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Comparative study of Energy efficiency Indoor Envelope – Green Building Case Study, Gandhinagar - India

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Abstract*— An environment friendly construction and reducing footprint in construction industry is really big challenge in India as well as around the world. In this way, development of green building is significant and step towards structure a domain, which is free from carbon impression, and free from negative impact of using our valuable natural resources. This article centre around a contextual case study of Green Building built in Gandhinagar city at Gujarat territory of INDIA, which is one of the greenest city of INDIA in terms of green cover. The study highlight the concept of green building with its conceptual drawing, design criteria, siting criteria, the efficiencies of energy, materials & water to maintain LEED parameters which are very important elements for certification of LEED.

This paper basically centre on the analysis of energy efficient systems and control, roof materials to be used for insulation, Building envelope and construction to maintain built environment & economic benefit profit in general execution.

Keywords*— Green Building, Insulated roof material, Eco friendly building envelope, Indoor health quality, Energy Efficient appliances.

I. INTRODUCTION

Building "green" is a chance to utilize our assets effectively while making more beneficial structures that improve human wellbeing, assemble a superior situation, and give cost reserve funds. However, there have been extensive debates on what a green building is or what the green building should cover (1).

A green structure is a structure that is planned, fabricated, revamped, worked, or reused in a biological and asset productive way. The building ought to provide for its inhabitants solid and agreeable environment in all atmospheres.

Green structures are intended to meet certain destinations, for example, securing tenant wellbeing; improving worker profitability; utilizing vitality, water, and different assets all the more effectively; and diminishing the general effect to the earth. A structure where the characteristics of both the indoor and open air situations have been considered and ensured during its plan, development, operation ,use and destruction. The term Green building means not a green in colour but stays cool in summer, warm in winter, inside completely shielded from downpour, gives normal contamination free air and light through entryways, windows and ventilators with no simulated means. For specific prerequisites it has sun based, wind power and eco-friendly electrical, mechanical and many other parameters. Green building is one of the measure been put forward to mitigate significant impact of the building stock on the environment (2)

Now-a-days in INDIA, new practice are always being produced to support current development practices in making eco-friendly structures, the regular goal of green structures is to decrease the general effect of the assembled environment on human wellbeing and the common habitat by:

- Efficiently utilizing energy, water, and different assets
- Protecting tenant wellbeing and enhancing representative profitability
- Reducing waste, contamination and environmental degradation.

The expression "Green" alludes to naturally, neighbourly practices from building configuration to the finishing decisions. It additionally hopeful person and Economic vitality use, water utilize, and storm water and waste water reuse. Green building concept in the construction industry has an epoch-making significance, can reduce the waste of resources, improve resource utilization, along with reduce impact of human activities on the destruction of nature, and is conducive to improving people's quality of life.

II. DESIGN CONCEPT OF GREEN BUILDING:

A green building is one whose development and lifetime of operation guarantees the most beneficial conceivable environment while speaking to the most productive and slightest problematic utilization of land, water, vitality, and different assets. Green architecture, or green design, is an approach to building that minimizes harmful effects on human health and the environment. The "green" architect or designer attempts to safeguard air, water, and earth by choosing eco-friendly building materials and construction practices it also produce environment ,social and economic benefits (3).

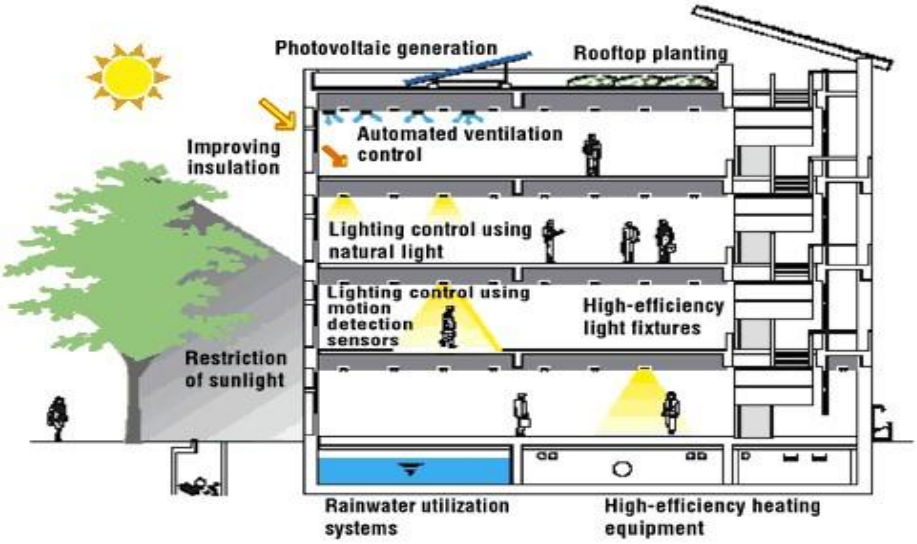

Fig.1 Conceptual Drawing of Green Building (2)

