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Retrofitting of Academic Building by Energy Efficient Techniques

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Abstract - *A building or office which includes unique construction methods for maximizing the efficiency with which buildings and their sites use resources like energy water and materials while minimizing energy waste, ensuring human health, safety and comfort throughout the building lifecycle without requiring special materials or construction skills. This paper aims to illustrate –*

- *To attain modification in building which use the nonrenewable natural resources to minimal during operation.*
- *A commercially practical energy efficient building with cost effective design and materials.*
- *To maximize the use of efficient construction materials and practices and minimize the energy use to run itself.*
- *To boost the use of natural resources and sinks in building's surroundings, reduce and ultimately eliminate the impacts of buildings on environment and human health, making it eco-friendly.*

In present paper we tried and proved that the retrofitting and slight modification in an existing or a new structure by low energy materials and energy efficient techniques can cut the overall energy consumption by 25% to 30% as per literature studies available during 50years of lifecycle of the building.

Keywords: earth air heat exchanger (EAHE), energy efficiency, green buildings, solar chimney, solar rooms

1. INTRODUCTION

We define green building as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction.

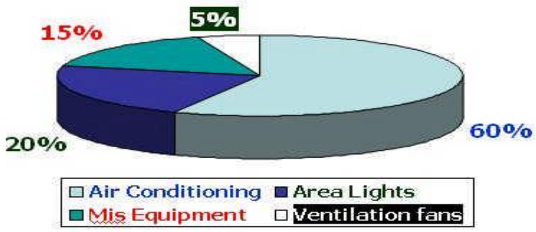

Fig-1: Typical break-up of energy consumption in an academic building using conventional electronic devices

Such building requires careful planning, training and quality control during construction:

- The potential for energy saving is 40% to 50% in buildings.
- For existing structures, the potential can be as high as 20-25% which can be accomplished by implementing housekeeping and retrofitting measures.
- The incremental cost acquired for accomplishing energy efficiency is 5-8%.

2. LITERATURE REVIEW

Traditional buildings were energy efficient because architecture depended on the places. Buildings in the hot and dry regions, had corridors directing the wind to cool naturally. In wet regions, structures using natural light and breeze were used. Some examples are HawaMahal - Articulated windows provides cool breeze in a desert area, Golconda Fort, Hyderabad - Ventilation is designed to let in fresh cool breeze, in spite of summer.

The Indira Paryavaran Bhavan is India's first net zero energy building that has been constructed with adoption of solar passive design and energy-efficient building materials. Total energy savings of about 40 per cent have been achieved through the adoption of energy efficient chilled beam system of air-conditioning. As per this, air-conditioning is done by convection currents rather than airflow through air handling units, and chilled water is circulated right up to the diffuser points unlike the conventional systems. Green materials like fly ash bricks, regional building materials, materials with high recyclable content, high reflectance terrace tiles and rock wool insulation of outer walls have been used. Use of renewable bamboo jute composite material for doorframes and shutters, Calcium Silicate ceiling tiles with high recyclable content and grass paver blocks on pavements and roads. Reduction in water consumption has been achieved by use of low-discharge water fixtures, recycling of waste water through sewage treatment plant, use of plants with low water demand in landscaping, use of geothermal cooling for HVAC system, rainwater harvesting and use of curing compounds during construction. Some more examples of energy efficient buildings in India with their key technologies are listed below:

(i)Turbo energy limited, Chennai (Key: Solar air-conditioning)

(ii)TCS Technopark and Grundfos Pumps, Chennai (Key: Thermal storage)
(iii)Infosys,Pocharam campus (Key: Radiant cooling)
(iv)Hotel Leela Palace, New Delhi (Key: Green and solar reflectance index roof)
(v) RMZ Millenia Business Park, Chennai (Key: Lighting Controls – Daylight sensors, Occulux Sensors)
(vi) ITC Royal Gardenia, Bangalore (Key: High Performance Envelope)
(vii) Suzlon One earth, Pune (Key: Wind hybrid solar charger)

3. ENERGY EFFICIENT TECHNIQUES FOR GREEN BUILDING

Energy Saving Approach in Buildings:

I. Orientation of building
II. Earth air heat exchanger
III. Solar Chimney
IV. Trombe wall
V. Solar water heating system
VI. Sun spaces on south side of building
VII. Green Roof
VIII. Miscellaneous techniques

I. Orientation:

This is the initial step to achieve energy efficiency.

