International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 02 | Feb - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Window Size, Door Proportions and Orientation as Carbon-Smart Design Tools in Indian Residential Architecture

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Abstract - Operational energy use and carbon emissions are significant issues for many residential buildings throughout India because early planning and designs often did not include considerations for climate-responsive design principles. While many low-carbon strategies utilize technology as their focus, fundamental basic design principles such as the size of windows, ratio of doors, and orientation of the building play equally important roles but have not yet received attention. This paper will examine how these fundamental architectural characteristics are essentially being used as carbon smart design elements within Indian residential architecture.
This paper investigates the interaction between opening ratios, solar gain, daylighting and natural ventilation and the combined effects of these characteristics for cooling and lighting energy loads. By reviewing the literature and climate-responsive design principles related to both, this paper finds that both improperly sized windows and solar gain can greatly increase thermal discomfort and operational carbon emissions. Conversely, however, if climate-responsive window-to-wall ratios, properly sized door openings and buildings orientated to take advantage of the climate are utilized, the need for air conditioning can be significantly diminished. Ultimately the results of this paper illustrate the importance of architectural fundamentals as cost effective means of reducing operational carbon emissions for residential buildings in India.

Key Words: Carbon-smart architecture; Window size; Building orientation; Operational carbon; Indian housing; Climate-responsive design

1. INTRODUCTION

India's residential buildings consume significant amounts of energy and release substantial amounts of carbon due principally to poor architectural design and a growing reliance on mechanical cooling and artificial lighting. Urbanization has further increased energy use in residential buildings, therefore, operational carbon reduction must be a primary focus of architectural design.

Low-carbon architecture is typically associated with innovative technologies; however, many fundamental design decisions have not received enough attention at the early design stage. The size of windows, the ratio of doors to windows, and the orientation of a building are among those factors that directly affect the amount of solar gain and daylight received in a building as well as the amount of natural ventilation available, and therefore have a direct effect on the indoor environment and energy use of that building. Also, if openings and orientation are not adequately designed, the cooling and lighting load will be increased therefore increasing operational carbon emissions.

Using the fundamental design parameters evaluated in this research paper, low-carbon design tools will be identified for Indian residential architecture. By establishing the connection between fundamental architectural design and operational performance, this research paper highlights that early design decisions can be used to create low-carbon housing affordably and with impact on future climate change.

2. METHODOLOGY

1. Data collection:
2. Secondary data collection from published literature, books, and research reports on climate-adjusted and energy-saving residential architecture.
3. Analysis
4. Conclusion

3. ANALYSIS

The dimension of a window plays an important role in maintaining thermal comfort and energy efficiency of dwellings in India. An appropriately sized window allows substantial quantities of natural daylight into the house so that less artificial lighting is needed during the day. However, windows also form a significant means of heat transfer from the interior to the exterior. Oversized windows in hot and composite climates will increase the amount of solar heat gain, particularly on buildings that have windows on their east and west sides, hence, raising indoor temperatures; this will subsequently cause increased dependency on mechanical cooling systems and greater amounts of energy usage and carbon emissions. Research has indicated that optimization of the window-to-wall ratio is essential for balancing daylighting and thermal comfort.

Although less often mentioned in studies of energy-efficient design, the ratio of doors is very important in creating indoor environmental quality. Throughout history, doors have been a common feature in homes due to their ability to aid in natural ventilation and promote the movement of air through the structure; many traditional Indian residential buildings utilized tall, wide openings to maximize the chances of gaining both cross- and vertical-flow of air. In these buildings, the use of large-sized door openings provided opportunities for hot air to escape, while encouraging cool air from outside to enter, enhancing thermal comfort without requiring the use of energy. Today, however, many newly constructed residential buildings utilize standard-sized or smaller door openings that were determined based on parameters other than their effect on indoor environmental quality. The resulting decrease in the potential for natural ventilation within these buildings has caused an increase in the accumulation of heat in the interior spaces of these structures and thus has contributed to an increase in the amount of time that fans or air- conditioning units operate as well as to an increase in the net amount of carbon produced as a result of the operation of these systems.

