = 21.79 (two semicircle ofdiameter 3.47ft)

Rectangular window
There are 6 rectangular windows of size 8ftby 5ft.
Their area is calculated as follows6*8*5 = 240ft

Aggregate glazed area = 240ft + 21.79ft + 20.29ft + 21.79ft +60.66ft = 364.53sqft

Figure 4.14: Concrete Pavement (North) (AU-HUB Building)

Concrete pavement with spaces for vegetation cover is provided. A masonry perimeter wall of stone material is provided.

Analysis

It is a building within Andhra University Engineering College. It is a 4-story building Used for technical and innovation meetings. Pressure on infrastructure due to overpopulation has deteriorated the indoor environment causing various health issues. It has also contributed to sick building syndrome making a huge monetary burden to the economy optimum quantities of light and proper ventilation express the quality ofthe indoor environment Also the use of natural light and ventilation is definitely an advantage with the raining concerns regarding cost and environment impact of energy use Natural light and ventilation canreduce building construction and operation cost and reduce energy consumption.

Visakhapatnam climate

The climate is the long-term pattern of weather in a particular area. Weather can change from hour-to-hour, day-to-day, month-to-month or even year-to-year. A region's weather patterns, usually tracked for at least 30 years, are considered itsclimate. Visakhapatnam has a tropical wet and dry climate. The specific climatic aspects of the area have been analysed below;

Temperature

Temperature, is a measure of hotness or coldness expressed in terms of any of several arbitrary scales and indicating the direction in which heat energy will spontaneously flow. Three temperaturescales are in general use today. The Fahrenheit (°F) temperature scale is used in the United States and a few other English-speaking countries. The Celsius (°C) temperature scale is standard in virtually all countries that have adopted the metric system of measurement, and it iswidely used in the sciences. The Kelvin (K) scale is an absolute temperature scale. The average annual temperature range in Visakhapatnam is 26.4 degrees, the maximum temperature reaches 33.6 degrees whereas the minimum temperature in winter is approximately 17.1 degrees.

Humidity

Humidity is the concentration of water vapour present in the air. Water vapour, the gaseous state of water, is generally invisibleto the human eye. Humidity indicates the likelihood for precipitation, dew, or fog to be present.

Wind

The predominant average hourly wind direction in Visakhapatnam varies throughout the year. The wind is most oftenfrom the south for 3.8 months, from February 8 to June 3 and for 1.4 weeks, from September 25 to October 5, with a peak percentage of 69% on April 17.Average annual wind speed 4m/s. Highest wind speed in July reaching 11m/s. Monsoon winds from SW and winter winds from NE.

4.2.2.4 Visakhapatnam solar path

Sun path, sometimes also called day arc, refers to the daily and seasonal arc-like path that the Sun appears to follow across the sky as the Earth rotates and orbits the Sun. Sun path diagrams can tell you a lot about how the sun will impact your site and building throughout the year. The stereographic sun path diagram of Visakhapatnam can be used to read the solar azimuth and altitude for a location as shown in Fig 4.15.

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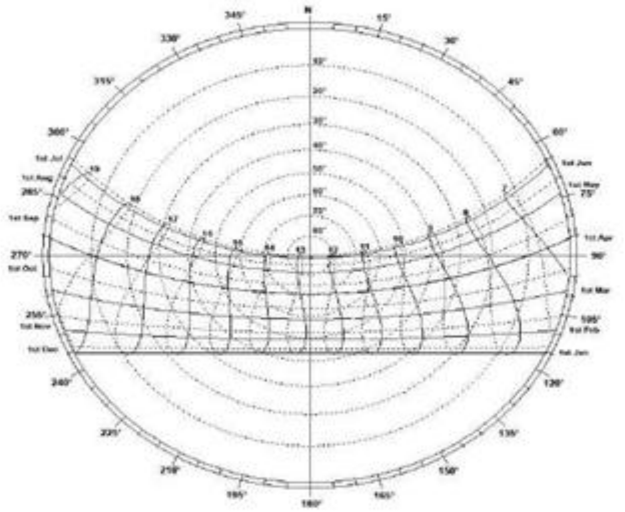

Figure 4.15: Visakhapatnam SolarPath Diagram (source: Researchgate.com)

Solar radiation

Solar radiation, often called the solar resource or just sunlight, is a general term for the electromagnetic radiation emitted bythe sun. Average daily Visakhapatnam radiation is 5.8kmh/m whereas annual radiation is 2100kmh/m. The diffusedradiation is 760kmh/m. There are is high number of sunshine hours approximately 3100hours.

