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Passive Architectural Elements for Tropical Climate

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ABSTRACT

The use of passive architectural features for building design in India's tropical environment is the main topic of this study paper. The paper offers a thorough assessment of the literature on the various passive design techniques that can be used to enhance indoor thermal comfort in tropical buildings. The study looks at the difficulties brought on by the hot, humid, and sunny environment of India, as well as the efficiency of passive architectural features in reducing these difficulties. The study also looks into the many design approaches applied to the placement of these components, such as the selection of the right materials, positioning, and orientation of apertures to encourage natural ventilation and the use of materials with a high thermal mass to lessen temperature variations. The study emphasises the advantages of including passive architectural features in building design, such as enhanced thermal comfort indoors, decreased energy use, and lower carbon footprint. The study makes suggestions for architects and designers regarding the best design approaches for passive building components in various tropical climates in India. The results of this study can help with energy-efficient and sustainable building design in India, enhancing indoor comfort while reducing environmental effect.

1. INTRODUCTION

India has a climate that is mostly tropical, marked by high temperatures, high levels of humidity, and long stretches of direct sunlight. These weather factors provide a significant barrier to building design since they might result in unpleasant inside temperatures and higher cooling energy costs. A sustainable and energy-efficient approach to these problems is passive architecture design. Architects and designers may reduce the need for mechanical cooling and increase indoor thermal comfort by adding natural ventilation, shading, and other passive design techniques. The usefulness of passive architectural components in tropical climates, particularly in the Indian context, has been the subject of several studies. A thorough analysis of the current literature on the issue, with an emphasis on the tropical climate in India, is still required.

By reviewing the literature on passive architectural components for building design in the tropical environment of India, this research seeks to fill this knowledge gap. The study's goal is to provide architects and designers with the knowledge and resources they need to develop environmentally friendly and energy-efficient building designs in the area by studying the advantages and disadvantages of passive design solutions in an Indian setting.

The design of buildings in tropical climates, such as India, presents unique challenges due to the high temperatures, humidity, and intense sunlight that characterize these regions. To maintain indoor thermal comfort in such conditions, buildings often require significant energy inputs for cooling, leading to increased energy consumption.

Passive architectural elements offer a sustainable and energy-efficient solution to these challenges. These design elements leverage natural resources, such as ventilation and shading, to reduce the need for mechanical cooling and promote indoor thermal comfort. The use of passive architectural elements can also contribute to lowering carbon footprints, making them an important component of sustainable building design.

The focus of this research is to review the existing literature on the use of passive architectural elements for building design in the Indian tropical climate. By examining the effectiveness and challenges of passive design strategies in this context, the study aims to provide architects and designers with the information and tools they need to create sustainable and energy-efficient building designs in the region.

The research will explore the different types of passive architectural elements that can be used in building design, including the use of appropriate building materials, the orientation of buildings, the placement of openings, and the use of materials with high thermal mass. The study will also examine the cultural and social factors that may influence the use of passive architectural elements in Indian building design.

This research aims to contribute to the understanding of passive architectural elements in tropical climates, specifically in the Indian context, and to promote sustainable and energy-efficient building design practices that can help reduce the impact of buildings on the environment.

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2. Design Strategies For Regulating Temperature And Ventilation In Buildings

Orientation: Orienting the building in a way that maximizes the use of natural light and minimizes direct exposure to the sun can help regulate temperature and reduce the need for artificial cooling. This can be achieved by aligning the building along the east-west axis to take advantage of the prevailing winds and optimizing the building's shape.

Insulation: Insulating the building envelope can prevent heat loss or gain, keeping the interior temperature stable. Insulation materials such as mineral wool, cellulose, or foam can be installed in the roof, walls, and floor.

Natural ventilation: Natural ventilation can help reduce the need for artificial cooling by using the natural flow of air to regulate temperature. This can be achieved by incorporating operable windows, vents, and louvers in the building's design.

Shading: Shading devices such as overhangs, awnings, and louvers can block direct sunlight from entering the building, reducing heat gain and glare.

High-performance glazing: Using high-performance glazing, such as double or triple-glazed windows, with low-emissivity coatings can reduce heat transfer and help maintain a comfortable temperature inside the building.