By utilizing green products/materials and practices, buildings can be more energy efficient and cost proficient. The design concept of green building includes all or some of below characteristics.

- Ventilation systems designed for efficient heating and cooling
- Energy-efficient lighting and appliances
- Well orientation of building envelope
- Rain water harvesting & Water-saving plumbing fixtures
- Landscapes planned to maximize passive solar energy
- Minimal harm to the natural habitat
- Alternate power sources such as solar power or wind power
- Improved indoor air-quality, use of non-toxic products
- Maximum use of Locally available materials
- Responsibly-harvested woods
- Adaptive reuse of older buildings and materials
- Use of recycled architectural salvage
- Efficient use of space (4)

III. A CASE STUDY OF GREEN BUILDING (LEED CERTIFIED),GANDHINAGAR, INDIA

Fig 2 A. Existing unused structure

B. 3D drawing of build strucutre

A. Design parameters:

1) *For the Site Development with connecting nature:* Maximum open area is preferred with vehicular movement around the structure. Green Landscaping & natural Water body are preferred to get environment friendly feel with no harm to existing trees and no contamination of site soil.
2) *Building Materials:* To achieve LEED criteria in material section, Maximum use of local materials & minimum or no use of fresh wood is preferred. Material quality should be tested if required. No compromise on quality of materials and proper material management is required as the stack area available will be less.
3) *Building System:* The building is required to be conditioned considering the outside temperature in Gujarat. The lighting shall be done considering the natural light and lux level for comfort.
4) *Equipment's & Appliances energy efficiency:* It is achieved by selecting energy star rated or BEE rated as far as possible. Equipment's & Appliances required in pantry, for copy, printing etc., shall be of high quality and reliability.

5) *Waste Management:* All construction waste is to be diverted to recycling & salvage units. Minimum amount should be diverted to dump yards. The building shall undergo construction, operation and maintenance phase with the minimum disturbance to nature and surrounding environment. A waste management importance in also considered for efficient waste management and control over generation of waste. At site, nearly 95% of construction waste diverted for reuse, recycling & salvage. Operational Waste Management is converted for reuse and recycle and targeted to achieve nearly 90-95%. The intention is to achieve a level of comfort ability and serviceability with minimum impact on the environment by consuming less energy resulting into a comfortable and healthy work environment

B. Design methodology:

The parameters considered for this site are the resource, energy and water efficiency, building orientation and building envelope systems, Building Materials (Walling, Glazing, Roofing), Building Air Conditioning and Building Lighting Equipment's & Appliances, Plumbing system & Fixtures, Rain Water Harvesting etc. Some of them are discussed with performance analysis.

1) *Illustrating - Building function:* With the ideas and issues talked about in the past segments, the proprietors depicts the necessities and prerequisites for the new office space. Focusing the environment and natural resources, the need is given to inhabitant's solace and vitality utilization. Following gives a brief of proprietor's task prerequisites.

The Primary reason for structure is for office Space serving for least of 50 tenants. The task ought to likewise mirror a social obligation message towards condition just as give an appropriate and sound workplace for the staff. The site area and advancement is in Gandhinagar and according to neighbourhood administering body. The current structure is to be utilized subsequent to checking its possibility for remodel alongside strength criteria. No other unsettling influence to the structure is to be done while obliging the requirements.

The way toward structure and the finished result ought to mirror the thought of following issues during the plan and development stage like Local/Site Ecology, Minimum Land/Air/Water Pollution, Maximum outside Views, Natural Light, Pleasant and Healthy Indoors, Rain Water Harvesting, and Easy Operations and Less Maintenance(5). Notwithstanding that the ecological duty, wellbeing and solace of tenants is the main role of eco-friendly structure. To accomplish proficient framework and plan of green structure various parameters to be considered. Vitality productivity is accomplished by thinking about lighting and air conditioning framework, various machines and its framework activity, checking units and control framework. The use of environmentally friendly energy-saving technologies in green buildings should run through the whole process of building design, construction and use, enabling green energy saving technologies to maximize their effectiveness in construction (15).