Rain

Rain is water droplets that have condensed from atmospheric water vapour and then fall under gravity. Visakhapatnam collects an average of 955mm (37.6 in) of rainfall per year, or 79.6 mm (3.1 in) per month. On average there are 65 days per year with more than 0.1 mm (0.004 in) of rainfall (precipitation) or 5.4 days with a quantity ofrain, sleet, snow etc. per month. The driest weather is in December when an average of4mm (0.2 in) of rainfall (precipitation) occurs. The wettest weather is in October when an average of 179 mm (7 in) of rainfall (precipitation) occurs.

Indoor Air Quality

It is the quality of air quality of air inside the building and its near surrounding and is represented by the concentration of pollutants and comfort parameter like the thermal (temperature and relative humidity) conditions that affect the health and performance of the occupant. It is an important environmental health concern as people spend 60-90% of their life indoor environment like offices, schools, etc. Poor IAQ leads to sick building syndrome whererapid increase in the amount of pollutants result in defiled air leading to discomfort.

Positive Impacts of NaturalSunlight and Ventilation

Light and ventilation are one of the major components considered while designing a green infrastructure and determining the indoor air quality .Moreover, before the development of antibiotics, ventilation, natural sunlight and cleanliness were the three pillar of infection control and were considered key in preventing diseasesspreading in a building. Sunlight induces vitamin d production, stimulates the hormonal systems synchronizes the body biological rhythms. A lack of exposure to sunlight will lead to a gradual generation ofthe body.

Indian Green Building Council

It has seen an important issue to stimulate the reliance on green infrastructure. Encourage the reliance of a sustainable infrastructure and strategically gaining equilibrium between economy and sustainability are the prime agenda of ecologists drag construction companiestowards eco sensitive zone, Indian green building council has been established for the regulation of green building. Green buildings – are the structures that ensure efficient use of natural resources like building materials, water, energy and other resources with minimal generation on non- degradable waste promoting quality environment. The development of IGBCgreen homes rating system is another important step in this direction (IGBC, 2012).

Study Area

A 4-storey building nearly constructed as an innovation Centre located at Andhra University College of Engineering has been selected and studied. The building consists of homogenous floors. Each floor consists of a hall, toilets (ladies and gents), staircase space, and lift space. Different parameters like carpet area, number and area of windows, glass type used, type of ventilation, total openable area including doors, sunlight, etc. were studied. Mathematical calculations were done based on the ratios of openable area etc. to check the accessibility for the proper light and ventilation.

The present study was done as per the norms laid by the IGBC rating system. Thebuilding under study has ground +4 floors with a hall and a toilet on each floor. The glazing factor for light and the openable area for ventilation for each unit was calculated and compared to the rating system given by IGBC. All sides of the building have no construction in proximity. So far, hence the way for ventilation is not blocked. Likewise, the position of the building under study is such that the surrounding projects would not be blockingthe way of sunlight too. Moreover, the height of the surrounding building is way too less than the study area. For day lighting analysis calculations are as in the table 4.1

Table 4.1: Day Lighting Analysis of AU-HUB

Room	Floor area	Window area	Actual visible transmittance of glazing	Constant	Glazing factor
Hall	(34.02*11.96)- (4*5.67)=406.88- 22.68=384.2	19*(1.5*2.4)=68.4	0.89	0.24	3.169
Actual area	3.78*11.96=45.2	2*1.5*2.4=7.2	0.89	0.20	2.83

For ventilation analysis

For good ventilation, IGBC has provided minimum openable areas in percentages as 4% for washrooms, 10% for halls. The calculations have been done as shown in the table 4.2.

