

Passive House Standards in Building Design

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Abstract

Passive buildings are proving to be a solution to menaces of energy crisis and greenhouse gas emissions across the world. Such buildings tend to exhibit low energy demand owing to their cleverly designed envelopes, which comprise of walls, roofs, doors, windows and other openings. This requires use of new materials and technology, leading to an increased initial construction cost. However, with reduced energy consumption, the lifecycle cost of a passive building may be lower than that of a conventional building. These passive buildings also need to cater to occupants' comfort which is subject to local climatic conditions and climate change. This article discusses economic feasibility and climatic adaptability of a passive building, in addition to advances in passive building strategies. Owing to lack of general awareness and standards related to passive building construction, these buildings have not achieved enough popularity. While many countries are striving hard to bring passive buildings to common masses, a large number of countries are yet to initiate the move. This article outlines several active organizations, standards and rating systems for passive buildings. This article also presents some of the recent research trends and a comprehensive bibliography for the benefit of researchers and practitioners. The term Passive House refers to a performance-based energy standard for high-efficiency buildings. It is clearly defined, with validity for all climates of the world. Under cold climate conditions, the design typically focuses on minimising heat losses and optimising solar gains. In milder climates, moderate insulation, including improved window qualities, is sufficient, but on the other hand, the building performance during summer requires more careful consideration. For hotter

climates, the insulation requirements increase again, and solar loads through windows, walls and roofs must be limited. In hot and humid climates, humidity loads are also minimised or reduced. In practical implementation, every Passive House has its own, specific boundary conditions which lead to different constructions and technical solutions to fulfil the stringent requirements of the Passive House standard.

Keywords: *Passive House, Thermal Insulation, Ventilation, U-Value, solar gains.*

INTRODUCTION

Unsustainable development in the post-industrial revolution era has resulted in an ever-growing energy demand and greenhouse gas emissions, across all sectors including buildings, transport and industries. This has led to change in climate across the globe, with noticeable extreme weather phenomena and rising mean sea levels. The rate of climate change has been observed to increase steadily over last four decades [1, 2]. As a result, 196 parties comprising mostly of nations entered into the Paris Agreement of 2015, which is a legally binding international treaty on climate change. It was agreed that the global mean temperature rise be restricted to 2 °C over a century [3]. It has also been evident that with gradual shift in nature of occupations from farms to indoors, buildings have turned into a major contributor towards energy use and greenhouse gas emissions. Globally as of 2021, buildings and building construction industry account for 36% and 37% of energy and emissions respectively as shown in Fig. 1 [4]. The contribution of a paradigm shift in nature of jobs can be understood if these numbers for countries at different levels of the development ladder are assessed. For instance, in 2019, buildings' share in total energy consumption in countries in Asia barring China and those in Central and South America was in the range of 23–25%, which is lesser than the global levels by almost 12 percentage points [4]. However, there are multiple factors such as energy source for domestic usage, efficiency of transport network and levels of industrialization, which influence buildings' share in total energy consumption. On an average, buildings and building construction industry in African countries together contributes to 60% of total energy consumption. The region's high dependence on bioenergy for its domestic energy needs is attributed to this high share of buildings in total energy consumption [4]. Another important perspective is the rapid growth in buildings' share in total energy consumption for the developing countries such as India and Brazil as compared

to United States and European nations, for the period 1990–2010 [5]. It can be assessed that the developing nations should learn from the examples of developed nations and thereby act pro-actively to avoid getting into deeper waters. The effect of population growth and urbanization on buildings' share in energy consumption and greenhouse gas emissions is also worth noting [5]. Despite the variation in these shares across nations, the global average share of 36% and 37% to energy consumption and emissions makes it crucial to design and construct energy efficient and environment friendly buildings in order to achieve goals set by the Paris Agreement. The annual reports indicate that the present development in this direction has not been satisfactory [4, 6], as only 80 countries have either mandatory or voluntary building energy codes at national and/or sub-national levels [4]. In order to improve the acceptability of the need to switch to energy efficient and environment friendly buildings, awareness related to such buildings among masses is required. People should be made aware of vernacular and modern strategies to improve energy efficiency and reduce carbon footprint in buildings, which will enable them to make informed choices. These strategies can be either active or passive [7, 8]. Though this article reviews elements of passive buildings in particular, understanding of these two types of strategies is important. Most of the building projects in the developing world still award the contract to the option with lowest initial cost. The significance of considering lifecycle cost as the criterion is now being understood, but unavailability of reliable data, divergence in lifecycle costs standards, and lack of awareness among vast majority of population hinder the use of lifecycle cost as a deciding parameter in most projects [9]. It is intuitive that initial costs of energy efficient and environment friendly buildings is usually higher than conventional buildings. However, with reduced energy consumption and shrunk carbon footprint, such buildings are likely to have a lower cost over its design life. However, in a bid to make a building highly energy efficient and environment friendly, a design may be arrived which may not render the building economical in its design life. Such designs are examples of over-investment and should be avoided. It is therefore imperative to arrive at the optimal level of investment in energy efficiency and emission reduction [10], which would imply one to understand how to estimate lifecycle cost for buildings.

OBJECTIVES

Passive House standards aim to create highly energy-efficient buildings that maintain comfort while minimizing environmental impact. The key objectives are:

1. **Energy Efficiency:** Minimize the building's energy demand for heating and cooling through superior insulation, airtight construction, and high-performance windows.
2. **Comfort:** Ensure consistent indoor temperatures and high indoor air quality by employing mechanical ventilation with heat recovery and minimizing drafts.
3. **Sustainability:** Reduce the building's overall carbon footprint by lowering energy consumption and promoting the use of renewable energy sources.
4. **Cost Efficiency:** Achieve long-term cost savings through reduced energy consumption and lower operational costs despite potentially higher initial construction costs.
5. **Durability:** Enhance the building's durability by using high-quality materials and construction techniques that improve longevity and reduce maintenance needs.

