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Planning of Eco Friendly Residential G+4 Building for Indore City

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ABSTRACT: Rapid increase in urbanization has resulted in exhaustive utilization of natural resources affecting the environment. Booming construction sector worldwide has been one of major sector deriving its requirement from natural resources. Concepts such as green buildings in construction sector has been promoted as a suitable option for curtailing the resource demand optimizing the use of natural resources. Green building refers to a structure adopting environmentally sound practices enhancing resource efficiency throughout the life cycle of building. Green buildings are the need of the hour as conventional building consume nearly 50% of world total energy directly or indirectly. Green building, employing processes such as resource efficiency during the planning, construction a land operational phases leading reduction of its environment impact in its life cycle. Green building provide the benefit of saving 40-50% energy by reducing CO_2 emissions into the atmosphere it also saves 20-30% water by using rain water harvesting. The present work discusses about the planning of eco friendly building incorporating features such as rain water harvesting, earth air tunneling and utilization of solar energy through photo voltaic modules in the Indore City. Theoretical estimates predict that eco friendly G+4 building reduces energy utilization, water use, leading to reduce CO_2 emission and also optimized heating, ventilation and air conditioning during its operational phase enhancing environmental, economic and social benefits.

I. INTRODUCTION

Green buildings are structures incorporating green features promoting environmentally responsible and resource efficient approach throughout the structure's lifecycle; starting with site selection to design, construction, operation, maintenance, renovation and demolition. The green building concept takes into consideration the practices that would enhance the living standards of the occupants in an environment-friendly atmosphere with minimum harm to the environment. Basically, a green construction or sustainable building uses an optimum amount of energy, consumes less water, conserves natural resources, generates less waste and creates spaces for healthy and comfortable living [5].

A. Objective of Green Building

There are five fundamental principles of green building are Sustainable Site Design, Water Quality and Conservation, Energy and Environment, Indoor Environmental Quality, Materials and Resources.

B. Life Cycle Assessment (LCA)

Life cycle assessment is a method to gather, analyse, valuate and document comprehensive information on buildings and constructions. Life cycle assessment is a tool to systematically evaluate the environmental impacts and aspects of a product, a service, a production system or a service system through all stages of its life cycle [14].

Major stages in building life cycle are product stage, construction stage, use stage, end of life stage. Environmental burdens associated with each phase are numerous, pproduct stage includes manufacturing and transportation of building materials, the construction phase utilizes energy for detailed summation of materials for the construction. The usage phase involves impacts mainly due to cooling, heating and ventilation systems it compasses all activities related to the use of building, over its life span. These activities include maintaining comfort condition inside the buildings, water use and powering appliances.

Demolition phase includes destruction of the building and transportation of dismantled materials to land fill sites and recycling plants [13, 15].

C. Environmental Issues in Conventional Constructions

The design and construction of buildings has a significant impact on the environment and the economy. Study estimates predict that ttraditional construction is responsible for 45% of the world's total energy use, 50% of all materials and resources, 35% of the world's CO_2 emissions, 80% of potable water use, 25% of freshwater withdrawal (including power plants), 40% of municipal solid waste destined for local landfills, 50% of ozone-depleting CFCs still in use, 45% of the world's total energy use, 50% of all materials and resources, 35% of the world's CO_2 emissions, 80% of potable water use, 25% of freshwater withdrawal (including power plants), 40% of municipal solid waste destined for local landfills, 50% of ozone-depleting CFCs are still in use. Structures also affect watersheds, habitat, air quality, and community transportation patterns [17].

D. Study Area

Indore has been considered asproposed location for the planning of G+4 eco friendly building. City has been rapidly growing both in terms of population and infrastructural needs. The work proposes planning of building incorporating green features such as earth air tunneling, utilization of renewable energy and rainwater harvesting; focus has been for effective space management from planning stage itself optimizing occupant comfort during utilization phase. The work also discusses the relative benefits that can be derived during the utilization phase in comparison to conventional construction. The building was planned in a total area of 2080 m^2, the number of flats per floor is 4 (20 in total) for population of 80 (assuming the family size as four).

Objective of Project

To study the existing norms and standards for selection and planning an eco friendly building, to finalize the feasible eco friendly options for planning and designing the G+4 building and Comparison of benefits between conventional building and eco friendly building in terms of energy consumption and water requirement during operational phase.