Table 4.2: Ventilation analysis for Hall

Room	Area	Natural ventilation for openable area	Actual openable area	Minimum openable area reassurement
Hall	384.2	47.7	12.2	10%
Washroom	4*5.67=22.68	2.68	11.8	4%

Thermal Analysis

The determination of the thermal properties of a building envelope is fundamental for the correct design of efficient energy condition. The main ways of heat transfer, conduction, radiation, and convection can be reduced through techniques and material selection. The insulating capacity of a wall depends on its global layout and on the characteristics of its single layers. The thermal properties of multilayer walls can be reduced from the declared date of heat transmission of the single layers given by the manufacturer.

The thermal transmittance ofopaque walls

Built opaque wall means a vertical structure at least 6 feet in height constructed of cedar, masonry, redwood, or pressure treated lumber resistant to rot , that is opaque when viewed from a 90 degree angle directly in front of and behind the wall.

Evaluation of thermal transmittance

Step 1: calculate the thermal resistance R of each uniform building material which constitutes the building units as shown below.

For the AU-HUB Building, using equation 3.5, calculate the thermal resistance

L= $300mm$ = 0.3 m.

K = $0.81 w/mk$

R = $0.300/0.81 = 0.37 w/mk$

Step 2: Find the total thermal resistanceusing equation 3.6.

Following values are taken;

Outside film coefficient at an air velocity of $8km/h$ $(f0) = 19.6 w/mk$ (constant)

Inside film coefficient at still air $(f1) = 9.36$ (constant)

Rt=$1/19.6 + 1/9.36 + 0.3/0.81$=0.05+0.107+0.37 =0.527

Step 3: Using equation 3.7, determine the Thermal transmittance (U)

$U = 1/R$ = 1/0.527 = 1.897 w/mk

Concrete parameter, thermal performance

The thermal performance of a pavement is defined as the change in its temperature (most often Surface temperature) over time or influenced by properties of paving materials (albedo, thermal emittance, thermal conductivity, specific heat and Surface Convection) and by the ambient environmental Conditions (sunlight, wind, air, temperature).

From the above explanation, it is deduced:

For Concrete Pavement Specific heat= $900 J/kg.k$

Thermal conductivity= 1.5 $w/m.k$

Emittance= 0.90 W/m

Albedo= 0.5

Thermal transmittance is the fundamental parameter to characterize the heat lesser of building envelopes. It is commonly measured in controlled laboratory conditions or estimated by means of numerical simulations starting from the values of thermal conductivity of the single layers constituting the opaque structure.

Sun Shading

The solar radiation is relatively intense in Visakhapatnam, especially in March to May. Excessive solar radiation brings about high temperature and people may feel stuffy and uncomfortable indoors. On summer, the daily average temperature raises up to 33 degrees. The solar radiation intensity of the four elevations during summer is shown in table 4.3 indicates elevation orientation and radiation intensity.

Elevation orientation Summer radiation intensity Judgment (necessity)

Table 4.3: Sun shading criteria

Elevation orientation	Summer radiation intensity	Judgment (necessity)
East elevation	Max<28	Sun shading not
	0	necessary
West elevation	Min>28	Sun shading
	0	necessary
South elevation	Max<28	Sun shading not
	0	necessary
North elevation	Min >	Sun shading
	280	necessary

Building Colours

External colours have very important effect on reflect or absorbent the sun radiation, which increase or decrease the heat gain through the wall. Black Painted enclosure in Visakhapatnam generally Show a temperature of 3°C higher than White Coloured enclosure during summer in Visakhapatnam daytime. Black Painted enclosure shows nearly 1.5 °C higher temperature than white coloured enclosure during winter in Visakhapatnam, day time. During night time, the different coloured enclosure shows nearly same temperatures in winter and summer. This is due to the fact that black colour is a good absorbent of radiant heat whereas white. Colour is a good reflector of radiant heat. The reflection and absorption capacity various gradually from white colour as the darkness increases and is extreme at black colour. The above relationship is shown in fig 4.1

Absorption-level of absorption reduces from black to white colour.

