Original Article
ISSN (Online): 2582-7472

ShodhKosh: Journal of Visual and Performing Arts
International Conference on Multidisciplinary Aspects of Built Environment
June 2024 5(ICoMABE), 195–206

ENHANCING HEAT RESILIENCE OF AFFORDABLE HOUSING IN DELHI NCR THROUGH CROSS VENTILATION

Dr. Deepashree Choudhury [1], Harshita Sharma [2]

[1] Professor, School of Architecture and Planning, Apeejay Institute of Technology, Greater Noida, Uttar Pradesh, India

Corresponding Author
Dr. Deepashree Choudhury,
ar.deepachoudhury@gmail.com

DOI 10.29121/shodhkosh.v5.i ICoMABE.2024.2253

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

In regions characterized by extreme temperatures like the Delhi National Capital Region (NCR), ensuring the heat resilience of affordable housing is paramount for the well-being and comfort of residents. This research paper investigates the role of cross ventilation in enhancing the heat resilience of affordable housing in Delhi NCR. Through a comprehensive analysis of existing literature, building design principles, and case studies, this study elucidates the multifaceted benefits of cross ventilation in mitigating the impacts of heat stress in affordable housing settings.

The research highlights that cross ventilation plays a pivotal role in natural cooling by facilitating the exchange of indoor and outdoor air. This process reduces indoor temperatures and alleviates the need for mechanical cooling systems, thereby enhancing energy efficiency and reducing utility costs for residents. Moreover, cross ventilation improves indoor air quality by expelling pollutants and moisture, contributing to a healthier living environment, which is particularly crucial in densely populated affordable housing units.

Furthermore, the study underscores the significance of cross ventilation in passive cooling strategies, emphasizing its integration into building design principles such as window placement, building orientation, and airflow optimization. These strategies not only enhance thermal comfort but also bolster the resilience of affordable housing to power outages, providing a reliable cooling solution even in the absence of electricity.

Through a synthesis of theoretical frameworks and practical insights, this research proposes cross ventilation as a cost-effective and sustainable approach to address heat resilience challenges in affordable housing in Delhi NCR. By advocating for the incorporation of cross ventilation into building codes, policies, and urban planning initiatives, this paper aims to empower stakeholders in the affordable housing sector to create more livable and resilient communities in the face of rising temperatures and climate variability.

Keywords: Cross Ventilation, Heat Resilience, Affordable Housing, Delhi NCR, Natural Cooling

1. INTRODUCTION

Climate change and urbanization are imposing significant pressures on cities worldwide, including Delhi NCR. Issues such as heat stress, air pollution, and energy consumption are emerging as major challenges to creating healthy and equitable living conditions for citizens in cities today. In the case of affordable housing, where resources are limited, these issues seriously impact the target population, who are often marginalized in terms of economic and social conditions. In such scenarios, affordable housing often becomes vulnerable, with residents facing increased health risks and discomfort due to extreme temperatures. Among other urban difficulties, the issue of urban heat emerges as the most serious, particularly in Delhi NCR, which faces extreme summers and winters. In this context, ensuring the heat resilience of such housing is crucial for the well-being and comfort of its inhabitants. This issue needs particular attention, as the target segment for affordable housing often cannot afford air conditioners and other mechanical means of achieving climatic comfort, nor can they afford to employ costly building materials and techniques for achieving heat resiliency. Under such circumstances, passive cooling techniques like cross ventilation remain the most potent way to ensure heat resiliency. By emphasizing the importance of cross ventilation in enhancing the heat resilience of affordable housing, this research seeks to facilitate the creation of more resilient and livable communities in the Delhi National Capital Region (NCR).

1.1. AIM AND OBJECTIVES

The primary aim of this research is to explore and demonstrate the effectiveness of cross ventilation in enhancing the heat resilience of affordable housing in Delhi NCR. By conducting a thorough investigation encompassing existing literature, building design principles, and case studies, this study aims to elucidate the multifaceted benefits of cross ventilation in mitigating the impacts of heat stress in affordable housing settings.