Passive cooling: Passive cooling techniques such as radiant cooling or evaporative cooling can be used to cool the building without relying on mechanical cooling systems. Radiant cooling uses a system of pipes or panels to circulate cool water through the building's floors, walls, or ceilings, while evaporative cooling uses the natural cooling effect of water evaporation to cool the air.

Energy-efficient HVAC systems: High-efficiency HVAC systems, such as geothermal or air-source heat pumps, can be used to heat or cool the building while minimizing energy consumption and greenhouse gas emissions. The HVAC system should also be designed to deliver fresh air to the building's occupants and be equipped with filters to remove pollutants from the indoor air.

By incorporating these design strategies into buildings, it is possible to regulate temperature and ventilation effectively, reducing energy consumption and promoting a healthier and more comfortable indoor environment.

3. Case Study 1: The Institute Of Rural Research And Development At Gurgaon

India's Gurgaon, Haryana at a height of 224.6 metres over sea level. The district's average annual temperature is 31.2°C (88.16°F), which is 5.23% warmer than the country's average. Approximately 20.73 millimetres (0.82 inches) of precipitation and 21.81 rainy. The Institute of Rural Research and Development at Gurgaon is a case study of a sustainable institutional building located in the Indian tropical climate. Completed in 2008, the building was designed by architect Ashok B. Lall for the S. M. Sehgal Foundation. The building is north-south oriented, which reduces solar radiation on longer facades. The use of double glass panes for windows helps to minimise heat gain, while the external walls are composed of 45mm stone cladding, 40mm PUF (for the southeast wall, a 40mm cavity), 230mm brick, and 15mm cement mortar. The walls have a thermal conductivity of 1.56 W/sq.m.K. (for the southeast wall) and 0.45 W/sq.m.K. for the others.

The roof of the building consists of a 13-mm broken China mosaic, 65-mm brick, 50-mm PUF (R-13), 9.5-mm screed, waterproofing, and a 203-mm concrete slab on the interior, with a thermal conductivity of 0.36 W/sq.m.K. The building also uses an internal courtyard to allow diffused daylight into the building, avoiding unwanted glare and heat gain from incident sunlight.

A radiant cooling system is installed in the building, with modulation of mixing valves installed on the common radiant header and control of re-circulating for the radiant cooling system. The building also features shading devices designed to allow daylight into the space while preventing solar heat gain through the glazed area. The external shading device framework and chajjas are detached from the main structural system of the building to reduce the conduction of heat. A 35-kW solar photovoltaic installation also helps to reduce energy consumption.

The building's performance is monitored through slab temperature monitoring, room temperature sensors, room humidity sensors, and the common header temperature in the radiant piping system. The building has a 19.84% window-to-wall ratio and has achieved a 30% reduction in CO2 emissions compared to conventional buildings. The use of passive architectural elements such as proper building orientation, shading devices, and thermal mass has contributed to the building's overall energy efficiency and sustainability.

Figure 1: Exterior façade view

Figure 2: Interior view

4. CASE STUDY 2: NET ZERO ENERGY BUILDING AT CEPT UNIVERSITY

The average temperature for the year in Ahmedabad is 27.8°C. The warmest month, on average, is May with an average temperature of 33.9°C. The coolest month on average is January, with an average temperature of 20. 9°C.The highest recorded temperature in Ahmedabad is 47.2°C, which was recorded in May. The lowest recorded temperature in Ahmedabad is 5.6°C, which was recorded in December. The average amount of precipitation for the year in Ahmedabad is 767.1 mm. The month with the most precipitation on average is July with 299.7 mm of precipitation. The month with the least precipitation on average is March with an average of 0 mm. There is an average of 24.8 days of precipitation, with the most precipitation occurring in July with 8.3 days and the least precipitation occurring in February with 0.2 days.