ENERGY EFFICIENCY IN ELECTRIC APPLIANCES	
AC System	21%
Lighting System	29%
Motor Equipment's and Appliances	20%
System Operations, Monitoring and Controls	22%

The water effectiveness is accomplished by decreasing utilization of water and utilization of downpour water or reuse of water. Approx. 10-15 % decrease in utilization is finished by utilization of downpour water and about 60-70 % decrease accomplished by productive installations and shrewd framework. The Green Building Design course introduces methods of rainwater harvesting, grey water systems, and living pools (6).

WATER EFFICIENCY	
By Rain water use	10-15%
Through Fixtures	60-70%

2) *Indoor Environment quality and health:* Indoor environmental quality (IEQ) as a criterion for green building rating has different areas of assessment in which, occupancy comfort survey is one of the criteria for assessment. This occupancy comfort survey is an assessment based on overall satisfaction with the parameters of IEQ (13). To keep up indoor air quality and inhabitant heath, various machines are utilized to screen indoor air quality like Carbon-di-oxide, Carbon monoxide and Humidity observing gadgets, Temperature Monitoring equipment's. It's additionally important to associate with Natural condition with indoor condition. Indoor lighting is criteria is set up by Artificial Light Integration and association with outside nature light during day time. The fuel breakdown is measured with the help of monitoring device as Fuel breakdown–seasonal performance and carbon emission (7).
3) *Insulating material in Wall and roof:* Walls are the main structure of a building and bear the weight, but walls also act as some sound insulation and heat insulation. Wall materials lead to a huge cost impact on building overall cost,

but can save a lot in a green way. In this part, wall materials designed and used as green materials for cement reinforcement and recycled waste construction material (16). Increasing the air cavity thickness beyond these limits will not increase the thermal resistance of the cavity due to the development of natural convection. The thermal resistance of concrete block and brick hollow depend mainly on thermal emissivity, the thickness of the air cavity and on the temperature difference between surface and air of this cavity (17). The walling system consists of core walling material fly ash bricks with fly ash based cement with air cavity of 50mm. External plaster is of 20mm and internal is gypsum board panelling which is 20mm thick with air cavity of 35mm between panel and core wall as shown in fig 3 (a and b). The opaque portion is externally covered with light grey coloured Aluminium Composite Panel (ACP). And on the side facades it is covered with GI Sheets. This added layer also provides air cavity between the core wall and the ACP which reduces a considerable amount of heat gains.

A. Top View

B. Side View

Fig. 3 (a) Top view (b) Side View, Cavity wall 20mm thick with air cavity of 35mm between panel and core wall

The roof assembly is a combination of concrete slab of 150 mm thickness above which is the insulating layer of mud pots (small pots of 3'' height) with insulate as shown in fig 4 (A and B), which is having 90% post-industrial (agricultural) waste. High Solar Reflectance tile materials and Insulated Roof using industrial waste and local available material satisfy the design parameters. The natural insulating material is a good solution for reuse of waste and has excellence performance (16). In accordance to that the China mosaic in broken small pieces of white tiles with almost 100 % reflectance (8) which is finished with white cement joints are laid on floor as shown in below figure. The same is tested for leakages by retaining water on the surface for one week to ensure waterproofing.

A. China Mosaic

B. Terracotta Pots

Fig.4 Insulating layer

4) *Vertical Fenestration:* The structural glazing is design to Maximum outside View with Reduced Heat Gains and Natural Light integrated with Glare Control. The glazing is of Double Glazed Units with aluminium structural frame having recycled content. The SHGC, VLT & U-value are kept in line with ASHRAE requirement and exceeds the same. The section is of 6/12/8 mm (6mm Aquamarine Glass + 12mm Air Gap + 8mm Clear Toughened Glass) are installed as shown in fig 5. The glazed portion has chajjas to obstruct direct sun rays during noon 13:00 to 16:00 hrs. and aluminium louvers are to be installed vertically to obstruct direct rays during evening from 16:30 hrs.