To achieve this aim, the following objectives are set forth:

1) To analyze existing literature on cross ventilation, affordable housing, and heat resilience in the context of Delhi NCR.
2) To investigate building design principles that incorporate cross ventilation and their impact on indoor thermal comfort.
3) To examine case studies illustrating the successful integration of cross ventilation in affordable housing projects in similar climatic regions.
4) To propose recommendations for the incorporation of cross ventilation into building codes, policies, and urban planning initiatives for affordable housing in Delhi NCR

2. MATERIALS AND METHODS

For this research endeavor, a multifaceted approach was adopted to investigate the effectiveness of cross ventilation in bolstering the heat resilience of affordable housing in Delhi NCR. The foundational step involved a comprehensive literature review, which entailed scouring academic databases like PubMed, Google Scholar, and JSTOR for relevant scholarly works published within the last decade. The search was guided by keywords such as "cross ventilation," "affordable housing," "heat resilience," and "Delhi NCR." The collected literature encompassed peer-reviewed articles, books, reports, and case studies, forming the basis for thematic analysis to identify common threads, challenges, and opportunities associated with cross ventilation in the context of affordable housing.

Building upon the insights gleaned from the literature, the study delved into the exploration of building design principles integrating cross ventilation. This phase involved an in-depth review of architectural journals, textbooks, and other pertinent publications, supplemented by the analysis of case studies showcasing successful integration of cross ventilation in affordable housing projects. Additionally, consultations with seasoned architects and building designers provided invaluable insights into effective design strategies.

The investigation also included an examination of case studies from climatically similar regions as Delhi NCR, focusing on affordable housing projects with documented success in cross ventilation implementation. Through the review of project documentation, architectural drawings, and post-occupancy evaluations, the study assessed the impact of cross ventilation on enhancing heat resilience and indoor thermal comfort. Furthermore, semi-structured interviews with architects, project managers, and residents of selected case study projects provided qualitative insights into their experiences with cross ventilation.

Drawing from the literature review, case study analysis, and stakeholder input, the study formulated recommendations for the incorporation of cross ventilation into building codes, policies, and urban planning initiatives for affordable housing in Delhi NCR. This process involved a thorough review of existing policies, identification of gaps, stakeholder consultations, and feasibility assessments. Throughout the research process, ethical considerations regarding data privacy and human subjects' welfare were paramount, adhering to institutional ethics guidelines and obtaining necessary approvals where applicable.

3. LITERATURE STUDY

3.1. CROSS VENTILATION, AFFORDABLE HOUSING, AND HEAT RESILIENCE: A LITERATURE REVIEW

The literature surrounding cross ventilation, affordable housing, and heat resilience in Delhi NCR provides valuable insights into the complex interplay between environmental factors, socio-economic conditions, and housing design. Numerous studies have highlighted the importance of natural ventilation as a cost-effective and sustainable means of enhancing indoor thermal comfort and mitigating heat stress in urban environments. Researchers have emphasized the role of cross ventilation in facilitating airflow within buildings, reducing reliance on mechanical cooling systems, and improving indoor air quality.

Within the context of affordable housing in Delhi NCR, existing literature has shed light on the unique challenges and opportunities associated with integrating cross ventilation into housing design. Studies have identified a range of factors influencing the feasibility and effectiveness of cross ventilation in affordable housing developments, including building orientation, layout, and materials. Additionally, researchers have explored the socio-economic barriers that often hinder the adoption of passive cooling strategies in low-income communities, such as limited access to resources, lack of awareness, and cultural preferences. (Gopalan, 2014)

3.2. EXAMINATION OF CHALLENGES AND OPPORTUNITIES

Despite the potential benefits of cross ventilation, implementing this passive cooling strategy in affordable housing settings presents several challenges. One of the primary challenges is the constrained spatial and financial resources typically associated with affordable housing projects. Limited land availability and budget constraints may restrict the incorporation of design features that promote natural ventilation, such as larger window openings, courtyards, or atriums. Additionally, the rapid pace of urbanization and densification in Delhi NCR may further exacerbate these challenges, leading to the construction of high-rise buildings with limited opportunities for cross ventilation.

Moreover, socio-cultural factors and user behavior patterns can influence the effectiveness of cross ventilation in affordable housing. Studies have pointed out that residents may be reluctant to open windows or doors due to concerns about security, noise pollution, or privacy. In some cases, cultural preferences for closed, air-conditioned spaces may override the potential benefits of natural ventilation, leading to suboptimal indoor environments. Addressing these challenges requires a holistic approach that considers not only technical design solutions but also social, cultural, and economic factors shaping housing preferences and behaviors.