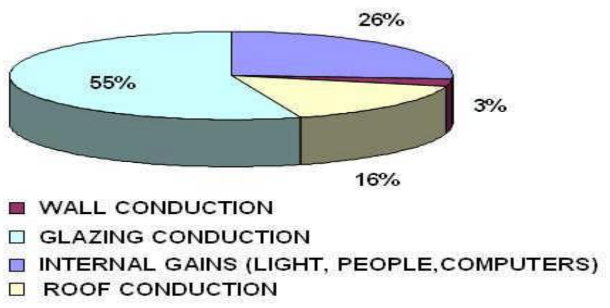

Fig-2: Typical breakup of heat gain in an academic building

The following measures can be considered:

a. Select high performance glazing with low U-valve, low Shading Coefficient and high VLT (Visual Light Transmittance).
b. Using insulating material for the wall like – Extruded polystyrene, Expanded polystyrene (thermocol), Glass wool etc.
c. Brick wall with air cavity can also considerably decrease the heat entrance.
d. Hollow blocks, Fly ash bricks and Autoclaved Aerated Concrete (AAC) Blocks can be mainly used as insulators.
e. Consider shading devices for window openings.

II. Earth air heat exchanger:

The temperature inside the earth at 4m depth remains nearly constant (about 26°C to 30°C) throughout the year, which is transferred to building using pipes which are embedded in the form of tunnel at 4m depth below ground level. Most systems are generally built from 100 to 600 mm (4 to 24 inch) diameter, smooth-walled, rigid or semi-rigid plastic, plastic-coated metal pipes or plastic pipes coated with inner antimicrobial layers. Larger diameter tubes can be used replacing thin tubes yielding high volume & energy transfer rate. To draw filtered passive cooling air, in larger diameter tube, solar chimney can use natural convection to create vacuum. For less turbulent flow, two 45 degree bends can be used in spite of having one 90 degree, having smooth walls. For having heating or cooling effects earth's geothermal system can be used.

The usage of EAT[Earth Air Tunnel] or earth to air heat exchanger, not only reduce quantity of bacteria and fungi, air pollution, also facilitate safer air for inhale providing proper cleaning facilities. An alternative to the earth-to-air heat exchanger is the "water" to earth heat exchanger similar to a geothermal heat pump tubing embedded horizontally in the soil (or could be a vertical) to a similar depth of the earth-air heat exchanger.

III. Solar Chimney:

An easiest way of improving the natural ventilation of building is using convection of air heated passively by solar chimney. The solar chimney height 10m and diameter 0.4572m (18") connected with solar collector size 2x2x2m^{3}resting on a concrete pedestal foundation of diameter 1 meter at top and 2 meter at bottom. Circular rings are provided at different levels to facilitate the tying of Guy strings for holding Solar Chimney in vertical positions. The 57m long EAT of diameter 0.4572m as a combined unit is included in the system to draw cool air from the cooling tube in summer season and provide heat by hot air in winter season, providing cooling tube in two horizontal rows of 27 m each with Tees and Vents.

For automatic operation of Air Blower, the above two techniques are installed in a facility of size 20x5 m having outlet of the cooling tube added with air blower 0.5 hp and thermostat device. The Air Blower is separated from the room by separation wall to insulate the room with the heat of the Air Blower during running condition. The Solar collector size 2x2x2 meter is provided between facility and solar Chimney with connecting pipes made of plywood and glass having inlet end of the cooling tube or tunnel terminating at the fresh air intake chamber above the ground with intake grills in all four sides with RCC cover at the top.

Working principle- The reduction of density of warm air than ambient air occurs due to incidence of solar radiation

on solar chimney, facilitating rise in temperature. This reduced density creates buoyant forces to move air upwards through the top suctioned within the room so that air is circulated inside the room through cooling tube. Since earth temperature at 4m depth is constant at about 26°C, the air drawn through cooling tube have a low temperature than the room temperature and feels cool in the summer season & contrary in winter season, feels hot.
Air Blower (attached with thermostat) overcome the incapability of solar chimney at night hours receiving no radiation, drawing cool air automatically throughout night hours, using external supply. Both in summer & winter thermostat has to be readjusted accordingly.

The maximum temperature difference between room and ambient is observed as 4°C.

Advantages of system-

(i) Reduction in pollution as A.C. system do producing toxic gases.
(ii) Energy efficient as less dependency on external power saving natural resources.
(iii) Reduction in harmful bacteria production, facilitating more air flow inside facility.