Reflection - level of reflection increases from black to white colour

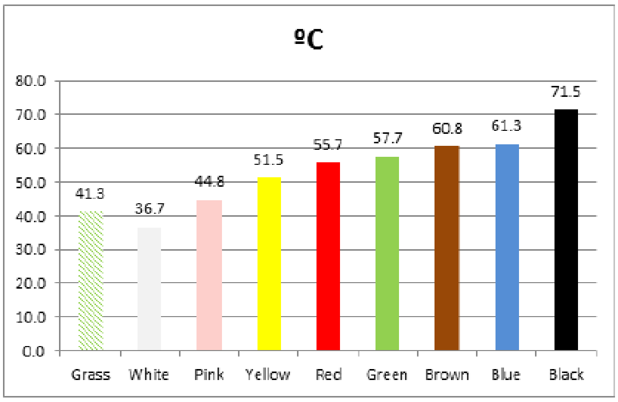

Figure 4.1: Colour against Temperature Absorption (Source: Oxford Croquet)

Wind and Orientation

Orientation is how a building is positioned in relation to the sun's paths in different seasons, as well as to prevailing wind patterns. In passive design, it is also about how living and sleeping areas are designed and positioned, either to take advantage of the sun and wind, or be protected from their effects. Wind has significant effects when it flows around buildings. Average annual wind speed in Visakhapatnam is 4m/s. Monsoon winds are from South west. Winter winds are from North West. Highest wind speed in July reach 11m/s. Wind direction is W and SW. The innovation building is oriented along East West and facing south.

Outside Compound

The area around the building is covered with concrete pavement in three directions of the building. Concrete reflects a lot of heat which will likely have effect on the temperatures of the building. Concrete pavements are widely used to carry heavy load and provide long-lasting solutions in highways, airports, and bridge decks. Cement concrete roads (hereinafter concrete roads) have a great advantage overasphalt pavement: durability, strength, and resistance to frost heaving of the road base.

Glass Works

The glass used in the building is mostly translucent glass and partially transparent glass. The north facade is covered withlarge portion of HPL glasswork. This type of glass also improves thermal comfort witha sense of openness for people working inside. This style of glass has a frosted appearance and is produced by sandblasting or acid-etching clear sheet glass. By creating a marked surface on one side of the pane, the light is scattered and diffused. The effect is that it blurs images while still allowing light to pass through.

Design Modifications

Recommendations on the possible buildingdesign and surrounding improvements on the building has been provided

Analysis of the building was done based onthe Indian Green Building Council recommendations. Various modification parameters have been suggested.

The study suggested the design modification in the built-up area, ventilation, thermal aspects etc. The details of each of the modification are presented below.

Modification in the Built-up Area

Vegetation is a flexible controller of solar and wind penetration in buildings. The vegetation will reduce direct sun from striking and heating up surface and will lower outside air temperature which in turnaffects the heat transfer from outside to building envelope and interior. The trees will start at a distance 5m from the north facing facade to allow daylight. Evergreen closely spaced trees for shading west facing walls will be used. Evergreen trees spaced at a distance 5m for shading east facing walls.

In the South, deciduous trees that can provide solar access during winter along with deep veranda on south side. A plantation should be made on the north sideto for funnelling wind to the building. Wellmaintained evergreen grass on all sides of the building to aide thermoregulation.

Day Lighting and Ventilation

Provide sliding 17 windows of sizes 253by 150 cm.
Total window area in this case can beillustrated as below;
$=243*17*150 = 619,650cm^2 = 61.965m^2$

To allow for free wind flow, sliding panes are used for opening day time. Clear glass will enhance day lighting in the hall. Sliding windows will usher in ample amount of natural light. The large windows will provide better overall lighting Conditions, Reducing reliance on natural lights.

Ventilators are provided on the staircasearea.

Heating

Although heat loss and heat gain can happen through any part of the building's envelope. The opposite of heat loss is heat gain, also referred to as solar gain. Heat gain occurs when warmth comes into the space via radiant heat as the sun shines through the glass. It's also a sign of a low Uvalue rating. Heating is to be controlled through the following mechanisms; Asouth-facing conservatory, for instance, in an uninhabited house may seeconsiderable solar heat gains on a daily basis, particularly in summer, but no heat gains from heating appliances and people. In contrast, a north-facing room in winter may receive very little solar heat gains but be warmed byconsiderable heat from central heating, lights and people. Thermal control regulates the temperature within a structure. Heating in a building is controlled through the following mechanisms:

Wall insulation

In this building, the thermal insulation part is of vital importance for cold and heat resistance. Thermal insulation should be distributed widely in the building and varieties of materials e.g. polymers and wood should be used for the insulation function. In this part, natural insulation materials and photochromic glass are specially reviewed because of their great potential for sustainability.