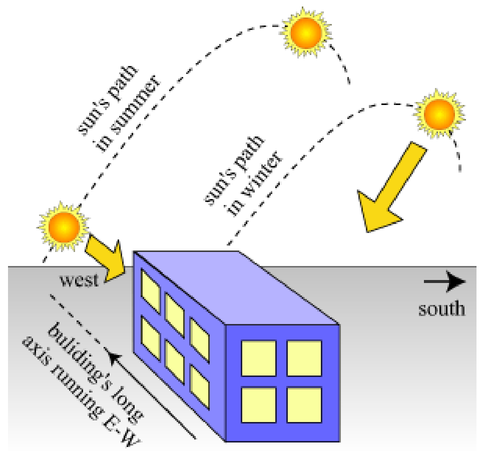
Despite these challenges, there are several opportunities for promoting cross ventilation in affordable housing developments. Innovative design strategies, such as modular construction, passive solar design, and green building techniques, offer promising avenues for optimizing natural ventilation while minimizing costs and environmental impact. Furthermore, advances in building materials and technologies, such as low-emissivity glazing, thermal insulation, and ventilation control systems, provide opportunities to enhance the performance and comfort of affordable housing units.

In summary, the literature review underscores the importance of cross ventilation in enhancing the heat resilience of affordable housing in Delhi NCR. While challenges exist, there are significant opportunities for promoting the adoption of passive cooling strategies through innovative design approaches, community engagement, and policy support. By addressing these challenges and leveraging these opportunities, policymakers, designers, and developers can contribute to the creation of healthier, more sustainable, and resilient housing environments for all residents.

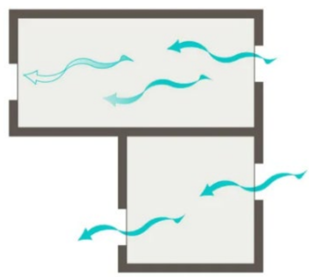
3.3. BUILDING DESIGN PRINCIPLES AND INDOOR THERMAL COMFORT:INTEGRATING CROSS VENTILATION

Building design plays a pivotal role in facilitating cross ventilation and ensuring indoor thermal comfort in affordable housing settings. An investigation into the principles governing building design reveals various strategies aimed at maximizing natural airflow and minimizing the reliance on mechanical cooling systems.

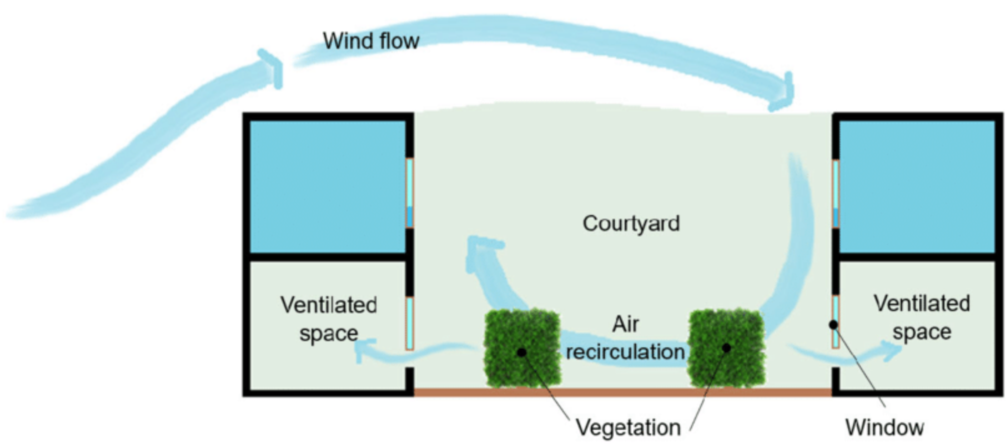
Orientation and Layout: The orientation of buildings relative to prevailing wind directions is a crucial factor in promoting cross ventilation. Buildings oriented perpendicular to prevailing winds can capture airflow more effectively, while courtyards and open spaces within the layout can act as wind channels, facilitating airflow through the built environment. (Asfour, 2010)



(ii) Window Design: Proper placement and sizing of windows are essential for optimizing cross ventilation. Designing buildings with strategically placed windows on opposite walls allows for the creation of cross drafts, promoting airflow throughout the space. Additionally, incorporating operable windows that can be adjusted to control airflow enables residents to regulate indoor thermal conditions according to their preferences. (Bramiana, 2023)



(iii)Atriums and Courtyards: (KRISHAN, 2013).



