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Integrated Passive and Active Energy Design Strategies

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Abstract - Buildings are the largest consumers of energy worldwide, contributing to greenhouse gas emissions and climate change. This global demand of energy leads to energy efficiency through sustainable strategies for modern construction and urban development. This research paper reviews key sustainable design strategies that enhance building energy efficiency, including passive design principles, high-performance building envelopes, renewable energy integration, efficient building systems, and smart technologies. These various strategies reduce energy demand, minimize environmental impact, and various economical benefits.

***Key Words*: -**Renewable energy integration, high-performance building envelopes, shading devices, passive strategies, photovoltaic system, building orientation, clerestory windows etc

1. INTRODUCTION

The buildings and construction sector was responsible for about 34% of global energy related CO_2 emissions and consumed 32% of global energy Rapid urbanization, population growth, and increased demand for higher indoor comfort levels have intensified energy use in residential and commercial buildings. Sustainable energy efficient building strategies aim to reduce energy consumption while maintaining occupancy comfort levels and minimizing environmental impact. Energy efficiency in buildings not only reduces operational costs and energy demand but also enhances global sustainability goals.

2. LITERATURE REVIEW

Energy efficient design strategies have been widely discussed in architecture research as practical ways to reduce energy use while creating healthier and more comfortable spaces for people. Instead of relying only on mechanical systems, many studies emphasize starting with smart design decisions such as positioning a building for natural sunlight, natural cross ventilation, using shading devices, and selecting materials that naturally regulate indoor temperatures. These passive strategies are often considered the foundation of energy efficiency because they reduce the need for artificial heating and cooling.

Benefits	Evidence
Reduced Energy Consumption	Passive and active strategies can reduce energy demand by 40 to 80%.
Lower Carbon Emissions	Buildings with integrated renewables approach net-zero emissions.
Improved Occupant Comfort	Better ventilation, lighting, and indoor climates increase comfort.
Economic Benefits	Recycle Materials can reduce building cost.

Table 1: Benefits of Energy Efficient Building

3. RESEARCH METHODOLOGY

This study uses a qualitative approach with secondary data sources. The approach comprises Analysis of academic journals, books, and architectural literature on Energy Efficient building design. Analysis of various types of energy Efficient strategies through published reports and international and Indian articles. Two major Indian Case study of hotel and office with green ratings. Comparative analysis between conventional housing and energy efficient building to identify differences in energy consumption

Fig 1: Energy Efficient Building Strategies

4. TYPES OF ENERGY EFFICIENCT DESIGN STRATEGIES

4.1 ACTIVE ENERGY DESIGN: SOLAR PHOTOVOLTAIC SYSTEMS

A photovoltaic system, referred to as a PV system or solar power system, which is an electric power system that uses photovoltaics to generate usable solar power. It consists of various parts, such as solar panels that absorb and transform sunlight into electricity, a solar inverter that changes the output from direct to alternating current, and other electrical accessories for mounting and system setup. To increase electricity production, many photovoltaic systems use tracking systems that follow the sun's daily trajectory across the sky.

4.2 PASSIVE ENERGY DESIGN: BUILDING INSULATION SYSTEM

A building's walls roof, floors, and foundation consist of insulation systems. Fiberglass, mineral wool, expanded or extruded polystyrene (EPS/XPS), polyurethane foam, cellulose, and other natural materials like cork or sheep's wool are examples of common insulation materials. These materials slow down the flow of heat by trapping gas or air inside their structure. The R-value is used to gauge how well insulation performs. Greater resistance to heat transfer is indicated by the higher values.

4.2.1 Wall Insulation Materials:

Wall insulation materials are used to reduce heat transfer through external walls and maintain indoor temperature and comfort. Cavity wall is a common method of wall insulation in which insulation materials are placed in between layers. Materials used are Glass wool, Expanded Polystyrene (EPS), Extruded Polystyrene (XPS).

4.2.2 Floor Insulation Materials:

Floor insulation materials reduce heat loss through ground floors and suspended floors. Insulation is placed below the ground floor slab in layers to prevent heat loss to the ground. In suspended floors, the insulation materials are placed between floor joists. Material such Expanded Polystyrene (EPS), Extruded Polystyrene (XPS) and form glass.

4.2.3 Roof Insulation Materials:

Roof insulation materials are very important because roofs receive maximum heat from the sun. In warm roofs, insulation is placed above the roof slab to prevent heat loss and condensation. In cold roofs, insulation is placed below the roof slab and proper ventilation is required. Flat roofs use rigid insulation boards or foam insulation for better performance. Glass Wool, Rock Wool and Expanded Polystyrene (EPS) are also used.

4.3 BUILDING ORIENTATION AND FORM

Building orientation refers to the position of a building with respect to its sun path and wind direction. Building orientation helps in controlling heat gain and it improving natural lighting and ventilation. Buildings are oriented along the east to west direction had the longer sides facing north and south. This reduces heat gain from the low angle sun on the east and west sides. Proper orientation allows maximum daylight and reduces use of artificial lighting.

- **Build form**: It refers to the massing and shape of the building. The form of a building influences heat transfer, air movement, and daylight.
- Compact build forms are more suitable for cold climate as it reduces heat loss.
- Build forms with center courtyard are more suitable for hot climate as it improves airflow and daylight. It keeps the surrounding spaces cool.

4.3.1 Natural ventilation

Natural ventilation provides air circulation as it removing hot air from a building and maintain indoor temperature. It helps in exposure of natural daylight to the building. Proper placement of windows, ventilators, ventilation shafts, and courtyards helps in improving natural ventilation and reduces need for mechanical cooling.