The Net Zero Energy Building at CEPT University in Ahmedabad, India is a case study of an institutional building with a focus on sustainable design and energy efficiency. The building was designed by architect B.V. Doshi and HVAC engineer Pankaj Dharkar and Associates and was occupied in 2015. The building has a total floor area of 416 sq.m and is air-conditioned. The building is oriented in the north-south direction and has windows with UPVC frames and insulated double glazed units. The wall assembly consists of 110mm thick exposed brick, 50mm XPS insulation, and 230mm thick cement plastered brick masonry wall inside. The roof is an in-situ reinforced concrete roof with 32% fly ash content and has 45mm thick rigid urethane foam insulation on top with a 50mm concrete screed and white paint. The overall WWR is 26%, with maximum opening provided on the north direction and a WWR of 90%. The building has a radiant cooling system as the primary cooling system, supplemented by a dedicated outdoor air system with a heat recovery wheel and digital scroll cooling for providing conditioned fresh air for peak cooling periods and latent loads. The building also has a solar photovoltaic system of 30 kWp capacity installed on the south-facing sloping roof. The case study demonstrates the successful implementation of sustainable building design principles in an institutional building in a tropical climate.

Figure 3: Naturally daylit area of NZE Building

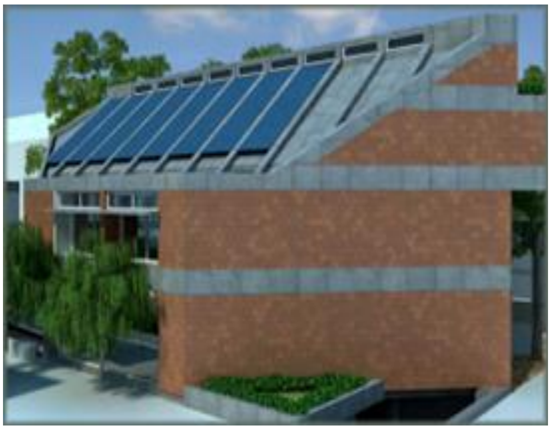

Figure 4: Solar PV installed on the south facing sloping roof.

5. Methodology

The methodology used in the research involved a case study approach to analyze two different buildings located in the Indian tropical climate zone. The first step involved the selection of the two case study buildings, i.e., the Institute of Rural Research and Development at Gurgaon and the Net Zero Energy Building at CEPT University in Ahmedabad.
The data collected included information on building design, orientation, envelope, HVAC systems, lighting, and renewable energy systems

6. Sustainable Design Practise Using Passive Design Components

Conduct a thorough analysis of the local climate conditions and cultural factors to determine the appropriate passive design elements for the specific context.
Determine the appropriate materials and construction techniques for implementing the passive design elements effectively.
Incorporate the passive design elements into the building design, including appropriate orientation, placement of openings, shading devices, natural ventilation, and thermal mass.
Monitor the building's performance to evaluate the effectiveness of the passive design elements in regulating temperature and ventilation.
Based on the performance evaluation, refine the design strategies for future projects and provide guidelines for sustainable and energy-efficient building design using passive design elements.

By following these steps, a sustainable design practice that utilizes passive design elements can be derived and used in further building design. This practice can help reduce energy consumption, minimize the use of mechanical systems, and improve indoor thermal comfort, contributing to sustainable and resilient buildings.

Conclusion

the two case studies of sustainable institutional buildings in Indian tropical climates demonstrate that it is possible to design and construct buildings that minimize their environmental impact while providing comfortable indoor conditions. The Institute of Rural Research and Development in Gurgaon and the Net Zero Energy Building at CEPT University in Ahmedabad both use a combination of passive and active cooling systems, high-performance building envelope design, and renewable energy technologies to achieve their sustainable goals.
Through detailed analysis of the building design and performance, it is clear that these buildings are highly efficient and can serve as examples for future sustainable building projects in India. The use of energy-efficient lighting, advanced HVAC systems, and renewable energy sources has resulted in significant energy savings and reduced carbon emissions.
Furthermore, both buildings demonstrate the importance of proper orientation, shading, and daylighting in creating comfortable indoor environments without the need for excessive cooling or lighting. By implementing these strategies, it is possible to create buildings that are not only sustainable but also promote occupant health and well-being.
Overall, these case studies highlight the importance of a holistic approach to sustainable building design that considers the entire building lifecycle and its impact on the environment and occupants. By adopting similar strategies and technologies, it is possible to create sustainable buildings that meet the needs of the present without compromising the ability of future generations to meet their own needs.

Conflict Of Interest

The authors declare that they have no conflict of interest.

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The author declare that they have no funding support for this study.

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