(iv)Building Form and Massing: The form and massing of buildings influence their aerodynamic properties and airflow patterns. Designing buildings with streamlined shapes and minimizing obstructions such as protruding elements or adjacent structures can reduce air resistance and enhance cross-ventilation effectiveness.

3.3.1. ANALYSIS OF THEIR IMPACT ON INDOOR THERMAL COMFORT IN AFFORDABLE HOUSING SETTINGS

The integration of cross-ventilation principles into building design has a significant impact on indoor thermal comfort within affordable housing settings. By promoting natural airflow and reducing reliance on mechanical cooling, these design strategies contribute to maintaining comfortable indoor temperatures, particularly during periods of extreme heat.

(i) Improved Air Quality: Cross ventilation promotes the exchange of indoor and outdoor air, facilitating the removal of indoor pollutants and improving air quality. Fresh, well-ventilated spaces contribute to a healthier indoor environment, reducing the risk of respiratory issues and promoting occupant well-being.

(ii) Enhanced Thermal Comfort: Effective cross ventilation helps regulate indoor temperatures by dissipating excess heat and promoting evaporative cooling. As a result, residents experience more comfortable living conditions without the need for air conditioning, reducing energy consumption and utility costs.

((Ruggiero, Influence of cross-ventilation cooling potential on thermal comfort in high-rise buildings in a hot and humid climate, 15 January 2024,)

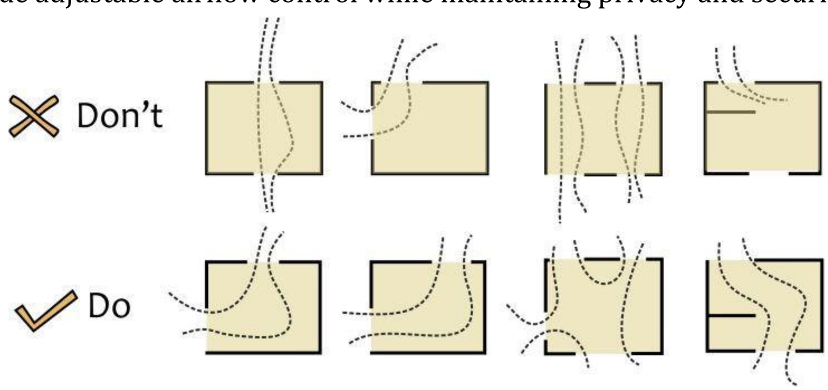
(iv) Occupant Satisfaction: Studies have shown that buildings designed with cross ventilation principles are associated with higher levels of occupant satisfaction and well-being. Residents appreciate the ability to control indoor thermal conditions naturally, leading to increased comfort and overall quality of life.

3.3.2. BUILDING DESIGN PRINCIPLES AND INDOOR THERMAL COMFORT

Integrating cross ventilation into building design requires a strategic approach that optimizes natural airflow and enhances indoor thermal comfort. Key principles include:

Building Orientation and Layout: The orientation of buildings plays a critical role in maximizing cross ventilation. Buildings should be oriented perpendicular to prevailing wind directions to capture and channel airflow effectively. The layout should promote unobstructed wind paths through the use of aligned openings on opposite walls, allowing air to move freely from one side of the building to the other. This alignment helps create a pressure differential, facilitating natural ventilation.

Window Placement and Design: Windows are fundamental components in promoting cross ventilation. They should be strategically placed on opposite sides of a room to enable airflow. Operable windows that can be fully opened are preferred to maximize ventilation. The use of high and low window placements can help harness buoyancy-driven ventilation, where warm air exits through higher windows and cooler air enters through lower openings. Additionally, louvered windows can provide adjustable airflow control while maintaining privacy and security.



Locate inlet openings perpendicular to (or at most ±45° from) the prevailing winds. Locate outlet openings on the opposite side of inlet openings, and make them equal to, or greater in size than, the inlet opening

Internal Layout and Openings: The internal layout should minimize obstructions that could impede airflow. Open floor plans, internal courtyards, and atriums can enhance cross ventilation by providing direct pathways for air movement. Openings such as vents, transoms, and internal windows between rooms further promote airflow within the building, ensuring that even interior spaces benefit from natural ventilation.

Building Form and Massing: The shape and massing of the building affect its aerodynamic properties and ability to capture wind. Streamlined forms with minimal protrusions facilitate smoother airflow around the structure. Staggered or terraced forms can also enhance ventilation by creating wind eddies that promote air movement around and through the building.