IV. Trombe Wall:

A Trombe wall consists of a thick wall (150mm to 300mm) faced with a selective surface solar absorber, air gap, and high transmissivity glass pane. It is used above the wall to decrease the exposure when sun is high in summer and no heat required contrary to winter when more heat is required.

V. Solar water heating system:

A small drain back reservoir is installed in the collector loop. When this system is filled with water it is only filled to the top of reservoir. Since it is located below the collectors, they remain dry when the pump is not circulating. When the collectors are hotter than the water in storage, the pump circulates the water in the reservoir through the collectors where it is heated. The heat from this water is then transferred to the solar storage tank through a heat exchanger located either in the storage tank or drain back reservoir. When the collectors approach the same temperature as the water in the storage tank or this water has reached a preset temperature, the pump shuts off and all the water drains back the reservoir. The drain back system eliminates all the problems inherent in the other types of systems.

VI. Sun spaces on south wall or Solar Rooms:

The glaze and insulation facilitates solar green houses to augment and mitigate solar gain and heat loss respectively, having south facing wall, solar roof glazed and east, west facing wall insulated if at least two layers of glass or plastic are used instead of one. Use of Teflon should be provided as protective layer and for high incidence of sun light as each additional layer blocks it providing each layer must be sealed tightly to prevent structural damage from possible moisture condensation between glazing panels.

VII. Green Roof:

It is partially or completely covered with vegetation or soil or both, helps retaining rain water, reduce heating effect both inside and surroundings, increase the lifespan of a roof, increase green space, improve aesthetic environment, adsorb traffic and other common outdoor noises and provide inhabitant for airborne species. It effectively lowers the energy about 30% or more required for cooling the home which is major contribution in energy saving by slight modification using highly reflective type of paint, a sheet covering or highly reflective white glazed tiles or shingles.

VIII. Miscellaneous Techniques:

· Air lock lobby at the entrance (to minimize heat loss during entrance and exit).
· Solar heat collector Wall (glazed wall provided in the front of the building).
· Wall insulation by Polyurethane board (insulation against sun heat through outer wall).
· Sun shading by vegetation (to provide direct entry of sun rays into the building through doors and windows).
· Fountain court with water columns (to cool the inner atmosphere of the building).
· Earth Berming (technique for reduction of heat from sun's radiation).
· White reflecting colour on walls (reflect and reject sun radiation).
· Day light with skylights (roof is provided with glazed panels to allow sunlight in day hours).
· Fenestration and shading (proper design of windows and ventilators in the rooms).
· Energy efficient lighting systems like Light Emitting Diodes (LEDs).
· Reduction of heat gain by air cavity in walls and roofs (hollow air spaces within walls as an attic space, in the roof ceiling).
· Hybrid system with upto 50KW bio mass gasifier (utilizes waste organic materials converted into gas).
· Hollow concrete blocks to reduce heat gain (provide thermal insulation against outside sunheat).
· Adjustable venetian blinds (to cutoff insulation and allow daylight).

Above techniques can be suited according to building environment and geographical location.

4. EXAMPLE

On implementation of energy saving techniques in an institutional building in order to draw more energy saving from an existing conventional building we made following modification:

i. White glazed tiles on roof
ii. Double Pane Windows
iii. Energy efficient electrical equipments
iv. Solar Panels
Thus, by retrofitting of institutional building with above technologies, we made following calculation by audit and observation:

(i) Calculation for white glaze tiles:

Area of roof $=6022970 \times 10^3$ mm^2
Cost of tiles per 600 × 600mm = Rs.38/-
Number of tiles required
$= (6022970 \times 10^3) \div (600 \times 600) = 163730$ tiles
Total cost of tiles = No. of tiles × Cost of one tile
$=16730 \times 38 =$ Rs.635740

(ii) Calculation for double Pane Windows:

Total number of windows = 516
Area of each window $=6 \times 4$ ft^2 = 24 ft^2
Cost of per sq. foot = Rs.250/-
Total cost = number of window × area of each window × cost of window per feet^2
$= 516 \times 24 \times 250$
Total cost = Rs.30, 96,000/-

(iii) Calculation for replacement of electrical equipments:

As per the audit and the data gathered from civil store (in academic building) we can obtain table I which is shown below In table I, majorly four basic electrical equipments are taken which are Electric fans, Tube lights, A.C. and Computers that are to be replaced by energy saving electronic devices which are readily available under subsidy schemes run by government of India.