II. MATERIAL AND METHODS

A. Earth Air Tunnelling

This technique is used for both passive cooling as well as heating of building, a feat utilizing the earth acting as a medium for massive heat sink. The temperature of the earth's surface is controlled by the ambient conditions. However, the daily as well as seasonal variations of the temperature reduce rapidly with increasing depth from the earth's surface. At depth beyond 4 to 5m, both daily and seasonal fluctuations die out and soil temperature remains almost stable to the year. It is equal to the annual average ambient air temperature at the place. The temperature of the soil at depth beyond 4 to 5m can however be modified by suitable treatment of the earth's surface.

B. Working and Principle

The earth-air pipe system consists of a pipe of appropriate dimensions buried at a depth of about 4 to 5m in the ground. Ambient air is blown through it by a blower at one end of the pipe. The other end is connected to the building to which it supplies conditioned air. The temperature at a depth of about 4 to 5m is very stable and is equal to the annual average ambient temperature. It remains unaffected even if heat is withdrawn from or supplied to the ground, due to its large thermal capacity. The earth air pipe system takes advantages of this fact. Ambient air flowing through the pipe gets cooled (in summer) or heated up (in winter) before entering the living space of a building. If the pipe is of adequate length (for a given air flow rate), the desired heating or cooling effect can be realized. To meet the thermal load requirement of the building, one may use more than one pipe buried at the same depth a few meter apart. However, it is possible for the relative humidity of the air from the earth air pipe system to be higher than the ambient humidity, depending on the soil conditions. If the air fed to living spaces is not reused, the system is called single passed system. The earth air pipe system can also be used in the re-circulation mode. In that case air from the living space is re-circulated through earth air pipe and is supplied back to the living space.

C. Procedure

In Earth Air Tunnelling we have to calculate the temperature and the diameter and length pipe.

The temperature T_{AL}at the end of a pipe of length L can be calculated by the following formulae -

$T_{AL} = T_{EO} + (T_{AO}-T_{EO})\, e^{(-L/L_P)}$

Where,

$L_P = m_a C_{PA} R_{th}$; $m_a = \pi R^2_{ip} v_A \rho_A$

$R_{th} = 1/2\pi R_{ip} h_i + \ln(R_{op}/R_{ip})/2\pi k_p + \ln[Z/R_{op} + \sqrt{(Z/R_{op})2-1}]/2\pi k_g$

$T_{EO} = T_{EM} + (T_{Emax} - T_{EM})\, e^{(-Z/\xi)} \cos(2\pi t/t_y - Z/\xi)$

$T_{AO} = T_{EM} + (T_{Amax} - T_{AM}) \cos(2\pi t`/t_h)$

$\xi = \sqrt{t_y k_g / \pi \rho_g C_{pg}}$

C_{PA} = Specific heat of air (J/kg-K)

C_{pg} = Specific heat of soil (J/kg-K)

h_i = connective heat transfer coefficient for the inner surface of the pipe to air (W/m^2-K)

k_g = Thermal conductivity of the soil (W/m-K)

R_{ip} = Pipe inner radius (m)

R_{op} = Pipe outer radius (m)

t = time (zero on the day when T_{Emax}occurs) (s)

t` = time (measured from the time one maximum temperature of the day occur) (s)
t_h = duration of the day (86400 s)
t_y = time duration of a year in seconds (365*24*3600s = 31.5*106s)
T_{EM} = annual mean ambient air temperature (^oC)
T_{Emax} = maximum of the daily mean temperature of the year (^oC)
T_{AM} = daily mean ambient air temperature (^oC)
T_{Amax} = maximum temperature of the day (^oC)
v_A = air flow velocity (m/s)
Z = pipe length (m)
ρ_g = density of the soil (kg/m3)
ρ_A =air density (kg/m3)

Rain Water Harvesting (12). Water harvesting is the collection of runoff for productive purposes. Instead of runoff being left to cause erosion, it is harvested and utilized. In the semiarid drought prone areas where it is already practiced, water harvesting is a directly productive form of soil and water conservation. Both yields and reliability of production can be significantly improved with this method.

Rain Water Harvesting Code and Its Components. The IS code use for a rainwater harvesting is IS 15795. The scope of this standard lays down guidelines for roof rainwater harvesting. Roof top rainwater collection is one of the solutions for solving or reducing the problem of water availability, where there is inadequate ground water supply and surface sources are either lacking or insignificant.