Use of Shading Devices: Shading devices such as overhangs, awnings, and pergolas can prevent excessive solar heat gain while allowing for ventilation. These elements reduce the cooling load by keeping indoor temperatures lower and maintaining a comfortable environment. The design should balance shading and ventilation to ensure optimal thermal performance.

Material Selection: Lightweight, thermally responsive materials can enhance the effectiveness of cross ventilation. Materials with low thermal mass cool down quickly, preventing heat retention and promoting faster indoor temperature reduction. Reflective coatings and finishes can also reduce heat absorption and improve overall thermal comfort.

3.3.3. IMPACT ON INDOOR THERMAL COMFORT IN AFFORDABLE HOUSING SETTINGS

The integration of cross-ventilation principles into affordable housing design has a profound impact on indoor thermal comfort. Key benefits include:

Enhanced Air Quality: Cross ventilation facilitates the exchange of indoor and outdoor air, diluting indoor pollutants and reducing humidity levels. Improved air quality contributes to better health outcomes and reduces the risk of respiratory illnesses among residents.

Temperature Regulation: By promoting natural airflow, cross ventilation helps dissipate accumulated heat, maintaining indoor temperatures within a comfortable range. This is particularly important during hot weather, where cross ventilation can reduce the reliance on mechanical cooling systems, lowering energy consumption and utility costs.

Energy Efficiency: Buildings designed for effective cross ventilation require less energy for cooling, resulting in significant energy savings. This is especially beneficial in affordable housing, where residents often have limited financial resources. Lower energy bills contribute to overall affordability and economic resilience.

Occupant Comfort and Well-Being: Cross ventilation enhances thermal comfort by preventing overheating and providing a consistent airflow. Occupants can enjoy a more stable and comfortable indoor environment, which positively impacts their well-being and productivity. The ability to control ventilation through operable windows and vents empowers residents to manage their comfort levels naturally.

Sustainability and Environmental Impact: Utilizing natural ventilation reduces the carbon footprint associated with air conditioning and other mechanical cooling systems. Sustainable building practices that incorporate cross ventilation contribute to broader environmental goals by promoting energy conservation and reducing greenhouse gas emissions.

Adaptability to Climate Variability: Buildings designed with cross ventilation are better equipped to handle variations in climate, including extreme heat events. This adaptability ensures long-term resilience, providing a sustainable living environment amidst changing climatic conditions

4. CASE STUDIES ON CROSS-VENTILATION INTEGRATION

CASE STUDY 1 : Sheik Sarai housing (Raj Rewal)

Category	Data Point	Details
General Information	Name of the Housing Group	Sheik Sarai Group Housing
	Location	Sheik Sarai, Delhi
	Number of Units	500
	Types of Units	1BHK, 2BHK, 3BHK
	Total Area	20,000 sq. meters
Demographics	Average Family Size	4.5
	Age Distribution	Children: 20%, Adults: 60%, Seniors: 20%
	Occupation Distribution	Professionals: 50%, Business: 20%, Retired: 30%
Housing Details	Average Price per Unit	₹1.5 crore
	Price Range	₹1 crore - ₹2.5 crore
	Average Rent	₹25,000 per month
	Rent Range	₹18,000 - ₹40,000 per month
Facilities and Amenities	Number of Parks	2
	Number of Playgrounds	3
	Gymnasium	Yes
	Swimming Pool	Yes
	Community Hall	Yes
	Security Features	24/7 Security, CCTV Surveillance

Parameters based on design techniques

Technique Name	Description	Benefits	Implementation Cost	Maintenance Cost	Effectiveness
Green Roofs	Roofs covered with vegetation to reduce heat absorption.	Reduces building temperature improves air quality.	High	Moderate	High
Cool Roofs	Roofs designed with reflective materials to minimize heat absorption.	Lowers indoor temperatures , reduces energy costs.	Moderate	Low	Moderate
Urban Greening	Planting trees and shrubs in urban areas to provide shade and cool the environment.	Provides shade, improves air quality, reduces urban heat island effect.	Varies	Varies	High
Cool Pavements	Pavements made with materials that reflect more sunlight and absorb less heat.	Reduces surface temperatures, enhances pedestrian comfort.	Moderate	Low	Moderate
Passive Cooling Design	Architectural design that enhances natural ventilation and minimizes heat gain.	Reduces need for air conditioning , enhances comfort.	Varies	Low	High
Water Features	Incorporating water bodies like fountains and ponds to cool the surroundings.	Cools the air through evaporation, provides aesthetic value.	High	Moderate	Moderate