Double glazing

Double Glazing is two layers of glass with insulating gas trapped in between them. Not only does this act as a shield against cold weather, it means you use less heating, which in turn reduces your energy bills while helping the planet. Double glazed windows reduce carbon dioxide emission to up to 680kgs per year.

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Sun shading
Shading should be provided by natural landscaping or by building elements such as awnings, overhangs, and trellises. Shading devices will also function as reflectors, called light shelves, which bounce natural light for day lighting deep into building.

Colours

External facades
They are to be painted snow white. This will increase reflectance on the walls. For aesthetics, a cream-white lining is to be provided at the columnar linings.

Internal facades
Internal facades are to be painted purely snow white including the ceiling area. Painting interior walls white can also reduce energy costs during periods when the room is actively being cooled. Most of the light generated from a light fixture endsup as heat.

Green Roof
Green roofs also known as 'vegetated roofs' or 'living roofs' — are ballasted roofs consisting of a waterproofing membrane, growing medium (soil) and vegetation (plants) overlying a traditional roof. Well-designed, engineered and maintained green roofs provide multiple environmental, social, economic and aesthetic benefits.

Heat conductivity on concrete roof $= 1.5\ W/m.K$

For this building, length$=37.8 metres.$
$=1.5 * 37.8\ W.$
$=56.7W$

Green Pathway and Road
A green highway/road is a roadway constructed per a relatively new concept for roadway design that integrates transportation functionality and ecological sustainability. An environmental approach is used throughout the planning, design, and the construction. Green roads/highways are constructional systems of roadway projects, which include five main aspects, i.e., (1) ecosystem conservation, (2) storm watermanagement, (3) life-cycle energy and emission reduction, (4) recycled, reused,and renewable materials, and (5) overall societal management.

Power emittance saved on replacing concrete pavement with green road is as demonstrated below

Emittance$=0.90W/m2$ for concretepavement

Area of concrete pavement is as follows;
= (90*76) – (37.8*12.19) =6379.2W

The Emittance saved = 0.9*6379.2
=6425.28W =6.4 KW

Green Facades
Green facades are passive techniques and provide benefits in reducing the energy requirements of the building, but also enhance the aesthetic appearance of the building and any other structure. In the past decade, people are slowly beginning to realize the benefits of green architecture which is considered a new perspective for the urban heat island problem. Thus, these green solutions in buildings become an essential element and a rescue for regainingbalance in the urban environment.

Area = $(0.5 + 0.5 + 0.45) * 12) * 10$
$= 1.45 * 12 = 17.4 * 10 = 174m^2$

Saving on conductivity on placing green facades is as illustrated below;
$=1.5 * 37.8 = 56.7W = 5W$

Saving on emittance when a green façade is applied is explained below;
$=0.9 * 174 = 156.6W$

Sensor Based Lighting
A motion sensor light triggers a response when motion is detected. They can be installed indoors, on walls, ceilings, and in doorways, or outside, on the exterior of buildings and homes. Some kinds of motionsensor lights, called occupancy sensors, operate by turning off lights in unoccupied rooms and spaces.

Rooms where lights frequently get left on and forgotten should be fitted with sensor based lighting i.e. Washrooms, Staircase, Halls. CFL lights should be used instead of incandescent lamp since CFL uses a 1/5th as much electricity as an incandescent lamp.