These objectives help create buildings that are energy-efficient, comfortable, and environmentally friendly.

LITERATURE SURVEY

A literature survey on Passive House standards in building design involves reviewing and synthesizing existing research and publications on this topic. Here are key areas and themes that such a survey might cover:

Overview of Passive House Standards:

Definition: The Passive House standard is a rigorous, voluntary standard for energy efficiency in a building, reducing its ecological footprint.

Origins: Developed in Germany in the late 1980s by Dr. Wolfgang Feist, the standard emphasizes energy efficiency, comfort, and sustainability.

1. Core Principles

Thermal Insulation: High levels of insulation to minimize heat loss.

Airtightness: Very low air leakage to ensure controlled ventilation.

Thermal Bridge-Free Construction: Design strategies to avoid heat loss through thermal bridges.

High-Performance Windows: Triple-glazed windows to enhance thermal performance.

Mechanical Ventilation with Heat Recovery (MVHR): Ensures fresh air supply while recovering heat from exhaust air.

2. Design and Construction Techniques

Envelope Design: Emphasis on creating a continuous thermal envelope.

Building Orientation: Maximizing solar gains through strategic placement of windows.

Materials: Use of high-performance and sustainable materials.

3. Energy Performance

Heating and Cooling Demand: The Passive House standard typically limits space heating demand to 15 kWh/m² per year.

Primary Energy Demand: Limits the total energy consumption for all domestic services to 120 kWh/m² per year.

4. Case Studies and Applications:

Residential Buildings: Examples of homes built to Passive House standards.

Commercial Buildings: Adaptation of standards for larger-scale projects.

Retrofitting Existing Buildings: Techniques and challenges in upgrading existing buildings to meet Passive House criteria.

5. Benefits and Challenges:

Benefits: Reduced energy costs, improved indoor air quality, and increased comfort.

Challenges: Higher initial costs, need for specialized design and construction practices, and potential for limited material availability.

6. Regional Variations and Adaptations:

Climate Adaptations: Modifications to suit different climatic conditions.

Local Building Codes: Integration with or adaptations of local building regulations and codes.

7. Future Directions:

Technological Advances: Innovations in materials and systems that could enhance Passive House performance.

Policy and Incentives: Role of government policies and incentives in promoting Passive House construction.

To conduct this literature survey, you would review academic papers, industry reports, case studies, and standards documents related to Passive House design. Key databases and journals related to building science, energy efficiency, and sustainable architecture would be primary sources of information.

Passive House standards focus on creating highly energy-efficient buildings that maintain comfortable indoor temperatures year-round with minimal energy input. Here's an overview of the methodology and materials typically used.

METHODOLOGY

Thermal Insulation

Objective: Minimize heat loss in winter and heat gain in summer.

Materials: High-quality insulation materials like expanded polystyrene (EPS), extruded polystyrene (XPS), polyurethane (PUR), or mineral wool.

Airtight Construction:

Objective: Reduce air leakage to improve energy efficiency.

Approach: Use of airtight membranes, gaskets, and proper sealing techniques around windows, doors, and joints.

High-Performance Windows and Doors:

Objective: Minimize thermal bridging and heat loss.

Materials: Triple-glazed windows with low-emissivity coatings and insulated frames.

Heat Recovery Ventilation (HRV) Systems:

Objective: Ensure a continuous supply of fresh air while recovering heat from outgoing air.

Components: Heat exchangers that transfer heat between incoming and outgoing air streams.

Thermal Bridging Reduction:

Objective: Avoid heat loss through structural elements.

Approach: Use thermal breaks and carefully designed detailing to avoid conductive heat loss.

Solar Gain Optimization:

Objective: Utilize passive solar energy for heating.

Design Elements: Strategic window placement, shading devices, and thermal mass to capture and store solar heat.

Building Orientation and Design:

Objective: Maximize natural light and heat gain from the sun while minimizing exposure to cold winds.

Considerations: Building orientation relative to the sun, wind direction, and surrounding landscape.

Materials:

Insulation Materials:

Options: Rigid foam boards (EPS, XPS), spray foam, cellulose, or mineral wool.

Criteria: High thermal resistance (R-value) and low thermal conductivity.

Windows:

Types: Triple glazing, low U-values, gas-filled cavities, and high-quality spacers.

Frames: Thermally broken frames made of materials like fiberglass or composite.

Sealing Materials:

Products: Airtight membranes (e.g., polyethylene sheeting), high-quality sealants, and expanding foam.

Ventilation Systems:

Components: HRV or ERV units with high heat recovery efficiency.

Filters: High-efficiency filters to ensure good indoor air quality.

Building Envelope:

Materials: High-performance building wraps, vapor barriers, and weather-resistant barriers.

By integrating these methodologies and materials, buildings can achieve Passive House standards, which lead to superior energy efficiency, reduced operational costs, and enhanced occupant comfort.

CONCLUSION

The Passive House standards represent a rigorous set of criteria aimed at maximizing energy efficiency in building design. These standards focus on achieving significant reductions in energy consumption for heating and cooling through a combination of high-performance insulation, airtight construction, and efficient windows. By adhering to these principles, buildings can maintain a comfortable indoor environment while minimizing their environmental impact and energy costs.

Adopting Passive House standards in building design not only contributes to reduced energy use and lower utility bills but also enhances indoor air quality and comfort. As a result, these standards offer a sustainable approach to construction that aligns with global efforts to mitigate climate change and promote energy efficiency.

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