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NZEB: A Case Study of Indira Paryavaran Bhawan

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Abstract: The net zero energy building design concept has gained wide international attention for the mitigation of carbon dioxide emission by adopting renewable energy and energy efficient technologies in the building sector. It is now considered widely with the introduction of net metering system of onsite renewable energy generation and grid power utilization. Integration of solar photovoltaic power plant has boosted the morale of owners and building design professionals for construction of energy efficient buildings and use of clean and green renewable energy. The design strategy of net zero energy building is the ultimate solution to reduce energy consumption in the building sector resulting considerable carbon dioxide emission reduction. The architects and building design professionals have attempted this new design concept on the some important buildings, one of them is the Indira Paryavaran Bhawan constructed at New Delhi in composite climate zone in India. In this research paper, a case study of Indira Paryavaran Bhawan has been discussed in respect of energy efficiency and integration of renewable energy. Various design strategies adopted in this building have been analyzed which can help in developing design considerations for Net Zero Energy Building (NZEB) in the composite climate.

Key words: Clean and Green Renewable Energy, Energy Efficiency, Net Metering, Composite Climate

I. INTRODUCTION

Climate change caused by the release of greenhouse gas emission into the atmosphere is one of the greatest threats in future. Building sector is one of the largest consumers of energy, responsible for 33% of energy related carbon dioxide emissions worldwide [1]. Design and construction of energy efficient buildings is one of the solutions to combat global warming. Enhanced energy efficiency can be accomplished by addressing the related issues every stage of building, from planning, designing, material arrangements, construction and use. It is testimony to the fact that necessity for design of functional and energy efficient buildings has been very well recognized. The efforts are needed to design and construct buildings that would function in conformity with the climate and not against it[2]. Availability of appropriate and cost effective building materials and equipment and facilities to test the performance of these materials and equipment is being addressed through the establishment of testing centres in the country[3]. Incorporation of simple energy efficient measures in buildings can reduce a significant amount of energy consumption. Appropriate knowledge and technology is available for creating energy efficient and green buildings but behavioral, organizational and financial barriers need to be overcome for achieving desired results[4]. Some construction and building materials will deserve a special attention under the sustainable development focus of horizon 2020. It includes eco-efficient thermal insulators, materials for mitigating building cooling needs, material with reduced embodied energy, materials capable of reusing a high waste content and nanotech energy efficiency building materials [5].

The orientation of the buildings should remain in east west direction; less radiation will be received by walls in summer and more in winter in comparison to other orientations. It minimizes the heat load in summer and is a very effective passive cooling strategy. Cavity walls are also very useful in controlling the heat gain of the building[6]. Energy efficiency in buildings can be achieved only by addressing various codal requirements right from planning and design and right through the construction phases of building projects[7]. With appropriate use of green construction materials like fly ash brick, Pozzolana Portland cement and recycled steel significant amount of cost and CO_2 emissions saving is achieved[8]. With little extra investment, tremendous energy and water savings are possible. The relevant code and the star rating program will go a long way to encourage energy efficiency[9].

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The sustainability of PV system is affected by its installation, orientation and location. Higher incident solar irradiance is one key for the sustainability of BIPV technology applications[10]. Innovative and customized solutions for sustainable, environmentally friendly and cost effective construction of buildings can only be realized if the conflicting priorities of sustainability, cost effectiveness and design can be reconciled[11]. The effect of PV shading on heating, cooling and lighting energy has to be taken into account. The analysis of overall performance of PV window is based on the simulations and measurements[12,13]. Considering the current state-of-the-art technology for BIPV roofing systems, with some modification/revisions, the existing technologies may be converted to vertical BIPV that would meet owner desired criterion developed through the matrices established[14,15]. The definition of PV integration criteria seems one of the necessary instruments for the solar implementation within historicized contexts, aimed to technological innovation and energy efficiency[16]. With the drastic fall in prices of solar photovoltaic modules and balance of systems on the one hand, and the high and rising tariffs of certain consumer categories in India on the other, grid-connected solar Rooftop PV systems are becoming increasingly viable economically[17,18]. Integration of passive design technologies, energy efficient measures and renewable energy system are the key focus areas to define criteria of net zero energy building for composite climate zone[19]. The zero energy buildings have the promising potential to reduce the energy use and increase the share of renewable energy[20]. There is a need of robust zero calculation methodology to reach at net zero energy building design.