Energy saved on replacing conventionallighting with sensor based lighting is asillustrated below;

A CFL light with $60w/hr\ per\ year$
$= (60 * 300 * 8 * 16 * 0.0065)$
= 13,824 Rupees saved on lightingannually

Material
Green building materials are composed of renewable, rather than non-renewable resources. Green materials are environmentally responsible because impacts are considered over the life of the product. This entails all materials for internal flooring, ceiling, furniture etc. as explained below;

Use linoleum tiles as material forfloor tiles
Linoleum flooring is made of a mix of renewable natural materials. While the actual composition will vary by manufacturer, it primarily contains a mixture of linseed oil, jute, cork powder, tree resin and wood floors. Unlike vinyl flooring, linoleum has the design embedded throughout the material instead of multiplelayers.

Mineral fibre ceilings
These ceiling tiles are made from recycled newspaper, perlite, fiberglass, mineral wool, and binding agents, making them a highly reliable sound-absorbing solution. Mineral wool insulation is non-combustibledoes not conduct heat and can resist temperatures above 1,000°C, making it an ideal fire-retardant product. It can sheath building supports and girders, be used as covering for ceilings as well as in fire- resistant doors and partition walls. They are 100% recyclable with the highest level of post-Consumer

recycled context.

Wood furniture
Wood is the most environmentally friendlyraw material. It's renewable. In fact, wood is the only building material made from sun, rain, and carbon from the air. It's infinitely replenish-able and renewable. The most sustainable furniture woods are black cherry, beech, maple, ash, eastern red cedar, mango, and bamboo. These woods are highly available thanks to large populations and wide natural ranges.

Aluminium doors and windows
Aluminium is one of the most environmentally-friendly metals, which is why it's often referred to as the 'green metal', due to the fact that aluminium is fully recyclable. When aluminium windows or doors reach the end of their life they canbe removed and recycled to be reused as either a new window or a multitude of uses. Aluminium doors and windows have a very low carbon footprint. They reduce carbon emissions with energy savings counteracting original energy.

Pervious/porous concretepavement in the parking area
Pervious concrete pavement is a unique andeffective means to address important environmental issues and support green, sustainable growth. By capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm water runoff, and meeting IGBC (Indian Green Building Council) storm water regulations. Impermeable pavement inhibits groundwater recharge, contributes to erosion and flooding, conveys pollution to local waters, and increases the complexity and expense of storm water treatment.

5. Summary and Conclusions

5.1 Summary

Green building is a holistic concept that starts with the understanding that the built environment can have profound effects, both positive and negative, on the natural environment, as well as the people who inhabit buildings every day. Green buildingis an effort to amplify the positive and mitigate the negative of these effects throughout the entire life cycle of abuilding.

Descriptions of green building generally focus on specified elements, which in various documents may also be referred to by other terms such as attributes, life-cycle parameters, performance areas, or impact categories.

The goals of a given green building project may vary depending on the needs of the stakeholders, including a building'sexpected occupants. As a result, different elements may be prioritized in differentprojects. Local factors such as climate zoneand flood risk may influence the design process in ways that affect the relative emphasis placed on the various elements discussed below.

Andhra University is located in Visakhapatnam city. The city is located on the eastern coast of India, which is particularly vulnerable to climate change induced extreme events like cyclones and storm surges. The city experiences differentseasons i.e. summer from April to June, Monsoon from July to September and winter from October to March. All this environmental and climatic conditions of the city have been put together to create a better environment for the residents with a good indoor air quality and sustainable in nature.

In order to develop a systematic process forbuilding analysis and modification, this research project has completed the following tasks:

1) Gather insight into the theory on green building construction and guidelines on the basis of a comprehensive study of the available IGBC guidelines as well as the available literature on green building from other sources, within and outside India and a review of principlesand theories related to passive design.
2) Adoption of systematic procedures– methodologies of analysis using techniques , procedures and formulae from various scholars and majorly centering the analysis on the proposed IGBC guidelines to lay ground for an accurate extensive estimation of materials , design parameters and spaceratios.
3) Implementation of the procedural work through the use of the identified formulae and principles of passive design, techniques, tools, and methods that have developed in the project work.
4) Demonstration of the process through data collection and analysis of the AU- HUB Building in Andhra University Visakhapatnam through site visit, photography and Engineering drawingsanalysis from the Engineers office, Andhra University, Visakhapatnam.
5) A discussion of results generated from the above process and on provision of design modification recommendations based on the available materials, techniques and technical knowhow while centering the approach on the IGBC guidelines on green building construction.