- windows and doors are provided on opposite sides of building that helps in Cross ventilation of air flow, allowing air flow from one side to the other.
- Stack ventilation consists of principle, that hot air rises and flow through high level openings, while cool air enters and flow through lower openings.
- Single sided ventilation should be avoided as the air flows occurs through enters and exits openings of the same wall and it is less effective.

4.3.2 Daylighting

Daylighting improves visual comfort and enhances indoor environment as it is the most common source of indoor light for daytime. It reduces the use of artificial lighting and best way to saves energy. Windows are designed and placed properly to allow daylight in rooms. Larger openings are placed on the north and south sides to avoid glare and excess heat in indoor spaces.

- Shading devices such as overhangs, louvers, and light shelves are preferred to control direct sunlight and reduce glare.
- Skylights and clerestory windows are used in buildings for daylight.

5.4 HIGH PERFORMANCE BUILDING ENVELOPE

The building envelope work as the outer shell of a building that separates the indoor environment from the outdoor environment. It includes building elements such as walls, roofs, floors, windows, and doors. A high-performance building envelope is designed to minimize heat gain, heat loss, indoor temperature and moisture control. Building insulation increases thermal resistance and maintains indoor temperature. Airtight environment prevents unwanted air infiltration. High-performance glazing reduces heat transfer and allows daylight. Building envelope improves indoor comfort and energy efficiency in buildings. It consisting of walls, roofs, doors, and windows, plays a crucial role in regulating occupancy comfort and reducing energy demand. A well-designed building envelope consists of insulation system and leads to energy savings.

- **Glazing Systems**: Residential window coatings with one or two layers of glazing allowed roughly 75% to 85% of the solar energy to enter a building.
- **Thermal Mass Materials**: Materials such as concrete and brick help in regulation of indoor temperatures by absorbing and releasing heat.
- **Cool Roofs and Reflective Surfaces**: These reduce heat absorption and improve indoor comfort without excessive use on air conditioning.
- **Airtight Construction**: Sealing gaps and using weather stripping around doors and windows prevent air leaks and enhance energy efficiency.
- **Overhangs**: on south-oriented windows provide effective shading from the high-altitude sun. An extended roof shades the entire north or south wall from the noon sun. East and west openings need much bigger overhangs, which allows air flow.

4.5 GREEN ROOFS

Green roofs are rooftops that are partially or completely covered with plants growing in a layered system. These layers typically include a waterproof membrane, root barrier, drainage layer, growing medium (soil), and vegetation. There are two main types, extensive green roofs, which use shallow soil and low-maintenance plants like grasses or sedums, and intensive green roofs, which have deeper soil and can support shrubs, trees, or even gardens. Green roofs help in improve building insulation, lowering energy use for heating and cooling, and manage stormwater by slowing down rainwater runoff.

4.6 PASSIVE DESIGN STRATEGIES

Passive design strategies are used in buildings to achieve thermal comfort, ventilation and lighting by using natural resources such as sunlight, wind, and climate. The design strategies depending much on natural system avoiding mechanical systems like air conditioners or artificial lighting. Passive design is used to reduce energy consumption, improve indoor comfort, and create environmentally friendly buildings. These strategies are planned during the initial design stage. Passive design helps in maintaining comfortable indoor temperatures, reducing electricity bills, and improving the overall quality of indoor spaces.

5. CASE STUDY

5.1 Sohrabji Godrej Green Business Centre.

- Located Hyderabad and rated LEED and IGBC Platinum. It was established in the year 2004, as CII's Developmental Institute.
- The building waste are recycling and reused within.
- The building is made up of only recycled materials.
- The large array of solar panels installed on the buildings generate around 100-120 units of electricity
- The roof of the building is covered with vegetation to keep temperatures regulated.

5.2 ITC Maurya Hotel

- Located in Delhi and based on Mauryan Architecture
- Building has been awarded the LEED Platinum Certified. The hotel Recycle 90% of its solid waste.
- Use parabolic solar concentrators
- The building is that it uses low VOC (volatile organic compound) paints.

6. COMPARISON WITH CONVENTIONAL BUILDINGS

Energy Efficient buildings can reduce energy consumption by up to 30 % compared to conventional buildings, while also improving indoor environmental quality and the health of building occupant. In terms of the difference between actual energy consumption and the benchmarks, green buildings recorded a narrower gap of (26.49%) than conventional buildings (34.99%).

7. REGULATORY FRAMEWORK AND ENERGY STANDARDS

There are various building codes, standards, and certifications focusing on energy efficiency some of them are Leadership in Energy and Environmental Design (LEED), Green Building Rating System (GRIHA), Integrated Green Building Council (IGBC) and international rating system such as the Building Research Establishment Environmental Assessment Method (BREEAM) etc.

8. SUSTAINABLE BUILDING MATERIALS.

Among the various options available, materials like recycled steel, bamboo, reclaimed wood, and low-VOC paints stand out for their reduced environmental impact. Recycled steel, requires less energy to produce compared to normal steel, and bamboo serves as a rapidly renewable resource, great choice for flooring and structural elements. Additionally, implementing low-VOC (volatile organic compounds) paints and finishes can enhance indoor air quality and contribute to healthier living spaces

9. CONCLUSION

Energy Efficient building design is crucial in addressing present-day environmental challenges while promoting economic savings and enhancing the quality of life for users. The methodologies and technologies that facilitate energy efficiency in architecture, it becomes evident that such approaches are not only advantageous but essential for sustainable development. The vision of more sustainable living spaces can increasingly be realized through the application of these innovative strategies

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