CASE STUDY 2: Yamuna housings apartment Delhi (charles correa)

Data Point	Description	Passive Technique	Importance
Site Orientation	The positioning of the building concerning the sun's path and prevailing winds.	Optimizing natural light and airflow	High
Building Envelope	Materials and design of the outer shell of the building, including walls, roof, windows, and doors.	Insulation, thermal mass	High
Natural Ventilation	Use of windows, vents, and other openings to allow air movement without mechanical systems.	Cross-ventilation, stack effect	Medium
Daylighting	Maximizing the use of natural light to reduce the need for artificial lighting.	Window placement, light shelves	High
Shading Devices	Features like overhangs, louvers, and pergolas that reduce heat gain from direct sunlight.	External shading	Medium
Thermal Mass	Materials that absorb and store heat during the day and release it at night.	Concrete, brick, stone	Medium
Insulation	Materials and techniques used to prevent heat transfer through the building envelope.	High-performance insulation	High
Glazing	Type and quality of glass used in windows and doors to control heat gain and loss.	Low-E glass, double glazing	Medium
Green Roofs and Walls	Vegetated surfaces that improve insulation and reduce the urban heat island effect.	Living walls, green roofs	Low
Rainwater Harvesting	Systems for collecting and using rainwater for irrigation and other non-potable uses.	Water conservation	Low
Landscaping	Design and placement of vegetation to provide shade, reduce heat island effect, and enhance natural cooling.	Strategic tree planting	Medium

Building Form and Layout	The shape and internal arrangement of spaces to optimize natural light and ventilation.	Compact design, open floor plans	Medium
Reflective Surfaces	Use of materials with high albedo to reflect more sunlight and reduce heat absorption.	Cool roofs, reflective coatings	Low
Energy-efficient Lighting and HVAC	Use of systems and appliances that consume less energy while maintaining comfort.	LED lighting, efficient HVAC systems	Medium
Solar Gain Control	Strategies to control the amount of solar energy entering the building.	Solar control glass, shading devices	High
Building Automation Systems	Technology for controlling building systems efficiently.	Smart sensors and controls	Medium

Other case study

Case Study	Design Features	Remarks	Sketches/Photos
The Indore Habitat Project aimed to provide affordable housing for low-income families in a hot climate.	Buildings oriented to capture prevailing winds,Large, operable windows on opposite walls, Internal courtyards for airflow, Shading devices to reduce solar heat gain	- Significant reduction in indoor temperatures,Improved air quality,High occupant satisfaction,Reduced need for air conditioning, leading to lower energy costs	
The Cairo Affordable Housing Initiative focused on creating low-cost housing solutions in a desert climate.	Narrow building forms with cross-ventilation corridors,High ceilings,Strategically placed windows-Courtyards and wind towers to enhance airflow	Lower indoor temperatures, Comfortable living spaces without mechanical cooling, Use of local, low-cost materials ensured affordability while maintaining thermal comfort	
The Dhaka Slum Redevelopment Project aimed to upgrade informal settlements with sustainable housing solutions	Staggered layouts with ample cross ventilation, Operable and secure windows, Shading elements, Light-colored materials to reflect heat	Improved thermal comfort, Better air quality,Reduced indoor temperatures,Residents reported improved health and well-being, Effective in dense urban environments	

Evaluation of Effectiveness

Evaluation Criteria	Indore, India	Cairo, Egypt	Dhaka, Bangladesh
Thermal Comfort	Significant reduction in indoor temperatures	Lower indoor temperatures	Improved thermal comfort, reduced indoor temperatures
Energy Efficiency	Reduced need for air conditioning, leading to lower energy costs	Comfortable living spaces without mechanical cooling	Reduced reliance on mechanical cooling, energy savings
Air Quality and Health	Improved air quality, fewer respiratory issues	Not specifically mentioned, but likely improved due to enhanced ventilation	Better air quality, improved health and well-being
Occupant Satisfaction	High occupant satisfaction, appreciated natural control of indoor environment	High occupant satisfaction, local materials appreciated	High occupant satisfaction, appreciated secure and operable windows

Adaptability and Scalability	Local materials and cost-effective solutions ensure adaptability and scalability	Local materials and cost-effective solutions ensure adaptability and scalability	Effective in dense urban environments, adaptable design solutions
Resilience to Climate Change	Maintained comfortable indoor temperatures without energy-intensive cooling systems	Effective in extreme heat conditions without mechanical cooling	Maintained comfortable indoor temperatures, resilient to climate variability

Recommendations for Policy and Urban Planning

Revision of Building Codes:

Mandatory Cross Ventilation Requirements: Update the building codes to include mandatory requirements for cross ventilation in all new affordable housing projects. This includes stipulations on window placement, building orientation, and minimum ventilation openings.