5.2 Conclusion

Passive design is an approach to building design that uses the building architecture to minimize energy consumption. The ultimate vision of passive design is to fully eliminate requirements for active mechanical systems (and associated fossil fuel-based energy consumption) and to maintain occupant comfort at all times. Using passive design, building form and thermal performance of building elements (including architectural, structural, envelope and passive mechanical) are carefully considered and optimized for interaction with the local microclimate. The present project work resulted in the following conclusions and recommendations about the specific green building approaches that will improve the overall energy performance of the AU- HUB building.

1) Carefully detailed and constructed high-performance insulation should be included in the envelope with minimal thermal bridging, including exterior walls and roofs.
2) Solar gain control should be enhanced using clear high-performance windows with a low-e coating in combination with operable external shading to block solar gains during summer and shoulder seasons and

admit solar gains during winter.

3) Window to wall area ratio should be limited to <50% for proper thermal performance. Sliding windows have been proposed to enhance wind circulation in the building whenever needed.
4) Cream white color should be applied inboth internal and external facades to prevent heat absorption while enhancing reflectivity.
5) Incorporate vegetation to reduce direct sun from striking and heating up surface as well as lower the outside air temperature which in turn affects the heat transfer from outside to building envelope and interior. The trees should give an allowance of 5m from the building all around its perimeter to allow for day lighting.
6) In order to reduce the need for artificial electric lighting and ventilation, the following features should be incorporated:
   - Space planning-sitting arrangement should be in clearly defined rows and columns with clear passages,
   - All internal finishes should be in bright white colours,
   - Light shelves,
   - Skylights and light tubes,
   - Clerestories in the circulation area
   - Window area to be increased – sliding windows of 8.5 by 5.5ft havebeen proposed
7) Insulated facades with operable shading elements and operable windows to act as thermal buffer spaces, preheat ventilation air in the winter, and block solar gains and provide natural ventilation in the summer.
8) Building shape and massing that enhances natural ventilation and day lighting should be implemented. This ideally should entail central atria and ventilation towers.
9) Thermal mass should be provided on the interior side of the insulation, located in the floors, external walls, and walls between adjoining units i.e., party walls.
10) Enhance passive cooling strategies, such as nocturnal ventilation to pre-cool spaces during summer and ventilation air intakes located in cool areas and delivered to the building using earth tubes.
11) Ensure an air- and moisture-tight envelope to prevent heat losses and gains
12) Reduce the heat island problem by incorporating a green roof. This will greatly save on conductivity and emittance (56.7W of hourly conductance will be prevented) whilst improving the building aesthetic characteristics.
13) Provide green facades to reduce heat absorption and emittance while also improving aesthetics. Up to 156.6W of hourly emittance will be prevented.
14) Provide a green pathway to reduce heat emittance, solar reflection while minimizing storm water flow. Up to 6.4 KW of hourly emittance will be prevented.
15) Fit sensor based lighting for rooms where lights frequently get left on and forgotten i.e. Washrooms, Staircase, Halls. This would save on the cost of energy. This would save on the cost of energy i.e. up to 13,824 Rupees will besaved on lighting annually.
16) CFL lights should be used instead of incandescent lamp since CFL uses a 1/5th as much electricity as an incandescent lamp.

The following improvements on material have also been suggested

1) Reduce peak storm water flow and water pollution as well as promote groundwater recharge by incorporatingporous concrete on the parking space.
2) Use aluminum material for windows and doors since it's recyclable, reusableand has a low carbon footprint. This will reduce carbon emissions withenergy savings counteracting originalenergy.
3) Use Mineral fiber for ceilings since it is an excellent fire-retardant product. Mineral fiber should also be used to sheath building supports and girders and also as covering for fire-resistant doors and partition walls.
4) The furniture used in the building should be majorly wooden since wood is replenish-able and renewable.
5) Use linoleum flooring which is incredibly versatile and long-lasting forevery room in the building except the toilets. Use wooden tiles for toilets. Linoleum material does not emit harmful by products, is a volatile organic Compound and is easy to maintain.

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