Out of different climate zones, composite climate zone has typical mix of hot, dry, humid and cold climatic conditions – a challenge for the design professionals to design net zero energy building. The building of Indira Paryavaran Bhawan has been set up to demonstrate energy efficient technologies and use of renewable energy through roof top solar power plant to meet the total energy requirements of the office building. This building is selected for carrying out case study for net zero energy building falls under composite climate zone.

II. INDIRA PARYAVARAN BHAWAN

The Indira Paryavaran Bhawan is the office building of the Ministry of Environment and Forest (MoEF) and is built under the concept of Net Zero Energy Building (NZEB). It is situated at Aliganj on JorBagh Road in South Delhi. This new building was constructed by providing minimum change to the old building and minimum disturbance to the surrounding ecosystem. The work of designing the building was carried out by the Central Public Works Department (CPWD) and the sustainable design consultants, Architects and Planners. The aim and objective of designing this building was to bring maximum energy efficiency and generate onsite sufficient renewable energy to run the building. Special emphasis was given to reduce energy demand by providing adequate natural light, shading, landscape to reduce ambient temperatures and provision of energy efficient active building systems. Apart from energy efficiency measures, energy conservation measures were also adopted by the design team to reduce the energy loads and generating energy from the onsite solar panels thus meeting the net zero building criteria. The various strategies involved in designing the building and meeting all the criteria's of a net zero building have been discussed in this case study.

Fig. 1 North Edge Road View of The Indira Paryavaran Bhawan

First design consideration was taken to preserve as many existing trees as possible without compromising on its functional efficiency and user comfort. Various design option were considered and finally decided to place twin North South facing blocks with a large open space court at the centre (Fig. 2). The height of the building was kept in tune with the surroundings and taking maximum allowed ground coverage. Only 19 trees were chopped out of permission granted for 46 trees. The layout of the building was designed to make it most environments friendly and energy efficient.

Fig. 2 Final design of twin North South facing blocks with central open space court

The landscape and horticulture design of planting native species and use of efficient irrigation systems leads upto 50% reduction of water requirement. The balance demand of water was designed to meet by recycling, reusing the waste water and rainwater harvesting system. Further water efficient fixtures have been used and provided effective site water management system making it zero discharge to the city storm water system (Fig. 3).

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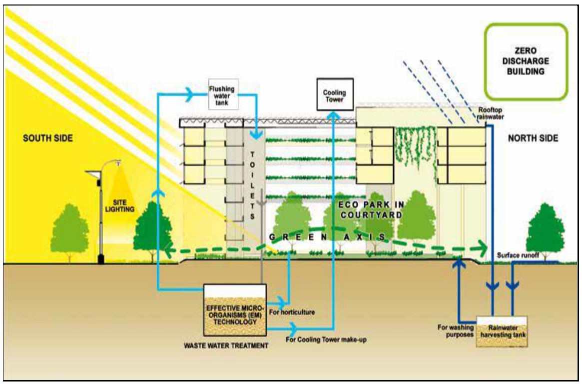

Fig. 3 The Efficient water management makes it zero discharge building

2.1 DESIGN STRATEGY

The design of the Indira Paryavaran Bhawan involves three design strategies. First is Passive Design Strategy, second is Active Design Strategy and third is use of Renewable Energy System used to make it most energy efficient building. All the three design strategies discussed simultaneously to reach at the most effective and workable environment friendly and energy efficient design of the building.

2.1.1 PASSIVE DESIGN STRATEGY

All the passive components such as orientation, Landscaping, day-lighting, ventilation, building envelope, materials and constructions techniques were looked upon during the design phase of the building.

Orientation: The orientation of the building was set towards north south direction with two separate blocks connected through corridors. A huge central court yard was placed for natural sky light and air movement in the building. It creates a landscaped connection with rest of the vegetation, provides cross ventilation within the building. The hot air escapes easily and the cool air is preserved. It minimizes the heat ingress in to the building. The optimal window to wall ratio is provided.

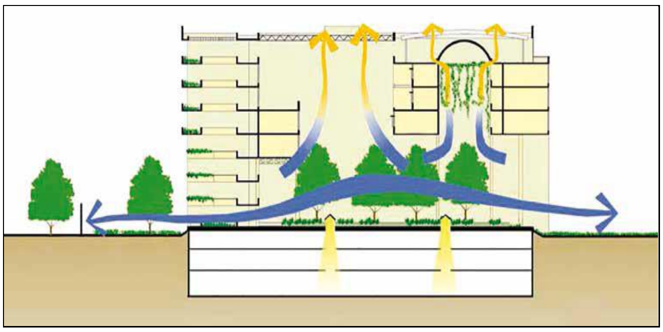

Fig. 4 The courtyard creates cross ventilation within the building

Landscaping and horticulture: The building is covered with plantation from outside. Circulation roads and pathways are soft paved to enable ground water recharge.