Rainwater harvesting have the following basic components

- Catchment
- Gutters
- Downtake pipe
- Filters and first flush devices
- Storage tanks
- Delivery systems
- Pumps

Procedure. The rational method is used for calculating the rainfall water collected. The Rational equation is the simplest method to determine peak discharge from drainage basin runoff.

The rational method equation is as follows

$Q=ciA$

Where,
Q = Peak discharge
c = Rational method runoff coefficient (ranges between 0.75 - 0.95)
i = Rainfall intensity
A = Drainage area

The Rational method runoff coefficient is a function of the soil type and drainage basin slope.

Solar Energy. Solar energy is radiant light and heat from the sun harnessed using a range of ever evolving technologies such as solar heating, photovoltaic, solar architecture. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar and active solar depending on the way they capture and distribute solar energy or convert it into solar power.

Photovoltaic Module. A photovoltaic (in short PV) module is a packaged, connected assembly of typically 6×10 solar cells. Solar Photovoltaic panels constitute the solar array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications.

Photovoltaic or PV module can be manufactured from a variety of different materials. The most common material for solar panel construction is crystalline silicon which has semiconducting properties. There are four main types of solar panels –

1) Monocrystalline Silicon solar PV module.
2) Polycrystalline Silicon PV module.
3) Thick film silicon PV module.
4) Thin-Film Solar. (19, 20)

Data Collection. The different climatic factors for the Indore city are -

Climatic Factors	Corresponding Data
Temperature	$17^o – 36^o$
Rainfall	Average Rainfall – 945mm
Wind Direction	WNW
Wind Speed	6-12
Relative Humidity	Max-85 Min-26
Latitude	22°42'N
Longitude	75°47'E

The annual average temperature in Indore, Madhya Pradesh, India is fairly hot at 25 degrees Celsius (77 degrees Fahrenheit). Mean monthly temperatures have a variation of 14.2 °C (25.6°F) which is a low range. There is a range/ variation of diurnal average temperatures of 14 °C (25.2 °F).The warmest month (May) is very, very hot with a mean temperature of 32.4 degrees Celsius (90.32 degrees Fahrenheit).January is the coldest month (somewhat warm) with a mean temperature of 18.2 degrees Celsius (64.76 degrees Fahrenheit).(9)(19)

Planning (17). In the planning of green building site selection occupy an important position site condition such as land form vegetation water bodies etc play an important role in selecting a site. Proper analysis of these condition can enable one to choose a site and make suitable design plan.

Orientation. The orientation of building depends upon the sun path as it effects of the sun location of windows and also effect the solar radiation receives. The south facing windows in the northern hemisphere have the greatest exposure to the sun west facing windows need to be carefully designed as the low angle of setting sun can cause over heating.

Foundation, Walls and Roofs. While designing a green building it is important to the determine how much energy is required for heating and cooling system. The challenge in designing in foundation, walls and roof is to minimize conductive heat loss/gain while minimize uncontrolled moment air into the building.

HVAC (Heating, Ventilation, Air Conditioning). To reduce heat load of the building it is necessary to install a small heating and cooling system.

Lighting. US Department of the energy research found that lighting and appliances consumed approx 14% of energy used in the residence. Occupants want living/working spaces that a bright and inviting. The building should be designed such a way that it can make use of natural day light in living of working spaces.

III. RESULTS AND DISCUSSIONS

A. Rain Water Harvesting

The following are the results obtained on calculations based on rational method -

Water collected from roof = 360.83m^3

Water collected from roads = 12.735m^3

Water collected from garden = 4.245m^3

Assuming an average water demand as 150 lpcd for population of 80

Average daily demand = 150*80 = 12 m^3/day

Maximum daily demand = 1.8* Average daily demand = 21.6 m^3/day

Maximum Hourly Runoff -

Q = CIA/360

Intensity(I) = 25mm/hr (assumed considering the peak rainfall events)

So, Q = .85*25*.046/360 = 9.775 m^3/hr

Assuming a depth of 2m, size of water tank = 2.21m*2.21m*2m

Water utilization period -

Average number of days rain occurred = Average rainfall / Rainfall = 922.84 / 25 = 37 hrs

Number of days water harvested can be used = Average runoff in a season / Average daily demand = 9.775*37 /12 = 30.13 days.

During the operational phases of rainwater harvesting system components such as pumps and rapid sand filter are needed for continuous utility in the same building.