Standards for Ventilation Openings: Specify standards for the size, placement, and type of ventilation openings to ensure optimal airflow. This can include guidelines for operable windows, vents, and other architectural features that facilitate cross ventilation.

Incentives for Developers:

Financial Incentives: Offer financial incentives such as tax rebates, grants, or subsidies to developers who integrate cross ventilation and other passive cooling strategies in their affordable housing projects.

Fast-Track Approvals: Provide fast-track approval processes for projects that demonstrate compliance with cross ventilation and sustainable design standards. This can encourage developers to adopt these practices.

Urban Planning Initiatives:

Zoning Regulations: Modify zoning regulations to prioritize the placement of buildings in ways that optimize natural airflow. Encourage the development of green spaces, courtyards, and open areas that enhance cross ventilation in densely populated areas.

Community Layouts: Plan community layouts that promote natural ventilation, such as the strategic orientation of streets and buildings. Integrate open spaces and parks that facilitate airflow and reduce urban heat islands.

Education and Awareness:

Training Programs: Implement training programs for architects, builders, and urban planners on the principles and benefits of cross ventilation. This can help professionals incorporate these practices into their designs.

Public Awareness Campaigns: Launch public awareness campaigns to educate residents on the benefits of natural ventilation and encourage behaviors that support effective cross ventilation, such as keeping windows open and using shading devices.

Research and Development: (Varley, 2012)

Pilot Projects: Fund pilot projects that demonstrate the effectiveness of cross ventilation in affordable housing. Use these projects as case studies to refine guidelines and showcase best practices.

Technological Innovations: Support research into new materials and technologies that enhance cross ventilation, such as advanced window designs, passive cooling systems, and smart ventilation controls.

Collaboration and Partnerships:

Public-Private Partnerships: Foster collaborations between government agencies, private developers, and non-governmental organizations (NGOs) to promote the integration of cross ventilation in affordable housing projects.

International Collaboration: Learn from international best practices and collaborate with cities in similar climatic regions to share knowledge and strategies for effective cross ventilation.

Discussion on Potential Challenges and Strategies for Implementation

Implementing these recommendations will undoubtedly face several challenges. Here are some potential challenges and strategies to overcome them:

Challenge	Description	Strategy
Financial Constraints	Affordable housing projects often operate with tight budgets, making it difficult to allocate funds for design enhancements.	Leverage financial incentives and subsidies to offset additional costs. Encourage cost-effective design solutions that do not significantly increase project budgets.
Resistance from Developers	Developers may resist changes due to perceived increases in complexity and costs.	Provide clear guidelines and demonstrate the long-term financial benefits, such as reduced energy costs and higher occupant satisfaction. Highlight successful case studies and offer technical support during the design and construction phases.
Regulatory Hurdles	Updating building codes and zoning regulations can be a slow and bureaucratic process.	Engage stakeholders early in the process to build consensus. Pilot projects and phased implementation can help demonstrate benefits and build momentum for regulatory changes.
Lack of Awareness and Expertise	Builders, architects, and residents may lack knowledge about the benefits and implementation of cross ventilation.	Invest in education and training programs. Develop easy-to-understand materials and workshops to educate stakeholders on best practices and benefits.
Climatic Variability	The diverse climatic conditions within Delhi NCR may affect the uniform application of cross ventilation principles.	Customize guidelines to account for local climatic conditions. Use flexible design principles that can be adapted to different microclimates within the region.
Monitoring and Compliance	Ensuring compliance with new building codes and standards can be challenging.	Implement robust monitoring and evaluation mechanisms. Use building inspections, performance assessments, and feedback loops to ensure adherence to ventilation standards.