Building orientation is considered one of the most important considerations when making design decisions during the early stages of residential building design and their energy performance. The first consideration for any residential building developed is the orientation of the residential building. The internal heat gain and thermal comfort of the residential building will be affected by the amount and duration of the solar exposure on the internal surfaces of the residential building, including the amount of sunlight they receive. The amount of heat gained through operational energy consumption, daylighting, and thermal comfort for residential buildings varies significantly based on the orientation of the residential buildings relative to the sun in the Indian environment.

Specifically, residential buildings oriented toward the east-west direction will have a high level of solar exposure with a low angle of incidence, which typically occurs in the early morning and late evening, thereby causing the future cooling loads and the associated thermal discomfort in the residential building. Conversely, by orienting a residential building toward the north-south direction, a residential building can control the amount of solar exposure and maintain comfortable thermal conditions and maximize the amount of daylighting it receives while minimizing the amount of internal heat generated by operating systems. Decisions regarding a residential building's orientation will impact the long-term performance of the residential building because the orientation of the residential building cannot easily be modified after the construction process is complete. As such, orienting a residential building to reduce the operational demand for energy represents a low-cost and effective carbon-smart strategy to reduce the operational energy demands of residential buildings.

4. ROLE & CHALLENGES

Role of Architectural Fundamentals in Operational Carbon Reduction

Fundamentals of architecture play a key role in helping to reduce operational carbon emissions because they shape the environmental performance of the building from the earliest stages of design. Design parameters related to window size, door proportion, and orientation create solar gain, natural day lighting, and airflow in residential buildings. Designing these parameters to respond to climates decreases the use of artificial lighting and mechanical cooling, which are two main users of operation energy in Indian residential buildings. Because architectural fundamentals are passive throughout the entire life cycle of a building compared to technological solutions that are added during later phases, they are also cost effective and durable carbon-smart solutions.

Because of the diversity of climate & increasing desire for thermal comfort in home construction/practice; orientation & sizing of the window/door openings can aid in reducing indoor thermal discomfort due to excessive heat gained through on-site solar energy or inadequate natural light/ventilation into the dwelling. Architects will reduce operational energy consumption through these fundamental design principles without an increase in construction costs. Through this design process, architects have an opportunity to help mitigate climate change.

Challenges in Implementing Carbon-Smart Architectural Design

There are several problems in today's world that face these effective carbon-smart design principles used in residential structures. One concern is the huge level of use of design strategies and standardized house layouts within the residential marketplace, which often fail to consider how they will impact the environment. Many of them are designed primarily for aesthetic purposes or maximizing the amount of land occupied, rather than for passive energy conservation. As a consequence, an individual house will not be afforded the same and/or optimal orientation and size/positioning of openings, and thus will not be able to achieve the same level of passive energy savings.

The second challenge is that from the time before construction, there are very few opportunities for an architect to measure or assess the carbon-based (or carbon impact) operational performance of their design. For this reason, the principles and design ideals associated with architecture are often seen as optional, rather than mandatory. Furthermore, there are many limitations arising from site operational and geographical constraints placed on the design of residential dwellings in India's urban centers that further compound the inability to achieve optimal orientation and opening (window) placement when designing a residence.

5. CONCLUSION

The significance of basic architectural principles is underscored by this analysis regarding their role in curbing operational carbon emissions in India’s residential buildings. The investigation of such elements as window size, door ratio, and building orientation as carbon-smart design elements has shown that substantial energy and carbon savings can be achieved using basic architectural principles in the early stages of design development, as opposed to relying solely on high-tech solutions. These basic architectural principles have a direct influence on daylighting, natural ventilation and solar gain, which in turn affect indoor thermal comfort and energy consumption.

The results of the analysis performed in this study indicate that basic architectural principles can still be considered a viable and cost-effective strategy for achieving low-carbon residential buildings through climate-resilient design. Given India’s current circumstances of rapid urbanization and increasing cooling demand creating a burden on the energy supply chain, incorporating carbon-smart thinking into basic architectural design principles presents a significant opportunity for reducing operational energy consumption.

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