B. Horizontal Shading Device

A. Day lighting (Outside view with Glare control with window to wall ratio: 0.48)

Fig.5 Glare Control

It's Control with natural light use avoiding direct incident sun rays and heat. The louvers Glare installed are of aluminium with post-industrial recycled content. The angle of installation with the horizontal and the width are designed considering the sun path for the respective longitude and latitude. The design is respective of orientation of all three sides of the building envelope i.e. each side wall louvers are designed as per the sun movement and the building response as per the existing orientation. The priority is given to morning sun, north lights and the evening sun. The chajjas are installed at every floor level as well as intermediate level to avoid the direct sun rays during the late noon. The chajjas are also of aluminium with post industrial waste contents.

C. Measurement of Building envelope performance:

The performance of building envelope are compared between ASHRAE base case and design case for components like wall construction, opaque doors, vertical fenestration, floor and roof. Overall design helps for better thermal performance hence, reduced heat gains and maintained indoor ambient temperature band. Its results in reduced ac system capacity and optimized design with overall electric energy saving. Vertical fenestration and opaque openings provides maximum possible outside view. In lighting criteria, lux level is maintained with combination of maximum use of natural light result in reduced connected load for lighting along with optimized use of artificial lighting due to natural light integration system(9)(10). The use of T5 lamps, CFLs and LEDs are established for higher light level output with lower power input with glare protection. Direct-indirect 3D geometric louvers and diffusers are also installed.

Component	Base Case	Design Case
	ASHRAE 90.1 2004 Prescriptive Requirement	**Building as Designed**
Building Envelope		
Wall Construction (Prerequisite requirement U-0.58)	U-0.12 (Steel Framed)	U-0.188
Opaque Doors	U-0.70	U-0.65
Vertical Fenestration	U fixed- 1.22	U fixed-0.46
	SHGC-0.25	SHGC
(Prerequisite requirement not more than 50%)	WWR-40%	WWR-48%
Floor	U-0.35	U-0.51
Roof (Insulation entirely above deck)	U-0.063	U-0.0628

Table.1 Comparison between base case and design case

To maintain suitable temperature R-410a Refrigerant based VRF AC System and Air-cooled VRF units - 60 HP capacity of Cassette type-duct able & wall mount type indoor units are used. Its specification includes higher seasonal operation capacity & energy efficiency and it's able to control temperature to much tighter band, thus ensuring higher customer comfort (11, 12).

The system consumes energy based on the required load, irrespective of the connected load. During the loaded state, the fixed and orbiting scrolls are always engaged and the compressor delivers 100% capacity. During the unloaded state, the top scroll moves up axially by 1.0 mm. Since there is no scroll sealing now, the compressor delivers 0% capacity. The operating range for a single Digital Scroll is from 10% to 100%. Wide operating range ensures fewer start-stops on the compressor WI Fewer start-stops ensure higher system performance.

System Type	Base Case	Design Case
	Standard package Ductable	VRF System
COP	1.190	3.310
Electricity (kWh) (Seasonal)	55.20	43.20
Energy Use (x 103 Btu)	188.23	147.31
Energy Use (per day kWh)	4960	388.80
Energy Annual Cost (INR)	1032847.2	808315.20

Table.2 AC System – design and performance comparison

IV. CONCLUSIONS AND DISCUSSIONS

From the analysis of lighting and other operation, energy saving with photo sensors are nearly 10% and operational schedules nearly 16% against manual operation. In contrast, higher Initial cost of implicating operational appliances, which have payback period of 3-5 years according to usage.
AC control system also have 12-20 % higher initial investment compare to conventional system but in long run, energy saving payback with 10-12 % difference of benefit each month in energy consumption.
The cost of green material for roof and flooring with chajjas are initially less (approximately 15%) than normal building, as they are recycled or reuse materials and insulation benefits and reduction on cooling system load are additional benefit. It is worth noting that all leading green building assessment tools such as LEED, BREEAM and GBCA Green Star are designed according to local climatic and geographic conditions. The bench-marking study needs to take this into consideration when comparing the effectiveness of these green building rating tools (18).

Its overall conclusion is that the operation cost of green building is less compared to the normal building in long run of building life cycle. If peoples start using the concept of Green Building in future construction, it may be successful in reducing the negative impact on environment which human being had done knowingly or unknowingly. Unless we resort to such technique as green building, the future of earth and people in general, will neither be healthy nor green.

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