Earth Air Tunnelling – Assuming the values of the parameters that are used in the design of Earth Air Tunnel according to the mnre.gov.in in the code of practice 3.

On calculating, we get

IN SUMMER	IN WINTER
T_{AO} = 40.91 °C	T_{AO} = 26.08 °C
ξ = 2.586	ξ = 2.586
T_{EO} = 26.48 °C	T_{EO} = 23.5 °C
R_{TH} = .346	R_{TH} = .346
L_P = 42.9	L_P = 42.9
m_a = .124	m_a = .124
T_{AL} = 30.98 °C	T_{AL} = 24.3 °

We obtain concrete pipe with following dimensions

Internal Radius = .150 m

External Radius = .160 m

The benefits of the system during operational phases was shown in figure below:

The hourly cooling potential Q_c(in kWh), and heating potential Q_h(in kWh) can be calculated from the relations

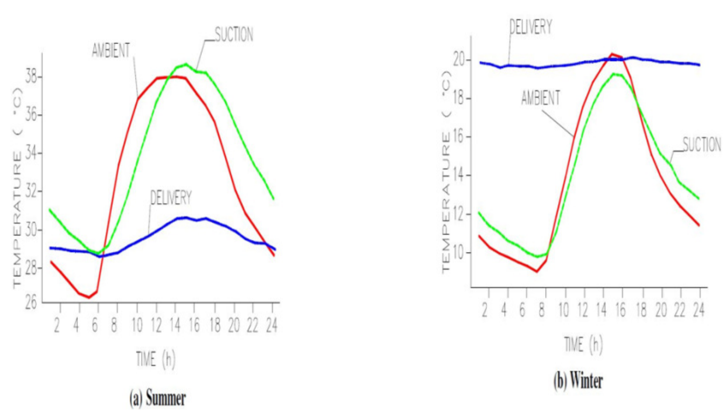
$Qc = m_A C_{PA} (T_{AO} - T_{AL})$

$Q_h = m_A C_{PA} (T_{AL} - T_{AO})$

On calculating,

Qc = 1.23 kWh

Qh = .22 kWh



It is seen that in summer, the exit or delivery temperature is about 30.98°C when outside can be as high as 43°C. In winters, the delivery temperature is maintained at about 24.3°C, when outside air is about 6°C – an increase in temperature by about 18°C. Thus, the earth-air pipe system performs well both in summers as well as in winters. The system provides an average daily cooling potential of 242 kWh (thermal) in a summer month and about 365 kWh in a winter month. As the blower's power is 3 hp (2.2 kW), the coefficient of performance (COP) of the system is 4.5 in summer and 6.8 in winter.

Solar Energy Calculation. Energy cconsumption of each flat has been estimated on the basis of electricity consumption of standard appliances commonly used in buildings.

Energy consumption of 1 house = 10.860 kW-h/day
Energy consumption of 20 houses = 217.2 kW-h/day
Size of panel – 1.65 X 0.99 m^2
Power generated = 235 Watt
Roof area = 460 m^2
70% of roof area covered by solar panel = 322 m^2
No. of Solar panels = 195
Average annual daylight hours = 11 hours
Considered daylight hours for power output = 7 hours
Total energy generated = 195 x 7 x 235 = 320.8kW-h/day
The energy generated is in accordance with more than half of duration in an year.

IV. CONCLUSIONS

1) Eco-friendly G+4 building designed reduces energy utilization, water use, leading to reduced CO_2 emissions throughout its operational phase enhancing environmental, economic and social benefits.
2)The eco-friendly building incorporating the following features in planning such as orientation of building, room space, windows provision provide adequate day lighting, enhanced indoor environment and also provide opportunities for harnessing the solar energy
3) Earth air tunnelling designed in present work maintains the room temperature in summer and winter reducing the energy consumed in heating, ventilation and air conditioning providing better occupant comfort. Major benefit could be in the summer season as it can reduced the room temperature upto 10 degree Celsius.
4) The region receives a fair amount of rainwater harvesting of roof top rainwater provides the benefits to satisfy all the water requirements for 30 days.
5) The present study area considered in the work receives large number of sunny days hence the capture of solar energy through photo voltaic modules for converting it into electricity to reduces the load on conventional energy resources. On a average during sunny days 320 units of energy can be generated by utilizing the available roof top area and projections.

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