Table -1: Shows the electrical equipments that are currently in use

Equipments	Quantity	Power (Each) (W)	Energy used per year (KWh)
Electric Fans	991	100	138740
Tube lights	520	40	29120
A.C.	98	3504	480748
Computers	652	250	228200

After summation of energy used per year (duration 200 days, 7 hours per day) we get total energy consumption, which is used for comparison to get its payback period. The total energy consumed by these equipments is 876808KWh.

Table -2: Represents the energy saving equipments

Equipments	Quantity	Power (Each) (W)	Energy used per year (KWh)
Electric Fans	991	30	41622
LED bulbs	520	9	6552
A.C.	98	230	59332
Computers	652	65	31556

The total energy consumed by these equipments which is obtained after summation from Table 2 is 1,39,062 KWh.

Table 3: Represents the capital cost of energy saving equipment's

Equipment's	Quantity	Cost of each	Total cost (in rupees)
Electric Fans	991	1000	991000
Tube lights	520	60	31200
A.C.	98	35000	3430000
Computers	652	15000	9780000

So, total cost in replacing of equipment is found to be Rs.1,42,32,000/-

(iv) Calculation for Solar Panels:

The energy produced by solar panel is given by
$$E = A \times r \times H \times PR$$
where, A = Area of panels (m^2)
E = Energy Produced (kWh)
r = Efficiency of panel (15-20 %)
H = Average annual solar radiation (KWh/day)
PR = Coefficient of losses (usually 0.75)

Now, for calculations, we take 80 %of the total roof area i.e. $6022.97 \times (80 \div 100) = 4818.37$ m^2
Efficient is average of 15-20% i.e. 17.50%
$E = 4818.37 \times (175.50 \div 100) \times 5.28 \times 200$
E = 667826.082KWh

As we required 139062 kWh annually, so to reduce capital cost we can reduce the area taking 139062 ≈ 1, 40,000.
Thus, $1,40,000 = A \times (17.50 \div 100) \times 0.75 \times 5.28 \times 200$
$A=757.57$m$^2 \approx A=760$
Hence we can install solar cells at an area of 757.57m^2 to fulfill our demand.

The capital cost for installation of solar panel is:
Per unit cost = Rs.40

Total unit to be consumed =1, 40,000
Total cost will be = 1, 40,000 × 40 = 56, 00,000
Hence Rs.56,00,000 is required for solar panels.
NOTE: Working hours are taken as 7hrs (10am-5pm)
Working days are taken as 200 days (Academic calendar based)

All equipment's cost is taken from various shops and contacts (including tiles, windowpane etc.)

5. RESULT

As per one audit 1 unit of electricity cost Rs.17-18 including electricity and diesel cost.
At present we have 876808 units electricity consumption.
Cost of 876808 units = 876808×7.50 = Rs.1,53,44,140/-
If we are not using present conventional equipment and present electricity system, we can save Rs.1,53,44,140/-

Table 4: Total cost of retrofitting of alternatives

Technologies	Amount (in Rupees)
Tiles	6,35,740
Windows	30,96,000
Replacement of equipment	1,42,32,200
Solar panels	56,00,000
Total	2,35,63,940

Savings per year by retrofitting = 1,53,44,140 INR
Hence, to compensate amount of 2,35,63,940 INR, it will take approximately 19 months.

6. CONCLUSIONS AND FUTURE SCOPE OF WORK

Retrofitting and slight modification in an existing or a new structure by energy efficient techniques can boost the use of natural resources and ultimately making it eco-friendly and energy saving throughout the life cycle.

Future work can be done for similar other energy efficient techniques for cooling, heating, ventilating, air conditioner and insulation the buildings to develop more other energy efficient systems to prove cost effectiveness of these techniques in comparison to conventional methods, so that adoptability of energy efficient system in building can be increased to made them acceptable for public, thereby goal of energy saving can be achieved.

The air blower which is used in the combined system of solar chimney and earth air heat exchanger to draw cool air during the night hours and in day hours as per the requirements, is operated by external source of energy can also be operated by the photovoltaic solar panels. At present, the P.V. system have very high initial cost (about Rs.170 per watt) so air blower cannot be feasible to operate through PV system. But with the continuous reduction of the cost of PV every year, it can be provided in future. Also, solar panels, PV cells and energy saving appliances will become cheaper in future under various subsidy schemes run and planned by government of India.

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