5. FINDINGS

Aspect	Sheik Sarai Delhi	Tara Housing Delhi	Yamuna Group Housing Delhi
Passive Cooling Techniques	Earth Sheltering	Natural Ventilation	Orientation for Solar Gain
Insulation Materials	Low-cost Insulation	Recycled Materials	Earth-based Insulation
Thermal Mass	Utilization of Local Materials	Incorporation of Mud Walls	Concrete Floors
Shading Strategies	Overhangs	Plantation and Awnings	External Louvers
Cross Ventilation	Utilization of Courtyards	Building Orientation	Openable Windows
Solar Heat Gain Control	Strategic Window Placement	Reflective Surfaces	External Blinds
Passive Solar Design Principles	South-facing Windows	Solar Chimneys	Solar Panels Integration
Water Conservation Techniques	Rainwater Harvesting	Greywater Recycling	Low-flow Fixtures
Use of Renewable Energy Sources	Solar Panels Integration	Solar Water Heaters	Biogas Plants
Integration with Surrounding Environment	Indigenous Landscaping	Preservation of Green Spaces	Community Gardens
Cost-effectiveness	Low-cost Construction Methods	Cost-efficient Materials	Minimal Maintenance Costs
Overall Sustainability	Reduced Energy Consumption	Environmental Preservation	Sustainable Community Living

6. RECOMMENDATION

1) Incorporation of Passive Design in Building Codes
2) Financial Incentives and Subsidies
3) Public Awareness and Education
4) Collaboration and Stakeholder Engagement
5) Research and Development
6) Regulatory Support and Compliance
7) Implementation Strategies
8) Financial Models and Incentives
9) Monitoring and Evaluation
10) Community Engagement and Education
11) Policy Integration

Policy and Implementation Recommendations

Incorporate Passive Design in Building Codes

Revise building codes and standards to mandate passive design components in affordable home developments

Incentivize Developers

In order to make inexpensive homes more appealing and practical, developers should be given financial incentives and subsidies for incorporating passive design approaches.

Public Awareness Campaigns:

Start awareness efforts to inform locals and developers about the advantages of passive design techniques and how they affect energy savings and thermal comfort.

Training and Capacity Building:

Provide architects, builders, and urban planners with training programs to improve their understanding of and proficiency with passive design principles.

Pilot Projects

Conduct pilot projects in several Delhi NCR neighborhoods to show the value of passive design techniques and offer concrete examples for broader adoption.

Collaboration with Stakeholders:

Engage a range of players, such as governmental organizations, nonprofits, and the commercial sector, to encourage joint efforts in the development of cheap, heat-resistant housing.

Monitoring and EvaluationProvide

a structure for tracking and assessing the effectiveness of passive design strategies in affordable housing to guarantee ongoing development and modification.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

REFERENCES

Stasi, R., Ruggiero, F. & Berardi, U., 2024. Natural ventilation effectiveness in low-income housing to challenge energy poverty. Energy and Buildings, Volume 304, p. 113836.

Sun, K., 2021. Passive cooling designs to improve heat. Passive cooling designs to improve heat, pp. 45-55.

H.R. Tewani (2017), Methodology Used In Low Cost Housing, https://www.researchtrend.net/ijet/pdf/34-%20149

Sophia Immanuel & K. Baskar (2022), A state-of-the-art review on sustainable low-cost
housing and application of textile reinforced concrete, https://doi.org/10.1007/s41062-022-01010-8

Ravijanya Chippagiri, Ana Bras, Deepak Sharma, and Rahul V. Ralegaonkar (2022),
Technological and Sustainable Perception on the Advancements of Prefabrication in Construction Industry, https://doi.org/10.3390/en15207548

Dr. Manoj P K (2017), Construction costs in affordable housing in kerala: relative significance of the various elements of costs of affordable housing projects,

Sk. Subhan Alisha, Sajja. Neeraja, Sk. Akber, G. Sai Manoj (2016), Architecture Of Uttarakhand and Construction Techniques for Affordable Housing,
https://nanoient.org/upload/pdf/ENT172247_1499952948

Ganga Warrier, Pavankumar Tadepalli and Sivakumar Palaniappan (2019), Low-Cost
Housing in India: A Review, https://iopscience.iop.org/article/10.1088/1755-

Deepak Bansal, V. K. Minocha, Arvinder Kaur, Vaidehi A. Dakwale, and R. V.
Ralegaonkar (2021), Reduction of Embodied Energy and Construction Cost of Affordable
Houses through Efficient Architectural Design: A Case Study in Indian Scenario,
https://doi.org/10.1155/2021/5693101

Dharini Sridharan, Akhil Singhal, Tarun Garg, Shatakshi Suman (2022), Prescriptive