Day-lighting: The inner courtyard serves as a natural light well. The day light is covered more than 75% of building floor space. The dependence on artificial sources of lighting has been reduced to minimum.

Ventilation: Central courtyard helps in air movement as natural ventilation happens due to stack effect. Windows add to cross ventilation.

Building Envelope and Fenestration: The window assembly of U-value 0.049 W/m^{2}K, VLT 0.59 and solar heat gain coefficient of 0.32 is used to optimize the building envelope. The windows with uPVC frame are hermetically sealed double glazed using high efficiency and low heat transmittance index glass. Rock wool is used for insulation for wall assembly. The roofs are made with cool roof treatment using high reflectance terrace tiles for low heat ingress, high strength and hard wearing.

Materials and construction techniques: Autoclave Aerated Concrete blocks are used for walls with fly ash cement plaster. Local stone was used for flooring. Bamboo jute composite doors, frames used as natural resource which is replenished faster than regular timber trees. Light shelves are made for diffused sunlight.

2.1.2 ACTIVE DESIGN STRATEGY

Various active design strategies were adopted during the design of the building.

Lighting Design: Interior and exterior lighting system was designed by providing energy efficient lights. The artificial lighting is controlled using lux level sensor to optimize energy efficiency in lighting. The lighting power density is maintained near to 5 W/m^2 which is 50% more efficient than Energy Conservation Building Code provisions.

Optimized HVAC system: The chilled beam system technology was used to reduce energy consumption upto 50% as compared to conventional system. 160 TR of air conditioning load of the building is met through Chilled beam system. Chilled beam are used from second to sixth floor. Variable frequency drives used for water cooled chillers, double skin air handling units. The fresh supply air is pre cooled from toilet exhaust air through sensible and latent heat energy recovery wheel. Integrated building management system is set up to control HVAC equipments and monitoring of all systems. The room temperature is being maintained at 26 ±1 ° C optimizing energy efficiency in HVAC.

2.1.3. GEOTHERMAL HEAT EXCHANGE SYSTEM

Geothermal heat exchanging system has been set up with 180 vertical bores to the depth of 80 meter all along the building premises. Minimum 3 meter distance is maintained between any two bores. Each bore has HDPE pipe U-loop of 32mm outer diameter and is connected to the condenser

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water pipe system in the central air conditioning plant room. Single U-Loop of 0.9 TR heat rejection capacity combined together with 160 TR of heat rejection is obtained without using a cooling tower.

2.1.4 Renewable Energy System

The building integrated photovoltaic (BIPV) Power Plant has been installed to meet the reduced energy demand of the building with clean and green renewable energy system Fig. 5. Roof top solar photovoltaic power plant of capacity 930 kW has been set on total area of 6000 m^2 with solar panel area of 4650 m^2. This solar power plant is generating 14.3 lakh unit of electricity annually.

Fig. 5 Photovoltaic Power Plant at Indira Gandhi Paryavaran Bhawan

III. Acknowledgement

The work done by Ar. Deependra Prashad is really acknowledgeable for setting an example of net zero energy building in the complex composite climate conditions with his visionary and holistic approach towards sustainability. Ministry of Environment and Forest has given the free hand to the architect and design professional to set up an example of net zero energy building by using passive architecture, energy efficiency technologies and optimising on site renewable energy. The building was constructed with the sincere efforts of Central Public Works Department. It has achieved the 5-star GRIHA Green Rating and the LEED India NC Platinum rating. The building has also received various awards such as the Adarsh/GRIHA of MNRE for exemplary demonstration of Integration of Renewable Energy Technologies.

IV. Conclusion

The case study reveals that the annual energy consumption of Indira Paryavaran Bhawan is 14.21 Lakh kWh which is met with equivalent annual energy generation of 14.3 lakh kWh from Solar Power Plant installed on site. It is a set example of net zero energy building design in composite climate zone and is a sustainable paradigm of energy self sufficiency of an office building. It will help to boost the confidence of architects, design professionals and builders to adopt these building design strategies for future construction of new and upcoming buildings. The design parameters adopted in the building will enlighten the academician and professional for defining design criteria of net zero energy buildings in composite climate conditions.

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